

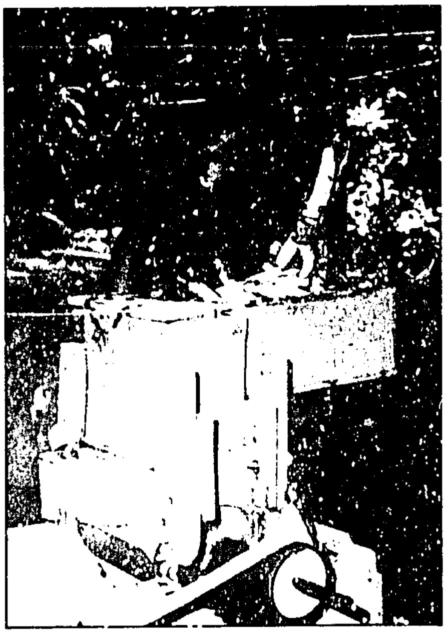

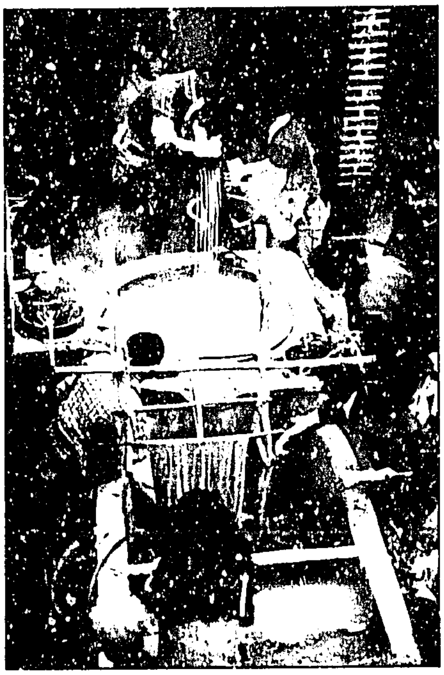


Product Development for Root and Tuber Crops

Volume I - Asia

INTERNATIONAL POTATO CENTER (CIP)

VISAYAS STATE COLLEGE OF AGRICULTURE

THE INTERNATIONAL POTATO CENTER (CIP) is a scientific, autonomous, and non-profit institution dedicated to developing and disseminating knowledge for greater use of the potato, sweetpotato, and other tuber crops as basic foods in the developing world. CIP was established by agreement with the Government of Peru and is supported by the Consultative Group on International Agricultural Research (CGIAR) whose members provide funding for international agricultural development.

EL CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT) is a development-oriented agricultural research institution dedicated to the application of science towards lasting alleviation of hunger and poverty in developing countries.

CIAT is one of 17 international agricultural research centers under the auspices of the CGIAR.

THE INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE (IITA) is a non-profit, international agricultural research and training institute supported primarily by the CGIAR. IITA employs about 180 scientists and professional staff members from over 40 countries and about 1,400 support staff, mostly from Nigeria. IITA's four objectives are: (1) to improve agricultural production systems for the African humid and subhumid tropics which can be sustained without degradation of the environment; (2) to improve the performance of selected food crops which can be integrated into improved and sustainable production systems; (3) to develop national agricultural research capabilities including human resources on a basis of shared responsibility with IITA, by means of training, information, and other outreach activities; and (4) to improve food quality and availability, including food storage, processing, and marketing.

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Product Development

for

Root and Tuber Crops

Volume 1—Asia

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Abstract

Processing of root and tuber crops is the focus of increasing interest by farmers, traders, researchers, and policymakers in many parts of Asia. This publication includes a wealth of information on the progress made to date with new or improved products and processes that utilize cassava, sweetpotato, or potato. Individual papers discuss work underway in China (including Taiwan), the Philippines, Indonesia, Thailand, Vietnam, Korea, India, and—in the case of aroids—the countries of the South Pacific. Particular attention is given to production, marketing, and consumption trends that either have facilitated or resulted from the growth in processing. In addition, an overall approach to product development is outlined followed by specific papers on each of the components including: assessing processing potential; research in support of product and product development; pilot plants; and expansion to commercial operation. Examples are provided for each of these components based on experiences in the countries represented. Case studies outlining the knowledge acquired and lessons learned include cassava processing for animal feed, new snack foods from sweetpotatoes, and village-level potato processing for flours and mixes. The document also contains an overview of country needs; recommendations for future horizontal collaboration; and specific proposals for added support from the International Potato Center (CIP) and the Centro Internacional de Agricultura Tropical (CIAT) for work on product development for roots and tubers in Asia.

Compendio

El procesamiento de raíces y tubérculos es de creciente interés para los agricultores, comerciantes, investigadores y políticos en muchos países de Asia. Esta publicación incluye una amplia compilación de información sobre el progreso observado hasta la fecha con productos y procesos (sean nuevos o mejorados) de yuca, batata (camote) y papa. Las presentaciones discuten trabajos que ya están en marcha en China (incluyendo Taiwan), Filipinas, Indonesia, Tailandia, Vietnam, Korea, India y, para el caso de aroideas, los países del Pacífico Sur. Se presta especial atención a las tendencias de producción, comercialización y consumo de estos cultivos, en la medida que han facilitado el crecimiento de la actividad de procesamiento o han sido resultado de ésta. Además, se presenta un enfoque global seguido por ponencias específicas sobre cada uno de los componentes incluyendo: la evaluación del potencial del procesamiento; investigación sobre productos y procesos; establecimiento de las operaciones en plantas piloto, y la expansión hacia la operación comercial. Se presentan diversos ejemplos de cada componente para los países mencionados. Entre los estudios de caso que sintetizan la experiencia adquirida y las lecciones aprendidas para un producto o proceso específico, están el procesamiento de yuca para la alimentación animal, bocaditos y dulces de camote, y procesamiento de papa a nivel rústico para hacer harinas y mezclas. El documento contiene también un resumen de las necesidades de los países, en lo que se refiere al desarrollo de nuevos productos y procesos de raíces y tubérculos; recomendaciones para la colaboración entre países de la región; y propuestas para el apoyo del Centro Internacional de la Papa (CIP) y el Centro Internacional de Agricultura Tropical (CIAT) en el desarrollo de productos de raíces y tubérculos en Asia.

Résumé

La transformation des racines et des tubercules ne cesse de recueillir l'attention soutenue des fermiers, des commerçants, des chercheurs et des politiciens dans nombreux pays d'Asie. Cette publication inclut un bon nombre d'informations sur les progrès réalisés jusqu'ici sur les produits et procédés nouveaux ou améliorés ayant trait à la cassave, la patate douce ou à la pomme de terre. Les travaux présentés discutent des oeuvres en cours en Chine (y compris Taiwan), aux Philippines, en Indonésie, en Thailande, au Vietnam, en Corée, en Inde et pour les aroides, dans les pays du Sud du Pacifique. Une attention particulière est portée sur les diverses tendances de production, de commercialisation et de consommation de ces produits dans la mesure où elles ont rendu plus faciles ou ont contribué aux augmentations observées. D'autre part, une vue globale est donnée sur le développement des produits en question, suivie de documents spécifiques sur chacun des composants, y compris: le potentiel des méthodes d'évaluation, la recherche sur les produits et procédés, les projets pilotes et le déroulement des opérations jusqu'à celles de commercialisation. Des exemples ancrés sur les expériences des pays représentés sont fournis pour chacun des composants. Des études de cas exposent, les connaissances acquises et les leçons apprises sur la transformation de la cassave pour l'alimentation des animaux, celle de la patate douce dans l'élaboration de noveaux types d'aliments pour snack bar et celle de la pomme de terre pour préparer de la farine et des mélanges dans les villages mêmes. Les rapports des différents pays ont permis d'identifier les facteurs limitants et des créneaux de recherche pour l'avenir. Le document contient aussi un résumé des nécessités par pays, des recommandations pour une collaboration entre pays voisins quant au travail sur le développement de produits à partir de racines et de tubercules en Asie, ainsi que des propositions de coopération avec le Centre International de la Pomme de Terre (CIP) et le Centre International d'Agriculture Tropicale (CIAT).

Contents

Foreword

Over the last two decades, many Asian countries have learned to reduce postharvest losses and increase value added for root and tuber crops by improving traditional technologies and adopting new ones that better suit their needs. In the years ahead, accelerating urbanization, the need for greater rural employment, and aspirations for higher incomes and more diversified, easier-to-prepare diets will push postharvest issues higher on the agenda on most national agricultural research institutes. Postharvest research, training and information are an integral part of the International Potato Center's (CIP) work. Processing, storage, marketing, breeding for processing, consumption and nutrition continue to be key components of CIP's work in Asia, Africa, and Latin America. With the addition of sweetpotatoes and six lesser-known Andean roots and tubers to CIP's portfolio of activities, postharvest activities will take on even greater importance.

Exciting developments—such as the explosive growth in the transformation of sweetpotatoes for animal feed in China—have convinced us that tremendous opportunities exist in Asia to expand postharvest activities for roots and tubers. There is also a need to provide access to technical and socioeconomic information about these achievements to interested individuals in other parts of the world.

We are grateful to the Visayas State College of Agriculture (ViSCA) for hosting the workshop on which this proceedings is based. Furthemore, CIP is pleased to join with the Centro Internacional de Agricultura Tropical (CIAT) and the International Institute of Tropical Agriculture (IITA), as well as ViSCA, to help diffuse years of accumulated experience documented in this publication. We look forward to helping bring about similar successes in the years ahead.

Hubert Zandstra
Director General
International Potato Center (CIP)
Lima, Peru

Objectives of the Workshop

The objectives of the workshop on processing, marketing, and utilization of root and tuber crops in Asia included:

- Document recent trends in production, marketing, processing, and utilization of roots and tubers for Asian countries and for the region as a whole;
- Discuss results, problems, and opportunities in the field of product development for roots and tubers in Asia as well as other parts of the developing world among national researchers, development workers, and specialists from international organizations;
- Present and analyze procedures—including specific research methods, development approaches, and strategies to integrate the work of different disciplines, institutions, interest groups—involved in the development of products and processes for roots and tubers;
- Analyze mechanisms to address the priority needs of national programs in the area of product and process development for roots and tubers; to encourage greater public and private support for product development efforts for roots and tubers including adoption of appropriate government policies, and to involve commercial enterprises in research and development initiatives; and,
- Review proposals to promote greater horizontal cooperation between national institutions in the field of postharvest research generally and new product development specifically, and to broaden the scope for interaction between the International Potato Center (CIP) and the Centro Internacional de Agricultura Tropical (CIAT) in response to the common needs of the region.

Recommendations

On the basis of the oral presentations, written contributions and the discussions that took place during the course of the workshop, the participants provided numerous suggestions for improving the proposed manual on root and tuber processing, marketing, and utilization in developing countries. These covered style (include more diagrams and flow charts, standardize terminology, minimize jargon), content (include information on anti-nutrition factors, storage, specific market opportunities) and organization (e.g., make reference to case studies, reduce preface and introduction, add a topical outline for each chapter). They also formulated a series of recommendations regarding:

- country-level priority needs to facilitate/promote product development for roots and tubers;
- proposed areas of collaboration between national researchers and the international centers at the country-level;
- suggested contributions by country representatives to regional efforts in product development; and
- areas for collaboration among the international centers at the regional or national level.

I. Country Needs

National requirements to further advance work on product development for roots and tubers at the local level are as follows:

Market assessments

- Training in assessing the market potential for fresh produce and processed products from roots and tubers specifically sweetpotato (Indonesia).
- Institutionalizing market assessment capabilities within the Root Crop Center (Philippines).
- Methodologies for conducting production and marketing surveys for fresh and processed roots and tubers (Vietnam).
- Assistance with prefeasibility studies on the economics of root crop processing (China, the Philippines).

- Support for an analysis of regional marketing trends for roots and tubers (the Philippines).

Varieties/Clones/Germplasm

- Varieties/clones from China/Japan that are cold resistant and with high (30%) starch content (Korea).
- Guidelines, i.e., specifications of desirable characteristics for sweetpotato varieties for specific uses (Thailand).

Products and Processes Research

- Support for research and development in the utilization of starch from root crops, especially sweetpotato (Thailand).
- Support for basic research on starch characterization (Vietnam).
- Support for chemical analysis for starch and cyanide content of roots and tubers (Indonesia, China).
- Information exchange on existing processed products (Thailand).

Equipment/Machines

- Information on processing equipment (Philippines).
- Technical assistance with chipping machines (China).

Pilot Plants

- Support for pilot testing of lab-tested products, i.e., cassava intermediate products (Vietnam).
- Support for setting up pilot plant and equipment for cassava flour (Indonesia).
- Assistance with evaluating/improving household, on-farm sweetpotato food processing, utilization (Vietnam).
- Assistance to demonstrate the economic potential of processing through pilot testing (Philippines).

General Training and Mid-Career Professional Exchange

- Training of postharvest scientists (Vietnam).
- Support for training extension workers (Indonesia).
- Mid-career professional exchanges to up-grade institutional capabilities (Philippines).

- Assistance to strengthen research capabilities in the social sciences (China).

II. Collaboration at the Country-level

National representatives also expressed their willingness to collaborate with the International Potato Center (CIP) and the Centro Internacional de Agricultura Tropical (CIAT) in specific research and development initiatives on product development for roots and tuber crops as follows:

General

- Working to bring the potential of roots and tubers to the attention of policymakers.
- Greater integration of sweetpotato and cassava initiatives in the field of product development.
- Greater CIAT presence in the region for utilization research.

Research

- Joint project with CIAT on cassava starch quality (Thailand).
- Collaboration in research on sweetpotato starch extraction and fresh cassava storage (India).
- Integration of local initiatives into existing regional networks for cassava and sweetpotato research and training (Vietnam).
- Joint participation with CIP and CIAT in pilot stage projects (Philippines).
- Collaboration (through FAO-CIP-CIAT) with the Philippines on household/village-level processing (South Pacific countries).
- Participation on initiatives to strengthen linkages between research institutions and the private sector (Philippines).

Training

- Scholarships for processing/utilization research at/by the international centers (General).
- Participation in joint training exercises (Vietnam).

Information

- Collection and distribution of information on traditional products and processes (General).

- Continued information exchange through workshops (Thailand).

III. Country Contributions to Product Development

Specific areas where participating country representatives felt that their national institutions might contribute to product development for root and tuber crops in the region include the following:

Research/Technical Assistance

- Village-level processing technology (Vietnam).
- Technical assistance on root crop processing including large-scale sweetpotato starch extraction and alcohol production as well as ensilage technology for animal feed (China including Taiwan).
- Technical assistance in the areas of postharvest equipment, food-product processing, and varietal improvement (Philippines).
- Varietal exchange for starch processing (Indonesia).

Training

- Training (including scholarships from Taiwan) for root crop processing (China, including Taiwan).
- Training in the area of small-scale cassava flour and food-product processing (Indonesia).
- Training in the area of processing equipment, food-product processing (Philippines).

IV. Support from CIP and CIAT

The workshop generated both suggestions from the country participants and proposals from the Center representatives for support from CIP and CIAT for research and training in the area of product development for root and tuber crops in Asia.

Suggestions to CIP and CIAT

In addition to the collaborative initiatives and country needs previously alluded to, the following specific suggestions for CIP and/or CIAT support were made by country representatives present.

- Support from CIP economist stationed in Indonesia for one year to work with an Indonesian group to assess market potential and future prospects for sweetpotato roots and sweetpotato products as well as help set up an overall plan for sweetpotato development.

- Facilitate the supply of sweetpotato varieties from various sources, particularly China, to countries of the region.
- Help national institutions secure financial support for product development initiatives.
- Document existing processing equipment for root crops (catalog).
- Assist in the exchange of information between researchers in the region working on product development for roots and tubers and professional counterparts in developed countries.
- Facilitate access to Center databases on roots and tubers in developing countries.

Proposals from CIP and CIAT

Both Centers are eager to help identify priority projects in the area of product development for roots and tubers. In the past, such projects typically have been evaluated on a case-by-case, country-by-country basis. However, both Centers are increasingly aware of the need for and advantages of closer integration of their work with national and network counterparts in this field. As specific circumstances may require, both Centers are willing to join with local counterparts in the search for special project funding.

- CIP places high priority for the immediate future on market/technology/policy assessments as a first step toward broader interaction with national institutions in the area of product development for sweetpotatoes. These assessments will analyze not only the economic potential for processed sweetpotato products but also the technical capabilities and government policies that may influence such activities for the purpose of prioritizing across a wide array of possible alternatives.
- CIAT places similar emphasis on processing research that is demand-driven, i.e., based on the prior analysis of marketing problems and/or opportunities for cassava.
- CIAT has expertise in the following fields: small-scale processing of chips, flour and starch; conservation of fresh cassava roots; analysis of cassava characteristics such as eating quality, starch, and cyanide content; and, design of project proposals for research and pilot testing. Short-term (up to five weeks) individual or group training in these fields can be arranged related to projects in which trainee expenses are covered.
- Both CIP and CIAT have considerable information on product development for roots and tubers that can be accessed through contacting their respective information units, or local representatives in the region.

Acknowledgments

Production of this document would not have been possible without the active collaboration of a number of institutions and individuals. In the Philippines, sincere thanks are due to the hosts of the workshop, Visayas State College of Agriculture (ViSCA) in particular, Dr. Mariano Villanueva for his permission to hold the event there; to members of the ViSCA workshop committes who so ably assisted with planning, food, accommodations, and field trips; to Dr. Joe Bacusmo, Julieta Roa and Alan Loreto of the Philippines Root Crops Research and Tranining Center (PRCRTC) for their help in organizing the event; to Dr. Truong Van Den of ViSCA for his support in planning the workshop; to Dr. Enrique Chujoy and the International Potato Center (CIP) staff in Los Baños for their assistance with invitations, logistics, and printing of the proceedings; and, to the workshop participants for their conscientious replies to all of the queries about their papers. In Indonesia and India, a word of thanks to Dr. Siert Wiersema, Dr. Mahesh Upadhya and CIP's regional staff for their help. In Colombia, a note of gratitude goes to Dr. Rupert Best and Dr. Christopher Wheatley of the Centro Internacional de Agricultura Tropical (CIAT) for their help in organizing and conducting the workshop. At CIP headquarters in Lima, Peru, particular appreciation is due Gisela Castro and Mónica Aliaga for word processing, and to Yolanda Rivas for proofreading, page layout and cover design. Thanks go as well to Víctor Madrid for drawing the figures and maps, to Anselmo Morales for preparating the cover, and to Víctor Suárez for assistance with computer programming.

Abbreviations and Acronyms

AARD	Agency for Agricultural Research and Development
ADAB	Australian Development Assistance Bureau
ADAP	Australian Direct Action Program
ANOVA	analysis of variance
AVRDC	Asian Vegetable Research and Development Center
BORIF	Bogor Research Institute for Food Crops
CAAS	Chinese Academy of Agricultural Sciences
CAER	Center for Agro Economic Research
CBS	Central Bureau of Statistik
CFTRI	Central Food Technological Research Institute
CGPRT	Coarse Grains, Pulses, Roots and Tuber Crops Center
CIAT	Centro Internacional de Agricultura Tropical
CIP	International Potato Center
cm	centimeter
CRIFC	Central Research Institute for Food Crops
CTCRI	Central Tuber Crops Research Institute
CTI	Compatible Technology, Inc.
DMRT	Duncan's Multiple Range Test
EC	European Community
FAO	Food and Agricultural Organization of the United Nations
g	gram
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
ha	hectare
HCN	hydrocyanic acid
hp	horsepower
hr	hour
IARCs	International Agricultural Research Centers
ICAR	Indian Council for Agricultural Research
IDRC	International Development Research Centre
IFPRI	International Food Policy Research Institute
ILRAD	International Laboratory for Research on Animal Diseases
IRD	integrated rural development
IRR	Internal Rate of Return
kcal	kilogram per calorie
kg/hr	kilogram per hour
kg/m^2	kilogram per square meter
km	kilometer
KUD	Village Cooperative Units
KVIB	Khadi and Village Industries Board
LAB	lactic acid bacteria
m	meter
m/sec	meters per second
MARIF	Malang Research Institute for Food Crops
mg	miligram
min	minute
mm	milimeter
mo	month
MSG	monosodium glutamate

NARDS	National Agricultural Research and Development Systems
NGOs	non-government organizations
NPV	Net Present Value
PER	protein efficiency ratio
PP	Payback Period
ppm	parts per million
PRCRTC	Philippine Root Crop Research and Training Center
R&D	research and development
RDA	Recommended Daily Allowance
RMA	Rapid Market Appraisal
RMB Yuan	Ren Min Bi Yuan
ROI	Return on Investment
RTC-RD	Regional Training Center for Rural Development
RTVD	Research, Training, and Village Development Center
SAAS	Sichuan Academy of Agricultural Sciences
SAPPRAD	Southeast Asian Program for Potato Research and Development
SCP	single cell protein
SEAMEO	Southeast Asian Ministers of Education Organization
SEARCA	Southeast Asian Regional Center for Graduate Study and Research in Agriculture
SFCDP	Secondary Food Crops Development Project
SOTEC	Society for Development of Appropriate Technology
SURIF	Sukamandi Research Institute for Food Crops
t	metric ton
UPLB	University of the Philippines at Los Baños
UPWARD	User's Perspective with Agricultural Research and Development
USAID	United States Agency for International Development
VISCA	Visayas State College of Agriculture
vs.	versus
WHO	World Health Organization of the United Nations

I. Overview

This publication has three basic objectives. The first is to report on global, regional, and national trends in production, marketing, processing, and utilization of roots and tubers with particular emphasis on Asia. The second is to present an overall strategy for the successful development of new products and processes made from roots and tubers. The third is to document the progress made in processing, market assessments, or pilot plant operations in the case of particular commodities in specific Asian countries, with some additional examples from Latin America.

The document contains six sections and three appendices. The first paper in Section I (Overview) and the nine papers in Section II (Country Reports) provide a descriptive analysis of trends in production, commercialization, transformation, and utilization for roots and tubers first at the global and regional level; then, in the case of cassava and sweetpotato, at the country level. The second paper in Section I presents a strategy for new product and process development. Key components of this strategy are subsequently elaborated on in the initial papers of Section III (Assessment of Processing Potential), Section IV (Products and Processing Research), Section V (Setting Up Pilot Plants) and Section VI (Expansion into Commercial Production). The remaining papers in these sections document experiences with each of these components in Asia and in a few instances, Latin America.

Much of this publication is dedicated to documenting location-, time-, and commodity-specific experiences with developing new or improved products or processes for cassava, potatoes, and sweetpotatoes in Asia. Section I aims to provide a broader context for this material. It begins with an overview of recent trends for roots and tubers in developing countries. This is followed by the presentation of an overall strategy for processing and utilization initiatives.

The last three decades have witnessed a remarkable expansion of processing and new product development for root and tuber crops in developing countries generally and in Asia in particular. In **Transforming Traditional Food Crops: Product Development for Root and Tuber Crops,** Gregory J. Scott first quantifies these overall trends, perhaps less apparent at the project or even country level. He then examines the factors that have contributed to them. These include the agronomic and biochemical characteristics of root and tuber crops themselves; and, the evolution of production, consumption, and utilization for cassava, potato, and sweetpotato in Asia in comparison to Africa and Latin America. Special attention is given to the growth in utilization of cassava and sweetpotato for animal feed since the mid-1960s and the prospects for continued expansion in the years ahead. Scott goes on to note that future processing developments will be influenced by demographic changes, income growth, government policies, and new technologies for roots and tubers. The paper includes a bibliography of recent publications on root and tuber processing in developing countries.

In the paper **Integrated Root and Tuber Crop Projects: A Strategy for Product Development,** Christopher Wheatley and Trudy Brekelbaum briefly review essential strategic elements of an integrated project including a systems orientation, inter-institutional collaboration, multi-disciplinary focus, active participation by final users, and an emphasis on demand-driven technological research. Such elements are necessary, they argue, if improvements of the postharvest system are to benefit small farmers. They then go on to describe the stages of an integrated project beginning with problem and opportunity identification; applied research on products, processes, and equipment; a pilot project phase; and expansion to commercial-scale operation. Wheatley and Brekelbaum conclude by pointing out the benefits of such an approach and its relation to other rural development efforts.

Transforming Traditional Food Crops: Product Development for Roots and Tubers

Gregory J. Scott[1]

Abstract

Recent trends in production and utilization of roots and tubers point to a growing interest in new product development. This paper outlines the factors that have influenced the growing importance of product transformation of roots and tubers in developing countries over the last three decades. After a review of the agronomic and bio-chemical characteristics for cassava, potato, and sweetpotato, the paper analyzes global and regional patterns for production and use of these commodities. Sharp increases in potato production for fresh consumption; explosive growth in cassava processing in particular countries; and, the use of sweetpotato for animal feed in China and Brazil are highlighted. Development trends including demography, income growth and government policies are noted as key factors influencing future prospects for expanded processing.

Key words: cassava, potato, sweetpotato, production, utilization, new products, developing countries.

Introduction

The last three decades have witnessed remarkable increases in food production in many developing countries. Nevertheless, decision makers as well as members of the scientific community feel that further increases in productivity, farm incomes, and food consumption could well be realized. An emerging consensus among specialists in different disciplines suggests that this goal can best be achieved by an approach that emphasizes expanded utilization of agricultural commodities. The steps involved in this process is referred to in this publication as product development.

Product development is not a novel concept; but, on the eve of the 21st century, it has taken on new meaning in the agricultural sector of developing countries. There are many reasons for this. Perhaps, the most basic is that product development—albeit a general concept—is often associated with manufactured goods, the use of high technology, and developed countries (see e.g., Kotler 1986). The treatment here applies to food crops, both labor and capital-intensive techniques, and markets in developing countries (see also Austin 1981). In addition, the focus is on cassava, potatoes, and sweetpotatoes. These crops are frequently characterized as "traditional" or "subsistence" and not generally thought of as transformable for sale in a modern, commercial environment.

While certain modifications to the concept of product development might facilitate its application to roots and tubers, is there a justification for investing resources in this activity? The remainder of this paper addresses this issue by reviewing the different factors that contribute to the need for and advantages of this procedure for these commodities in developing countries today. It initially describes the agronomic and bio-chemical characteristics of their parent plants. This highlights the peculiar features of roots and tubers that lend themselves to—if not require, transformation to facilitate greater utilization. An analysis of production trends pinpoints those tendencies in output, area planted, and yield that suggest both the opportunity (growing supplies) and the need (declining area planted) for alternative uses for these crops. Subsequent discussion of recent changes in prevailing utilization patterns emphasizes the extent to which location specific experiences might well be put to wider use. A brief mention is made of market developments—beyond those for root and tuber crops themselves—that influence these trends before concluding with a short statement about future potential and some unanswered questions.

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The Crops and Their Characteristics

This publication focuses largely on the three major root and tuber crops: potatoes (*Solanum tuberosum*), sweetpotatoes (*Ipomoea batatas*), and cassava (*Manihot esculenta*). Other roots and tubers that are given some, albeit minor, mention include: yams (*Dioscorea* spp.), cocoyam (*taro, yautia = Colocasia esculenta*) and tannia (*Xanthosoma* spp.).

Collectively, these crops occupy about 50 million ha worldwide (Horton et al. 1984), producing over 550 million t annually, about two-thirds of which is harvested in developing countries. Cassava alone is an important food crop for some 500 million people in the Third World (De Bruijn and Fresco 1989). Cassava, potatoes, and sweetpotatoes are now grown in roughly 100 developing countries in all parts of the world. Their wide adaptability to diverse growing conditions reflects, in part, their agronomic characteristics.

Both potatoes and sweetpotatoes have a considerably shorter vegetative cycle than other root crops (Table 1). Hence they fit better into tight cropping systems than, for example, cassava which has a growing period from 9 to 24 months, depending on soil fertility and ambient temperature. Although potato yields are highest under cool conditions, the crop is grown extensively in areas with high daytime temperatures; e.g., Tunisia and Bangladesh (see Horton and Monares 1984; Scott 1988). However, potatoes do not tuberize well at night time temperatures that exceed 20°C (Midmore and Rhoades 1987). Partly for that reason, prime planting and harvesting dates for potatoes in most developing countries coincide with particular seasons during the calendar year. In contrast, sweetpotatoes, cassava, and other roots are best cultivated under higher temperatures. Potatoes require less total rainfall than cassava; but rain must be fairly continuous, particularly at the beginning and during the tuberization phase of the vegetative cycle. Drought can be devastating for a potato crop, much less so in the case of cassava and sweetpotato. For commercial yields, potatoes need much higher inputs of fertilizer and organic matter, whereas cassava and sweetpotatoes are known as crops that will produce good returns even in poor soils and without chemical fertilizers or heavy doses of locally available organic matter. Cultural practices (e.g., handling of seed, weeding, pest control) all tend to be more demanding for potatoes than for cassava or sweetpotatoes. Furthermore, potatoes can normally be left in the ground for only short periods after their prime harvesting date. Cassava is "stored in the ground," unharvested for many months by farmers in developing countries. The seasonal nature of root and tuber production is one major reason why transformation of some sort is required to enable their continuous use throughout the year. The bio-chemical characteristics of these crops constitute another.

Biochemical Traits

Perishability and bulkiness are two singular traits of roots and tubers. Fresh cassava has a dry matter content of about 40%; sweetpotatoes, 30%; and potatoes, 20%. Physiological deterioration of fresh cassava roots begins 1-3 days after harvest (Ospina and Wheatley 1991). Although potatoes and sweetpotatoes have a much longer shelf life, their harvested roots and tubers are also living organisms that require adequate respiration and proper handling to prevent sprouting, spoilage, or pest damage. While these particular bio-chemical traits present serious problems for expanded utilization of these crops, others attributes—much less frequently mentioned—offer distinct opportunities.

As Horton (1988) points out, "Root crops are often thought of as 'starchy staples' that provide low-cost energy but little else to the human diet;" and he goes on to note, this generalization is misleading. Quantities of protein, essential vitamins, and minerals vary considerably across roots and tubers. On average, cooked potatoes and yams have about 2% protein, or twice that found in cassava (Table 2). Cassava, potatoes, and sweetpotatoes all provide ascorbic acid, whereas cereal-based foods have none. Potatoes and sweetpotatoes also contain the important amino acid lysine which commodities such as rice are deficient in (Woolfe 1987, 1992). Furthermore, cassava, potatoes, and sweetpotatoes significantly outyield the cereals in dry matter (i.e., caloric production) per unit area. Potatoes are particularly productive on a carbohydrate per hectare per day basis (Table 3). These various considerations have strongly influenced production trends for roots and tubers over the last three decades.

Production Trends

Developing countries produced 137 million t of cassava, 125 million t of sweetpotatoes, and 71 million t of potatoes in 1986-88 (Table 4). Production increases for the period 1961-88 were 85%, 35%, and 146% for the three crops, although output of sweetpotatoes actually declined by 12% in the latter half of the period. Area planted to sweetpotatoes also fell sharply in recent years. However, this was more than offset by a near doubling of yields. Area planted in potatoes grew steadily

Table 1. Characteristics of root and tuber crops.

Characteristics	Cassava	Potatoes	Sweet-potatoes	Tannia	Taro	Yam
Growth period (mo)	9-24	3-7	3-8	9-12	6-18	8-11
Annual or perennial plant	per.	ann.	per.	per.	per.	ann.
Optimal rainfall (cm)	100-150	50-75	75-100	140-200	250	115
Optimal temperature (°C)	25-29	15-18	>24	13-29	21-27	30
Drought resistant	yes	no	yes	no	no	yes
Optimal pH	5-6	5.5-6.0	5.6-6.6	5.5-6.5	5.5-6.5	n.a.
Fertility requirement	low	high	low	high	high	high
Organic matter requirement	low	high	low	high	high	high
Growable on swamply, water-logged soil	no	no	no	no	yes	no
Planting material	stem	tubers cuttings	vine cuttings	corms/ cormels	corms/ cormels	tubers
Storage time in ground	long	short	long	long	moderate	long
Postharvest storage life	short	long	short	long	variable	long

Source: Derived from Kay, D.E. 1973. Tropical Products Institute. London, as presented in Horton 1988.

n.a. = Data not available.

Table 2. Nutritional composition of a 100 g edible portion of various foods.

Food[a]	Water (%)	Pro-tein (g)	Food Energy (kcal)	Protein/ Calorie Ratio (g/000 kcal)	Fats (g)	Ash (mg)	CA (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)	Thia-mine (mg)	Ribo-flavin (mg)	Niacin (mg)	Ascorbic Acid (mg)
Maize (grits)	87	1.2	51	24	0.1	0.6	1	10	0.1	205	11	0.02	0.01	0.2	0
Potatoes	80	2.1	76	27	0.1	0.9	7	53	0.6	3	407	0.09	0.04	1.5	16
Plantains	80	1.3	77	17	0.1	0.7	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]
Taro (raw)	73	1.9	98	19	0.2	1.2	28	61	1.0	7	514	0.13	0.04	1.1	4
Yams (raw)	74	2.1	101	21	0.2	1.0	20	69	0.6	-	600	0.10	0.04	0.5	9
Rice	73	2.0	109	18	0.1	1.1	10	28	0.2	374	28	0.02	0.01	0.4	0
Spaghetti	72	3.4	111	31	0.4	1.2	8	50	0.4	1	61	0.01	0.01	0.3	0
Sweetpotatoes	71	1.7	114	15	0.4	1.0	32	47	0.7	10	243	0.09	0.06	0.6	17
Common beans	69	7.8	118	66	0.6	1.4	50	148	2.7	7	416	0.14	0.07	0.7	0
Cassava	68	0.9	124	7	0.1	0.6	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	--[b]	26
Fresh white bread	36	8.7	269	32	3.2	1.9	70	87	0.7	507	85	0.09	0.08	1.2	trace

Source: US Dept. of Agriculture (USDA). 1975. Composition of foods. US Dept. of Agriculture, Washington, D.C., USA; W-T. Wu-Leung, F. Busson, and C. Jardin. 1968. Food composition table for use in Africa. US Dept. of Health, Education and Welfare, Public Health Service. Bethesda, MD, USA, as presented in Horton 1988

[a]Boiled unless otherwise indicated. Edible portions of potatoes and other root crops and plantains do not include peels.
[b]Dashes denote lack of reliable data.

Table 3. Top ranking food crops in developing market economies in terms of dry matter production/ha and edible energy and protein production/ha/day.

Dry Matter Prod/ha		Energy Prod/ha/day		Protein Prod/ha/day	
Crop	t	Crop	mj	Crop	kg
Cassava	3.0	Potatoes	216	Cabbages	2.0
Yams	2.4	Yams	182	Dry broad beans	1.6
Potatoes	2.2	Carrots	162	Potatoes	1.4
Sweetpotatoes	2.1	Maize	159	Dry peas	1.4
Rice	1.9	Cabbages	156	Eggplants	1.4
Carrots	1.7	Sweetpotatoes	152	Wheat	1.3
Cabbages	1.6	Rice	151	Lentils	1.3
Bananas	1.5	Wheat	135	Tomatoes	1.2
Wheat	1.3	Cassava	121	Chickpeas	1.1
Maize	1.3	Eggplants	120	Carrots	1.0

Source: Horton and Fano 1985.

Table 4. Food crop production in developing countries, 1961-88.

	1986-88			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Rice paddy	449,968	140,012	3.2	52.3	41.7	115.9	17.7	4.4	22.9	29.5	35.7	75.7
Wheat	214,119	98,693	2.2	79.5	84.9	232.0	19.8	11.0	32.9	49.9	66.7	149.8
Maize	184,927	82,290	2.2	72.9	54.5	167.0	21.8	13.3	38.0	42.0	36.3	93.4
Cassava	137,412	14,869	9.2	41.8	30.6	85.2	29.5	15.6	49.7	9.4	13.0	23.7
Sweetpotatoes	125,359	8,980	14.0	52.3	-12.0	34.1	-4.0	-25.6	-28.6	58.7	18.4	87.9
Potatoes	71,245	6,095	11.7	74.1	41.3	146.1	32.1	30.0	71.7	31.8	8.7	43.3
Sorghum	44,332	40,205	1.1	38.5	8.2	49.9	-1.2	-1.7	-2.8	40.1	10.[illegible]	54.2
Bananas	42,628	3,865	11.0	43.1	39.5	99.7	41.0	21.3	71.1	1.5	5.0	16.8
Tomatoes	28,669	1,529	18.8	76.8	86.2	229.1	45.2	33.7	94.2	21.8	39.2	69.5
Barley	25,073	17,612	1.4	-7.1	34.9	25.3	-15.6	2.2	-13.8	10.1	32.0	45.3
Yams	24,520	2,466	9.9	4.5	19.5	72.7	0.5	15.0	15.6	43.8	3.9	49.4
Millet	24,393	34,341	0.7	17.9	-7.5	9.0	2.4	-14.3	-12.2	15.1	7.9	24.2
Groundnuts in shell	20,264	18,457	1.1	9.0	24.5	48.1	15.3	-1.4	13.7	3.2	26.2	30.2
Cabbages	14,803	806	18.4	64.6	63.3	168.8	29.8	17.0	51.8	26.8	39.7	77.0
Beans, dry	12,739	24,196	0.5	19.9	18.8	42.5	16.3	16.6	35.6	3.1	1.9	5.1
Chickpeas	6,952	9,642	0.7	-18.4	20.8	-1.4	-16.4	0.7	-15.9	-2.4	20.0	17.1
Broad beans, dry	3,422	2,786	1.2	-22.4	-4.0	-25.5	-23.7	-21.0	-39.7	1.6	21.5	23.5
Lentils	2,283	2,802	0.8	22.2	130.3	181.3	20.9	56.9	89.7	1.1	46.7	48.3
Yautia (cocoyam, taro)	171	29	5.8	14.1	16.9	33.5	6.1	10.2	16.9	7.6	6.1	14.2

Source: FAO Basic Data Unit, unpublished statistics.

[a]1 = (1973-75 vs 1961-63); 2 = (1986-88 vs 1973-75); 3 = (1986-88 vs 1961-63).

over the last three decades—up 72% since 1961; more, in fact, than any other of the major food crops (albeit that it started from a much smaller base than the coarse grains or beans). Area in cassava production grew by about 50%. Yields improved by half that amount. Prospects for product development for roots and tubers reflect, broadly speaking, all these tendencies; however, production trends have been highly varied, not only across commodities but also for the same commodity across (and even within) regions. Statistics on the evolution of output, area planted, and yield, therefore merit closer scrutiny.

Regional Distribution

Although cassava, potatoes, and sweetpotatoes all originated in Latin America, the principal locus of their production has gravitated away from this region. Two-thirds of current developing country output of these crops is in Asia, and this distribution has tended to become more concentrated over time. This pattern largely reflects the high concentration of potato (75%) and sweetpotato (93%) production in the region. China alone produces nearly 40% of the developing world's potatoes, and over 85% of its sweetpotatoes (Tables 5 and 6).

Table 5. Potato production, area, and yield in developing countries by regions, 1961-88.

	1986-88			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Africa[b]	5,967	704	8.4	74.8	86.5	226.2	85.3	60.1	196.8	-5.6	16.5	9.9
(Sub-Saharan)[c]	2,387	444	5.3	70.2	47.5	151.1	81.6	52.9	177.7	-6.2	-3.5	-9.5
Asia[d]	53,049	4,345	12.2	90.2	39.8	166.0	40.3	35.1	89.6	35.5	3.4	40.2
(China)	27,043	2,529	10.6	99.8	4.8	109.5	41.9	24.2	76.3	40.8	-15.6	18.7
Latin America[e]	12,228	1,045	11.6	29.1	31.8	70.2	1.2	1.1	2.3	27.5	30.3	66.3
Total	71,245	6,095	11.6	74.1	41.3	146.0	32.0	29.9	71.6	31.8	8.7	43.3

Source: FAO Basic Data Unit, unpublished statistics.

[a]1 = (1973-75 vs 1961-63); 2 = (1986-88 vs 1973-75); 3 = (1986-88 vs 1961-63).
[b]Africa not including South Africa.
[c]Africa - (Morocco, Algeria, Tunisia, Egypt, Libya) - (South Africa).
[d]Asia - (Israel, Japan) + Oceania - (Australia, New Zealand).
[e]North and Central America + South America - (Canada, USA).

Table 6. Sweetpotato production, area, and yield in developing countries by regions, 1961-88.

	1986-88			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Africa[b]	6,263	1,200	5.2	44.5	25.1	80.8	72.6	7.9	86.4	-16.3	15.9	-3.0
(Sub-Saharan)[c]	6,192	1,197	5.1	46.1	25.3	83.1	73.3	7.9	87.1	-15.6	16.0	-2.1
Asia[d]	116,811	7,480	15.6	53.8	-12.9	33.9	-8.7	-29.2	-35.4	68.6	23.0	107.6
(China)	108,062	6,306	17.1	57.9	-13.0	37.3	-10.4	-31.8	-38.9	76.4	27.5	124.9
Latin America[e]	2,284	298	7.6	14.6	-28.4	-18.0	12.6	-22.4	-12.6	1.7	-7.7	-6.1
Total	125,359	8,979	13.9	52.3	-11.9	34.1	04.0	-25.6	-28.6	58.7	18.3	87.9

Source: FAO Basic Data Unit, unpublished statistics.

[a]1 = (1973-75 vs 1961-63); 2 = (1986-88 vs 1973-75); 3 = (1986-88 vs 1961-63).
[b]Africa not including South Africa.
[c]Africa - (Morocco, Algeria, Tunisia, Egypt, Libya) - (South Africa).
[d]Asia - (Israel, Japan) + Oceania - (Australia, New Zealand).
[e]North and Central America + South America - (Canada, USA).

Africa still produces nearly half (43%) the developing world's cassava (Table 7). Output of potatoes and cassava grew much faster in Africa and Asia whereas production of sweetpotatoes in Latin America actually declined by nearly 30% since 1961.

Asia has the largest number (n=37) of potato-producing countries and the heaviest concentration of big producers (Table 8). Africa has more cassava-(n=39), and sweetpotato-(n=37) producing countries. In contrast, Latin America has numerous countries that produce minor quantities (<10,000 t/yr) of cassava (n=17) and sweetpotatoes (n=21).

Sweetpotato

Although cassava, potatoes, and sweetpotatoes are grown in many more countries than perhaps is commonly realized, production is concentrated in relatively few locations. For example, 15 countries with the largest sweetpotato production account for nearly 97% of this total (Table 9) and also for 98% of the change in output since 1961.

Recent trends in sweetpotato area planted and production have been highly uneven. In a number of countries, output and area have fallen (e.g., China, Indonesia, Philippines, Brazil) since the mid-1970s. Reasons cited for this include: (1) expansion of production infrastructure (i.e., irrigation) for other crops, and (2) switching to higher value vegetable crops in response to growth in urbanization, income, and the associated demand for a more diversified diet (see e.g., Calkins 1979; Chin 1989).[2] Trends in sweetpotato production have been just the opposite in several other countries. Sweetpotato output expanded rapidly during the last decade in various locations including Vietnam, Kenya, Rwanda, Burundi, the Democratic Republic of Korea, and Madagascar. Rapid population growth resulting in increased pressure on farmland was a prime factor explaining this trend in some countries; e.g., Rwanda (see von Braun et al. 1988). Economic and political disruptions of other agricultural activities probably contributed to this growth in others; e.g., Vietnam (Mackay 1989).

More broadly speaking, 12 of the 27 countries producing the largest amounts of sweetpotato have experienced a drop in production since 1973-75. In the absence of detailed information, most observers attribute this to weak demand or the lack of alternative markets (see CIP 1988, 1988a, 1989). A recent survey of national program scientists found that, in their opinion, these two factors were by far the most important constraints to increased production (CIP 1989a).

Table 7. Cassava production, area, and yield in developing countries by regions, 1961-88.

	1986-88			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Africa[b]	59,053	8,311	7.1	36.2	36.6	86.1	27.2	15.3	46.8	7.0	18.3	26.7
(Sub-Saharan)[c]	59,053	8,311	7.1	36.2	36.6	86.1	27.2	15.3	46.8	7.0	18.3	26.7
Asia[d]	47,735	3,936	12.1	61.6	57.5	154.7	26.9	33.9	69.9	27.3	17.6	49.8
(China)	3,387	232	14.5	99.1	43.4	185.7	92.4	19.8	130.6	3.4	19.7	23.8
Latin America[e]	30,621	2,620	11.6	33.4	-3.3	28.9	39.1	-3.7	33.9	-4.0	0.4	-3.7
Total	137,411	14,868	9.2	41.7	30.6	85.1	29.5	15.5	49.7	9.4	13.0	23.6

Source: FAO Basic Data Unit, unpublished statistics.

[a] 1 = (1973-75 vs 1961-63); 2 = (1986-88 vs 1973-75); 3 = (1986-88 vs 1961-63).

[b] Africa not including South Africa.

[c] Africa - (Morocco, Algeria, Tunisia, Egypt, Libya) - (South Africa).

[d] Asia - (Israel, Japan) + Oceania - (Australia, New Zealand).

[e] North and Central America + South America - (Canada, USA).

[2] Little quantitative research has been done on the relationship between changes in income and the consumption of fresh sweetpotato roots in developing countries. Studies carried out in the Philippines (Alkuino 1983; Bouis 1991) and Peru (Collins 1989) show this relation to be much more complex than previously believed with consumers' response depending on income levels, sweetpotato varieties, place of residence and so on (see also Watson 1989).

Table 8. Distribution of developing countries by volume of cassava (C), potato (P), and sweetpotato (SP) production, 1986-88.

	Number of countries											
	Africa			Latin America			Asia			Total		
Production	C	P	SP	C	P	SP	C	P	SP	C	P	SP
0/no information	15	21	17	14	21	15	39	28	34	68	70	66
< 10,000 t	7	10	10	17	9	21	11	10	13	35	29	44
< 50,000 t	2	9	12	4	5	3	3	5	6	9	19	21
≤ 250,000 t	9	7	7	4	3	4	4	9	3	17	19	14
> 250,000 t	21	7	8	8	9	4	8	13	9	37	29	21
Total	54	54	54	47	47	47	65	65	65	166	166	166

Source: FAO Basic Data Unit, unpublished statistics.

Table 9. Sweetpotato production, area, and yield in selected developing countries, 1961-88.

	1986-88			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
Country[b]	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
China[c]	108,063	6,306	17.1	58.0	-13.1	37.3	-10.5	-31.8	-39.0	76.5	27.5	125.0
Indonesia	2,087	243	8.6	-20.9	-14.1	-32.0	-26.6	-28.6	-47.6	7.8	20.3	29.8
Vietnam	1,913	325	5.9	-4.6	74.0	65.9	-5.0	48.7	41.2	0.4	17.0	17.5
Uganda	1,698	388	4.4	201.2	2.5	208.8	209.1	-20.1	147.0	-2.6	28.3	25.0
India	1,385	172	8.1	78.2	-21.4	40.0	54.1	-22.9	18.8	15.6	1.9	17.9
Rwanda	940	131	7.2	11.9	64.7	84.3	8.5	61.6	75.4	3.1	1.9	5.1
Brazil	734	74	9.9	15.5	-55.1	-49.4	5.9	-51.6	-48.7	9.1	-9.5	-1.3
Philippines	711	150	4.8	11.8	-12.6	-2.2	17.7	-13.8	1.4	-5.0	1.5	-3.6
Burundi	619	85	7.3	-11.3	48.4	31.6	-0.5	27.1	26.5	-10.9	16.8	4.1
Korea Rep.	596	27	21.7	45.2	-64.7	-48.8	18.8	-69.6	-64.0	22.2	16.2	42.0
Bangladesh	573	53	10.8	94.9	-16.1	63.6	63.1	-17.0	35.4	19.5	1.1	20.8
Kenya	523	40	13.1	80.0	93.9	249.0	24.2	26.3	56.9	44.9	53.5	122.5
Korea DP	492	34	14.6	38.4	55.0	114.5	42.9	44.3	106.1	-3.1	7.5	4.1
Papua New Guinea	471	104	4.5	36.2	17.1	59.4	21.8	15.7	40.9	11.8	1.2	13.1
Madagascar	467	92	5.1	-14.1	76.6	51.8	0.2	59.1	59.4	-14.3	11.0	-4.8
All developing countries	125,359	8,980	14.0	52.3	-12.0	34.1	-4.0	-25.6	-28.6	58.7	18.4	87.9

Source: FAO Basic Data Unit, unpublished statistics.

[a] 1 = (1973-75 vs 1961-63); 2 = (1986-88 vs 1973-75); 3 = (1986-88 vs 1961-63).
[b] Data are for the 15 countries with the largest production.
[c] Includes Taiwan.

Potato

Fifteen of the largest potato-growing countries produce nearly 90% of the developing world's potatoes (Table 10) and account for almost 90% of the increase in production since 1961. In addition to China, the biggest growth in output has taken place in South Asia (Bangladesh, India, and Pakistan) and North Africa (Algeria, Egypt, and Morocco). The potato fits extremely well into the cereal-based cropping systems found in these countries. The introduction of improved, short-duration varieties of wheat and rice into these systems has opened up a niche in the agricultural calendar. The availability of irrigation, abundant supplies of cheap labor—particularly in South Asia—and the introduction of improved varieties and chemical fertilizers, have facilitated a rapid rise in yields and an expansion in area planted (see e.g., Chowdhury and Sen 1981; Scott 1988; Kokab and Smith 1989).

The strong internal demand for food; the desire by the vast majority of low-income consumers to diversify their diets; modest per capita consumption of potatoes; in the case of the North African countries, the highly lucrative, European export market; and, in South Asia the expansion in postharvest infrastructure (i.e., cold storage facilities) have also contributed strongly to these trends. In several Latin American countries, on the other hand, potato production has been adversely affected by drought, cheap imports of cereals, and, in the case of Chile, a shift in area planted to higher value, fruit and vegetable crops for export (see Fu 1979; Scott 1985).

Several other, less important producers have witnessed substantial increases in potato output over the last three decades (e.g., Vietnam, Syria). In these countries, as well as the aforementioned cases, policy makers and potato scientists are increasingly interested in developing alternative uses for this commodity to avoid a possible collapse in prices resulting from an abrupt saturation of the domestic market. In a recent survey, unstable prices and supplies were cited by national program scientists as the most important constraints to increased potato production (see Scott 1991).

Table 10. Potato production, area, and yield in selected developing countries, 1961-88.

	1986-88			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
Country[b]	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
China	27,043	2,530	10.7	99.9	4.8	109.5	41.9	24.3	76.4	40.8	-15.6	18.8
India	12,403	853	14.5	82.1	139.5	336.2	41.8	[illegible]	122.0	28.4	53.0	96.5
Turkey	4,217	195	21.6	55.0	81.6	181.5	28.1	7.6	37.8	21.0	68.8	104.3
Colombia	2,284	161	14.2	68.5	103.8	243.5	56.2	60.8	151.2	7.9	26.8	36.7
Argentina	2,268	109	20.8	7.4	34.6	44.5	-30.8	-8.1	-36.4	55.1	46.4	127.1
Brazil	2,161	170	12.7	37.9	39.0	91.7	-2.6	-10.6	-12.9	41.5	55.5	120.1
Iran	2,046	133	15.4	64.6	292.5	546.2	86.9	300.2	648.0	-11.9	-1.9	-13.6
Korea Dpr	1,942	149	13.0	55.2	73.8	169.7	36.4	49.3	103.6	13.8	16.4	32.4
Peru	1,824	214	8.5	17.1	7.8	26.2	2.7	-18.5	-16.3	13.9	32.3	50.8
Egypt	1,647	88	18.7	90.7	121.9	323.2	73.3	109.0	262.1	10.1	6.2	16.8
Bangladesh	1,149	113	10.2	127.3	45.5	230.7	49.5	33.4	99.4	52.0	9.1	65.9
Mexico	908	68	13.4	76.5	[illegible]	148.5	17.6	21.6	43.0	50.1	15.8	73.8
Algeria	872	101	8.6	81.1	106.1	273.3	160.7	64.6	329.2	-30.5	25.2	[illegible]
Chile	816	57	14.3	-3.4	3.1	-0.4	-16.3	-25.6	-37.7	15.4	38.5	59.9
Bolivia	781	143	5.5	45.2	1.3	47.1	9.8	19.0	30.7	32.2	-14.9	12.6
All developing countries	71,245	6,095	11.7	74.14	1.3	146.1	32.1	30.0	71.7	31.8	8.7	43.3

Source: FAO Basic Data Unit, unpublished statistics.

[a] 1 = (1973-75 vs 1961-63); 2 = (1986-88 vs 1973-75); 3 = (1986-88 vs 1961-63).

[b] Data are for the 15 countries with the largest production.

Cassava

Five countries produce 70% of the developing world's cassava: Brazil, Nigeria, Zaïre, Thailand, and Indonesia (Table 11). Thus, although cassava ranks second in Latin America in annual production (fresh weight basis) among the 19 major food crops, Brazil harvests over 75% of the regional total. Zaïre and Nigeria account for about 50% of Africa's cassava; Thailand and Indonesia for roughly 70% of all the cassava grown in Asia. As with potatoes and sweetpotatoes, however, trends in cassava production across countries have been highly uneven.

Among the nine largest producers in sub-Saharan Africa, increases in cassava output for the period 1961-88 were 80% or more in seven cases. Dorosh (1989) argues that the major factors that have contributed to the growth of cassava production in these countries include "the low labor input requirements, ability to produce a crop on degraded soils, and drought tolerance." Unlike the labor-abundant economies of Asia, most African agriculture has a much lower man/land ratio. The relatively meagre manpower needed for cassava cultivation as well as the fairly flexible cultural practices make the crop attractive to farmers with a diverse set of farm and non-farm occupations. Population pressure, shorter fallows, and the shortage of fertilizers and organic matter are added reasons growers in Africa are attracted to cassava (ibid.).

Cassava has proven to be popular in Thailand because of its high drought tolerance, stable yields, and flexible planting and harvesting dates (Konjing 1989). With the growth in exports of dried cassava to the European Community (EC), strong market demand has also been a major contributing force to the growth in production (see Phillips 1979; Sarma and Kunchai 1989). Similar agronomic factors have been responsible for the growth in cassava output in the Philippines (Cabanilla 1989). Strong rural demand for food as well as the use of cassava for animal food and manufacturing in the domestic market—the Philippines exports only negli-

Table 11. Cassava production, area, and yield in selected developing countries, 1961-88.

	1986-88			Change (%)[a]								
	Production	Area	Yield	Production			Area			Yield		
Country[b]	(000 t)	(000 ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Brazil	23,586	1,913	12.3	28.7	-8.6	17.6	37.4	-6.6	28.2	-6.3	-2.0	-8.2
Thailand	19,038	1,374	13.8	221.2	200.5	865.7	283.2	198.6	1,044.3	-16.1	0.6	-15.6
Zaire	16,251	2,205	7.3	29.0	42.1	83.4	22.3	35.8	63.7	5.5	6.1	11.9
Nigeria	14,566	1,300	11.2	32.7	44.7	92.0	23.4	29.1	59.4	7.5	12.0	20.4
Indonesia	14,379	1,398	10.2	7.3	17.3	25.9	-3.9	-3.5	-7.2	11.6	21.6	35.8
Tanzania	6,142	703	8.7	54.3	37.2	111.8	35.0	-10.1	21.3	14.2	52.6	74.5
India	5,038	269	18.6	240.3	-20.9	169.0	42.3	-27.6	2.9	139.0	9.3	161 2
Paraguay	3,411	211	16.1	31.4	160.3	242.1	25.4	138.2	198.9	4.7	9.2	14.4
China	3,387	232	14.5	99.1	43.4	185.7	92.4	19.8	130.6	3.4	19.7	23.8
Mozambique	3,363	576	5.8	23.7	33.6	65.4	20.1	11.6	34.1	3.0	19.7	23.5
Ghana	2,796	376	7.4	50.2	64.4	147.1	67.3	53.9	157.6	-10.2	6.8	-4.0
Vietnam	2,783	317	8.7	-0.6	146.2	144.5	0.6	106.7	108.0	-1.3	19.1	17.5
Uganda	2,397	341	7.0	125.4	-3.7	116.9	82.9	-35.3	18.2	23.2	48.9	83.5
Madagascar	2,295	334	6.8	30.5	83.7	139.8	19.6	71.8	105.6	9.1	6.8	16.6
Angola	1,973	500	3.9	31.2	17.9	54.7	25.2	4.1	30.4	4.8	13.2	18.6
All developing countries	137,411	14,868	9.2	41.7	30.6	85.1	29.5	15.5	49.7	9.4	13.0	23.6

Source: FAO Basic Data Unit, unpublished statistics.

[a]1 = (1973-75 vs 1961-63); 2 = (1986-88 vs 1973-75 ; 3 = (1986-88 vs 1961-63).

[b]Data are for the 15 countries with the largest production.

gible quantities—have been other important reasons behind the growth in production. The Indonesian case presents both elements. Cassava exports are considerable in volume and value terms.[3] Roughly 35% of domestic output goes to the local starch industry for human consumption (see Kasryno 1989).

In Latin America, growers in Brazil have switched to other more profitable crops which, in turn, reflects weak demand; hence the decline (8.6%) in production and area planted (6.7%) between 1973 and 1988. Prospects for expanded utilization of cassava in northeast Brazil appear to have slowed, if not reversed, this trend in recent years (see Ospina and Wheatley 1991). The Brazilian experience with cassava—combined with similar developments in Colombia and Ecuador in Latin America (see Best and Wheatley 1990), as well as in Thailand and Indonesia in Asia—have contributed to renewed interest in the evolution of utilization patterns for roots and tubers generally.

Consumption and Utilization

Roots and tubers are often thought of as food crops first and last. While more than half of production goes for human consumption in fresh form, the share of output devoted to different uses varies considerably across crops, regions, and countries. Furthermore, utilization patterns for sweetpotatoes and, to a lesser extent, cassava have experienced noteworthy changes over the last 30 years. For example, processing for animal feed has assumed major importance in a number of countries. These trends, and prospects for similar developments in the future, mean consumption and utilization patterns for roots and tubers are the focus of increasing scrutiny. It also should be noted, however, that estimates of "processing" or "waste" as a percentage of root and tuber production are difficult to interpret. In many countries, waste in the form of damaged roots and vines is processed or fed to livestock. On the other hand, some production is lost due to physical or autolytic processes, microbiological attack, and pest damage (see NAS 1978). Furthermore, given the higher water content and bulkiness of roots and tubers, postharvest losses would appear to be higher than for the cereal crops (see Coursey 1982). But little quantitative information is available other than that based on inferences of an a priori type (e.g., sweetpotatoes are perishable; therefore, a certain percentage of the harvest is lost) or desktop "guesstimates." Consequently, available statistics must be interpreted with caution.

An estimated 80% of potato production in Latin America is for human consumption versus 73% in Africa and about 56% in Asia (Table 12). FAO Food Balance Sheets statistics indicate these percentages have remained constant over time. Potatoes are eaten in one of four different ways in the tropics: as a basic staple, a complementary vegetable, a seasonal vegetable, or a delicacy to be consumed on special occasions (Poats 1983).

In most countries, potatoes are a seasonal vegetable or a delicacy. They are the centerpiece of the diet only in the highlands of South America and parts of Central

Table 12. Changes in utilization (%) of cassava (C), potatoes (P), and sweetpotatoes (SP) in developing countries, 1961-88.[a]

	1961-63			1973-75			1986-88		
Utilization	C	P	SP	C	P	SP	C	P	SP
Food	69.5	63.4	74.4	68.7	60.7	69.2	71.0	61.4	54.8
Feed	13.0	13.0	10.0	14.0	17.0	16.2	12.0	14.8	29.4
Processing[b]	0.0	2.2	3.8	0.1	3.9	4.0	0.7	5.4	4.4
Seed	0.0	13.3	3.7	0.0	10.3	2.4	0.0	9.4	2.9
Waste	13.8	7.9	8.1	14.0	7.9	8.2	13.8	8.9	8.6

Source: FAO Food Balance Sheets, unpublished statistics.

[a]Totals may not add up to 100 due to rounding.

[b]Includes other uses.

[3] Exports of *gaplek* (i.e., dried cassava chips base) have fluctuated between 149,000 and 710,000 t since 1970. In 1986, 97% of these exports were to Germany (see Kasryno 1989).

Africa. What is noteworthy, however, is their rapidly expanding role as a complementary vegetable in South Asia (e.g., Pakistan, India, and Bangladesh), in North Africa (e.g., Egypt, Tunisia) and in eastern and southern Africa (e.g., Kenya, Rwanda, and Madagascar). Most consumers like the taste of potatoes, but find them too expensive to eat on a daily basis.

Traditional or simple rustic processing of potatoes for human consumption is a common practice in Peru, Bolivia, and, to a lesser extent, Ecuador. Typically potatoes are solar dried (see Yamamoto 1987). A modernized version of such practices has also been tried in Colombia (Mantilla 1988) and Guatemala (Esquite and Perez 1990). Simple processing of potatoes is also practiced in Madagascar on a limited basis (Rasolo et al. 1987) and is being tested experimentally in Cameroon (Nave 1989) and Zaïre (Ruvuna 1990). Potatoes are processed at the village-level in Bangladesh, India, and Pakistan (see e.g., CTI n.d.; Sikka 1988).

The potato tends to be a relatively costly commodity in most developing countries. Hence the value added involved in transformation makes them prohibitively expensive as processed food products for all but the highest income households, or simply non-competitive vis-à-vis cheap substitutes for industrial use (as starch) or livestock feed (see e.g., Gomez and Wong 1989). China is an exceptional case where a growing share of potato production goes to noodle-making, flour, and snack foods (Gitomer 1987).

Producer prices for potatoes in relation to unit production costs have generally been quite favorable as witnessed by the sharp increase in area planted in Asia, sub-Saharan Africa, and parts of Latin America. As a result, only in the last decade or so have bumper crops for potatoes in a number of countries stirred an interest in serious attempts to develop alternative market outlets.

Growth of the fast food industry in Southeast Asia, Central America, Mexico, and parts of South America (Colombia and Brazil) represent an exception to this scenario. Strong demand for potatoes in this particular market niche in these locations appears to override cost considerations in the short-run and serves as an attractive financial incentive to expand local supply to cater to industry needs in the medium term.

Feed statistics in great measure reflect the substantial use of potatoes in China for pig feed. Most of this involves the use of small, decayed tubers and vines (see Gitomer 1987). Feed use of potatoes in Africa and Latin America is negligible and largely confined to on-farm utilization of non-marketable tubers.

Sweetpotato Utilization

Utilization patterns for sweetpotatoes have undergone some major changes in the last three decades. While over 50% of the output still goes for human consumption in fresh form in all three regions, nearly 30% of the production now serves as animal feed (Table 12). Processing of sweetpotatoes for human and industrial use has also attracted growing interest.

Much less is known about consumption patterns for sweetpotatoes than cassava or potatoes (Horton et al. 1984). It is considered a "poor man's food" or a survival crop in many parts of Latin America, Africa, and Asia (see e.g., Collins 1989; Watson 1989). However, it is also eaten as a seasonal vegetable and, under certain market conditions, actually can be sold at a higher price than potatoes (see e.g., Maggi 1990).

Sweetpotatoes are most commonly boiled in developing countries. In China, for example, they are peeled and cooked with rice in a breakfast porridge. They are also served fried, roasted, or mashed. Sweetpotato leaves or "tips" are a delicacy in the Philippines, as well as an important supplementary source of essential vitamins and minerals at certain times of the year.[4]

Sweetpotato processing for human consumption is also remarkably diverse and widespread (Woolfe 1992). Some 5-10% of annual production in China is processed into noodles, starch, chips, and candy (see Tang et al. 1990). Ketchup, a soft drink, cakes, and candies are all made from sweetpotatoes in the Philippines (see Truong 1989). *Dulce de batata*, a cheese-like sweet, is among the most popular dessert dishes in Argentina (Boy et al. 1989). A recipe substituting grated, fresh sweetpotatoes for imported wheat flour has gained a foothold in the Peruvian bread market (Cavero et al. 1991). These are but a few of the most noteworthy examples.

Sweetpotato is almost always used—in some form, in some amount—as an animal feed wherever it is produced in developing countries. FAO statistics indicate sweetpotato use for animal feed is 40% of total output in China, 35% in Brazil, 30% in Madagascar, 17% in the Republic of Korea, and 5% or less in the

[4] Personal communication, Dr. Howarth Bouis, International Food Policy Research Institute (IFPRI), Washington, D.C.

remaining 11 of the 15 largest sweetpotato producers. The estimated percentages have remained stable during the last three decades in all the countries except China (12% in 1961-63) and Korea (2% in 1961-63). However, recent Chinese estimates indicate as much as 35% of sweetpotato output now goes to animal feed.[5] Explanations for this sharp increase include growth in cereal production—meaning fewer sweetpotatoes are needed to supplement cereal consumption; rising demand for meat products (principally pork) for which sweetpotatoes serve as a feed component; and changes in government policy; e.g., the introduction of the "responsibility system," which permits the sale of agricultural surpluses for profit. Furthermore, an EC bilateral agreement allowed China to export up to 600,000 t of dried sweetpotato chips to member countries duty free during the 1980s (see Calpe 1991).

Roots for pigs and vines for cattle are the most commonly cited forms of sweetpotato utilization as animal feed in Asia as well as in Africa and Latin America (Scott 1991a; Woolfe 1992). Both are employed in a variety of ways. Many sweetpotato farmers in northern China slice and then dry the roots before using them as pig feed (Lu et al. 1989). This type of simple processing often takes place in the field itself. Slicing, then sun-drying the roots, is a well-known procedure for production of pig feed from sweetpotatoes in Taiwan (Calkins 1979; Tsou et al. 1989). It has also been done—although on a more limited basis—in the Philippines (Palomar et al. 1989) and Vietnam (Hoang et al. 1989).[6] Virtually all feed production from sweetpotatoes takes place at the farmer or village-level. Only limited quantities of composite feeds are produced industrially.

Cassava Utilization

About 80% of cassava production goes to human consumption in Africa and Asia. Less than half of cassava output is eaten fresh in Latin America. According to FAO estimates, these percentages have remained stable over the last three decades (Table 12).

Although processing of cassava into dried chips for animal feed in Asia has attracted great attention (see Phillips 1979; Calpe 1991), on a fresh weight basis, Latin America uses six and half times the volume of cassava for feed purposes (1.7 vs 11.2 million t). The attention-getting in Asia has materialized because a hefty share of fresh cassava has been dried into chips for export to the EC. This highly lucrative market has spawned huge increases in production in selected countries, most notably Thailand, and has infused a profit-seeking dynamism into the processing sub-sectors for this commodity in several Asian economies. Price supports and subsidies to locally produced feed inputs as well as cheap imports—both largely the result of government policy—have dampened the stimulative effects on of a mushrooming demand for meat products on cassava production and processing in Latin America (see Lynam 1989).

The role of fresh cassava in the diet varies from that of a basic foodstuff among rural households in Central and West Africa, parts of South Asia, Latin America, and the Far East to a high-priced vegetable in urban markets in many of these same locations (Horton et al. 1984). The form in which cassava is consumed varies considerably.

In Latin America, Lynam (1989a) observes that the roots are traditionally eaten in one of three principal ways: fresh (boiled or fried); as a roasted flour called *farinha de mandioca* particularly in North and Northeast Brazil and neighboring territories; and, as a type of unleavened bread called *casabe* in the Caribbean basin (see also Lancaster et al. 1982). In sub-Saharan Africa, cassava roots are consumed fresh as a major staple in many areas or eaten as a vegetable in others (Dorosh 1989). Cassava leaves are also eaten as a vegetable particularly in Central Africa. *Gari*, a dry granular meal made from fermented cassava is the most common form of cassava consumption in West Africa. Dorosh (1989) estimates that "...*gari* may account for more than 70% of cassava consumption in Nigeria, 40-50% in Cameroon, 40% of consumption in Ghana, 30% in Côte d'Ivoire." Other common forms of cassava consumption include a sun-dried cassava flour (called *lafun* in southwest Nigeria) and a sticky *purée* or heavy soup made from fermented cassava (Nigerian *fufu*). In East Africa, cassava is commonly made into a flour from dried roots or chunks of roots.

According to George (1989), baked roots are the principal form of cassava consumption in India. He also observes that cassava is used in small amounts "...to make chips, flour, and *sago*, a type of wet starch that is roasted, dried, and finished." In Indonesia, cassava roots are eaten boiled, fried, or steamed (Kasryno 1989). They

[5] Personal communication, Prof. Z. Tang, Crop Research Institute, Sichuan Academy of Agricultural Sciences (see also Tang et al. 1990).

[6] In the Philippines, drying and slicing the roots has apparently not been profitable (see Palomar et al. 1989).

also are processed into *gaplek* (dried cassava chips) and starch.

Cassava has three other important uses in developing countri . animal feed for the domestic market; industrial purposes such as in starch and glue; and dried cassava for export. In sub-Saharan Africa, only negligibly recorded quantities of cassav go to these uses.[7] Feed (37%) and other non-food uses (7.6%) account for almost half of cassava output in Latin America. About 10% of cassava availability in Asia is for feed and processing. Asia annually exports another 20 million t fresh weight in the form of dried cassava—nearly the equivalent of regional production—primarily to Europe. This latter type of use has been the most dynamic, increasing from an average of 1.7 million t (in fresh roots) annually in 1961-63 to 20.3 million t in 1981-83 (Sarma and Kunchai 1989).[8] Unfortunately prospects for increased, if not at least continued, cassava exports to Europe and possibly other developed countries are overshadowed by impending changes in trade agreements; i.e., European unity in 1992 and the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). These developments suggest this type of cassava utilization has limited potential for expansion because of the possible abolishment of special trade arrangements that facilitated its emergence and growth. Partly for that reason, attention has increasingly focused on the internal market for cassava-based products in many developing countries.

Dry cassava for inclusion in concentrated feed rations has established itself as a growth node for rural development projects in parts of Colombia, Ecuador, and Northeast Brazil over the last ten years (see Best and Wheatley 1990; Ospina and Wheatley 1991). The success of these efforts has generated questions about the feasibility of replication in other parts of the developing world. This will depend on future developments in a number of key areas.

Future Developments

In addition to changes within the cassava, potato, and sweetpotato economies of developing countries, prospects for product development for roots and tubers will be greatly influenced by a series of other factors. These include demographic changes; growth in incomes; availability of substitute food and feed sources; the evolution of the market for derivative products (e.g., meat, processed foods); government agricultural and trade policies; and, improved production and processing technology.

Demographic Changes

With the notable exceptions of China (1.3%), Brazil (1.8%), India (1.8%), Indonesia (1.7%), and the Philippines (1.9%), most developing countries have projected population growth rates of well over 2.0% for the period 1989-2000 (World Bank 1990). Since the vast majority of these households are located in rural areas, the resulting pressure on land has important implications for both production and utilization of food crops. Growers will be compelled to modify their cropping patterns to give greater importance to higher yielding commodities, to bring more marginal land into regular cultivation, and to seek out ways for converting raw materials into higher valued products.

The demand for food, both on and off the farm, as well as the aspirations for the fullest possible exploitation of available production will stimulate farm families to reduce postharvest losses due to dehydration, spoilage, or pest damage. The incentives to convert what cannot be readily sold or consumed at harvest into marketable products should be formidable. In this regard, Coursey (1982) notes that there is great potential to combine the acquired ingenuity of traditional practices with the formal knowledge derived from modern science.

Urbanization will also have a strong influence on product development. Nearly one in three consumers in developing countries now resides in urban areas. Furthermore, rates of urbanization are two to three times the rates of population growth. For roots and tubers to compete more effectively with alternative commodities, e.g., to reduce transport costs, they will have to be processed in more significant quantities. Alternatively, urban consumers will increasingly demand food items that are easier to prepare and preserve. Changes in eating habits will also manifest themselves in greater demand for more diversified diets, i.e., less plant food and more livestock products, particularly meat. As a result, the established market niche for roots and tubers as animal feed could convert itself into a substantial share in the form of ingredients for feed concentrates.

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[7] FAO Food Balance Sheet statistics indicate less than 2% of cassava production goes to feed use or processing.

[8] Thailand alone accounted for 17.6 million t, China 1.5 million t and Indonesia 1.1 million t in 1981-83 (Sarma and Kunchai 1989).

Income Changes

Income changes have a somewhat more paradoxical effect on the outlook for product development. For example, rapid income growth may make the consumption of fresh roots and tubers less attractive to certain types of consumers; but then processed products such as french fries could become more affordable. Moreover, rising incomes typically increase the demand for meat products. Processed roots and tubers already serve as an important component in animal feed in many developing counties. Furthermore, this use has expanded as countries have been unable to expand feed production from cereal crops to satisfy mushrooming demand. China is a prime example (see Gitomer 1987).

Government Policies

Many countries have experienced dramatic reversals of government policy with regard to food and feed imports over the last few years, partly as a result of changes in world markets, the burden of accumulated debt, or in an effort to create more opportunities for domestic agricultural production. Similar changes in the years ahead will strongly influence the potential for root and tuber crops as processed products.

Several of the agro-biological and socio-economic factors outlined above will take time for their full impact to be felt. In the meantime, the prospects for the expanded use of roots and tubers as processed products would appear to be greatest in those regions and countries where a substantial supply of the commodity already exists, where food and/or feed shortages have already materialized, and where continued or expanded imports of food or feed do not appear to be sustainable for economic or political reasons. In the case of roots and tubers for animal feed, a number of countries in Asia (e.g., sweetpotatoes in China, see Gitomer 1987) and to a lesser extent in Latin America (e.g., cassava in Brazil, see Ospina and Wheatley 1991) would appear to meet these criteria. Preliminary indications also suggest an emerging market for processed potatoes in Central America and Southeast Asia. The prospect of accelerated changes in government policies—with the attendant impact on production and utilization patterns for roots and tubers—raise further questions about the potential for future technological improvements for these commodities.

Technical Change for Roots and Tubers

Improvements in yield, dry matter content, and digestibility of cassava, potatoes, and sweetpotatoes should make them increasingly more attractive as a primary material for processed products for human food and animal feed. For example, average yields for sweetpotatoes in developing countries doubled over the last 25 years, primarily because of developments in China (Table 1). Yet, the yield increases in the People's Republic appear to have been largely the result of changes in cultural practices, i.e., increased plant density, rather than the utilization of improved varieties or chemical fertilizers and pesticides (Mackay 1989). This is partly explained by the fact that up until recently sweetpotatoes have received relatively few resources for research and development (R&D). Relative to the value of production, funding for sweetpotato research worldwide has been lower than that for any other major food commodity (see Gregory et al. 1989). Average potato and cassava yields in developing countries are also well below what is technically possible. Potato productivity is about half that found in most developed countries. Cassava yields in sub-Saharan Africa are 50% less than those in Asia (Table 7).

Most sweetpotatoes currently cultivated in developing countries have a dry matter content of around 30%. Results of research at the Asian Vegetable Research and Development Center show that "...the mean dry matter content of breeding lines improved from 25.9% to 35.1% in five years. Theoretically this program increased chip yield for animal feed by 40%..." (Tsou et al. 1989). Moreover, the international germplasm collection for this crop includes varieties whose dry-matter content is as high as 45%.[9] Similar observations apply to cassava and potatoes. Consequently, the potential is there to raise the processing utility of these crops by incorporating varieties with higher dry matter content into the material available to growers.

Conclusion

Root and tuber crops have considerable unrealized potential as new products for human, animal, and industrial use as manifest the remarkable increases in their utilization in processed form in a number of developing countries over the last three decades. Several indicators point to an accelerated trend in this direction for these

[9] Personal communication with Dr. Zosimo Huaman, Dept. of Genetic Resources, International Potato Center (CIP).

commodities. Among the factors contributing to this emerging pattern are the agronomic and biological characteristics of the crops, recent trends in production, and developments beyond the food systems for these particular commodities. Because these factors encompass a diverse set of considerations (e.g., agronomy, demography, livestock production), the potential for developing new products from roots and tubers in any particular situation will depend on a knowledge of elements from different disciplines as applied to local circumstances. The remainder of this volume is dedicated to the presentation of this approach referred to as product development. It also includes country reports on the recent experience with particular commodities in this regard as well as papers that examine the results of specific attempts to transform roots and tubers into more readily marketable products.

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Integrated Root and Tuber Crop Projects: A Strategy for Product Development

Christopher Wheatley and Trudy Brekelbaum[1]

Abstract

Integrated projects have often proven to be a successful strategy for developing new products for roots and tubers in developing countries. This paper briefly reviews the essential elements of an integrated project including a systems orientation, inter-institutional collaboration, multi-disciplinary focus, active participation by final users, and an emphasis on demand-driven technological research. The paper goes on to describe the stages of an integrated project beginning with problem and opportunity identification, applied technical research, a pilot project phase, and then commercial-scale expansion. The paper concludes by noting the benefits of the integrated project approach as well as its relationship to broader, integrated rural development efforts.

Key words: postharvest technology, research, roots and tubers, developing countries, new products and processes.

Introduction

As can be seen from the previous paper, root and tuber crops have a tremendous potential for contributing to socio-economic development of rural areas. To realize this potential, an efficient combination of new products, prices, distribution systems, and promotion *foci* needs to be designed. When doing this, it is essential to bear in mind that the scale of these elements must be appropriate for root and tuber crop farmers who have mostly small or some medium-sized operations, and who generally have weak links to processing technology and non-traditional markets.

One strategy that has proven highly successful is that of integrated projects. These permit the agro-industrial transformation of the crop by linking improved production and processing technology, marketing techniques, and institutional innovations in processes requiring technical and socio-economic integration. In short, improvement in postharvest systems will not be achieved solely through the generation of technological innovations. Other components such as farmer organization and training, provision of credit, establishment of efficient distribution channels, and inter-institutional coordination and cooperation are all important aspects to be considered.

Essential Strategic Elements

Based on experiences in developing postharvest hanling, storage, and processing technologies for root and tuber crops, the following elements are considered essential for integrated development projects.

Multi-sectorial Integration

Simultaneous treatment of production, processing, and commercialization processes is key to the integration of a project. Although the manner of articulation will vary chronologically, what is important is that they are all part of a single process. This "systems orientation" for technology development should extend from produc-

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tion to include storage, processing, and utilization of the crop. The production and postharvest systems should not be divorced and developed separately since they can serve as a means of relating the producer to the final consumer for their mutual benefit. An optimum path to accelerate agro-industrial diversification of root and tuber crops, while activating producers' groups, is around inte-grated projects.

Inter-institutional Integration

Successful adoption of postharvest technology requires the close interaction of research and development (R&D) institutions in both the public and private sector throughout the process of technology generation and transfer. The most important interaction comes at the pilot project stage when researchers may test and adapt the technology; subsequently, extension workers can modify institutional and organizational schemes to facilitate technology transfer in close collaboration with farmer associations or coops. Private sector input can be particularly important in adapting technology generated by research institutions for commercial-scale production.

Functional integration also includes the articulation of technical, financial, and entrepreneur-ial assistance. The quality of assistance depends on the existence of a good general strategy and clear guidelines for managing the program, particularly where there are multiple organizations with different resources, loyalties, objectives, and strategies. Integration is coordinated around common objectives and activity plans. The more institutional participation there is in planning the program, the better will be the chance for success.

Multi-disciplinary Focus

Analyses of the potential role of root and tuber crops require a multi-disciplinary focus in order to conduct R&D research, determine the production potential, cost structures, competitive prices, and the potential demand for the crop and products based on the analyses, existence of local farmers' groups, institutional presence, and other important factors.

Individual R&D institutions rarely have sufficient resources to have a full-fledged staff with expertise in a wide range of disciplines. This is where creative arrangements can be made by setting up public and private sector inter-institutional working groups around specific tasks, benefitting from the disciplines available. When the Visayas State College of Agriculture (ViSCA) in the Philippines developed a sweetpotato beverage, for example, they entered into an arrangement with a large food and beverage company whereby a multi-disciplinary team was created between the two institutions. Thus, it was possible to bring together the expertise of a food product development specialist, a process development engineer, a marketing specialist, a fruit processing plant manager, an agricultural extension specialist, and the ViSCA researcher/ inventor for the scaling-up process.

Participation

When selecting a project site, a key criterion is the existence of producer groups that are interested in the program and that have the capacity to work with it. Project administrators need to analyze what incentives will stimulate farmers' participation and how much they are willing to sacrifice to work toward the objectives.

Active participation of root and tuber crop producers and processors in the planning and execution of activities increases the technical and economic efficiency of the programs. Participation is basically an apprenticeship process. Producers, administrators, and technicians need to interact in order to learn each other's perspectives, farmers' felt needs, and organizational capacities.

The long-term impact of the program depends on the producers'/processors' capacity to assume full responsibility for the operation and maintenance of processing activities implemented by the program. They need to know-how to discuss constructively, speak in public, negotiate, identify and solve problems, be familiar with technology and the market, know-how to administer resources and keep accounts, make efficient investments, and plan future activities. This capacity is created gradually through their daily involvement in solving problems, working in groups, and training new members.

Demand-driven Technology

Postharvest technology development should be based on the existing or potential demand for a product. The demand for a product implies the existence of a consumer who should be the starting point for the development of new or improved processes or products. The socio-economic status, habits, and preferences of the consumer are guides for the type of R&D work that will be carried out. This information will not only influence process and product design, but eventually crop production technology, as well.

Objectives of an Integrated Project

- Catalyze series of inter-institutional interventions to generate socio-economic development of a region and improve the incomes and well-being of root and tuber crop farmers.
- Provide technical assistance services and training related to root and tuber crop production, processing, and commercialization.
- Promote the formation and strengthening of farmer associations involved in root and tuber crop production and processing.

A Model for Postharvest R&D

Successful technology generation and transfer has required disciplinary, institutional, and sectorial integration in all phases of the processfrom opportunity identification, through product and process research, testing and adaptation, and ending in the final commercial introduction or adoption of the technology. This integration, which does not normally occur spontaneously, is best achieved within a project framework, with clearly defined objectives, activities, and responsibilities for each participating institution. There are four distinct phases, which are briefly dealt with here.

Problem and Opportunity Identification

The approach to postharvest R&D for roots and tubers undertaken by the International Agricultural Research Centers (IARCs) and their national counterparts is market orientated. It is based on identifying unsatisfied consumer needs; that is, problems and opportunities. At the same time, it is meant to solve the production and postharvest problems of root and tuber crop farmers who have mostly small or some medium-sized operations.

Research on Products and Processes

This is the stage in which market studies and consumer research are carried out in order to identify the demand and required characteristics of the selected product. Technical research is undertaken on the product itself and on the development of the process for its production.

Root and tuber crop producers cannot assume the costs of R&D; therefore, inter-institutional linkages become important in order to take advantage of technological developments in production and processing as well as advances in commercialization and promotion systems, within an atmosphere of minimizing risks for small farmers. In the Latin American situation, market and consumer studies have been carried out by local institutions with support from IARC social scientists. The technical research that is undertaken may be both basic and applied in nature. Since the IARCs and National Agricultural Research and Development Systems (NARDS) have limited resources to undertake research, they seek to enter into collaborative projects with food science and technology institutions that can provide specialized capital and human resources. Links have been formed with institutes and universities in both developed and developing countries.

Pilot Project

Once a processing or conservation technology has been thoroughly tested at the experimental level and the market and consumer studies indicate that a demand for the product exists, a pilot project is initiated. The objective of a pilot project is to introduce, into a specific growing region and on a reduced scale, both the postharvest technology that has been developed and the associated production technology that will enable farmers to increase crop productivity and reduce costs. This is achieved by adopting an approach in which production, processing, and marketing activities are linked within the same project framework.

The pilot stage is used to evaluate the technical, economic and operational feasibility of the postharvest technology under real conditions. At the same time, suitable market channels for the product are identified and preliminary promotional activities are undertaken. It is important to ensure that the product can meet the quality specifications as required by the potential clients. Experience is also gained in aspects of farmer organization and training which may be employed in the expansion stage to follow. Concurrently with the activities in the area of processing and marketing, production research is carried out both on-farm and at local experiment stations. At the end of the pilot project stage, sufficient firsthand data are available to formulate a proposal for a full-scale root/tuber-based development project.

Pilot projects can also provide a framework within which the IARCs can interact with NARDS. This interaction permits the validation and adaptation of existing production and postharvest technology, together with the techniques that have been developed for market analysis. Especially useful is the possibility of feedback, so that the research carried out by the IARCs and NARDS may be constantly adjusted or reoriented according to the requirements of the differing ecological or socio-economic conditions in each country. This mechanism is invaluable for improving the relevance of research.

Donor agencies have recognized the importance of pilot project testing and adaptation of production and postharvest technologies, therefore, funds can now be readily obtained for carrying out these activities. The IARCs also provide training to NARDS staff in formulating proposals to be presented to these agencies.

Commercial-scale Expansion

The experience of the pilot project stage provides the foundations from which to replicate or expand the use of the technology. Given the real cost of the technology is now known, the resources required to obtain its adoption on a wider scale may be calculated. This includes provision of credit for root/tuber production and the establishment of a processing capacity, the institutional requirements necessary to provide training and technical assistance to farmers and those involved in processing, and a plan for the efficient distribution and promotion of the product. The formation of second-order farmer/processor organizations to coordinate such activities as marketing, farmer training, and credit provision is often essential.

An important activity at this stage is to establish a monitoring system to determine exactly how the benefits of the introduced production and postharvest technology are being distributed. Such a system should be incorporated into the pilot projects so that the national executing agencies may assess the advance of the project and introduce any modifications in its orientation that may be necessary.

During this phase, administration of the project passes into the hands of the beneficiaries themselves. Throughout this process, crop producers and processors increasingly take over responsibility, until their association assumes complete control over the project. The project may be used as a model for the training of project personnel and participating farmers.

Benefits of an Integrated Approach

An integrated root and tuber crops project is valuable for improving the crop production system. It is also useful for mobilizing people around community development problems. The project creates enthusiasm and confidence in the participants' capabilities. This increases enormously the power of all parties involved, including small farmers, researchers, development agents, and public administrators. The integrated project is an important vehicle for reinforcing, stabilizing, and expanding local-level capacity to solve problems that previously inhibited social development. It is a way to generate conditions for economic and social development that will respond primarily to local needs and opportunities, after which it adopts regional and national projections.

Conclusion

The integrated project simultaneously addresses aspects related to production, postharvest treatment, and marketing of the crop. Nevertheless, none of these aspects is an end in itself; they are essential components that must be systematically articulated to develop a commercial product and make it accessible to the consumer. The integrated project defines the tasks of production and processing in such a manner that they are conceived and implemented as a part of the product development task. Product development is oriented in accordance with the specific characteristics of a final market and interprets the effectiveness of its actions from the standpoint of objectives that go beyond what is strictly agricultural.

Commercial acceptance of the final product is the element in which the activities of crop production, processing, and commercialization are integrated, and to which they are oriented. Therefore, the methodological starting point of the integrated project is the interface between the final product and the consumer; a contact that is established after commercialization and is essential for effective marketing. Hence the characteristics that consumers attribute to a product that they wish to acquire mark the critical starting point.

This methodological organization does not contradict the existence of an internal process in which the production, utilization and commercialization components each have a temporary preeminence in the process of final product development. On the one hand, it is possible to consider these functions as "episodes" (even parallel ones) at the rate in which they are integral—albeit distinct—parts of the whole. On the other hand, the functions of production, processing, and commercialization take turns in assuming the role of "leader" during the process of creating the final product. In all cases, the individual efficiency of each component strongly affects the results of the entire integrated project.

Integrated root and tuber crop projects require high levels of commitment, social participation, and administrative performance. In an integrated project, the design of effective organizational strategies for implementation is emphasized. This assumes an evaluation and refinement of systems that will gradually transfer power to farmers so they can autonomously administer root/tuber crop-based agro-industrial enterprises and also provide the general direction of the regional development that these enterprises will generate. The project also requires accentuating technical, administrative, and organizational training for farmers. Finally, it identifies channels and models for establishing cooperation between the various public and private institutions that offer support services in technology generation, product design, technical extension, credit, and marketing and promoting products.

An integrated root and tuber crops project has elements in common with integrated rural development (IRD) programs. Both emphasize the relationship and mutual support of economic and social development and the importance of active beneficiary participation. For both, decision mak-ing is a multi-faceted process because they seek multiple objectives at different levels. Hence the programs need to use multi-disciplinary teams. Both programs explicitly identify the rural poor as their principal clients. As a result, they seek to raise employment and income levels, to promote more equitable distribution of income, and to increase access to services for the less privileged sectors.

Nonetheless, an integrated root and tuber crops project differs from an IRD program. First, an integrated root and tuber crop project concentrates its activities in a reduced geographic area and seeks narrower objectives than those of an IRD program. A root and tuber crop project can therefore be incorporated with IRD. Second, an integrated root and tuber crop project requires public and private investment, but, above all, it is a technology-induced development program. The element that releases development is not so much the infusion of capital for infrastructure or operations but the adoption of technology. Technological innovations permit the exploitation of a series of national resources, especially local ones, that previously were underused.

II. Country Reports

National trends in production, marketing, processing, and utilization of cassava and sweetpotato in selected Asian countries are the subject matter of this section. Similar patterns are also discussed for aroids in the South Pacific countries. Such information complements the descriptive analysis of the aggregate data in the previous section by providing more detail about particular commodities. The country reports also identify contributing factors or limiting constraints to product development for roots and tubers in specific locations.

Cassava is the third most important food crop in Indonesia. Sweetpotato is a secondary crop nationwide; but, in Irian Jaya, it is a staple food. In the paper **Sweetpotato and Cassava Development: Present Status and Future Prospects in Indonesia**, Agus Setyono, Djoko S. Damardjati, and Husni Malian provide an overview of recent trends in production and utilization for these two commodities. Regional differences in consumption and marketing are also noted. Traditional processing techniques are described. While considerable potential for expanding production of these two crops exists, the authors contend that this will depend in large part on expanding and diversifying processing activities.

Sweetpotato ranks fourth as a food crop following rice, wheat, and corn in China with an annual production of about 110 million t. In **Sweetpotato in China**, Li Wei Ge, Wu Xiuqin, Cai Huiyi, and Du Rong outline trends in planted area, production, and yield (including maps); changes in market demand; and examples of current processing techniques as well as problems being faced. Important changes in government policy are also noted. Approximately 75% of sweetpotato output in China now goes to feed (30%) and processing (45%), a remarkable change from an emphasis in the 1970s on direct human consumption.

Thailand is the world's largest cassava producing country with about 23 million t of fresh roots, valued at nearly US$ 950 million. In the paper **Cassava Processing and Utilization in Thailand**, U. Cenpukdee, C. Thiraporn, and S. Sinthuprama note that cassava is utilized mainly for starch, and chips and pellets for export to the European Community (principally the Netherlands) to make pig feed and modified starch. They go on to document the rapid rise in fresh cassava output in response to foreign demand during the last two decades. They also describe more recent efforts at diversification in the Thai cassava processing industry to reduce dependence on the European market.

Sweetpotato is a minor crop in Thailand with annual production between 50,000 t to 100,000 t. As explained in the paper **Sweetpotato Production and Utilization in Thailand** by Saipin Maneepun and Sumalee Soontornnarurungsi, sweetpotato flour is currently being used to make noodles for export to Korea and Japan. According to the authors, this and other processing activities could be scaled up if yields, agronomic practices, and the quality of sweetpotato being supplied to processors could be improved.

Vietnam annually produces over 2.1 million t of sweetpotato and 2.6 t of cassava. As Quach Nghiem states in **Cassava and Sweetpotato Processing, Marketing and Utilization in Vietnam,** some 65% of these roots are used for animal feed. While sweetpotato is used for feed in fresh form, dried cassava is an important source of feed for pigs and other animals. Most utilization takes place in the farmer's own household. For cassava and sweetpotato to reach their full potential, Quach Nghiem indicates that more efficient techniques for processing, utilization and marketing need to be developed as well as effective government policies to help bring this about.

Sweetpotato is a crop in transition in Korea. According to Byeong-Choon Jeong in **Sweetpotato Processing, Marketing, and Utilization in Korea**, production has fallen from nearly 3.0 million t in 1965 to 0.6 million t in 1989. A variety of factors, including changing tastes and preferences as well as cheap imports for starch and animal feed, have influenced this trend. Still, consumers' recent desire to eat good quality sweetpotato roots and petioles as vegetables has been increasing. This and other new uses for sweetpotato are, in Jeong's view, the key to greater consumption and production in the future.

Sweetpotato production in Taiwan fell from 3.4 million t in 1970 to 0.2 million t in 1989. During this period, over 60% of annual output was used for animal feed and about 20% went for manufacture. W. Chiang claims in **Sweetpotato Production and Utilization in Taiwan** that in order to increase human consumption, high value products such as french fry-type sweetpotatoes need to be developed.

In **Root and Tuber Processing, Marketing, and Utilization in the South Pacific**, F. Bjorna notes the relative importance of aroids particularly *colocasia* in West Samoa, Niue, and Tuvalu. Cassava is important in the Cook Islands and Tonga. Little root crop processing takes place in the South Pacific. The main constraints are small markets, limited supplies, and long distances between growing areas and population centers. Export of fresh roots and tubers has some potential.

In **Processing, Marketing and Utilization of Cassava and Sweetpotato in India**, C. Balagopalan, G. Padmaja, and G.T. Kurup note that output for both crops started to decline recently. Of total cassava production (3.6 million t), about 17% goes for starch and more than 20% for animal feed. In contrast, the bulk of sweetpotato output goes for human consumption; only the vines are fed to cattle. Very recently, however, sweetpotato flour has appeared in Indian markets. Both crops have considerable unrealized potential for additional processing. Research priorities include storage techniques, waste recycling, animal and fish feeds, improved technology for starch extraction from sweetpotato, and an assessment of the market/technological potential of different processes and products.

Sweetpotato and Cassava Development: Present Status and Future Prospects in Indonesia

Agus Setyono, Djoko S. Damardjati, and Husni Malian[1]

Abstract

Cassava is the third most important food crop in Indonesia. Sweetpotato is a secondary crop nationwide, but in Irian Jaya it is a staple food. This paper reviews recent trends in production and utilization for these two commodities. Regional differences in consumption and marketing are also noted and traditional processing techniques described. Based on low average yields in farmer fields relative to experimental plots, considerable potential for increased production of cassava and sweetpotato would appear possible in Indonesia. Realizing this potential, however, will depend in large part on expanding and diversifying current processing activities.

Key words: cassava, sweetpotato, production, utilization, Indonesia.

Introduction

Cassava (*Manihot esculenta*) is the third most important staple food crop following rice and corn in Indonesia. Cassava production has been stagnant since the early 1970s. Two factors may have caused this stagnation: marketing problems and the low status of the crop.

This commodity has potential for development and occupies an important position in the agricultural economy of Indonesia. Due to the growing importance of cassava as food, feed, a raw material for industry, and as an export commodity, progress in development efforts has been made.

Sweetpotato (*Ipomoea batatas*) is not a major crop for most of Indonesia, but in Irian Jaya it is a staple food. Sweetpotato production and area planted in Indonesia show a decreasing trend over the last twenty years.

Farmers' yields for cassava and sweetpotato are still very low compared to those obtained in experimental plots, indicating a potential for yield increases. Stable prices and improved utilization technology will stimulate the demand and, therefore, production also.

Cassava and Sweetpotato Production

Cassava Production

At present, cassava is cultivated by farmers in almost all areas of Indonesia, from lowlands to highlands, dry or wet climates, and under various soil conditions. A national recapitulation of upland area land use can be seen in Table 1. Wargiono (1989) stated that the harvested area of cassava in Indonesia showed a decreasing trend of 0.7% a year. However, since 1986 the trend has increased slightly, and in 1988, the total harvested area was 1.31 million ha with a total production of 15.47 million t (Table 2).

There are 13 provinces in Indonesia that have more than 10,000 ha of cassava (seven of these are shown on Table 3; Map 1). These provinces are regarded as the main production areas for cassava and for sweetpotato.

The average yield per ha of cassava at the farmers' level is still very low at 12 t/ha. This can be increased

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Table 1. Recapitulation of national upland area (ha), 1984-87.

Kind of upland	Year 1984	1985	1986	1987
Cultivated	8,327,282	8,091,282	8,377,480	8,761,476
Temporary cultivated	2,750,485	2,826,683	2,902,528	3,125,278
Un-used/un-cultivated	7,371,511	7,409,646	8,097,646	8,320,418
Total	18,449,278	18,326,926	19,377,654	20,207,172

Source: SFCDP 1990.

Table 2. Harvested area, production, and yield of cassava and sweetpotato in Indonesia, 1984-88.

	Harvested area (000 ha)		Production (000 t)		Yield potential (t/ha)	
Year	Cassava	Sweetpotato	Cassava	Sweetpotato	Cassava	Sweetpotato
1984	1,350	264	14,167	2,157	10.5	8.2
1985	1,292	256	14,057	2,161	10.9	8.4
1986	1,170	253	13,312	2,091	11.4	8.3
1987	1,222	229	14,356	2,013	11.7	8.8
1988	1,303	248	15,471	2,159	11.9	8.7

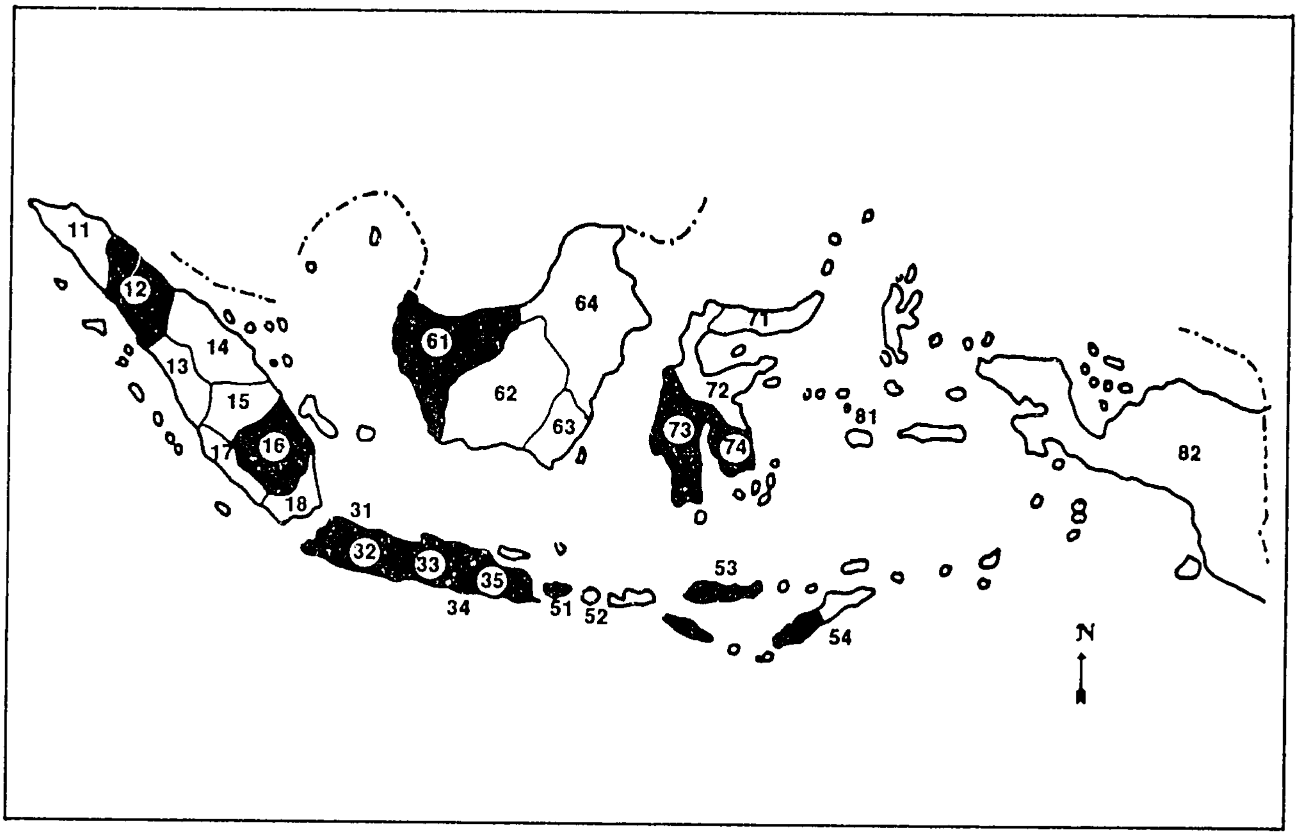
Source: SFCDP 1990.

Table 3. Harvested area, production and yield potential of cassava and sweetpotato at the production center, 1988.

	Harvested area (000 ha)		Production (000 t)		Yield potential (t/ha)	
Province	Cassava	Sweetpotato	Cassava	Sweetpotato	Cassava	Sweetpotato
North/South Sumatra	63	23	769	213	12.3	8.5
Lampung	151	2	1,915	23	12.6	9.5
West Java	150	46	1,922	465	12.8	10.1
Central Java/ Yogyakarta	338	27	4,195	268	12.2	9.8
East Java	290	24	3,439	228	11.8	9.5
Xalimantan	49	10	475	73	9.8	7.0
Bali/NTB/NTT	106	32	1,145	290	11.3	7.2
Irian Jaya	3	25	34	187	10.0	7.4

Source: Pabinru 1989.

Map 1. Major cassava producing provinces in Indonesia.



Legend:

11. Aceh
12. North Sumatera
13. West Sumatera
14. Riau
15. Jambi
16. South Sumatera
17. Bengkulu
18. Lampung

31. DKI Jakarta
32. West Java
33. Central Java
34. DI. Yogyakarta
35. East Java

51. Bali
52. West Nusa Tenggara
53. East Nusa Tenggara
54. East Timor

61. West Kalimantan
62. Central Kalimantan
63. South Kalimantan
64. East Kalimantan

71. North Sulawesi
72. Central Sulawesi
73. South Sulawesi
74. South-East Sulawesi

81. Maluku
82. Irian Jaya

Source: SFCDP 1990.

by introducing new technologies to farmers, e.g., improved varieties and cultural practices. In a cassava estate owned by a tapioca factory in Lampung, yields of 25-30 t/ha can be steadily achieved (Rusastra 1988). Furthermore, it has been reported that on an experimental scale the yield of cassava was 75 t/ha. It appears that the cassava yield at the farmers' level is still far below its real yield potential.

Some varieties of cassava which have been released are Gading, Walenca, SPP, Bogor Muara, Adira I, Adira II, and Adira IV (SFCDP 1990). A brief description of cassava varieties is presented in Table 4.

Sweetpotato Production

Harvested area of sweetpotato decreased from 0.37 million ha in 1969 to 0.23 million ha in 1987 (SFCDP 1988), though the actual decrease between 1984-87 was small. Sweetpotato yields did not change much during 1984-88 (Table 2). Therefore, it is anticipated that production increases will be mainly from increasing area planted. Currently, almost 50% of area planted is in Java (Table 3). Sweetpotato is used as a main staple food in Irian Jaya.

Eleven provinces in Indonesia are considered as the major production areas of sweetpotato, i.e., North and South Sumatra, West, Central and East Java, Bali, N.T.B., N.T.T., Central Sulawesi, South Sulawesi and Irian Jaya (Table 3; Map 2) (SFCDP 1990).

Average farmer's yields for sweetpotato is still very low at 7-10 t/ha. But total production could be increased by introducing high-yielding varieties. Improved varieties of sweetpotato that have been released in Indonesia are Puerto Rico, Southern Queen 27, Kawagoya, Tembakur Putih, Gedang, Tembakur Ungu, Taiwan 45, Daya, Borobudur, and Prambanan. A brief description of these sweetpotato varieties is presented in Table 5.

Consumption and Marketing

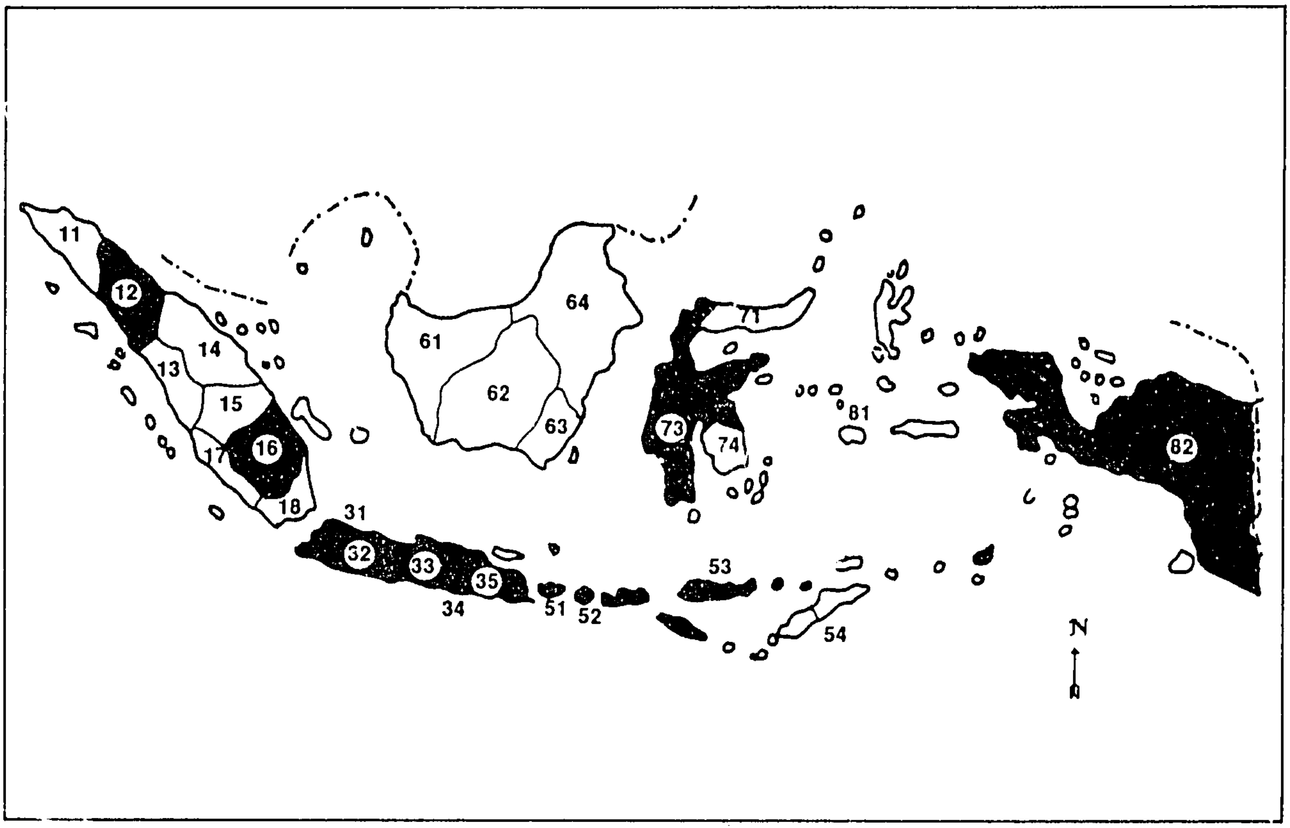
Cassava consumption per capita per year has tended to decrease gradually in Indonesia. Cassava consumption for food fell from 57.4 kg/capita in 1983 to 51.0 kg/capita in 1988 (Table 6). In rural areas, cassava consumption per capita also decreased from 76 kg in 1976 to 65 kg/capita per year in 1984. However, total consumption increased, which is presumably due to the increase in

Table 4. Characteristics of some promising cassava varieties.

Characteristic	Variety							
	Gading	Walenca	SPP	Bogor	Muara	Adira I	Adira II	Adira IV
Vegetative cycle (months)	7-8	8-10	10-11	8-10	7-10	7-10	8-12	10-12
Protein (%)	--	0.7	0.4	0.35	0.41	0.5	0.7	0.8
HCN (mg/kg)	40	40	100	100	100	27.5	124	68
Flour (%)	--	33.1	35.4	30.9	26.9	45	41	18-22
Root:								
Color outer layer skin	--	--	--	--	--	--	brown	brown
Color inner layer skin	--	--	--	--	--	--	brown	rose
Color flesh	white	white	white	white	white	yellow	white	white
Taste	sweet	sweet	bitter	bitter	bitter	sweet	slightly bitter	slightly bitter
Yield potential (t/ha)	15-20	15-20	20-30	20-30	20-30	22	21	35

Source: SFCDP 1990.

Map 2. Major sweetpotato producing provinces in Indonesia.



Legend:

11.	Aceh	52.	West Nusa Tenggara
12.	North Sumatera	53.	East Nusa Tenggara
13.	West Sumatera	54.	East Timor
14.	Riau		
15.	Jambi	61.	West Kalimantan
16.	South Sumatera	62.	Central Kalimantan
17.	Bengkulu	63.	South Kalimantan
18.	Lampung	64.	East Kalimantan
31.	DKI Jakarta	71.	North Sulawesi
32.	West Java	72.	Central Sulawesi
33.	Central Java	73.	South Sulawesi
34.	DI. Yogyakarta	74.	South-East Sulawesi
35.	East Java		
		81.	Maluku
51.	Bali	82.	Irian Jaya

Source: SFCDP 1990.

Table 5. Characteristics of some promising sweetpotato varieties.

	Variety									
Characteristic	Puerto Rico	Southern Queen 27	Kawa-goya	Tembakur white (Putih)	Gedang	Tembakur purple (Unga)	Taiwan 45	Daya	Boro-budur	Pram-banan
Vegetative cycle (months)	--	--	--	--	4	4	4	4	3.5-4	4-4.5
Protein (%)	1.3	1.4	1.1	--	--	0.8	--	0.8	0.60	0.64
Beta Carotene (mg/100g)	--	--	--	--	--	275	--	279	12.26	614
Vit. C (mg/100g)	20	20	11	--	--	4	--	4	4	5.4
Four (%)	25	28.5	28.7	--	--	--	--	--	28	28
Tuber:										
Color skin	light-red	yellow	red	yellow-white	orange	violet	white	yellow	orange	orange
Color flesh	orange	yellow	yellow	white	orange	white	white	orange	orange	orange
Shape	oval	long	spherical	spherical	spherical	spherical	spherical	oval	spherical	oval
Size	--	moderate	moderate	big	moderate	big	big	--	--	--
Taste	very sweet	nicely sweet	slightly sweet	slightly sweet	sweet	slightly sweet	sweet	--	sweet	nicely sweet
Yield potential (t/ha)	10	10-15	15-17	--	--	--	--	--	25	28

Source: SFCDP 1990.

-- = Data is not available.

Table 6. Average consumption of major food crops in Indonesia, 1983-88.

	1983		1986		1988	
Commodity	kg/year	calorie (cal/day)	kg/year	calorie (cal/day)	kg/year	calorie (cal/day)
Rice	145.21	1432	147.36	1453	150.18	1481
Cassava	57.41	230	51.49	154	51.00	153
Tapioca	0.50	6	1.35	13	1.00	0
Gaplek	--	--	--	--	1.46	14
Sweetpotato	12.46	42	11.05	32	10.93	32
Wheat	8.19	82	5.96	60	6.59	66
Corn	27.35	233	29.25	256	30.75	269
Soybean	4.45	40	8.80	80	9.49	86

Source: Central Bureau of Statistik.

-- = Data not available.

population. In general, cassava consumption is higher in rural areas than in cities and towns. For example, fresh root consumption is about five times higher in the countryside than in urban areas. Dried cassava consumption in the cities is around 0.10 kg/capita and in rural areas 4.0 kg/capita. Cassava flour consumption is 0.10 kg/capita and 0.57 kg/capita in urban and rural areas, respectively. In general, expenditures for cassava decline as the consumer's income increases. Still, the Ministry of Agriculture (1989) estimates that total domestic consumption would increase from 10.7 million t in 1990 to 14 .7 million t in 1995 and to 15.5 million t in 2000.

From the total production of cassava, consumption as human food is 54.8%, as food products is 1.8%, utilization for non-food industries 8.6%, for the tapioca industries 19.9%, and for export 18.9% (Tjahjadi 1989).

Sweetpotato consumption per capita per year has also tended to decrease gradually. Sweetpotato consumption for food decreased from 12.5 kg/year in 1983 to 10.9 kg/year in 1988 (Table 6). Although most sweetpotato in Indonesia is used for fresh consumption, some processing takes place. Little is known about current processing practices and products.

The Ministry of Agriculture has projected sweetpotato production at 57 million t in the year 2000. This projection corresponds to an annual increase of 5.8% starting in 1984. According to an estimate made by the Directorate of Root Crop Production, harvested area must be increased by 4.1% and productivity by 1.5% annually to achieve this target. Considering production trends observed during the last ten years, special efforts will be required to meet this projection.

Cassava utilization in Java is different from that observed in Lampung, therefore, marketing is also different. Most cassava produced in Java is utilized for human consumption and starch (tapioca). Farmers in East Java sell about 50% of their cassava in the form of fresh roots to traders who mainly supply the tapioca industry (Damardjati et al. 1990). The other 50% of production is processed into *gaplek* (cassava chips) and sold to traders. Farmers in Central Java sell about 80-90% of their cassava in the form of fresh roots to middlemen who mainly supply the tapioca industry. The remaining 10-20% of production goes for housesold consumption.

In Lampung, cassava is grown primarily by Javanese transmigrants in isolated areas. Farmers near starch factories tend to sell their fresh cassava directly to the factories, while those in remote areas sell their cassava to traders or middlemen. *Gaplek* is usually processed by the farmer and sold to traders, who transport it to pelleting factories or exporters in the city.

Sweetpotato processing appears to be restricted by discontinuous availability and price. At present, the difficulty of obtaining sweetpotato during the dry season limits the development of the sweetpotato industry. Unstable prices are another problem.

Processed sweetpotato products from home industry are sold to nearby markets, while products from larger industries are distributed much further. Marketing through retailers or groceries is done by cash payment or credit.

The price of cassava at the farmers' level is variable depending on location and harvesting time. The price fluctuates widely from Rp. 26.00 to Rp. 177.67/kg, and depends on the production center of cassava (Table 7). The price of cassava in Lampung is the lowest compared to those in other production centers which are about Rp. 27.00 to Rp. 62.25/kg. The highest cassava price is found in Irian Jaya, about Rp. 103.80 to Rp. 143.20/kg (Table 7).

The price of sweetpotato at the farmers' level is also affected by province and harvesting time. The price in East Java is lowest, about Rp. 71.00 to Rp. 80.20/kg, and in Irian Jaya highest at about Rp. 137.20 to Rp. 199.20/kg (Table 8).

Processing and Utilization

Postharvest Handling System

Fresh cassava and sweetpotato handling is very important at the farmers' level. This activity influences the characteristics and quality of cassava products.

Harvesting

The optimum harvesting time for specific varieties is seldom known and roots are frequently harvested either too young or too old. Harvesting of cassava is generally done by hand and heavy damage may occur due to lack of care when pulling the roots from the ground. Harvesting of sweetpotato is done by broad hoe, and here also damage may occur.

Transporting Fresh Roots

Cassava can deteriorate rapidly after harvest. Cassava and sweetpotato roots are very bulky which makes transportation difficult and expensive. Usually, farmers

Table 7. Average price of cassava (Rp/kg) at the farmers' level at the production center, 1984-88.

Month	South Sum.	Lampung	West Java	Central Java	East Java	Kali-mantan	Sulawesi	Bali/ NTT	Irian Jaya
January	35.00	34.00	84.75	62.00	65.00	57.00	110.67	109.50	131.20
February	39.75	27.00	93.25	63.20	66.40	65.00	106.00	99.00	139.40
March	56.00	32.67	81.00	88.60	66.60	75.00	90.25	91.50	143.20
April	86.00	32.67	76.00	70.80	69.80	62.50	99.33	101.50	140.80
May	68.00	42.00	80.75	74.00	58.50	107.00	103.00	132.00	117.60
June	41.00	41.33	81.00	68.40	66.60	81.00	23.33	116.75	133.20
July	45.00	47.75	75.50	62.75	69.60	86.00	98.00	75.67	116.00
August	26.00	62.25	70.00	68.00	81.00	57.50	108.00	125.00	123.40
September	--	41.25	65.50	47.67	66.40	51.00	96.00	104.50	115.00
October	27.00	40.75	62.75	54.50	67.00	70.00	94.00	147.00	103.80
November	37.50	47.50	61.75	60.25	69.40	85.00	111.00	177.67	106.40
December	41.00	42.75	65.50	64.60	66.00	84.50	102.00	102.50	114.50

Source: Central Bureau of Statistik.

Table 8. Average price of sweetpotato (Rp/kg) at the farmers' level at the production center, 1984-88.

Month	South Sum.	Lampung	West Java	Central Java	East Java	Kali-mantan	Sulawesi	NTT	Irian Jaya
January	106.33	65.75	110.20	75.80	72.20	109.00	105.00	101.33	192.80
February	99.00	57.50	111.60	78.60	71.00	115.00	112.00	146.00	188.40
March	109.33	59.00	114.40	77.80	71.80	170.00	97.75	159.00	191.60
April	113.50	103.20	154.00	99.00	78.75	117.50	129.33	103.50	194.20
May	84.00	101.80	119.20	98.20	78.75	113.50	127.33	90.50	192.40
June	75.00	88.00	124.40	102.20	78.80	136.33	116.67	113.00	199.20
July	95.50	91.40	107.60	86.00	79.00	143.50	108.00	88.33	172.60
August	--	105.20	96.60	99.20	76.80	84.00	118.00	99.00	168.20
September	90.00	91.50	104.40	77.33	77.60	111.00	103.50	115.00	176.00
October	100.00	109.75	109.80	82.00	77.80	110.50	92.00	176.67	161.00
November	120.50	142.67	113.20	88.25	80.20	113.50	120.00	175.00	137.20
December	97.50	92.75	109.40	85.20	74.40	141.00	114.50	96.00	163.60

Source: Central Bureau of Statistik.

bring the fresh cassava and sweetpotato to their house or community warehouse for further processing or sale.

Fresh Storage

Cassava roots often can not be processed or consumed immediately after harvest. If it is not processed within three days, a deterioration called *kepoyohan* will occur. The color changes, taste declines, and finally the roots spoil. To improve the storability of fresh cassava, the cleaned roots are layered and these layers covered with wet rice husk. Fresh cassava roots can be stored for 1-2 weeks in that way.

Present Utilization

According to Indonesian Food Balance Sheet data (CBS 1989), total cassava production in 1988 was 15.47 million t. Of this, 57.3% was consumed as fresh food, directly, or dried as *gaplek*, 10.5% was exported as *gaplek*, chips, or pellets, and 17.2% was used as raw material in industries such as tapioca (starch) (10.2%) and other non-food industries (7.0%). Postharvest losses are still relatively high, about 13.0% (Table 9).

Cassava utilization in Indonesia differs throughout the country. In Java where 60.0% of the population reside, cassava is consumed primarily as human food. Unnevehr (1982) reported that rural inhabitants utilize approximately 51% of the fresh cassava and 49% of the dried cassava (*gaplek*) for their family's needs. In addition to the fresh and dried cassava utilized by rural families, a fairly large percentage of cassava produced in Java is processed into starch for domestic consumption and into *gaplek* for export.

Few sweetpotato products are available in the market. Utilization of sweetpotato in food processing industries is still limited.

Fresh Cassava and Sweetpotato Processing

Cassava roots can be utilized in various forms, such as direct consumption after cooking (boiled, roasted, steamed, fried), fermentating to produce *tape*, drying (either whole tuber or slices) to produce *gaplek*, and extracting to produce tapioca (cassava starch). *Gaplek* can be kept as a food reserve or as animal feed. In Java, most cassava is utilized for human consumption. Therefore, many traditional products for local or domestic consumption are produced at the village level. Many of these products are produced by farmers' families for additional income. Human food products are made from both fresh and dried cassava. A multitude of product types, such as *ceriping*, *gemblong*, *gethuk*, *lemet or utri*, *kolak*, *kripik*, and *opak* are commonly produced from fresh cassava.

Studies on sweetpotato processing showed that a total of ten food products are produced on a commercial scale. The most important product in terms of number of enterprises involved and availability of product in the market is tomato-flavored ketchup. Products of less economic importance include *krupuk*, chips, and *permen* (candy). Sweetpotato chips are found in Bandung and Tangerang and are produced by a snack product factory which uses sophisticated packaging.

Fermented and DriedCassava and Sweetpotato Processing

Some traditional cassava processing techniques for home-industry scale are described below (see Fig. 1).

Cassava

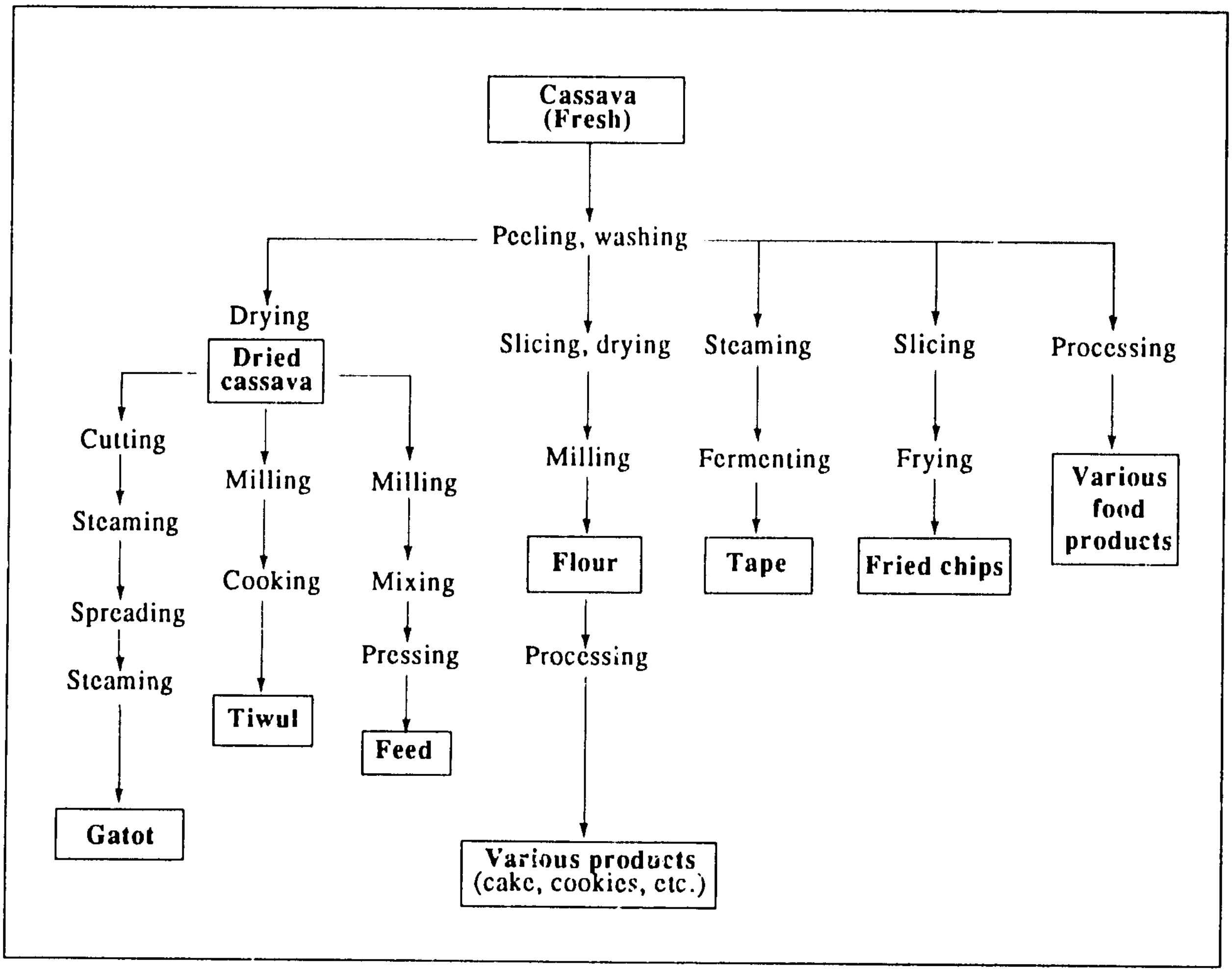
Tape/Flour Tape. Cassava roots are cut into pieces 5-10 cm in length, washed until quite clean and then half cooked. The cooked cassava is then fermented by inoculating with *ragi tape* or yeast (*Clamidomucor oryzae*

Table 9. Production and utilization trends for cassava and sweetpotato in Indonesia, 1983-88.

	Fresh roots or tubers (or equivalent)					
	1983		1987		1988	
Item of products	Cassava (000 t)	Sweetpotato (000 t)	Cassava (000 t)	Sweetpotato (000 t)	Cassava (000 t)	Sweetpotato (000 t)
Total production	12,103	2,213	14,356	2,031	15,471	2,159
Waste (losses)	1,476	221	1,866	201	2,011	216
Export	748	--	--	--	--	--
Manufactured for:						
Feed	227	44	287	40	309	43
Food	333	--	3,401	--	4,288	--
Industry	341	--	--	--	--	--
Food consumption	8,573	1,498	8,802	1,772	8,863	1,900

Source: Central Bureau of Statistik.

Figure 1. Flow chart of traditional cassava processing and its products.



and *Rhizopus oryzae*) and covered with banana leaves for 2-3 days. During fermentation, starch is converted to simple sugar by an enzyme which is produced by *Rhizopus oryzae*. Tape contains 0.5% protein, 0.1% fat, 42.5% carbohydrate, and 56% moisture.

Dried cassava or *gaplek* is mainly exported as animal feed but is also used for making food products. *Tiwul*, *gatot*, and other products are produced from dried cassava and consumed primarily by the Javanese. However, through Javanese transmigration, these products have also been introduced to other parts of Indonesia.

Tiwul. It is made from *gaplek* which has been pulverized and sieved. The meal is kneaded along with a little water into paste, mixed with sugar, and steamed. This gritty material is served to substitute for rice.

Oyek. Cassava roots are peeled and soaked in water for about one week, and then drained and ground. The ground cassava is kneaded with a little water, steamed, and sun-dried.

Gatot. *Gaplek* is cut into pieces, steamed, and spread out on a bamboo mat. The pieces are kept wet for 2-3 days by continually sprinkling water over them. Their color will turn black and they will acquire a specific taste. These can be served after steaming.

Sweetpotato

Some sweetpotato processing techniques applied at small to intermediate scale are described in Figure 2.

Kremes. Various materials are used. However, typically the materials required for making kremes are sweetpotato, cooking or vegetable oil (coconut oil), brown sugar, and vanilla.

The brown sugar is melted, and vanilla is added. The sweetpotato is peeled, sliced, washed, and drained. The slices are deep fried until they are floating; and then the sugar solution is added and the slices are removed and pressed.

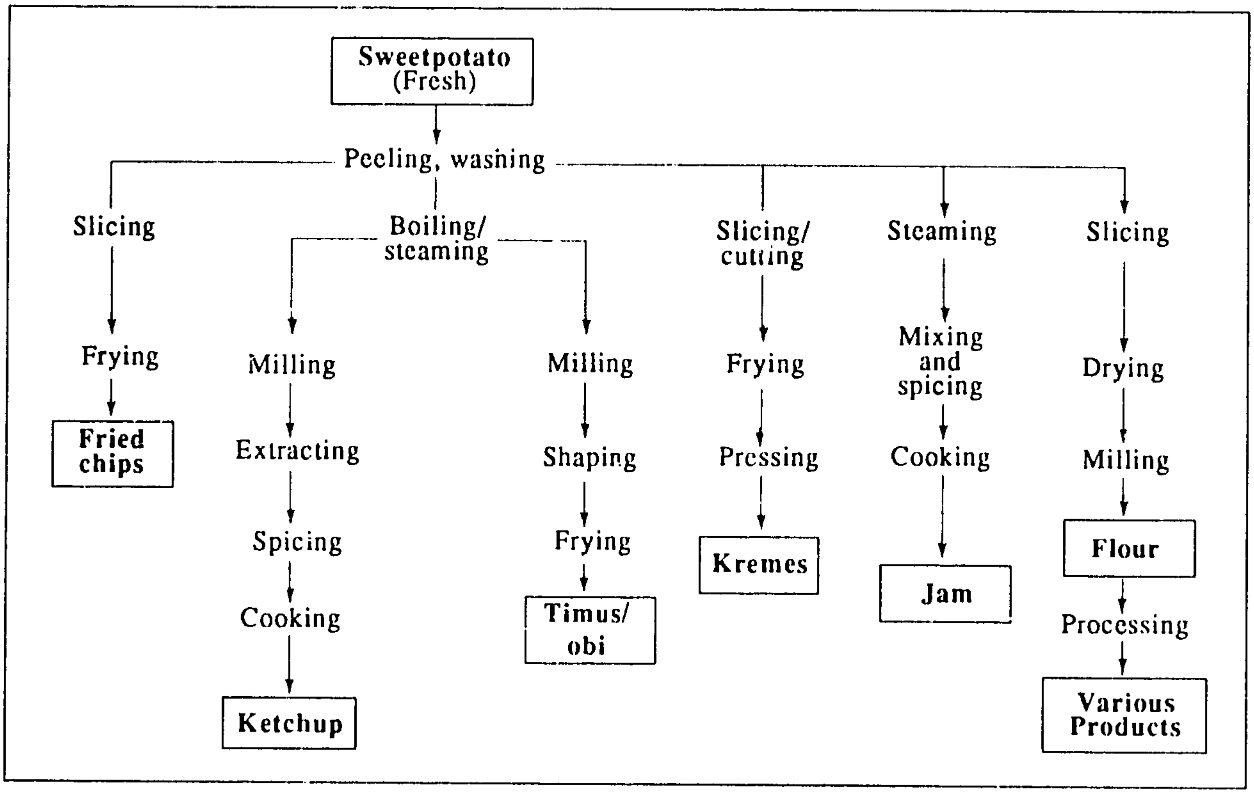
Ceriping/Keripik. There are two kinds of sweetpotato *ceriping*, salted or sweetened *cerpings* or *keripiks*. *Keripik* is made from sweetpotato, sugar, cooking oil, and vanilla powder. First, the sugar is boiled. The sweetpotato is peeled and sliced, and then washed and drained. The sliced sweetpotato is partly fried. The sugar solution is added when the slices are still hot, and then left for several hours. After that, the slices are fried again and then packed.

Sauce and Chily Sauce. The main material is sweetpotato which is combined with the different spices used by different factories. Different amounts of sweetpotatoes are used by the various factories, but the processing techniques are the same.

The ingredients are sweetpotato, corn flour, pepper, cayenne pepper, coloring agent, garlic, sodium glutamate, sodium benzoate, rock candy, salt, CMC, and vinegar. All spices are mixed. The sweetpotato is washed and then boiled. The boiled sweetpotato is milled, water is added, and the mixture is sieved. The spices are added to the porridge of sweetpotato which is then cooked for about . 0 min, cooled down for about one night, and then packed or bottled before they are pasteurized.

Timus. The materials required for making *Timus* are sweetpotato, cassava flour, sugar, vanilla powder, sodium benzoate, and salt.

Figure 2. Flow chart of sweetpotato processing and its products.



The sweetpotato roots are peeled, washed, and steamed. The steamed sweetpotato is milled and all the other ingredients are added and mixed thoroughly. The mixture is shaped into cylinders and then fried.

Obi. The raw material of *obi* consists of sweetpotato mixed with cassava flour, sugar, and vanilla powder. The sweetpotato roots are peeled and then washed and boiled. They are milled and mixed thoroughly with other ingredients. The mixed sweetpotato is then shaped into small balls and fried.

Prospects and Potential of Cassava and Sweetpotato Utilization

Cassava

Tapioca or starch is a major product of fresh cassava, and it is presently used in the food, pharmaceutical, textile, and paper industries in Indonesia. Modified starches have not been produced much. Hence, the production of modified starches will be a potential area of expansion for the domestic market. In addition, by-products of the cassava starch industry can be utilized as raw material in other industries.

Starch is used primarily in the food industry (as a thickener, filler, binder, or stabilizer), the pharmaceutical industry, brewing industry, paper and board industry, textile industry, and building, metal, and chemical industries.

Sweeteners or similar products, such as glucose syrup, fructose syrup, and dextrose, are produced by hydrolysing this starch. Further complex processing may be used to produce high fructose syrup from starch.

In addition to the sweeteners, other products which can be made from fresh cassava and/or from cassava starch are alcohol and single cell protein (SCP). Both of these are produced through starch hydrolysis and fermentation.

Sweetpotato

Sweetpotato is commonly served for food as steamed, boiled, fried, or roasted sweetpotato. In home industries, sweetpotato is processed into various products such as fried chip, kremes, ketchup, and timus (Setyono and Fagi 1989).

In larger industries, sweetpotato is processed into chips, sweetpotato flour, and fermented products. Prospects and potential for sweetpotato utilization are currently being studied.

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Sweetpotato in China

Li Wei Ge, Wu Xiuqin, Cai Huiyi, and Du Rong[1]

Abstract

This report gives a brief introduction to the past, present and, future situation of sweetpotato in China. Included are a general outline on the planted area, production, and yields; changes in the market demand; information on its place as a food source for human consumption, as raw material for processing, as animal feed, and feed products; examples of current processing techniques; effects of economic policy on its development, and problems being faced.

Key words: China, sweetpotato, production, utilization.

Introduction

Sweetpotato was introduced into China in the late sixteenth century during the reign of the Wan Li Ming Dynasty. Its cultivation is distributed over a wide area, from Hainan Province in the south to Heilongjiang Province in the north (48° northern latitude) (Map 1).

Sweetpotato ranks fourth as a food crop following rice, wheat, and corn. The current annual cultivated area is about 6 million ha with an annual production of about 110 million t. In the 1950s there was a rapid expansion of 24% in the sweetpotato cultivation area reaching 7.2 million ha cultivated, and an increase in production of 49% reaching 76.6 million t/yr. In this period the yield increase per unit area was 20%. In the 1960s after the "adjustment recovery period," there was a second expansion in the cultivated area, reaching approximately 9.5 million ha, with total production per year reaching 91 million t. However, yields dropped to 9.6 t/ha. This shows that the increase in total production was achieved only by the expansion of the cultivated area.

In the 1970s, government policy put more emphasis on agriculture, with an improvement of irrigation facilities, increased fertilizer supply, availability of better quality breeding material, and the introduction of innovative cultivation techniques. Cultivated area began to decline, stabilizing at about 6.7 million ha. Yields averaged about 13 t/ha, and total production reached over 100 million t. From this period on, growth of the total annual production was mainly achieved by yield increases (see Map 2 and Table 1).

In the past four decades, annual production of sweetpotato in China has more than doubled. Cultivated area has been declining, but, with the development of technology and more favorable government policies, there has been a notable increase in yields and annual production.

Changes in Market Demand

Before the 1960s, sweetpotato was used mainly as cereal food in the rural districts, secondarily as a feed source, and only a small portion processed into starch and alcoholic beverages. Between 1950 and 1960, sweetpotato utilization was as follows: food, 50%; feed, 30%; industrial raw material, 10%; and planting material, 10%.

In the latter part of the 1970s and in the 1980s, rural industry developed rapidly and the standard of living increased considerably. Sweetpotato's role as a food decreased while its role as raw material for processing increased. The Yellow River, Huai River, and Hai River

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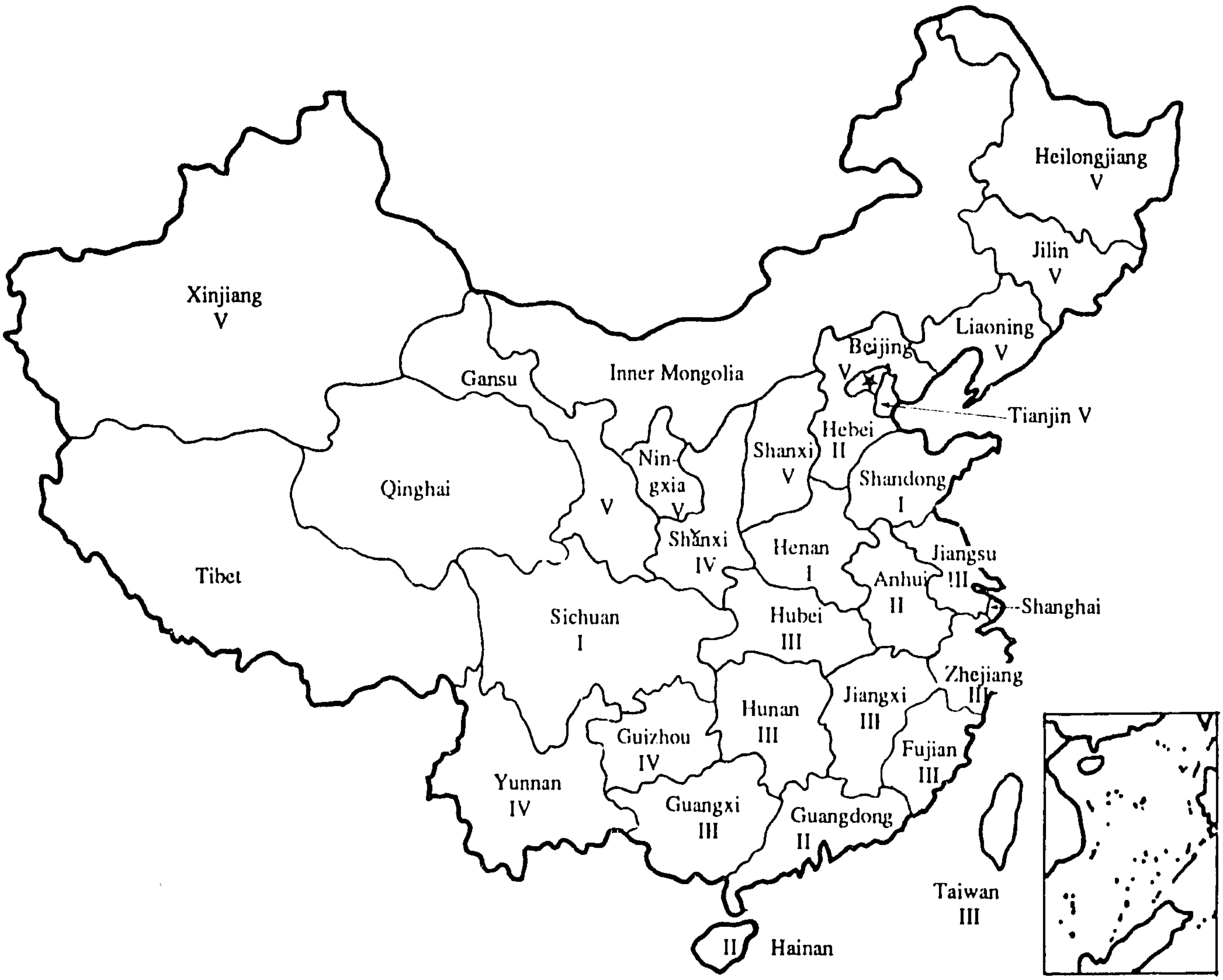
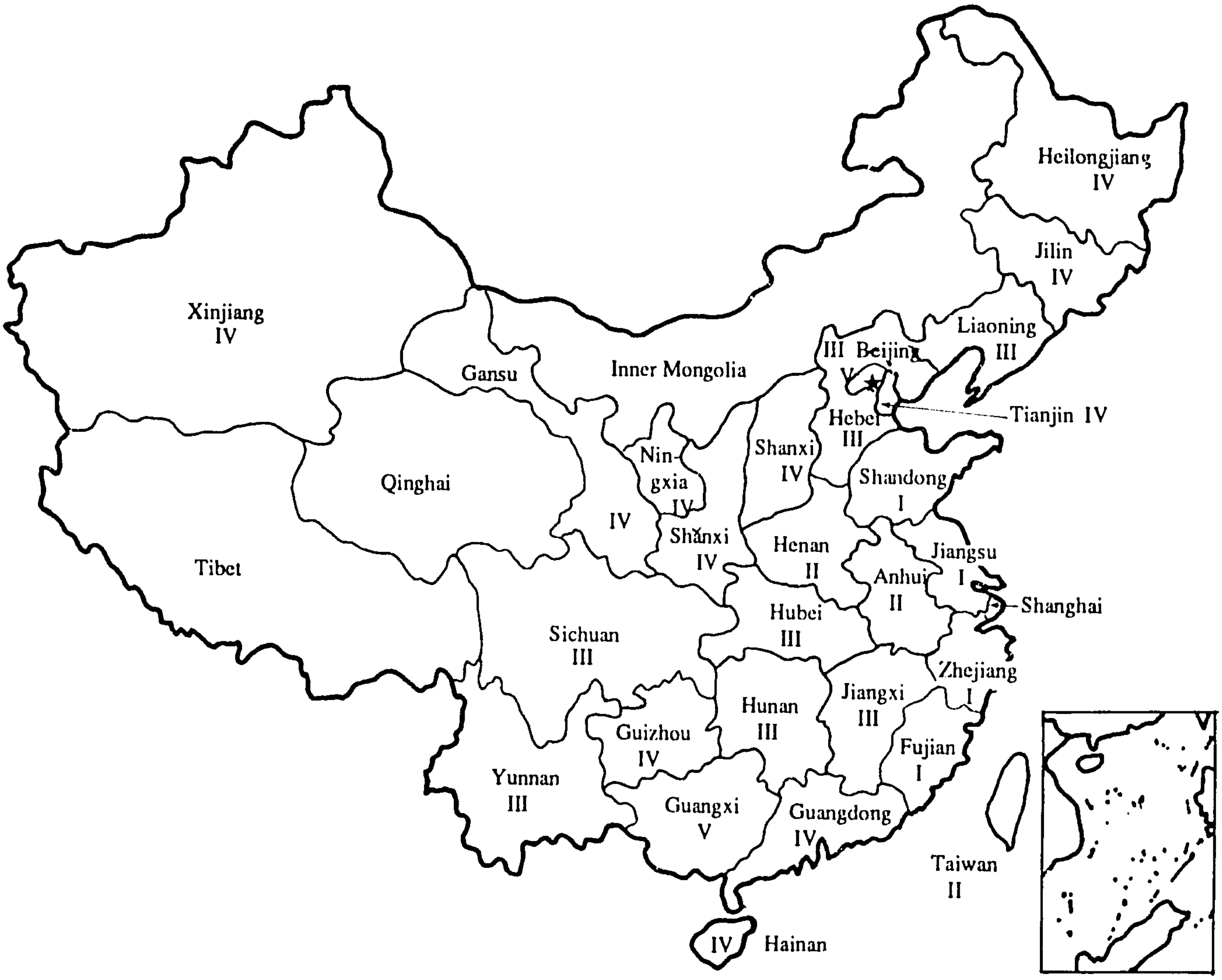
Map 1. **Sweetpotato area cultivated in different regions China.**



Legend:

I = 1.000-1.130 million ha
II = 0.340-0.670 " "
III = 0.093-0.330 " "
IV = 0.030-0.066 " "
V = below 0.030 " "

Map 2. Sweetpotato yields in different regions.



Legend:

I = 18-26 t/ha
II = 15-17 t/ha
III = 11-14 t/ha
IV = 07-10 t/ha
V = below 7 t/ha

Table 1. Cultivated area and yield of sweetpotato in China.

Decade	Cultivated area[a] (million ha)	Yield (kg/ha)	Total production per year[a] (million t)
1940s	5.8	8899.5	51.5
1950s	7.2	10650.0	76.7
1960s	9.5	9600.0	91.2
1970s	8.1	13350.0	108.1
1980s	6.7	16999.5	113.9
1990s	6.0	no data	no data

[a]Rounded to 1 decimal point.

districts are the main sweetpotato growing regions and their market trends are representative. Shandong, Anhui, and Jiangsu are three provinces in this region. We shall take them as an example. In the 1950s, the market demand was as a staple food, 50%; as feed, 30%; for processing, 10%; and for planting material and loss, 10%, with nothing for export. In the 1980s, great changes in utilization occurred; only 12% was used as staple food, 30% for feed, 45% for processing, 5% for export, and 8% for planting material and loss.

The trend is obvious. With the higher output of cereals for food, with more and better facilities, processing equipment, and know-how, sweetpotato is used in ways which involve progressively more processing, resulting in a series of products, each one having a higher value. More and more attention is given to comprehensive processing. More detail follows.

Current Utilization Patterns and Processing Techniques

Sweetpotato contains about 20% starch, 3% soluble sugar, and many vitamins. It can be utilized in three main categories:

- food and food products
- raw material for industrial products
- feed and feed products

Figure 1 provides a general overview.

Food and Food Products

Tender tips of the sweetpotato stem and leaf are often used as a vegetable in rural areas. Fresh roots and dried chips were once an important starch food source instead of cereals. Today fresh or stored roots are baked, boiled, steamed, or sliced and fried. The latter forms have become a type of pastry, with a selling price competing with fruit. Sweetpotato food processing utilizes fresh roots, root meal, and root chips to produce starch foods such as vermicelli, noodles, or sheet jelly. These are produced in large quantities and have many uses in the Chinese kitchen. Sweetpotato is also made into preserves. Quick convenience foods are being developed, also health foods with a high carotene, lysine, and calcium content. China now has about 50 types of commercialized sweetpotato processed foods with an annual production of approximately 1.2 million t. The Zhejiang Academy of Agricultural Sciences has done some research on extracting protein from sweetpotato, but so far none of the results obtained have an economic benefit.

Raw Material for Industrial Products

The starting material used is usually dry sweetpotato chips. The main products are starch, white or yellow wine, alcohol, malt, fructose, glucose, and citric acid. Other products are lactic acid, acetone, butyric acid, amino acid, fermentation products, starch derivatives, etc. The largest quantities are as starch, wine, and alcohol.

Examples of methods for processing potatoes are shown in Figures 2 and 3. Figure 2 describes a simple way of producing starch and Figure 3 shows another simple process, that of malting, that does not require specialized equipment.

Feed and Feed Products

Sweetpotato stem and leaf is an important feed source. It can be fed raw, cooked, or ensiled. Dry stem and leaf or its meal can also be used. We have a National Standard: GB 10391-89 sweetpotato leafmeal for feedstuffs.

Figure 1. Comprehensive utilization of sweetpotato.

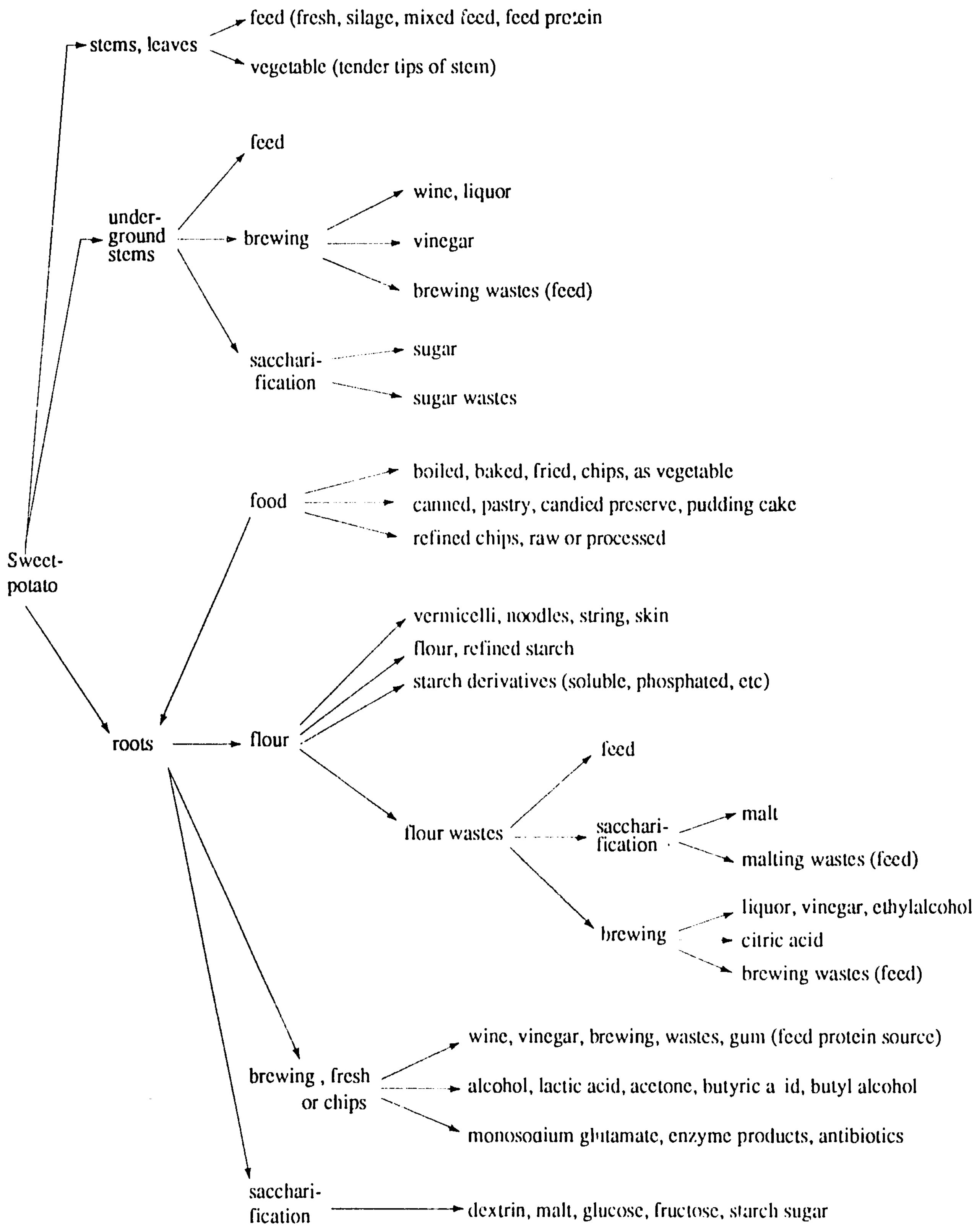


Figure 2. Processing procedures for using the natural precipitation method for producing starch.

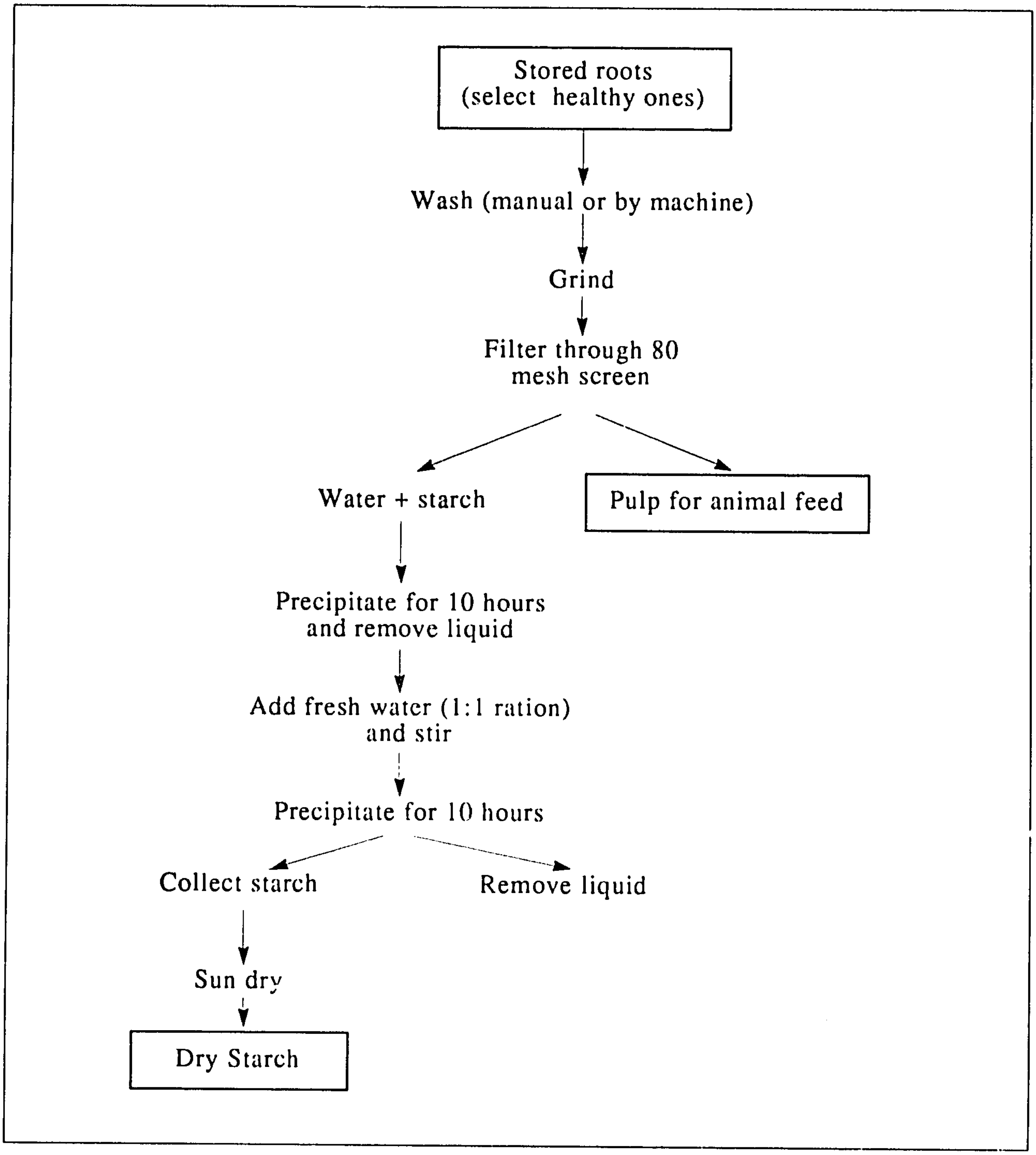
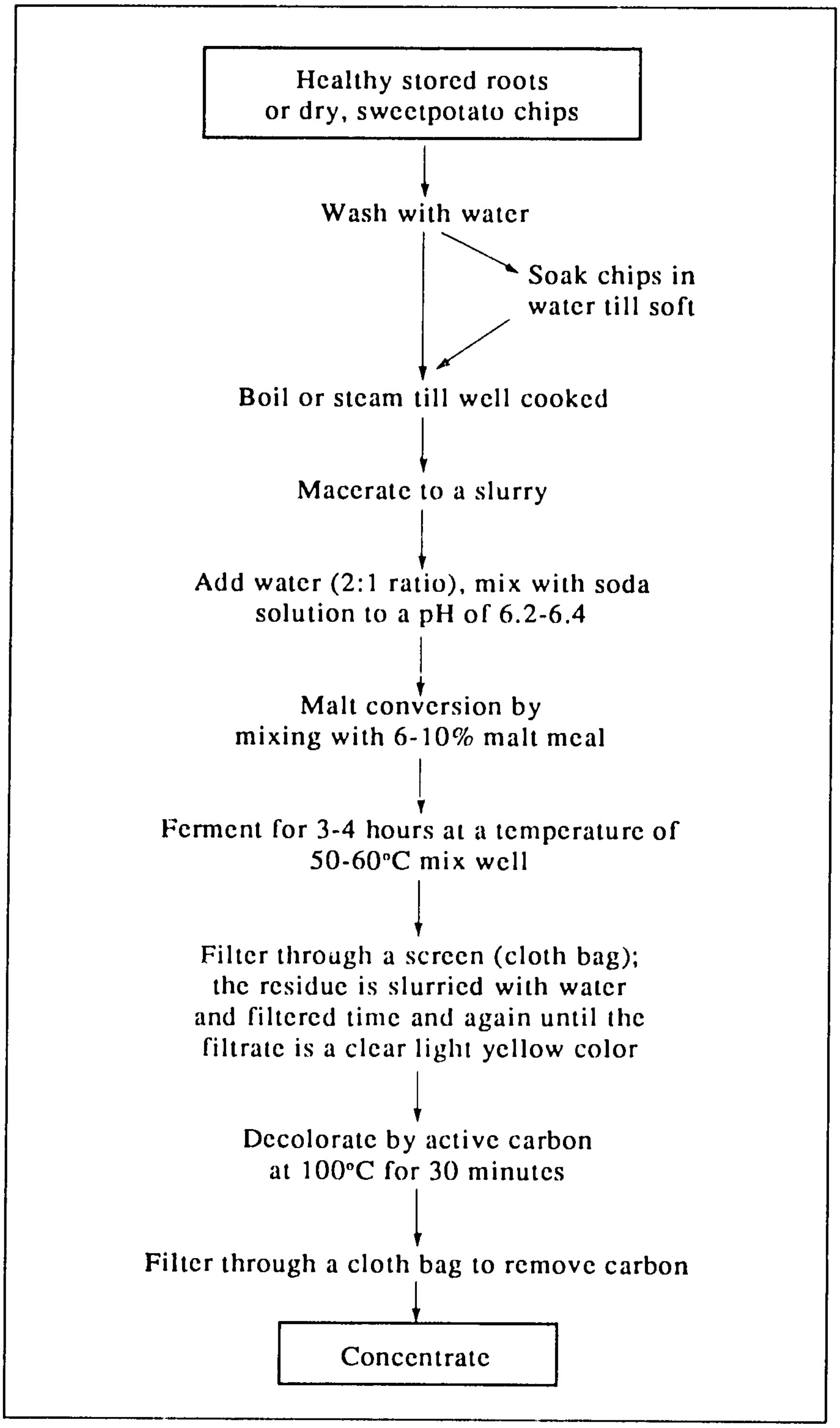


Figure 3. A processing procedure for producing malt which does not required special equipment.



Sweetpotato stem and leaf can be harvested 4-5 times in a production season. It can reach a total harvest of about 135 t/ha of fresh material, enough annual green feed for 105 hogs. Stem and leaf can be used raw or cooked for goats and cows. Often the fresh harvest is cut into one-inch pieces and mixed with wheat bran, corn flour, husk bran, and water. The suitable amount fed per kg of hog body weight is 0.1-0.12 kg of cuttings. Research in Hunan reported that the feed conversion ratio was 30:1 for hogs. This important feed source yields significant economic benefits (Table 2).

Ensiling. To prepare silage, harvested stem and leaf is left in the sun for 2-3 hours. During this period, about 25% of the moisture content evaporates. Subsequently, the material is cut into 1-2 cm pieces. Silage can be prepared in plastic bags, earthenware jars or in the silo. Ensiling increases the nutritional value as shown in Table 3.

The suitable amount fed per kg of animal body weight is 0.1-0.15 kg of silage; above this amount, diarrhea appears. Also there should be an adaptation period. The most suitable way of using sweetpotato fresh stems and leaves or silage is to mix it with formulated feed to save part of the more expensive product. Sweetpotato cuttings can be mixed with rice straw 1:0.3-0.5 to produce silage which can be used for milk cows.

Dry sweetpotato chips can be used for formulated feed. Some examples shown below are from a Jiangsu Academic Agricultural Sciences report.

1. The 35-60 kg fattening pig formulated feed: Dry sweetpotato chips 10.5%, dry sweetpotato stem meal 5%, corn 26%, wheat bran 20%, rice bran cake 17%, rape cake 10%, cotton seed cake 8%, silk worm pupa 2%, limestone powder 1%, and salt 0.5%.

2. Middle chicken formulated feed: Dry sweetpotato chips 25%, stem meal 1%, corn 32%, wheat bran 7.5%, rice bran cake 16%, bran 4%, rape cake 9%, blood meal 1%, silk worm pupa 2%, bone meal 1.6%, salt 0.4%, and additives 0.5%.

3. Layer hen formulated feed: Sweetpotato chips 8%, stem meal 3%, corn 40%, pea meal 3%, blood meal 2%, fish meal 4%, peanut cake 15%, silk worm pupa 3%, wheat bran 3%, rice bran cake 4%, rape cake 5%, calcium by phosphate 2%, egg shell powder 6.5%, additives 0.5%, and salt 0.5%.

Sweetpotato malting, fermentation, and other tastes are also used as a feed source. Most of these wastes are used by mixing with other feed. Research is also going on to produce monocellular protein from these wastes with a goal toward their use as a feed protein source.

Table 2. Economic benefits from sweetpotato as animal feed.

	Fattening hog	Goat milk	Beef	Cow milk
Kg of stem leaf to produce milk or meat	0.0243	0.2022	0.0421	0.1667
Economic benefit in RMB Yuan[a]	0.051	0.091	0.0842	0.107

Source: Cereal Institute, Honan Academy Agricultural Science, inter report Oct. 1987.

[a]RMB = Ren Min Bi.
5.2 RMB yuan = US$ 1.

Table 3. Nutritional value before and after ensiling (wind dry %).

	Water	Crude protein	Crude fat	Crude fiber	Crude ash	Ca	P	Non-nitrogen extract
Before	10.41	11.66	2.13	16.73	9.90	1.25	0.23	47.69
After	11.21	12.82	4.83	11.58	6.97	1.08	0.32	51.19

Source: Xuzhou Agricultural Institute, Yang Zhu (2):8-9. 1990.

Until now very little processing waste has been utilized. Much of it has become an environmental pollutant. A representative example from Bangfu shows that every year one alcohol factory using sweetpotato as raw material is fined around 200-300 thousand yuan for disposed waste polluting the environment.

In summary, something should be said about the benefits of processing sweetpotato. For example, 1.000 t of dry sweetpotato chips costs about 300,000 yuan (RMB=Renminbi). If exported, it will give foreign exchange US$ 125,000 equal to RMB 650,000 yuan. It can produce 500 t of wine worth 1.5 million yuan. This can produce 500 t of starch (crude) worth 540,000 yuan. 500 t of starch will produce 378 t of glucose worth 618,786 yuan. 378 t of glucose will produce 162 t of sodium glutamate worth 2,423,076 yuan. 1,000 t of dry sweetpotato chips if processed into lactic acid will yield 500 t, worth 2,0 million yuan. If made into citric acid, 295 t will generate US$ 354,000 if exported, equal to 1,840,800 yuan.

Government Policies and their Effect on the Development of Sweetpotato

As mentioned above, though there has been a notable increase in total production, the cultivated area for sweetpotato has been declining. One of the reasons for this trend is that there is no clear policy for the development of root crops. Additional reasons for the decline in the sweetpotato cultivated area include the following:

- The need to raise cereal production, the staple food for a population reaching now over one billion. For some years cereals have been taking over cultivated land from other crops, including sweetpotato.

- Sweetpotato is not considered an "essential" crop. Therefore, it has no well-defined policy as per its production and sale. Because processing is primitive the sales value is low, giving little motivation to the farmer. Fortunately, sweetpotato is a very adaptable, high-yielding crop with many possible uses. Also the farmers who plant sweetpotato can depend on getting a harvest, therefore they have never lost interest in cultivating the crop.

- With recent policies paying more attention to better irrigation and soil improvement, marginal land where sweetpotato was being grown became suitable for other crops and sweetpotato was replaced.

- Market price has also had its effect. Because of its use in the brewing industry, the market price of sweetpotato has steadily increased. With better cultivation methods, corn has become a very high-yielding crop. Since corn is a reliable crop, its cultivation has expanded. Also, corn prices have been very competitive in comparison to sweetpotato. Corn is also an important starch source and is easy to store and transport. Therefore, corn is replacing sweetpotato as a source of starch and feed.

- Policies have given very little attention to sweetpotato processing. Sweetpotato is a crop which should be processed on site. It needs simple processing equipment which is not available at present. This has also restricted sweetpotato production.

Relative Importance of Different Processing Units

The home unit utilizes the sweetpotato plant directly. Simple processing includes sun drying of stems and leaves, dipping fresh roots in an agrochemical solution before storage, and slicing fresh roots for sun-drying, and ensiling. The home unit is also usually the direct consumer of industrial processing wastes (pulp, etc.) of sweetpotato for hog breeding. These can be collected from large and small factories almost free of charge.

The specialized household unit and collective rural enterprises are the main processors of starch and noodle products, using manual or semi-mechanized methods. Rural enterprises also produce preserves, wine, and malt, using only simple equipment. Specialized hog raising household units process silage and other mixed feed for their own use.

Products that require intensive processing such as monosodium glutamate, alcohol, fructose, citric acid, starch derivatives, or enzyme products are mainly produced by industrial enterprises.

Areas Requiring more Support

To further develop production and processing of sweetpotato, more support on the following aspects is required.

- Stem and leaf of sweetpotato is an important feed source and much utilized. But, under usual conditions, it is used only in the growing season. To make it an all-year supply, transportable and easy to store, methods to process it into meal are needed. The methods should be simple and energy efficient.

- Fresh roots are difficult to transport over long distances and storage and management is inconvenient. To solve this problem, it is essential to develop primary processing methods and equipment that are economical and easy to master and handle, for use in home, specialized household units, and rural enterprises.

- Though little of the sweetpotato plant is wasted in China, utilization is usually primitive. For instance as a hog feed, it is fed directly. Being nutritionally unbalanced, the feed conversion ratio is low. As for pulp and other processing wastes, only a small portion is utilized, most is used as fertilizer or becomes a pollutant. More research should be done on feed formulations to more efficiently utilize the sweetpotato plant and its by-products.

- Research work on breeding should pay more attention to different uses of sweetpotato varieties. We have found much literature in China on the comprehensive utilization of sweetpotato. But it is mostly theoretical, very little reflects concrete research or practical results and conflicting data are often shown. This shows that, as a whole, sweetpotato has not been given the priority it should have.

Conclusion

In China, great strides have been made in the cultivation and processing of sweetpotato. Its economic value has multiplied and the farmer has profited. But the road toward comprehensive utilization has only just begun. More efficient exploitation of a 100 million t fresh root crop and its processing by-products and of an 80 million t harvest of stem and leaf should have great socio-economic benefits. To reach this goal, we need a more coordinated plan for research. Also a more favorable policy should be developed to channel funds into research and development of suitable processing machinery. Finally, more emphasis should be put into extension of technology and education at the grassroots level.

Cassava Processing and Utilization in Thailand

U. Cenpukdee, C. Thiraporn, and S. Sinthuprama[1]

Abstract

Cassava is a major crop in Thailand. Area planted in 1990 was over 1.5 million ha, mainly in the northeast. Production was about 20 million t of fresh roots, valued at nearly US$ 950 million.

Cassava in Thailand is utilized mainly for the production of cassava starch, cassava chips and pellets, as well as modified starch. Most factories in the cassava industry are modernized enabling the production of the super high-grade starch required for overseas and internal markets. The cassava chip and pellet industry relies mostly on the external market, particularly the European Community (EC) market which purchases about 5.25 million t of pellets. All 381 pellet factories produce high quality, hard pellets which are required in the world market because of their low dust pollution.

Modified starch is produced by three principle methods: degradation, pregelatinization, and derivation. The industry produces many industrial products such as paper, textile, glue, plywood, alcohol, and food products such as sausage, bread, ice cream, monosodium glutamate (MSG), glucose, and fructose.

Thai government policy is to increase the cassava production without an increase in the planted area by providing high-yielding cassava cultivars and maintaining soil fertility.

Key words: industry, postharvest technology, products, government policies.

Introduction

Cassava (*Manihot esculenta*) is one of the most important energy-producing crops in the tropics (Kawano 1980). It is used as a staple food in the diet of approximately 300 million people, and 38%, 36%, and 26% of the total world production is produced in Africa, Asia, and America, respectively (Leihner 1983).

Cassava is an economically important and easily grown crop. It prefers a sandy loam soil and adapts to a wide range of environments. The crop can be grown between 30°N and 30°S, but the cultivated area is mostly between 15°N and 15°S (Cock and Rosas 1975).

It is an ideal crop for use in various agro-industrial systems because cassava starch can replace petrochemicals derived from oil. Cassava tops can be processed into high protein leaf meal, while cassava roots are processed into pellets, starch, and derivatives from starch, such as glucose syrup, monohydrate, Vitamin C, ethyl alcohol, acetone, butanol, citric acid, and high fructose syrup (McCann 1976).

The Thai Cassava Industry

Cassava was introduced to Thailand during the 18th century and was first grown in the southern part of the country. However, its production increased dramatically only when people started to plant cassava in the eastern provinces, where weather conditions are more suitable than in the South which has too much rainfall. After cassava had been grown for 40 years in the East

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and soil fertility had decreased, production gradually shifted to northeast Thailand. This area now contains the largest cassava plantations (Sinthuprama 1983).

In 1973, total cassava growing area was only 0.4 million ha and total production was about 6.3 million t (Titapiwatanakun 1974). Planted area has increased gradually to about 1.5 million ha in 1990, with a total production of 20 million t of fresh roots (Table 1). Yields have remained constant at about 14-15 t/ha.

The rapid increase in area planted and production of cassava in Thailand is mainly due to high overseas demand. However, area planted declined in the Central Plain and the East when the Eastern Seaboard Projects started to occupy a lot of land. This reduction in area planted is also due to the reduced availability of agricultural labor, caused by the high labor requirements of many industries which provide a more stable income than agriculture. Thus, cassava production has gradually shifted to the Northeast, which now has a production zone of about 1 million ha, followed by the Central Plain and the North (Table 2). At present, most cassava production comes from the Northeast, being twice that from the Central Plain, which includes the eastern provinces. However, yields are similar for all regions.

Now that area planted in cassava is about 1.5 million ha, modern industries have been established for various cassava products, including starch factories, and chipping and pelletizing factories. With a good transportation system, the products are successfully transported to the Central Plain where the exporting companies are located. As a result, cassava production has increased dramatically.

In the past, the value of cassava products ranked about ninth or tenth compared to other important field crops. By 1990, cassava had become the fifth most important crop with a total value of US$ 513.4 million. Its value was similar to sugarcane and corn, but was less than that of rubber (Table 3). Total export value of cassava products (about US$ 959 million in 1990) became second, a little higher than sugarcane products, but less than rubber products.

Interestingly, Thailand is now the world's largest cassava producing country with more than 23.46 million t in 1989, more than both Brazil with 23.24 million t and Indonesia with 16.58 million t (Table 4). Thai cassava production increased rapidly over the past ten years with production at 15 million t in 1981, less than the production in Brazil which was over 24 million t.

Table 1. Cassava planted area, harvested area, production, and yield in Thailand, 1986-90.

Crop year	Planted area (million ha)	Harvested area (million ha)	Production (million ha)	Average yield (t/ha)
1986	1.240	1.204	15 [illegible]	12.67
1987	1.411	1.371	1[illegible]4	14.26
1988	1.581	1.547	2[illegible]07	14.42
1989	1.622	1.593	24.264	15.23
1990	1.529	1.487	20.701	13.92

Source: Office of Agricultural Economics, Thailand.

Table 2. Cassava planted area, production and yield by region in Thailand, 1990.

Region	Planted area (ha)	Harvested area (ha)	Production (million t)	Avg.yield (t/ha)
Northeast	951,473	915,138	12.408	13.55
North	115,341	113,939	1.667	14.63
Central plain	463,035	458,463	6.626	14.45
South	--	--	--	--
Total	1,529,849	1,487,540	20.701	14.21

Source: Office of Agricultural Economics, Thailand.

Table 3. Crop value of principal agricultural products and total export products, 1988-90.

Products	Crop value (US$ million)[a]			Total export products (US$ million)[a]		
	1988	1989	1990	1988	1989	1990
Rice	2718.8	3427.6	2833.6	26.2	32.7	37.0
Rubber	618.5	750.1	643.1	933.1	1272.9	1278.1
Sugar cane	356.7	484.0	515.5	373.9	414.5	808.2
Corn	27[illegible].8	489.9	514.8	--	--	--
Cassava	544.3	543.5	513.4	826.4	873.8	958.9

Source: Office of Agricultural Economics.

[a]Baht 25 = US$ 1.

Table 4. Major cassava producing countries, 1979-81 versus 1988-89.

Country	Production (million t)		
	1979-81	1988	1989
World total	123,504	138,237	147,500
Thailand	15,128	22,307	23,460
Brazil	24,315	21,588	23,247
Indonesia	13,592	15,166	16,581
Nigeria	10,833	14,000	16,500
Zaïre	12,942	16,254	16,300

Source: FAO Production Yearbook Vol. 43, 1989.

The Target of Thai Export Cassava Products

In 1991, the Thai government, the Thai Tapioca Trade Association, and the Thai Tapioca Flour Industries Trade Association set an export target for Thai cassava in the form of chips and pellets of about 7.752 million t (5.25 million t will sell inside European Community and 2.5 million t will sell outside the EC) or about US$ 752 million, and 800,000 t of cassava starch, or about US$ 196 million. The total production is about 8.3 million t, valued at US$ 948 million.

However, the price of cassava products inside the EC is higher than outside. So the Thai government tries to increase or maintain the quota from the EC. At the same time, the Thai Tapioca Flour Industries Trade Association encourages cassava starch factories to produce more super high-grade starch, which has a higher price and a higher demand in the world market than normal starch. Thai pelletizing factories also produce only hard pellets, which have a high demand in the EC.

Cassava Utilization in Thailand

The Cassava Starch Industry

Cassava starch is classified as miscellaneous starches, which are unswollen grains with roughly circular and concentric rings. The particle size is about 15-25 micron in diameter. The starch is different from potato starches, which are classified as oval starches, those having large oval or conchoidal grains (Phillips 1974). Cassava starch is important since it can substitute for other starches made from corn, sorghum, wheat, mungbean, etc. The utilization of cassava starch is divided into two categories. The first is native starch, which is used in the food industry for production of sausage, monosodium glutimate (MSG), glucose, bakery products, etc. The second is modified starch, which is used in many important industries, such as textile, glue, paper, plywood, and the pharmaceutical industry.

Cassava starch consists of amylase and amylopectin in an approximate ratio of 22:78. This ratio determines the quality of starch, as well as an can be changed by the application of heat, or by acid or alkaline treatment.

Cassava starch factories are located mostly in the east and northeast of Thailand where most cassava is planted. Factories use two simple methods for buying cassava roots. The first method is used mainly in the East where the buying price depends on the starch content, as measured by the Reihmann scale. Factories will pay the full price only at 30% starch content and will lower the price according to starch content (Table 5).

The root price is reduced gradually if the starch content is between 30% and 20%. The reduction in this range is 20 baht/t for a 1% decrease in starch content. If the starch content is below 18%, the starch price will be decreased by 30-40 baht/t for each 1% decrease in starch content.

The second method is used in the Northeast by a few factories. They will deduct 10% of cassava root weight from farmers if some soil or some planting pieces are mixed with the roots. In this way, farmers can get only 90% of the full price.

There are two kinds of starch factories in Thailand: those using traditional methods and those using modern methods of production. The traditional ones are now rarely found and are only in the *sago* industry. The system uses a simple method and a small number of laborers. The procedure consists of grinding roots into mash and then separating the starch solution from the fiber by passing through a fine sieve. The starch is allowed to settle and is then sun-dried on a concrete floor. When dry, the starch is ground to a powder. This kind of starch is a low-grade starch used only in some food products inside the country.

Factories using the modern system have many sophisticated machines which can save on labor costs. Also, the quality of starch produced is super high-grade starch for export and the modified-starch industries. The procedure starts with peeling cassava root, cleaning, grinding by rasper, and extracting. Then the starch solution is centrifuged by a separator, thus all chemicals, protein, and other components are eliminated at this stage. The starch is dried with hot air before it is packed in special bags (Fig. 1).

There are about 54 big starch factories which have capacities ranging from about 70 to 500 t of cassava starch per day. That is to say that the needed raw material of cassava roots amounts to 300-2000 t per day for particular factories. The biggest starch factory, "Sa-ngun-wong," is in Nakornrajasrima Province in northeast Thailand and it can produce approximately 500 t of starch per day. The important markets for Thai cassava starch are Japan 30.45%, Taiwan 22.83%, the former USSR 18.41%, USA 8.87%, Indonesia 4.25%, Singapore 5.31%, and others 9.88% (Thai Tapioca Flour Industries Trade Association 1987).

For export, the Department of Internal Trade looks after the quality control of starch by setting the following standards: (1) the moisture content should be lower than 12.5-13%; (2) starch or starch granules should be over 97.5% (dry basis); (3) the viscosity is about 400 B.U.; (4) the color is pure white; and (5) the pH should be 5-6.

The price of starch at the factories ranges from 5-5.5 baht/kg, depending on the quality of starch. The special

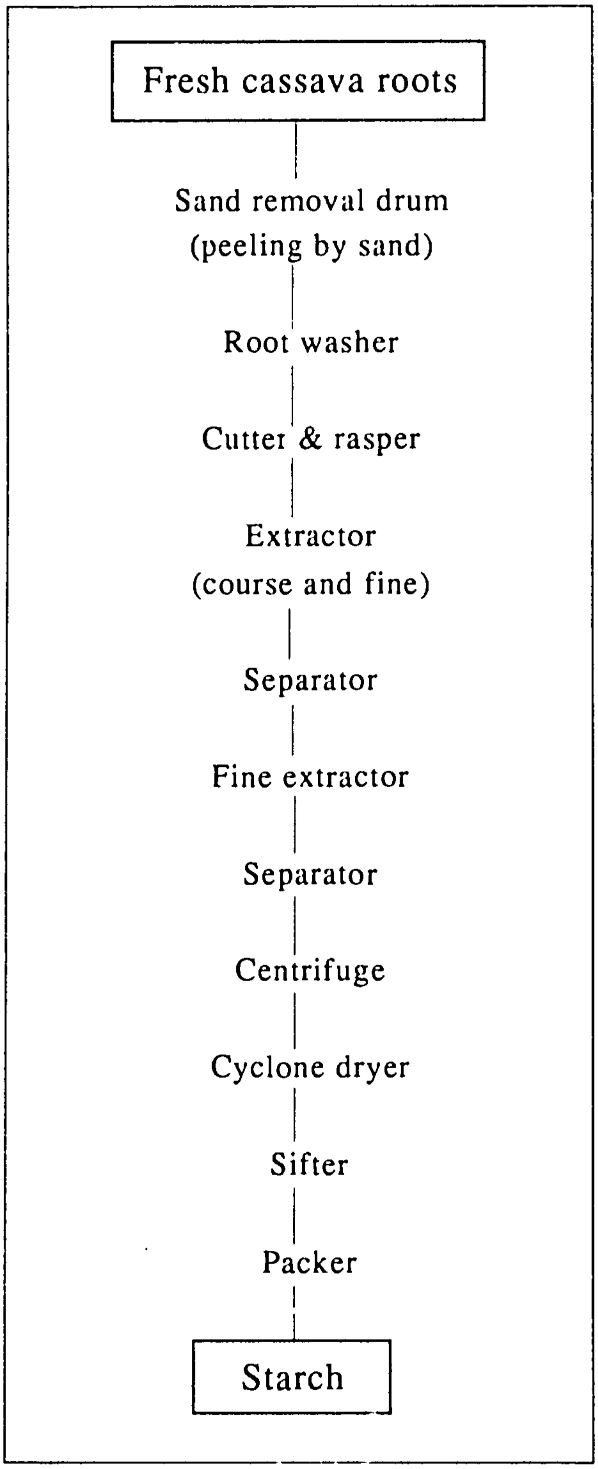
Table 5. A method of buying cassava roots by % starch, using the Reihmann scale.

Starch content (%)	Fresh root price[a] (baht/t)	Deduction (baht/t) per 1% lower starch
30	800	20
28	760	20
26	720	20
24	680	20
22	640	20
20	600	20
18	540	30
16	480	40

Source: Department of Internal Trade 1988.

[a]Price varies by the season.

Figure 1. Flow chart of starch processing (first grade).



Source: Setamanit et al., 1982.

grade is 5.5 baht/kg and normal grade is 5 baht/kg (personal communication with an owner).

Modified Starch Industries

Since Thailand produces surplus cassava starch each year, the Thai government and private sector try to utilize the starch efficiently. At present, there are many new modified-starch industries; their modifying methods can be classified into degradation, pregelatinization, and derivation (Fig. 2).

The degradation technique aims at reducing the viscosity of starch by three successive methods. The dextrinization is a method to roast starch with hot temperature and at the same time spray some acid to reduce the starch viscosity. The products from this method are white dextrin, yellow dextrin and British gum.

The oxidation method starts from mixing starch with chloride. These are then allowed to react together under low pH conditions. The reduction in viscosity depends on the amount of chloride used.

The third method is "acid treated." This method uses hydrochloric acid or sulfuric acid to reduce the viscosity.

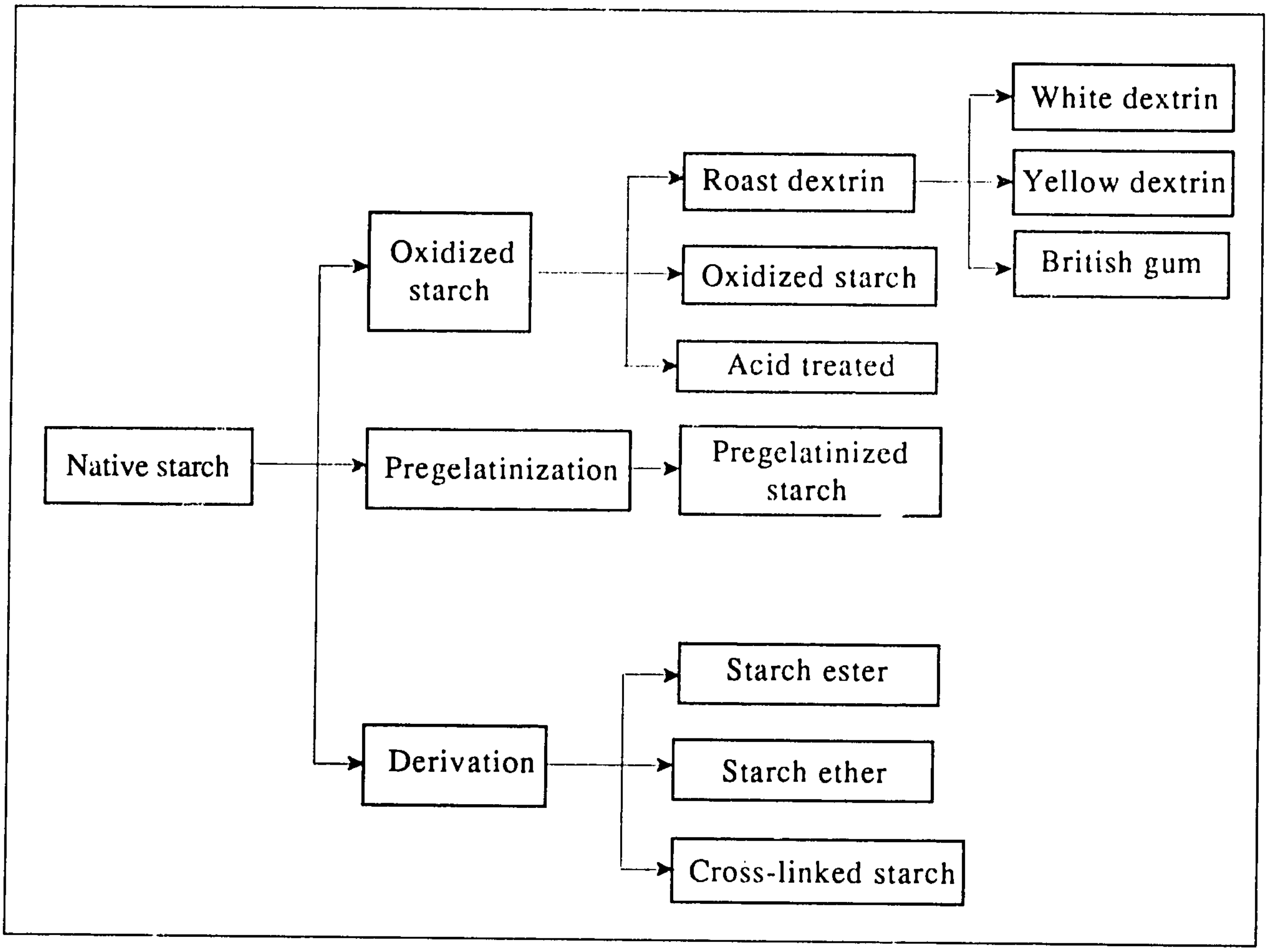
Pregelatinization is a method that uses a concentrated starch solution which is quickly dried on hot plates. The dried starch is ground and mixed with water until it becomes a kind of glue.

Derivatives are products obtained by modifying starch molecules by chemicals so as to produce acetated starch, cross-linked starch, hydroxyl propyleted starch, etc.

Industrial and Food Industry Use of Cassava Starch

The utilization of cassava starch can also be classified into industrial use and food industry use. For industrial use, cassava starch is used in many important industries such as paper, textiles, glue, plywood, and alcohol. A wide range of food industries use cassava starch according to the special characteristics of the starch. They produce soups, candies, pudding, sausage, bread, ice cream, many kinds of noodles, medicine, MSG, glucose, fructose, soft drinks, canned foods, etc. The following examples elaborate on some of these uses.

Figure 2. Processes used in the modified-starch industries.



Source: Thai Tapioca Flour Industries Trade Association.

Descriptionof Ethanol Processing

Pretreatment

Fresh cassava roots are peeled, washed, sliced, and grated into a mash (Atthasampunna 1990). The ground cassava is then converted into fermentable sugars by liquefaction and saccharification with the application of commercial amylolytic enzymes (&-amylase and gluco-amylase) and heat. The liquefaction is carried out at 80°C for 60 min and saccharification at 55°C for 2 hrs. (Fig. 3).

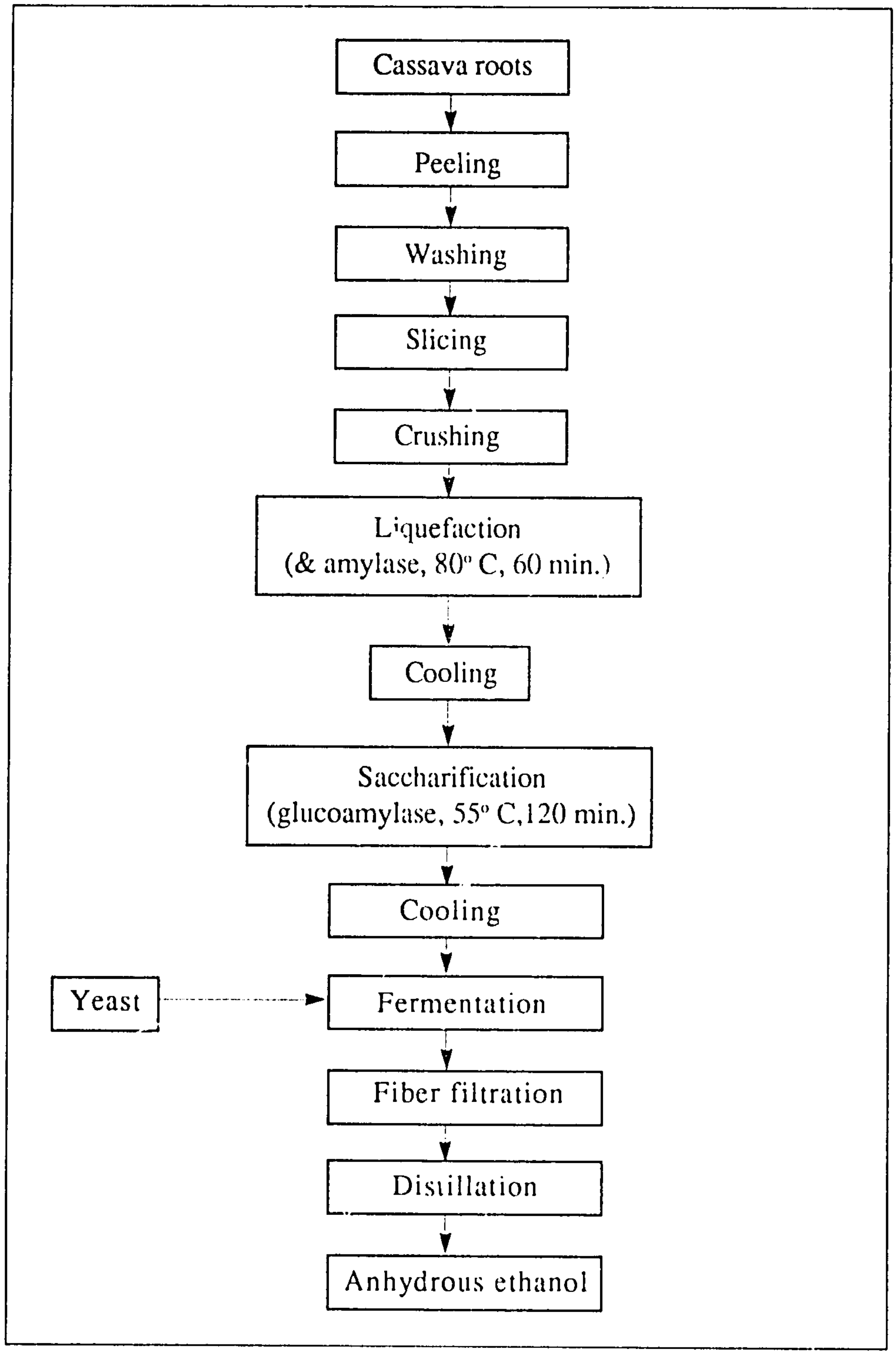
Fermentation

Yeast (*Saccharomyces cerevisiae*) is first cultured in a medium and then transferred into an active medium before transferring to a seed tank containing a sterile medium and leaving it for 24 hrs, after which it is ready for inoculation of the main mash in the fermenter. The fermentation is carried out in a series of fermentation tanks which are maintained at a temperature of 30-32°C for 48-72 hrs. The fermented mash is filtered to remove solid residues, and then distilled.

Distillation

The mash containing about 8% ethanol is preheated in a heat exchanger and fed into the mash-concentration column. This combined column is operated under controlled pressure of 1.4 kg/cm^2. The vapor from the column top is used as the heat source for the dehydration column. The dehydration column is operated under

Figure 3. Flow chart of cassava ethanol production.



Source: Atthasampunna et al. 1990.

atmospheric pressure on the ternary azeotropic system with benzene used as the extrainer. Ethanol of at least 99.5% (V/V) concentration is obtained from the bottom of the column.

Glucose Industries

The glucose industry is an important industry, which uses cassava starch at a level of 80% of all raw materials. The cassava starch used in this industry has to be of super high-grade. The demand for this kind of starch is about 10,000-15,000 t/yr.

There are three forms of sugar that can modified from cassava starch: glucose syrup, dried glucose syrup, and anhydrous dextrose. The process used in the glucose industry is gelatinization, started from an amylase addition to cassava starch, cooling, amyloglucosidase addition, filtration, decoloring, evaporation, purification, and crystallization (Fig. 4).

Cassava Chip/Pellet Industry

Cassava Chips

Cassava chips are produced simply by slicing fresh cassava roots into small pieces using a chipping machine. The fresh chips dry on a large concrete floor in about 2-3 days, depending on the solar radiation, until the moisture content is reduced to 14%. Most of the cassava chips are marketed directly to pelletizing factories.

Thailand has the capacity to produce over 15 million t of cassava chips per year, which is not fully utilized. The country can easily increase production if the demand from overseas markets increases.

The standard specifications of cassava chips for export are as follows: starch 65% minimum, raw fiber 5% maximum, sand 3% maximum, and moisture 14% maximum (Atthasampunna et al. 1990).

Cassava Pellets

Cassava pellets are produced from dried cassava chips by using a pelletizing machine. The small dried chips are preheated with steam, then pressed through a die having several hundred 7-8 mm diameter holes. At this stage the pellets are quite soft and warm, so they are cooled by the application of cool air to harden the pellets.

The traditional pellets, called "native pellets" are no longer produced, because of the dust pollution on handling these pellets at the port of destination. Dust-free hard pellets are now produced with better pelletizing machines.

Thailand is the world's largest producer of cassava pellets. Approximately 11 million t of pellets per year are produced by 381 pelletizing factories throughout the east and northeast part of the country.

The standard specification for hard pellets, set by the office of Commodity Standards in the Ministry of Commerce are as follows: starch 65% minimum, raw fiber 5% maximum, sand 3% maximum, moisture 14% maximum, hardness 12 kg/square inch force minimum by Kahl hardness tester, meal 8% maximum (1 mm sieve), and foreign matter nil.

The Netherlands is the largest buyer of hard pellets from Thailand at about 4.5 million t in 1987, followed by Spain, Germany, Portugal, Belgium, and Italy (The Thai Tapioca Trade Association Year Book 1987).

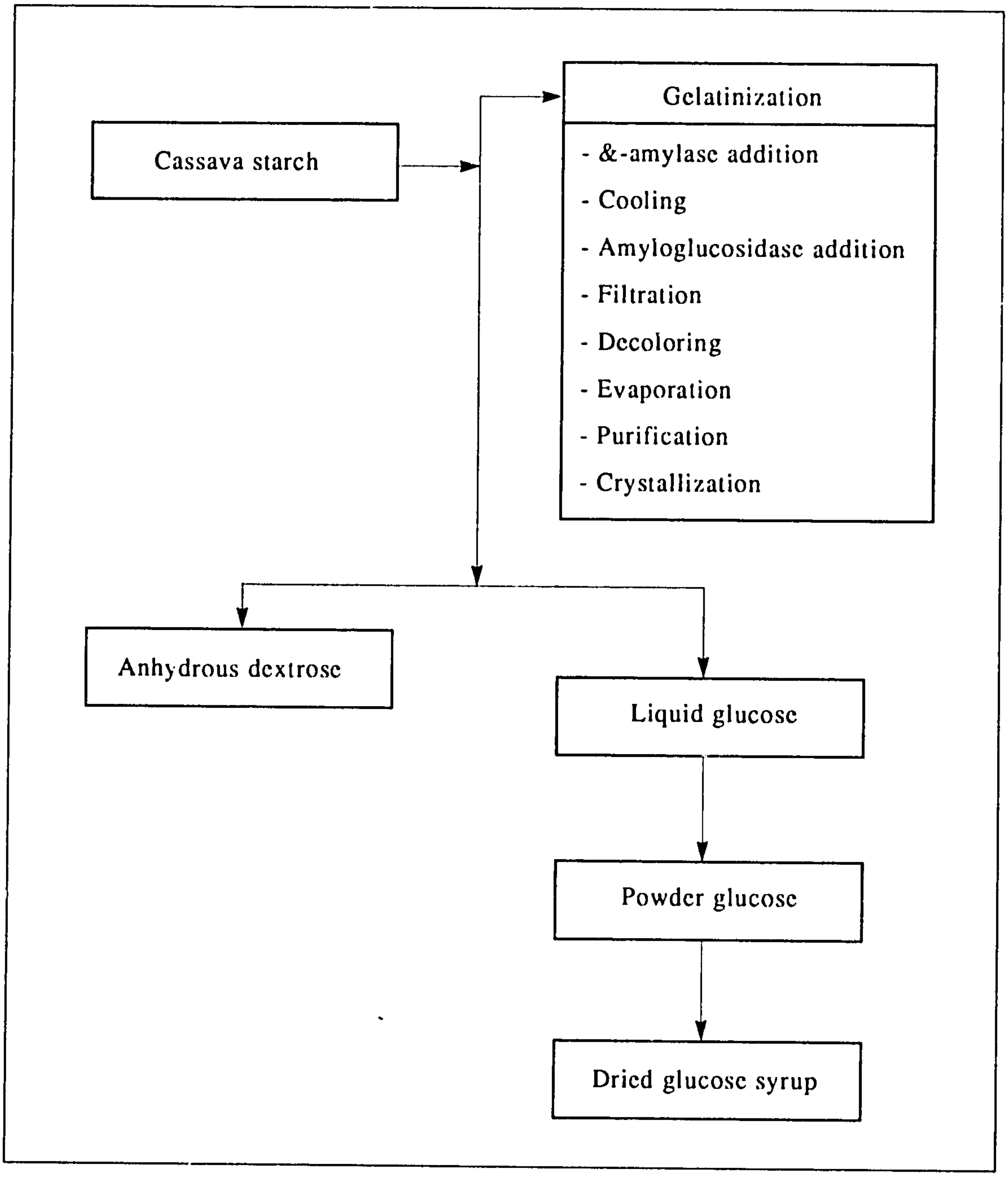
The demand for cassava pellets has rapidly increased in the Netherlands and this has become the most important European market for cassava, due to a high animal: land ratio; an efficient water transportation system, which enables imported feeds to be transported to many parts of Europe; a large compound feed industry which has developed utilizing computer formulation in feed rations; and an overall increase in demand for compound feeds in Europe (Phillips 1974).

The Netherlands, the greatest producer of pig feeds in Europe, prefers cassava pellets from Thailand, because in Thailand the chips are pressed into hard pellets after drying. As a result, the weight per volume unit increases, reducing transportation costs, while the hard pellets cause less dust pollution during unloading at the port of destination.

Thai Government Policies on the Development of Cassava Production

The Field Crops Institute, Department of Agriculture, Ministry of Agriculture and Cooperatives, is a Thai government institute which is directly involved in the research and development of cassava production. Its objective is to increase cassava production in terms of higher starch content and high dry matter yield per unit area. Research programs into cassava breeding and cultural practices were set up many years ago.

Figure 4. Processing of glucose.



Source: Thai Tapioca Flour Industries Trade Association.

Research on Cassava Utilization

Research on cassava utilization has been conducted on many topics useful to the Thai cassava industry by many institutes in Thailand (Atthasampunna 1990). Research topics involve production of animal feed, human food, industrial products, waste utilization, and recovery, etc.

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Sweetpotato Production and Utilization in Thailand

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Abstract

Sweetpotatoes have been grown in Thailand for a long time. However, they are neither a food staple nor a cash crop, but a secondary vegetable. This paper reviews recent production, marketing, and utilization trends for sweetpotato. It also highlights the factors that influenced the decline in production (e.g., sweetpotato weevil) and processing (seasonal supplies, unstable prices). Sweetpotatoes are currently utilized to make a variety of processed products. Research is needed to improve varieties, postharvest handling, and expand the market for alternatives products.

Key words: sweetpotato, cultural practices, processing.

Introduction

Sweetpotatoes have been grown in Thailand for a long time. They can be grown in almost every part of the country and year round. Consumption of sweetpotato has increased both for human food products and by-products for animal feed. Various parts of the plant, leaf, vine, and young top stems, are used for animal feed. A substantial quantity of sweetpotato is being processed for food products. The estimated amount of sweetpotato flour used in industry is about 2,250 t annually. Presently, sweetpotato flour is used for making noodles for Korean and Japanese markets (Thongjiem 1989). This industry could be scaled up if the quality of sweetpotato regularly being supplied was consistent.

Growers have faced several problems during production, such as planting techniques, inadequate knowledge about crop behavior, diseases, insects, and selecting varieties. Sweetpotato weevil is the insect which causes the most severe damage during the growing period. This damage results in low yield and poor quality for industrial use. The development of production techniques, selection of suitable varieties for both the wet and dry seasons, and development of disease resistance need to be emphasized with growers. Prospects for expansion of processed sweetpotatoes at the industrial level are good. In the future, sweetpotatoes could become a cash crop for growers.

Production

Production of sweetpotatoes in Thailand has fluctuated. Since it is neither a staple food nor a major cash crop, the government has no policy to promote its production. The use of sweetpotato in industry should accelerate production interest on the part of growers. Various areas of the country could grow sweetpotatoes because the crop tolerates hot climates and is drought resistant. It is considered to be a popular root crop for the growers since it can be used as both food and animal feed. Research results have been used for promoting yield and quality. Factors affecting crop characteristics have been investigated from plantation till harvesting. This research was undertaken by the Departments of Agriculture and Agricultural Extension.

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Availability Concerned with Sweetpotato Production

Plant materials

The general characteristics of plants available for propagation have been introduced to the growers for selection. Young plants as sprouts, cut-sprouts, slips or draws, and vine cuttings are commonly used to establish commercial and garden planting among the growers (Edmond and Ammerman 1971). Seedlings are used mainly by breeders.

Different varieties have been selected and are grown in different regions. The variety Mae-jo shows a high yield in the Northern Region but a low yield in the Central Region. In the Central Region, the variety Nigro produces high yields in the cool season, but low yields during the rainy season. Therefore, cultivated area and season have an influence on sweetpotato yields. Growers tend to select a variety which produces high yields in both the rainy and cool seasons.

The reasons for selecting sweetpotatoes can be classified into three types:

Harvesting periods: From planting to harvesting can be identified as 90 days for a light variety, 120 days for a medium variety, and 150 days for a heavy variety.

Flesh color: For different uses the flesh color may vary from white, yellow, and orange to purple.

Use: Variety selection has been done by the Horticulture Center in Phichit, Department of Agriculture. The main uses being introduced are industrial, fresh consumption, and feed.

Cultivation Management

As mentioned, sweetpotatoes can be grown in various parts of the country year round. Common practices are growing between June and September in the rainy season, October and January in the cool season, and February and May in the hot season. If irrigation is available, the crop can be grown 3-4 times/year. Sweetpotatoes can be grown in all types of soil but sandy soil is the best for preparation, harvesting, and production of large roots. Clay soil needs to be treated with manure to obtain a sufficiently loose soil texture.

Cultivated areas should be close to a water reservoir and have reasonably available transportation. Soil preparation, vine cuttings 30 cm long, and using proven spacing and planting techniques are advised. Crop maintenance includes replacing some of the wilted vines, watering, fertilizing, weeding, and trimming vines 1-2 months after planting.

Harvesting and Handling

The harvesting period depends on the variety and ranges from 90-150 days after planting. Manual digging is normally practiced for a small plantation. Tractors or animals pulling plows between planted rows is done to speed up harvesting. This harvesting method, however, may cause damage by bruising roots. Also, hand digging of left roots is needed. Harvesting sweetpotatoes must be handled carefully to prevent bruises which cause spoilage. Roots should be kept in the shade and be well ventilated. Rotten parts and insect damage must be trimmed and the sweetpotatoes washed before packing (for the retail market) in plastic bags with ventilation holes.

Prolonging the shelf-life of sweetpotatoes after harvest (e.g., to prevent rotting) can be achieved by (Poonpaim, Narin, and Chumnan Tongkat 1989): harvesting only mature roots (immature roots may cause rotting); digging or plowing roots and transporting with care to prevent bruising; soil may stick on roots during harvesting and roots should not be washed (they should be left to dry without washing before storage); storing in a ventilated area with air temperatures of 10-15°C; and, keeping roots on a shelf. Do not stack in large piles or step on roots. In addition, dehydrated roots are an alternative way to store; and dried pieces can be ground into flour.

Factors Affecting Reduced Production

Factors that may have influenced a reduction of sweetpotato production in Thailand can be summarized as follows:

- The majority of the growers grow sweetpotato as a minor crop. Therefore, a good price for the main crops may affect the sweetpotato planting area.
- The severe problem of sweetpotato weevil causes growers to reduce sweetpotato planting.
- Since the price of sweetpotato is uncertain, it causes the growers to reduce their planting areas or to diversify to other crops to obtain a better price.
- There are many competitive crops such as fruits and vegetables which give more income than sweetpotato.

Production Statistics

Statistics for sweetpotato production in Thailand during 1988-90 according to the report of the Department of Agricultural Extension (DOAE) are shown in Table 1. Area planted in sweetpotato ranged from 7,200-9,300 ha, annual production was between 75,000-112,700 t and the average yield was 6-12 t/ha. Production area can be divided into six regions throughout the country. The western part seems to comprise the largest area with up to 3,100 ha, and the second largest is in the South with about 2,000 ha.

Utilization

Sweetpotato has been consumed as food for a long time in Thailand. Previously, farmers grew sweetpotato for their families' consumption and to earn some extra income. Commercial plantations are very few. Since 1987, the Government of Thailand has had a National policy to promote commercial production through activities led by the Department of Agriculture and the Department of Agricultural Extension. In this regard, industrial use needs extensive research to develop an appropriate technology for processing a product. Presently, the processed sweetpotato products available are from simple processing, therefore the quantity is still small; however, the potential to expand consumption should be promoted. Most products are known and well accepted among consumers, but consumption is largely restricted to dessert or snackfood products.

Home and Cottage-industry Processing

More than 85% of sweetpotato roots are used for human food. They are considered to be a good source of carbohydrates with a high nutrient content compared with other starchy food products, e.g., rice, corn, and taro. A comparison of the nutrient content of sweetpotato, potato, rice, soybean, and mungbean is shown in Table 2. Sweetpotato can be a good source of Vitamin A. When prepared at home, the whole sweetpotato is consumed by boiling, steaming, and baking. Various dessert products are prepared by cutting roots into pieces and boiling in coconut milk or syrup and shredding into pieces and deep fried. Boiled and mashed roots are used as a filler food and often to replace potato.

The whole root is used in general food preparation at the home level. Therefore, dishes prepared from sweetpotato contain all available nutrients in the roots. Since this is so, the Department of Agriculture has a breeding program to improve the texture to one which is fine and dense. Those varieties in this program are Narin 03, Rai-et 7, PIS 091, and Nigro. In addition, young leaves and stems are commonly used as vegetables in the Northeast.

Recently, a study was carried out by the Department of Agricultural Extension to determine Thai food habits regarding sweetpotatoes. This was done in the Central Region and the South (Ayuttaya and Nakorn-Sritummarat) where most sweetpotatoes are grown. Results show that sweetpotato is quite a popular dish. Males and females of all ages who live in both city and suburbs consume sweetpotatoes. There are three types of products available: dessert, snackfoods, and main meal

Table 1. Sweetpotato production in Thailand, 1988-90.

	Area planted (ha)			Production (t)			Yield (t/ha)		
Region	1988	1989	1990	1988	1989	1990	1988	1989	1990
Northern	589	660	830	4,905	7,919	5,299	8.33	12.00	6.38
Northeastern	1,310	1,236	1,547	12,184	10,045	9,411	9.30	8.13	6.08
Central plain	1,470	1,160	545	10,452	11,600	2,978	7.11	10.00	5.46
Eastern	1,127	1,098	555	9,974	10,984	3,642	8.85	10.00	6.56
Western	1,613	3,155	3,539	27,306	60,446	22,818	16.93	19.16	6.44
Southern	1,120	1,994	873	10,584	11,747	5,004	9.45	6.00	5.73
Total	7,229	9,303	7,889	75,405	112,741	49,125	10.43	12.12	6.23

Source: Department of Agricultural Extension.

Table 2. Comparison of nutrient contents of sweetpotato, potato, rice, soybean, and mungbean.

Nutrients	Sweetpotato	Potato	Rice	Soybean	Mungbean
Moisture (gm)	70.0	67.0	13.0	8.0	11.0
Fiber (gm)	0.3	0.1	0.5	18.0	1.1
Calorie	113.0	75.0	354.0	325.0	320.0
Protein (gm)	2.3	2.3	6.5	36.8	22.9
Iron (mg)	1.0	0.7	0.6	7.4	4.9
Calcium (mg)	46.0	7.0	15.0	216.0	86.0
Vit. A I.U.	7.1	0	0	20.0	70.0
Vit. B_1 (mg)	0.1	0.1	0.1	0.4	0.5
Vit B_2 (mg)	0.1	0.1	0.1	0.3	0.3
Niacin (mg)	0.9	1.0	1.4	3.2	3.1
Vit. C (mg)	20.9	7.0	0	0	0

Source: Asian Vegetable Research and Development Center (AVRDC).

dishes. The most popular product is dessert which is prepared by using sugar as the main ingredient. Consumers are familiar with many suitable varieties for preparing these dishes.

Food shops in these areas have provided a sweetpotato menu to complement other food products. The village processing level is normally a supplier for vendor food shops. The most popular sweetpotato products from village proces-sing can be ranked in importance from snackfood to dessert and main meal dishes. The process used is quite simple, but the products have a short shelf-life. It was found that the processors could earn an income within the range of B 2,000-8,000/year/product (Bhat 25.56 = US$ 1).

The Department of Agricultural Extension has studied suitable varieties of sweetpotatoes and product quality which involved low-cost technologies. The purpose was to promote those technologies which could be applied at the village-level, especially for the grower families, to increase incomes through processing sweetpotato products. New processed food products being in-troduced are crisp sweetpotato chip, rice-sweetpotato chip, and sweetpotato sauce.

Industrial Processing

Sweetpotatoes can be processed into various food products at the industrial level. Because processed food products are widely consumed at the home processing level and commonly available in the marketplace, industrial processing seems to grow quite slowly. At present, the social structure is gradually changing with a large proportion of the population spending more time travelling to work. Processed food products are in high demand and good keeping quality is required. Currently, industrial processing of sweetpotato is still on a small scale. Sweetpotato starch has been processed by tapioca factories for use as an ingredient in snackfood processing. However, the annual demand for sweetpotato starch has never been estimated. Promoting utilization of sweetpotato at the industrial level needs further research to meet market requirements. The Department of Agriculture has a breeding program to produce a sweetpotato for industrial use. Sweetpotatoes known to have high starch content are two varieties, TIS 8250 and AIS 057-4. Potential processed food products could be classified into three types:

Whole Root Processing

These products have a sweetpotato appearance such as canned slices or puree, chips, and flakes. Canned slices or puree have not been manufactured for the local market. Chips and flakes are processed only at the home-level.

Flour and Starch

These products are processed using sweetpotato as an ingredient. Flour and starch are extracted and used in a mixture known as composite flour. This is used for noodles, cookies, cakes, jam, sweets and desserts, and extruded products (as snackfood). Starch may be further processed to improve the texture of food products. Few food factories have experimented in using sweetpotato flour and starch in their food products. Extensive research to seek an appropriate processing technology needs to be identified for both the availability of raw material (sweetpotato) and finished products that meet consumer preferences.

Various products (which cannot be identified as sweetpotatoes) are processed by the hydrolysis methods, such as glucose, alcohol, citric acid beverages, and ice cream. Those products are actually processed by using sweetpotato starch as the source of raw material through the hydrolysis process. The starch is transformed into sugar, alcohol, and acid. In this regard, if other starchy crops in the country are cheaper than sweetpotato, sweetpotato starch would not be used. Presently, such products are processed mainly from tapioca starch in Thailand because sweetpotato costs more than tapioca. Studies on processing technology using sweetpotato starch have been carried out.

Feed

About 10% of sweetpotato is used for feed processing. Vines, stems, and unmarketable roots are used for feeding hogs, cattle, rabbits, chickens, and fish. The breeding program of sweetpotato for animal feed has emphasized a high nutrient content in two varieties, CI 5?0-33 and PM 03-2. Experiments on the high nutrient quality of sweetpotato need to be developed. Effectively improving feed quality could assist in promoting sweetpotato utilization.

The utilization of sweetpotato as mentioned needs more research and development, especially the application of flour and starch in many products and the advantage of replacing sweetpotato for the other starchy crops, e.g., tapioca, potato, and taro, which are used in the food industry.

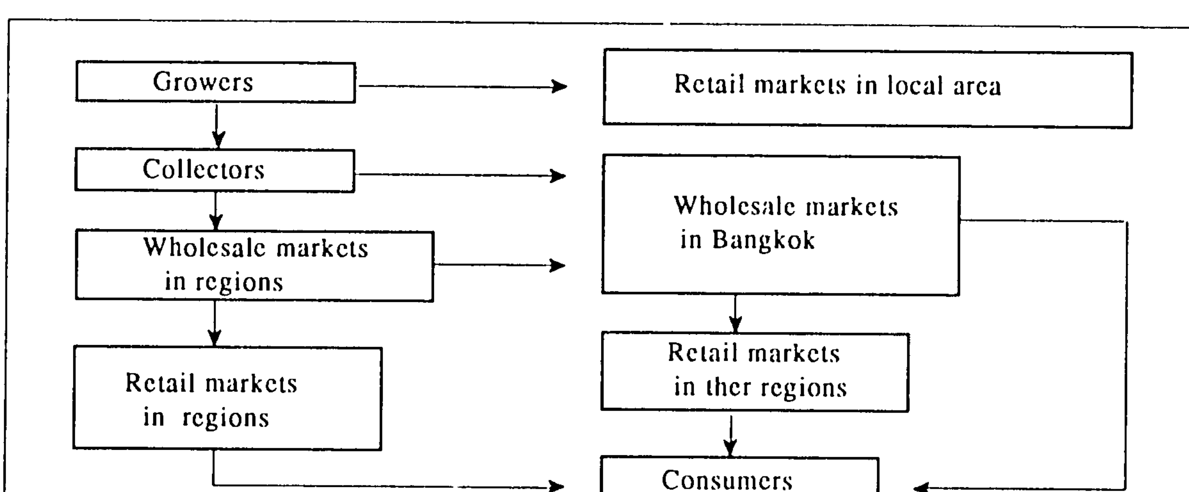
Marketing

Most sweetpotatoes produced flow through the market for fresh root consumption. A small amount is processed at the small-scale, village level. The market distribution of sweetpotatoes can be classified as growers who sell their sweetpotato in the local market, and growers who sell their sweetpotato at the farm gate (Fig. 1).

The growers who sell their produce through the local market are very small growers with an average 0.05-0.06 ha of planted area. The purpose of planting is for their own consumption. Any excess will be cleaned and packed for the local market and sold directly to consumers. This kind of commerce appears in almost every province.

For those who sell at the farm gate, the purpose of planting is for commerce. These growers are classified as medium to big growers with 0.16 ha to over 1.28 ha of planted area. After they get orders from middlemen, they will harvest the sweetpotato. They clean, grade, and pack them in plastic bags; each bag contains ten kg. The middlemen come and collect the crop from the growers. The produce will then be transported to the central market in the region such as Huaitt market in the South, Warin Chumrab markets in the Northeast, or Park-Klong Talad and Simum Muang markets in Bangkok. Retailers buy sweetpotatoes from these central markets and distribute to local markets all over the country.

Figure 1. Growers' market for sweetpotatoes.



Pricing

Pricing of sweetpotato is similar to other agricultural commodities. Middlemen usually give a price for their daily purchases. Growers have no power to set a price. The relationship between middlemen and growers is more complex than when the government intervenes to establish a price system. Advanced provision of agricultural materials, including financial support from middlemen to the growers, has strongly influenced crop production. Therefore, unfair prices for agricultural commodities have always caused the growers to become discouraged about production. If sweetpotato had a high industrial demand, raw material could come directly from the growers. However, first the crops need to be promoted for utilization at the industrial level. Currently, the average price of sweetpotato at the farm gate is only B 2-4/kg, again, depending on variety or characteristics. The price will be marked up about B 1-2/kg in the Bangkok market where the price is about 50% higher. Sweetpotato prices fluctuate quite a bit depending on the season. The in-season (August-September) price is low, about B 2-3.50/kg, while the off-season price is about B 3.50/kg or more.

Future Trends to Develop Sweetpotato

Production

There are still many production problems for sweetpotato growers, such as low quality standards and low yield due to unsuitable varieties being grown. Cultivation technology to be used when encountering diseases and insect infestation still requires more research. Increasing productivity and quality improvement have been emphasized as follows:

- research to identify varieties that can produce a high yield in both rainy and dry seasons, have disease and insect resistance for good quality roots, and have a high starch content for industrial use;
- research on appropriate technology in each plantation area, cultivation management, pre and postharvest including elimination of important diseases and insects; and,
- effective technology transfer to growers for plantation and cultivation management needs to be investigated and extension done to promote research results which are essential to establishing rapid communication between researchers and growers.

Utilization

Promotion of sweetpotato utilization and product development could help to prevent further decreases in price. Research should be emphasized as follows:

- select a proper variety for the processing industry;
- introduce sweetpotato processing that prevents nutrient loss;
- introduce low-cost technology to develop quality products, especially at the village processing level;
- develop improved products; and,
- investigate consumer preferences using sensory evaluation.

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Cassava and Sweetpotato Processing, Marketing and Utilization in Vietnam

Quach Nghiem[1]

Abstract

This report presents the current situation of cassava and sweetpotato processing, consumption, and utilization in Vietnam during the last ten years. Due to changes in the price system and to improved, low-energy consumption processing technologies, cassava and sweetpotato have gradually become important cash crops for local farmers and processors. Cassava has already become an important low-cost raw material for industrial processing. This report gives details on some recently developed or improved processing technologies appropriate for rural conditions: fresh root processing and preservation, sweetpotato transparent noodles, protein-enriched cassava and sweetpotato animal feed, cassava maltose, and cassava bread. These technologies have been effectively used in Vietnam. Finally, this report shows the main problems and needs for further research and development.

Key words: cassava, sweetpotato, processing, Vietnam.

Introduction

Cassava and sweetpotato are traditionally important food crops in Vietnam. They are used for animal feed and for human consumption either in fresh form or as dried slices. Both crops are grown in almost every province in the country. However, the development potential of cassava and sweetpotato is still enormous.

The economic value of sweetpotatoes and cassava remains low. The market for them is not yet fully developed and is affected by various economic and social factors. In a self-supplied, agricultural-based economy, root crops are primarily used in the farmer's own household. Only part of cassava production is used as a raw material for industrial processing. In order to develop cassava and sweetpotato production, more efficient techniques for processing, utilization, and marketing should be developed. Furthermore effective government policies are needed for the development of root crops so as to provide a stable income for root crop farmers and processors.

We present here the current status of cassava and sweetpotato processing, production, and consumption in Vietnam. Main problems in these areas are identified and the production potential and market demands of raw material are evaluated. Some appropriate technologies for fresh root processing and preservation, such as milk-sap removing cassava processing, transparent noodle making from sweetpotatoes, and protein-enriched animal feed made from sweetpotatoes and cassava, are appropriate to the farmer households and village conditions that have been developed and expanded in Vietnam. On-site processing systems, i.e., at the farmer and village level need further development.

Production and Distribution

In Vietnam, the distribution, utilization, and marketing of root crops has not been studied in great detail. The following remarks give only a general idea of the situation of root crop utilization and marketing.

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During the last ten years, cassava and sweetpotato production have not increased. The total output of sweetpotato has stagnated at 2.2-2.4 and cassava at 2.6-2.8 million t/yr (Table 1). The yield of sweetpotato is low, 6.5 t/ha compared with the world average yields of 14 t/ha. Vietnamese farmers invest little in sweetpotato cultivation. Farmers add only some animal manure or green manure, if available; they do not add any other inputs. The situation of cassava is no better. Nearly all cassava production is concentrated on the poorest soils. Cassava is grown without fertilizer and yields have declined due to nutrient depletion and soil erosion.

Table 2 and Map 1 give detailed information about the main regions of cassava and sweetpotato cultivation. Red River Delta and North Central are the two biggest sweetpotato cultivation areas where about 54% of sweetpotato is produced. The Northern Mid-elevation and Highlands and South Central areas produce 57.7% of the total cassava output.

In the Mekong Delta where the rice and corn output per inhabitant is the largest in the country (453 kg/capita/yr), root crops can play only a limited role in the food supply.

Utilization

Traditionally, cassava and sweetpotato have been the farmer's strategic food reserve and were consumed in the case of a rice crop failure. Until recent years, about 80% of cassava and 90% of sweetpotato were consumed and marketed only within rural areas. Both root crops were mainly used in the form of fresh or dried chips as animal feed and for human consumption.

In general, in the sweetpotato and cassava main cultivation regions, the maize and paddy rice production per capita is still low (170-240 kg/capita) (Table 2).

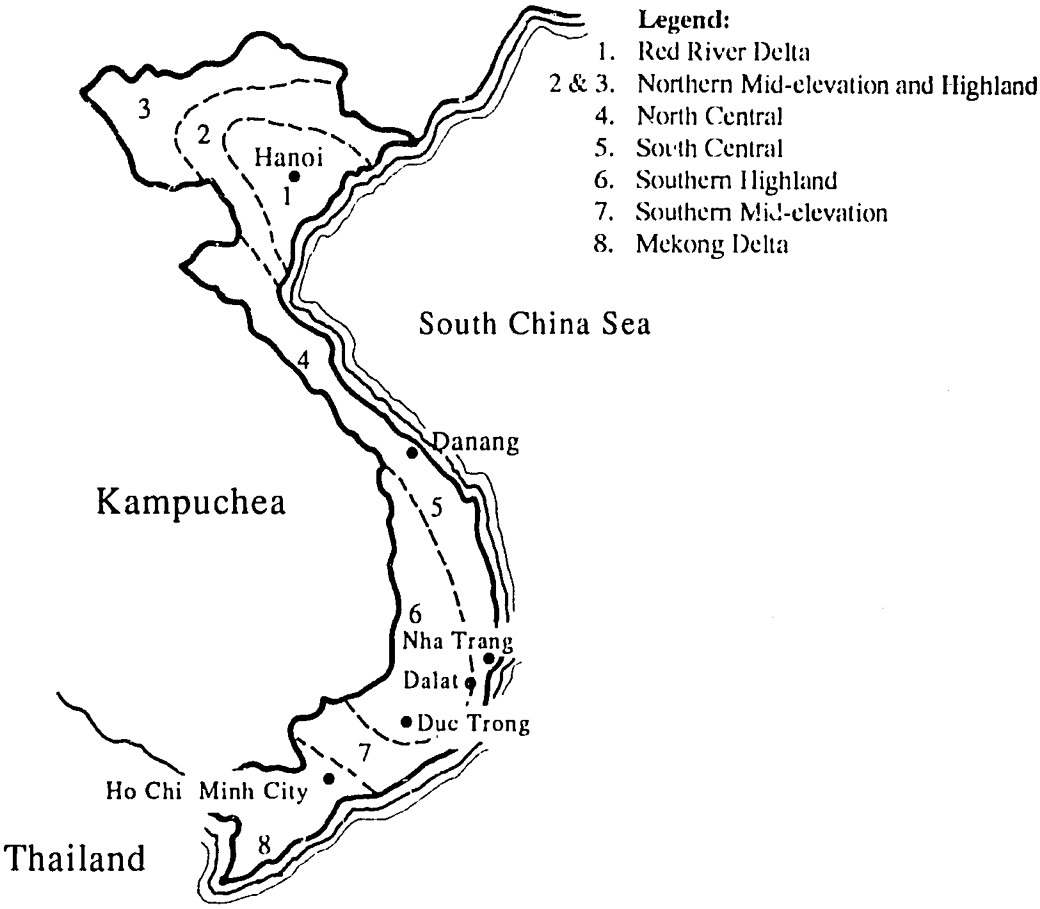
Table 1. Area planted, production, and yield of the 4 major food crops in Vietnam, 1988.

Crop	Area planted (000 ha)	Production (000 t)	Yield (kg/ha)
Rice	5,600	15,960	2,850
Maize	405	526	1,300
Cassava	330	2,622	9,200
Sweetpotato	285	2,145	6,500

Table 2. Food production in the main cassava and sweetpotato cultivation regions.

Region	Sweetpotato (000 t)	Sweetpotato % of total	Cassava (000 t)	Cassava % of total	Rice and maize (kg/capita)
Northern Mid-elevation and Highlands	360	16.3	818	31	191.5
Red River Delta (without Hanoi capital)	518.9	23.5	(141)	--	241.8
North Central	703	31.3	337	12.7	176.8
South Central	253	11.4	704	26.7	229
Southern	(54)	--	404	15.3	174.7
Mekong Delta	(203)	--	(127)	--	453

Map 1. Regions of Vietnam based on geography and climate.



In the central part of Vietnam, where root crops account for about 30% of the total food production, the local people have a tradition of using root crops as a daily food. There are different tasty dishes made from cassava and sweetpotato. Home processing of root crops is well developed in several provinces of Central Vietnam. In order to provide balanced nutrition, cassava and sweetpotato dishes are often eaten with mungbean, broad bean, sesame, and fish.

In the other regions where home processing of root crops is not common, the fresh roots or dried slices were traditionally consumed by the people in simple boiled or cooked forms along with rice for their breakfast or dinner. Due to the improvement of the rice supply in the country during the last three years, the proportion of root crops used directly for human consumption has been reduced. Human consumption of root crops in urban areas is very limited.

In Hanoi and Ho Chi Minh City, statistics show that about 15,000 to 30,000 t of fresh roots are used annually for breakfasts and for cake processing. The largest root consumption is for animal feed. About 65% of cassava and sweetpotatoes are used for animal feed in rural areas. While sweetpotatoes are used for animal feeding in the fresh form, dried cassava is an important food for pigs and other animals. The total green material from sweetpotatoes is equivalent to 50% of the root weight. This green material is also an important feed source for pigs in rural areas. Cassava leaves, as a green powder, are used in the animal feed industry. Finally, the use of root crops in farmer families depends on their household's economic circumstances. In areas where root crops are grown, cassava and sweetpotatoes are used as the main food to fight against hunger in the poorest households. A small part of the harvest can be used for animal feed. Less poor, more experienced households, usually use up to 100% of the roots produced for animal feeding. Thus, the root value will be increased by 60% and their products are free from the constraints of the consumption market. The larger amounts of roots sold in the market are mainly from households with much labor or limited capital and a lack of market knowledge. These households grow extensive root crop areas and root crops are considered to be their main cash crops. Income derived from root crop sales is used for paddy inputs and family needs.

Cassava and sweetpotatoes play an important role in animal feeding in areas where peasants used to cultivate paddy at which time they would buy additional amounts of cassava and sweetpotatoes for their animals.

About 9.5% of the cassava produced is used as raw materials for industry. Sweetpotatoes are not used so far for this purpose. Presently, about 6.3% of fresh cassava is processed into starch. At present, the confectionery, alcohol, and animal feed industries are the main consumers of cassava chips and cassava starch. In the near future, the fermentation industry will be developed and food prices in Vietnam will continue to increase until prices approach those in the international market. This also will contribute to the increase in domestic utilization of cassava and sweetpotato.

Besides producing cassava for domestic consumption, Vietnam also exports dried cassava chips. However, because of a shortage of storage and the hot and humid climate, the quality of dried cassava chips is not good for export.

Demand and Marketing System of Fresh and Halfproducts

In Vietnam, food marketing is considerably affected by the shortage of transport and storage, by the fluctuation of demand and supply, and by the low purchasing power of the average consumer.

The root crop market in Vietnam has been very unstable, even in rural areas. The price of roots has been dependent upon the price of rice because roots play a supporting role in the general food supply. In years when rice production was abundant, root prices dropped drastically. In the past, the price of rice was held artificially low as a result of government subsidies on fertilizer (Table 3). Consequently, the price of roots was too low and the income of root producers was not sufficient to permit any investment in the cultivation of cassava. The price of roots relative to that of rice was abnormally high due to these subsidies and, therefore, consumers generally preferred to consume rice rather than cassava or sweetpotato. Therefore, the marketing system for root crops had not developed.

Since the middle of 1990, however, the price situation has changed radically. Prices of rice and paddy were increased to be equivalent to the international price. In local markets, consumers have come back to root crops, and it is estimated that demand for root crops will increase. Demand for cassava for confectionery and fermentation industries and animal feed will increase at an estimated rate of about 8-15% per year during the next years.

Because the price of cane sugar is relatively high (1 kg of sugar costs the same as 2.5-3.5 kg rice), low-cost cassava malt is mainly used in the confectionery and fermentation industry in Vietnam (1 kg malt costs the same as 1 kg rice). The price of cassava starch is lower than the price of rice and wheat flour, so that cassava starch or milksap-free cassava flour will be an economically attractive raw material for the food-stuff, textile, and paper industries (see Table 3).

Table 3. The price (in Vietnamese dong) of urea, rice, wheat, and several cassava products before and after abolishment of the state subsidies on fertilizers in 1990.[a]

	Urea	Rice	Wheat flour	Cassava fresh roots	Cassava chips	Cassava starch	Cassava malts
Before subsidy (Jan. 1990)	680	500- 550	1,400	90	220	750	650
After subsidy (Mid-1990)	1,400	900-1,200	2,000-2,200	140	350	1,050	1,100

[a]US$ 1 is approximately 6,000 dong.

Because of the high price of rice in rural areas, sweetpotatoes and cassava will be used more as human food and animal feed. In urban areas where cassava and sweetpotatoes were rarely eaten, root crops now appear more frequently in the markets. Fresh roots are used by the urban poor as breakfast food and as low-cost confectioneries.

Not many studies on cassava and sweetpotato marketing have been carried out, except the recent study by Bottema and his colleagues (Bottema and Henry 1990). Two market forms for root crops may be distinguished. The main market is the circulation of food commodities in rural areas and the other is the market to industries and urban areas.

Traditionally, cassava and sweetpotato are exchanged between the root crop and the rice cultivated regions, mainly through direct exchange and also through the private wholesale system. The village market is the location of this exchange which has contributed to a reasonable food balance, in terms of quantity and quality, between the two regions. The village market system and direct market channel of root crop producer to consumers can reduce the marketing cost by about 80%. This market channel guarantees to keep prices at a level suitable for consumers in rural areas.

The market system supplying fresh roots and half products for urban areas and industries is more complicated. Particularly the fresh cassava which needs rapid transport to consumers and processing sites. Until now there have been various market channels operating in North and Central Vietnam (see Table 4). Underemployed farmers participate dynamically in the root crop marketing system. They collect and transport sweetpotatoes by bicycle to the markets (often over a distance of about 30 km); and in many cases, they retail the product themselves. This system is very intensive with small profit margins, but it has been in existence in populated areas.

In comparison with the wholesale system, the selling price of this system is about 20% cheaper. These activities are seasonal, and the root quality is low and frequently varied when compared to the quality of the wholesaler's commodities.

However, in the areas where village level processing is important, the root supply system is carried out by wholesalers and unemployed peasants. These root crop markets are stable and wholesalers collect roots from distant zones with the cheapest prices. They transport large amounts of roots by truck. Therefore, they sell (to processors) at a price which is about 64-72% cheaper than the price applied for selling to end users (see Table 4).

Root Crop Storage and Processing

Before 1975, the government of Vietnam had programs establishing cassava and sweetpotato processing enterprises in the provinces. About 5,000-15,000 t of roots were processed per year. Now, all these enterprises are closed down with the reasons being that: (1) these plants operated only two months a year, and (2) their product quality and prices were not guaranteed. The lesson learned is that raw material supplies and the output of each plant were insufficient. Root crops are grown in scattered places and harvesting depends on seasonal periods. Transport is a great problem; there is only 0.8 km of poor quality road per km^2 in rural areas. A root storage and processing system has been suitable to the small, scattered plantings of farmers.

However, for a long time, the factors that determine the methods and scale of processing technology and the organization of root processing were not adequately considered. Because of this, although better equipment and technologies were introduced, only a few of these were accepted by processors. Also storage and packing problems have not been solved and they account for the quick deterioration of processed cassava and sweetpotato chips and flour which in turn badly affects marketing of roots. The organization linking local processing with industrial processing becomes very important, but priorities remain the development of storage and processing networks at the village level.

During the last ten years, indications are that small-scale processing has developed well in Vietnam. These experiences have shown that farmers in villages, where agro-product processing is done, earn much higher incomes than farmers in villages which deal with production only (see Table 5).

The following products and processes are suitable for rural conditions: fresh root processing and fresh root conservation in starch or a milksap-free form (without the necessity of drying roots after harvest), hydrocyanic acid (HCN)-free cassava pellets, protein-enriched cassava or sweetpotato as animal feed, cassava maltose, sweetpotato transparent noodle, and cassava or sweetpotato bread.

Processing and Preservation Technology

At present, about 45-62% of the total cassava production and 40% of the sweetpotato produced in Central

Table 4. Prices and marketing costs (in 1991 prices) of fresh sweetpotato in different marketing channels in North Vietnam.

Price level	Rural marketing system		Rural-urban marketing system				Rural-processor marketing system	
cost (%)	Price	(%)	Price	(%)	Price	(%)	Price	(%)
Field	Producer		Producer		Producer		Producer	
assembly trader	250	100	250	100	250	100	200	100
Buying price add marketing cost			Field assembly trader (Underemployed farmers/transporters)		Field assembly trader			
Wholesalers					Wholesalers		Wholesalers	
Buying price add marketing cost					320	124	210	110
Retailers			Retailers		Retailers		Retailers	
			340	126	360	141	290	145
			(Underemployed farmers/transporters)					
Consumer	Consumer		Consumer		Consumer		Consumer	
	280	112	350	180	500	200	320	160
Total marketing cost as % of farm gate price	12		80		100		60	
Distance (km)	2-10		30-60		60-80		100-200	
Amount per sale (kg)	100		100-200		100-500		7,000-12,000	

Vietnam are processed into dried chips. The use of solar energy for drying root chips in Vietnam is often difficult because of high air humidity and short periods of sunshine during the main harvest in winter.

In the north, sweetpotatoes are mostly used in fresh form without processing into dried potatoes. The postharvest weight loss due to spoilage after two-month's preservation usually exceeds 30%.

For many years now, researchers at the National Institute for Agricultural Sciences (INSA) have been looking for a fresh root processing and preservation method which results in low loss and does not depend

Table 5. Production and income in villages with and without root crop processing.

	Que Duong (with processing)	Phung Thong (without processing)
Cultivated area (ha)	280	480
Rice yield t/year (ha)	10	10
Population density (inhabitants/ha)	35	19
Total income (%)	100	100
– Cropping	18-22	70-76
– Livestock	25-26	18-20
– Agro-product processing	45	8

on the weather, in order to gradually replace drying as the main processing method.

Fresh Cassava Preservation (method of Dr. Mai Van Le)

The use of antiseptic chemical solutions has permitted keeping fresh cassava for a period of more than six months. However, this method is not very practical because of the need to build a large tank while the value of the final product is low.

Cassava Process by Benet at the 600 ppm Concentration

This method preserves fresh cassava for one month and it can be applied to stored cassava destined for consumption.

The Technology of Removing Milksap and Starch Processing

The milksap is a good medium for the growth of microorganisms because its protein content fluctuates between 6-9%. For that reason, a technology for removing milksap from fresh roots was developed by the Department of Biochemistry and Food Technology of INSA in 1989. Milksap-free cassava is HCN-free, is easy to preserve in the wet or dried form, does not have a cassava taste, and can be used for different purposes.

With the new improved technology for processing starch, the amount of recovered, filtered starch is twice as high as before. This is due to a more efficient grinding and filtering technique. The present process of producing filtered starch or milksap-free cassava is as follows: (1) peeling and cleaning cassava roots; (2) grinding cassava into very fine particles; (3) isolating the milksap by a chemical mixture; (4) dewatering by pressure-equipment; (5) preserving wet cassava without milksap under anaerobic condition for 1-6 months; (6) filtering starch through a cloth (formation of cassava pellet or flour); (7) solar drying of HCN-free cassava pellets or flour; and (8) packing.

Anaerobic Preservation of Wet Starch and Milksap-free Wet Cassava or Sweetpotato

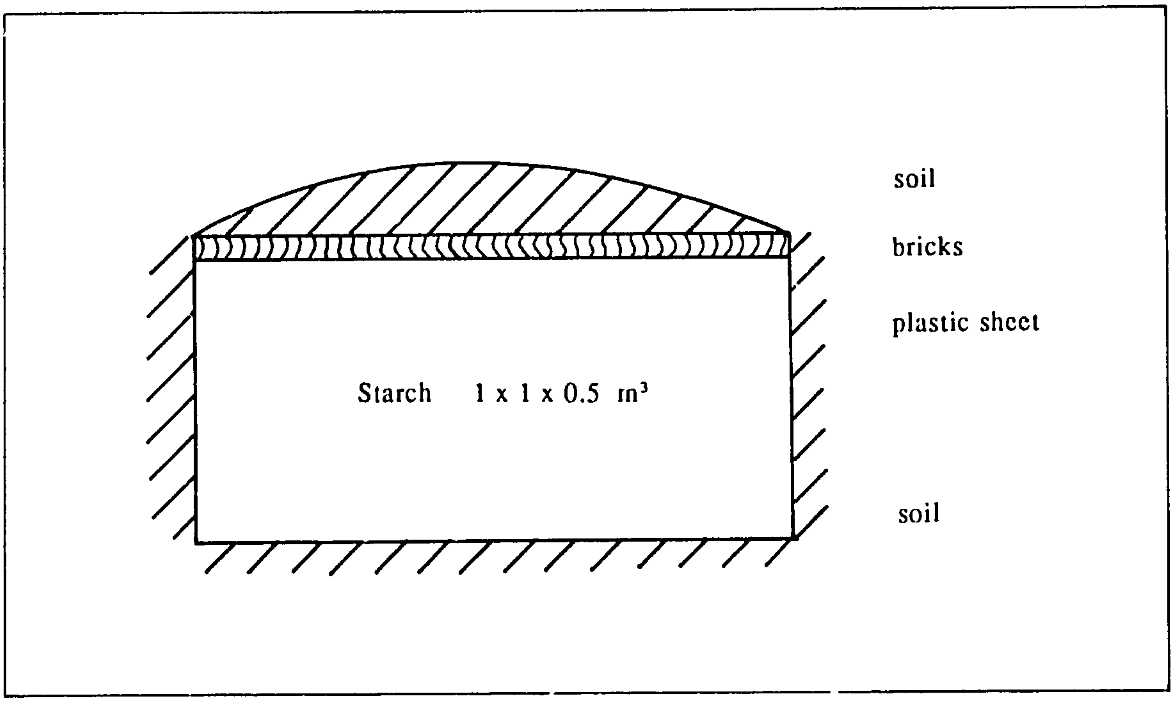
In rural areas, it is very expensive to build and maintain large tanks to preserve wet starch because of acid dissolution. Also, the rate of starch loss is as high as fermentation and hydrolysis. Therefore, we have developed the underground anaerobic preservation method (Fig. 1). This method needs only a plastic layer to prevent contamination with the soil, and wet starch can be maintained well in this state for a year.

Improved Technology to Process Animal Feed from HCN-free Cassava or Sweetpotato and Their Byproducts

The utilization of cassava, sweetpotatoes, and their processed wastes for livestock feed is a major field of utilization in rural areas. The root crops, however, have a low protein content (-2%). The method of improving the feed value of root crops for livestock is appropriate to the farmers' condition. This method is as follows: (1) prepare HCN-free cassava, sweetpotato, or waste; (2) mix with $(NH_4)_2SO_4$, rice bran, and microelements; (3) steam treat (gelatinization); (4) ferment by TB-ferment; (5) incubate at 25-30°C for 5-10 days; (6) gain protein-enriched feed (9-12%); and (7) feed directly to animals.

TB-ferment is a traditional home ferment containing *Aspergillus oryzae* and *Aspergillus niger*. We can see that the protein content will increase from 2% to 7.6-12% after a nine-day incubation period. The product is yellow or light yellow and has a specific smell. This

Figure 1. Wet starch preservation technique.



method is appropriate to small livestock holdings and increases the value of root crops by 26-40%.

Improved Technology to Process Noodles

This method was improved by INSA in 1988. Transparent noodles were traditionally produced from mungbean by the extrusion method but the product price was very high. The cost of 1 kg transparent noodle was more expensive than the price of 1 kg of pork. Cassava starch was used to process transparent noodles. Using cassava reduced the production price by 60%. However, the nutritional quality was not guaranteed and cassava noodle causes dyspepsia. The use of sweetpotato starch instead of cassava starch has improved the nutritional value and the quality of food, and has reduced the price of transparent noodles by about 40%.

It is impossible to equip the small-scale noodle producers with cleaning and drying equipment. Therefore, we have developed a method to form starch sheets which are cut into strands. This process is as follows: (1) purified sweetpotato starch (95%) is pretreated with aluminum sulfate; (2) mix with gelatinized starch (4-10%); (3) form a round elastic thin starch sheet by steam heating (100°C for 2-5 min.); (4) expand the round elastic starch sheet into 0.9 x 2 m sizes and semi-dry the starch sheet on bamboo screens, using the sun-drying method; (5) cut into strands; (6) final sun-dry; and (7) pack.

The output of each family-scale workshop is between 50-300 kg of noodle per day. Sweetpotato starch and transparent noodles are competitive in price and quality in the market. As a result of this process, sweetpotato consumption in Vietnam has increased.

Maltose Production from Cassava Starch

Due to the higher price of sweetpotato starch, maltose is processed only from cassava starch. One village, located in the suburbs of Hanoi, (consisting of more than 300 families) produces maltose from wet cassava starch with a total capacity of 4,000 t/year. Low-cost cassava maltose is mainly used in the confectionery and fermentation industry in Vietnam because the price of cane sugar is high.

The simple small-scale technology for producing cassava maltose was introduced beginning in 1980 and shows good production development in the rural areas. This cassava maltose production method is as follows: (1) mixing wet starch with boiling water to form a glue; (2) fermenting by amylase (from germinated rice seedlings); (3) incubating (hydrolysis) overnight; (4) filtering; (5) concentrating maltose by heating (45-60 min per 20 kg batch); and (6) packing in double plastic.

Chip Production Technology from Starch or Flour Without Cooking Oil

In 1987, INSA developed a process for making starch chips (similar to *krupuk*) without cooking oil by using old gas bottles as pressure ovens (Fig. 2).

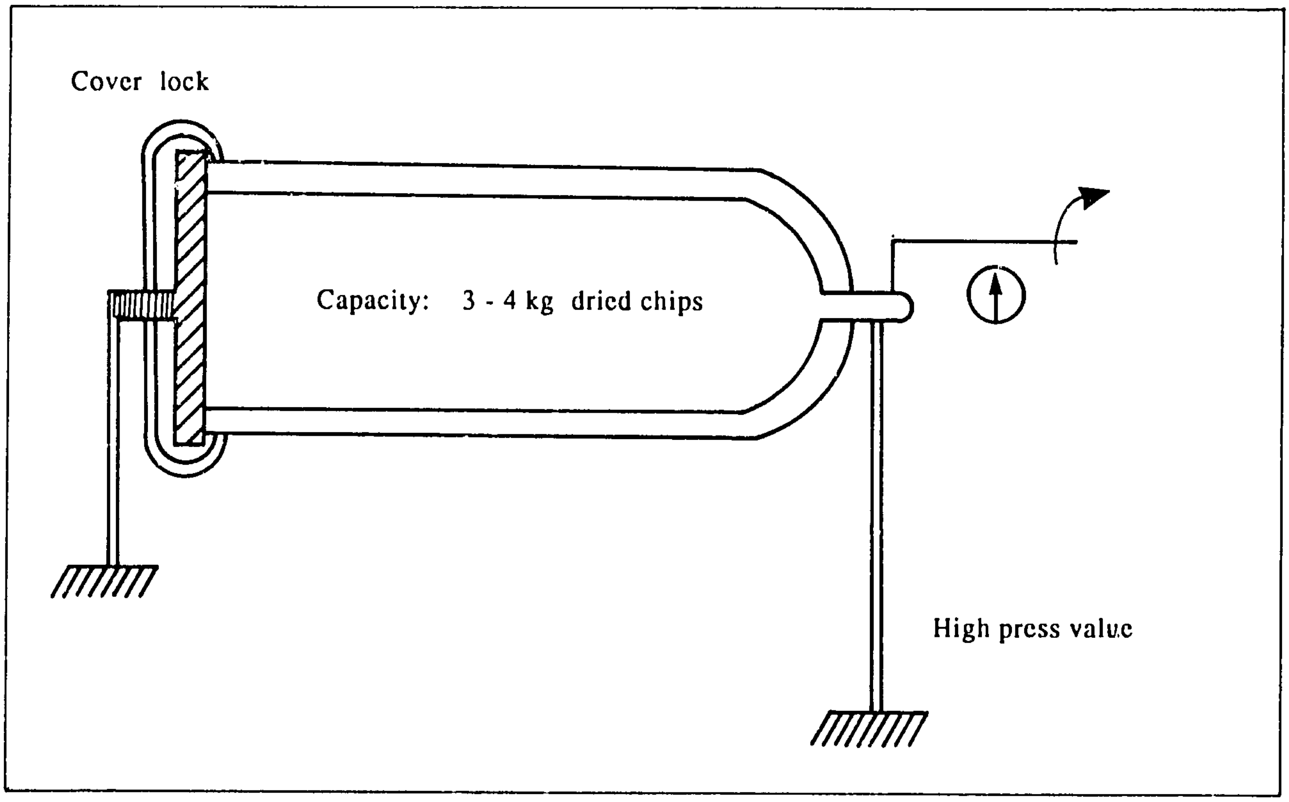
Chip processing steps are: (1) formulating paste from root starch or flour; (2) cutting of chips; (3) steam treating at 100°C for 5 min; (4) solar drying to 14% and oven drying to 10% moisture; (5) high pressure treating at 8 atm. by heating in an old gas barrel oven (15 min for 3-4 kg chips); (6) reducing pressure to 1 atm to cause the volume to expand 30-40 times; and (7) packing.

Bread Production Technology Using Wet Cassava Starch

The price of wheat flour in Vietnam is two times higher than that of rice; thus, bread is very expensive. In 1989, INSA developed a process for using wet cassava starch (at a level of 50%) in bread production.

Compared to dry cassava starch, wet cassava starch has an expansion capacity which is 1.8 times higher. Therefore, bread made of 50% wet cassava starch has good elasticity. In order to maintain a high nutritional

Figure 2. Use of old gas bottle as a pressure oven for production of cassava starch chips.



quality, some soybean flour is mixed in while making the bread.

The bread production process with 50% wet cassava starch is: (1) preparing fresh cassava starch; (2) adding and mixing with soybean flour; (3) mixing 50% enriched cassava starch with 50% wheat flour and yeast; (4) annealing for 2-4 hrs, depending on the weather; (5) weighing and kneading, follow-up annealing for 1-3 hrs; and (6) cooking at a temperature of 210°C for 10-15 min.

Cassava bread has an expansion and moisture content equivalent to that of bread made of 100% wheat flour. It has a good smell, is tasty, and remains soft for a long time. The production cost of cassava bread is 25% lower than that of bread made only with wheat.

Other Technologies

Cassava is also processed to make cassava starch pearls and shrimp chips, as well as in the production of fermented products (e.g. alcohol, fermented sauces, monosodium glutamate, acid citric), in textiles, packages, and papers.

In general, if cassava and sweetpotato are used as a raw material for processing into high quality products, the value of root crops is increased many times; but development of several technologies for processing root crops is necessary to overcome the energy and marketing problems.

Research Activities and Research Needs

There are several research institutes, universities, and colleges that have conducted research on processing technology for cassava and sweetpotato.

However, the research and development (R&D) results are very limited due to the lack of an R&D strategy for root and tuber crops. For this purpose, we especially need a research strategy for marketing, production management, and development of some new products made from cassava or sweetpotato. With cassava, processing and utilization can perhaps best be conducted by the private sector. INSA can gain experience by close collaboration with experts from the private sector.

The R&D strategy for root processing, utilization, and marketing should include the following:

- to promote R&D of root crop processing systems;
- to stimulate the interaction between on-site processing and industrial processing;
- to study marketing and prices and to determine the market potential for root crop products;
- to identify the key social and economic constraints to cassava and sweetpotato consumption and propose possible solutions;
- to carry out studies on village-scale processing systems and promote technology transfer to farmers;
- to conduct research on the use of roots as a raw material for the manufacture of various products, and the development of new products at a low cost in order to expand the utilization of cassava and sweetpotato; and,
- to give priority to the development of technologies that reduce the energy requirements for processing and preserving root crops.

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Sweetpotato Processing, Marketing, and Utilization in Korea

Byeong-Choon Jeong[1]

Abstract

Sweetpotato production, processing, and utilization have declined considerably in Korea over the last three decades. This paper examines the various factors that have contributed to this development including consumer tastes and preferences, demography, and general economic development. The paper also describes current processed products and the emergence of new uses for sweetpotato that have resulted in shifts in cultural practices at the farm level. The paper briefly reviews prevailing marketing channels before calling for research and development on alternative uses/markets for sweetpotato so as to promote a recovery in production and area planted.

Key words: products, animal feed, consumers, diets.

Introduction

Sweetpotato is one of the important summer upland crops in Korea. It has been used as an industrial raw material, a human food, a vegetable, and an animal feed. But, since 1965—the peak area planted and production year—both area and production declined very quickly. This is thought to be due to several factors. First, in accordance with the recent rise in living standards, Koreans have tended to change their dietary patterns. They now eat more foods perceived to be of higher quality than sweetpotato. Second, sweetpotatoes for industrial raw material have been shortening the running period of manufacture factories because of their long-term storage disadvantage. Third, manufacturing starch or alcohol using sweetpotato costs more than imported corn and tapioca. Fourth, rapid industrialization and urbanization in Korea followed by decreasing farm populations and less rural labor, increasing rural labor costs, importation of agriculture products, decreasing rural incomes, and great socio-economic changes all of which have contributed to a decrease in the area planted and production of sweetpotato. In recent years, however, the utilization of sweetpotato has been highlighted as a non-polluted, natural health food. Consumers' desire to eat good quality sweetpotato roots and petioles for vegetables has been increasing. The result is production using a polyethylene film-mulched early culture.

For human food consumption in Korea, sweetpotato is eaten boiled, roasted, fried, or in salads. Starches from sweetpotatoes are mainly used to make Korean folk noodles. Alcohol extracted from sweetpotatoes has been used mainly for *Soju*, a traditional Korean alcoholic beverage. Increased demands for starch and alcohol have been supplied mainly with imported corn and tapioca.

Sweetpotatoes have had three kinds of marketing channels for industrial and food purposes. Sweetpotatoes produced by farmers are sent to factories or consumers through wholesalers, cooperatives, or retailers. Marketing margins in these channels vary from 15-50%.

Area Planted and Production

Sweetpotato has played an important role as a famine-relief crop, starch source, alcohol raw material, and feed and food crop because it is tolerant to environmental stresses such as poor soil, drought, and wind. It also

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gives a high yield in a short period of time compared to other crops.

Sweetpotato production and cultivated area have sharply declined. The area planted to sweetpotatoes decreased gradually from 150,000 ha in 1965 to 25,000 ha in 1988 as shown in Table 1. The amount produced has also fallen from 3 million t in 1965 to 560,000 t in 1988.

Many factors have contributed to the decline in the production of sweetpotatoes in Korea. The first cause of decreased planting area and production has been the change in the dietary life with increased consumption of other, high quality foods instead of sweetpotato. Second, in industrial utilization of sweetpotatoes, the disadvantage of the poor long-term storage capability of sweetpotato shortened running periods of manufacturing factories. Thus, its production cost per unit product amount was higher than imported tapioca and corn. Therefore, industrial consumption of sweetpotatoes produced in Korea is less. Furthermore, changes in the socio-economic environment caused by the shortage of rural labor and increasing labor costs have resulted in lower incomes and a decrease in sweetpotato area planted.

Utilization

The status of sweetpotato consumption in Korea is presented in Table 2 beginning with 1966, the peak consumption year (from the crop produced in 1965). When compared with the amount in 1966, the consumption amount in 1988 (produced in 1987) was 542,000 t, only 18% of the 1966 consumption. It corresponds to the dramatic decrease in area planted and production. As industrial raw material, in 1988, consumption for alcohol and starch decreased to 44% and 28% as compared with 1980 and 1971, the peak consumption years.

The amount of sweetpotato utilized for animal feed in 1988 decreased to 33% of that in 1980. Human consumption decreased more rapidly than any other use. The consumption amounts in 1988 and 1990 decreased to 7% and 58% when compared with those of 1966 and 1988. In 1989 (produced in 1988), consumption of sweetpotato increased a little for industrial utilization and the area planted for human food increased because of the use of polyethylene film mulched early culture. The conventional culture for human food may be substituted by the early culture for high quality sweetpotato, and also for industrial raw material.

Sweetpotato was an important crop when Korea had a shortage of staple foods. Recent modes of dietary life have changed to a greater consumption of meats, milk, and fruits. Also, sweetpotatoes have been considered an inferior food by the majority of people in Korea. Thus, the consumption of sweetpotato decreased yearly in accordance with the substitution of higher quality foods. The amount of sweetpotato and potato consumed per person per year in Korea is presented in Figure 1. In 1965, per capita consumption was 76.5 kg per year. The amount has decreased rapidly to 5.5 kg per person per year in 1988.

For human food consumption, sweetpotato in Korea has been boiled, roasted, fried, or used in salads. Most of the high quality sweetpotatoes are consumed as boiled snack food. Crops planted for this use are early cultured from late June to early August. Roasted and fried sweetpotatoes are sold by street merchants during the winter

Table 1. Sweetpotato area planted, production, and yield in Korea, 1965-89.

Year	Area planted (000 ha)	Production (000 t)	Yield (t ha)	Index: Area planted	Index: Production	Index: Yield
1965	152.4	2997	19.7	100	100	100
1970	126.9	2136	16.8	83	71	86
1975	94.6	1953	20.7	62	65	105
1980	55.0	1103	20.1	36	37	102
1985	33.5	787	23.5	22	26	120
1987	25.6	542	21.2	17	18	108
1988	24.6	561	22.8	16	19	116
1989	25.5	592	23.2	17	20	118

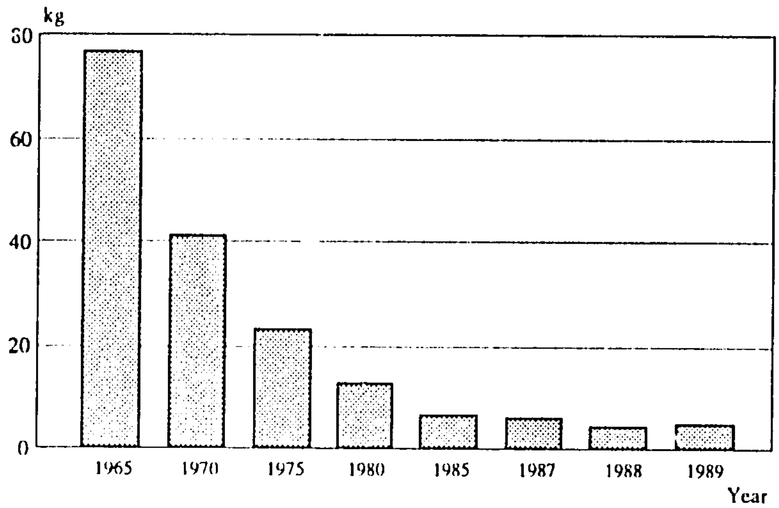
Source: The Korean Ministry of Agriculture and Fisheries Statistics 1990

Table 2. Disposal of sweetpotato (000 t) produced in Korea, 1966-90.

	1966	1971	1980	1988 (A)	1990 (B)	A/* (%)	B/A (%)
Alcohol	185	358	414*	184	290	41.4	158
	(6.2)	(16.8)	(29.9)	(34.0)	(48.9)		
Starch	92	271*	99	77	135	28.4	175
	(3.1)	(12.7)	(7.1)	(14 2)	(22.8)		
Feed	50	87	168*	55	32	32.7	58
	(1.7)	(4.1)	(12.1)	(10.1)	(5.4)		
Food	2102*	1210	463	152	87	7.2	58
	(70.1)	(56.6)	(33.4)	(28.0)	(14.8)		
Waste	568*	210	243	74	48	13.0	65
& seed	(18.9)	(9.8)	(17.5)	(13.7)	(8.1)		
Total	2997*	2136	1103	542	592	18.1	109
	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)		

Source: Food Grain Policy Bureau.
( ) = Percentage.

Figure 1. Consumption per capita by year of sweetpotato + potato.



Source: Food Grain Policy Bureau.

season. Petioles of sweetpotato have been a traditional vegetable in Korea, and are produced near the suburbs by early direct planting culture for fresh or dried vegetables.

Sweetpotato for animal feed has been utilized as a silage material which is considered to improve the meat quality of hogs. The silage mixed with crushed sweetpotato root and rice bran at the ratio of 80:20 (W/W) or crushed sweetpotato roots, vines and leaves, and rice bran at the ratio of 60:30:10 (W/W/W) and stored one month in silos would be a good feed for hogs (Table 3). It could be fed up to 60% of the total feed for hog fattening. However, in the future, sweetpotato root will probably not be used as animal feed because it is more expensive than other feed material.

Processing

Sweetpotatoes have also been used as industrial raw material in Korea. For example, they have been pro-

Table 3. Mixing ratio of sweetpotato ensilage for pigs.

	Mixing ratio of			
Ensilage mix	Roots (%)	Vines & leaves (%)	Rice bran (%)	Total (%)
1	70-80	--	20-30	100
2	60	30	10	100

cessed for starch and alcohol production. Recently, the demand for starch and alcohol has been increasing year by year. However, the use of sweetpotatoes as raw material for starch and alcohol production has decreased since 1970, the peak production year.

As shown in Table 4, starch production in Korea has increased yearly. However, sweetpotato and potato for starch production have decreased annually. Most starch in Korea is made from imported corn and the imported amount has been increasing. Of the total starch production, starch occupancy from sweetpotato decreased from 37% in 1975 to 2.2% in 1988. White starch occupancy from corn increased from 62% in 1975 to 98% in 1988.

The reasons for this include not only the problems associated with long-term storage of sweetpotato that affect the running period of factories, but also the fact that production costs were higher using domestically-produced sweetpotato than using imported corn.

Domestic and international starch prices are presented in Table 5. In domestic prices, the sweetpotato starch price is five times as expensive as corn starch. And when compared to the international price, domestic prices of sweetpotato starch were four times higher. Thus, the number of sweetpotato starch factories decreased from 67 in 1982 to 43 in 1988 (Table 6).

Table 4. Raw materials (000 t) used for starch production and starch produced (000 t) in Korea, 1975-88.

	1975		1980		1988	
Material	Material	Starch	Material	Starch	Material	Starch
Sweetpotato	186.2	32.6 (37.2)	96.4	15.2 (6.7)	94.1	15.5 (2.2)
Corn	81.7	54.1 (61.9)	406.8	209.8 (91.4)	1032.9	670.4 (97.5)
Potato, wheat	5.2	0.8 (0.9)	8.3	4.5 (1.9)	9.3	1.8 (0.3)
Total (Demand)		87.5 (100.0)		229.7 (100.0)		687.7 (100.0)

Source: Annual of Agricultural Cooperative Federation.

( ) = Percentage.

Table 5. Domestic and international price (US$/t) of starch made from sweetpotato, potato, and corn, 1989.

	Sweetpotato	Potato	Corn
Domestic	2,274	2,350	441
International	543	808	319
Index	419	291	138

Table 6. Number of starch manufacturing factories, 1982-88.

Year	Sweetpotato	Corn	Potato	Wheat	Total
1982	67	6	1	1	75
1985	53	6	3	2	64
1988	43	7	6	2	58

Source: *Annual of Agricultural Cooperative Federation.*

Factories manufacturing sweetpotato starch have very small-scale, primitive facilities. Most factories extract starch by the tank precipitation method and dry the starch water with natural solar heat. Only a few factories have modern facilities with centrifugal machines and instant driers. Because considerable capital is required to modernize their facilities, most factories do not want to enlarge their capacity. As shown in Table 7, the starch produced from sweetpotato has been mostly used for Korean native noodles. Only a small amount has been used as food, adhesive, medicine, and raw material for paper.

Sweetpotatoes for alcohol production have been sent to factories by agricultural cooperatives who act as mediators. Roots are transported fresh, sliced, or dehydrated. As shown in Table 8, alcohol production in Korea has been increasing annually. However, the utilization of domestic sweetpotato for alcohol production has been decreasing annually. Alcohol production from sweetpotato decreased from 53% in 1976 to 11% in 1990 of the total alcohol production. Sweetpotato's limitations have led to most of the raw material for alcohol production in Korea being dependent on imported tapioca.

Table 7. Utilization (000 t) of sweetpotato starch, 1981-89.

	1981	1983	1985	1987	1989
Noodle	13.5	12.9	11.1	15.3	17.1
	(80)	(63)	(65)	(93)	(92)
Others	3.4	7.5	6.0	1.1	1.4
	(20)	(37)	(35)	(7)	(8)
Total	16.9	20.4	17.1	16.4	18.5
(Supply)	(100)	(100)	(100)	(100)	(100)

Source: *Korea Starch Industrial Cooperative.*

( ) = Percentage.

Table 8. Sweetpotato used for alcohol production and alcohol produced, 1976-90.[a]

	Materials	1976	1982	1986	1990
Fresh	Raw materials (000 t)	178.6	11.9	20.2	8.6
	Alcohol(A) (000 D/M)	105.9	7.0	11.9	5.1
Dehydrated	Raw materials	113.2	88.9	92.6	55.2
	Alcohol(B)	217.1	171.0	178.2	106.2
	(A+B)	323.6	178.0	190.1	111.3
Total production	(C)	605.2	801.3	892.6	1020.0
	(A+B)/C (%)	53	22	21	11

Source: *Korea Alcohol & Liquor Industry Association.*

[a]D/M = Dry matter.

Table 9 presents the raw material cost of alcohol per unit volume. Fresh, sliced, and dehydrated sweetpotatoes were about five times higher than tapioca per unit amount alcohol production. Ninety percent of the alcohol extracted from sweetpotatoes was used to make *Soju*. The remainder was used for industrial chemicals, soft beverages, medicine, and as material for tobacco fermentation.

Sweetpotato Marketing in Korea

Marketing of early cultured sweetpotato in Korea goes on from late June to late August. Early harvested sweetpotato roots are sold for human food at a higher price. All of them are used for making snacks in the form of boiled sweetpotato.

As shown in Figure 2, the marketing channel has three or four steps: from the farmer through the local collector of the joint market, wholesaler, or retail dealer, to the consumer. A few consumers buy the crop at the farm house. Typically, cultured sweetpotatoes are harvested from September to October. In this case, except for human food and seed, all of them have been used as industrial raw material. Fresh, sliced, or dehydrated sweetpotatoes are sent to manufacturers through the agricultural cooperatives or commissioned collectors.

Table 9. Alcohol material cost per unit volume (1 D/M), 1990.[a]

	Sweetpotato		
	Fresh	Dehydrated	Tapioca
Required material per 1 D/M (kg)	1,685	510	511
Material cost (US$)	261	347	44
Index	593	789	100

Source: Korea Alcohol & Liquor Industry Association.

[a]D/M = Dry matter.

Figure 2. Marketing channels for fresh and dehydrated sweetpotatoes in Korea.

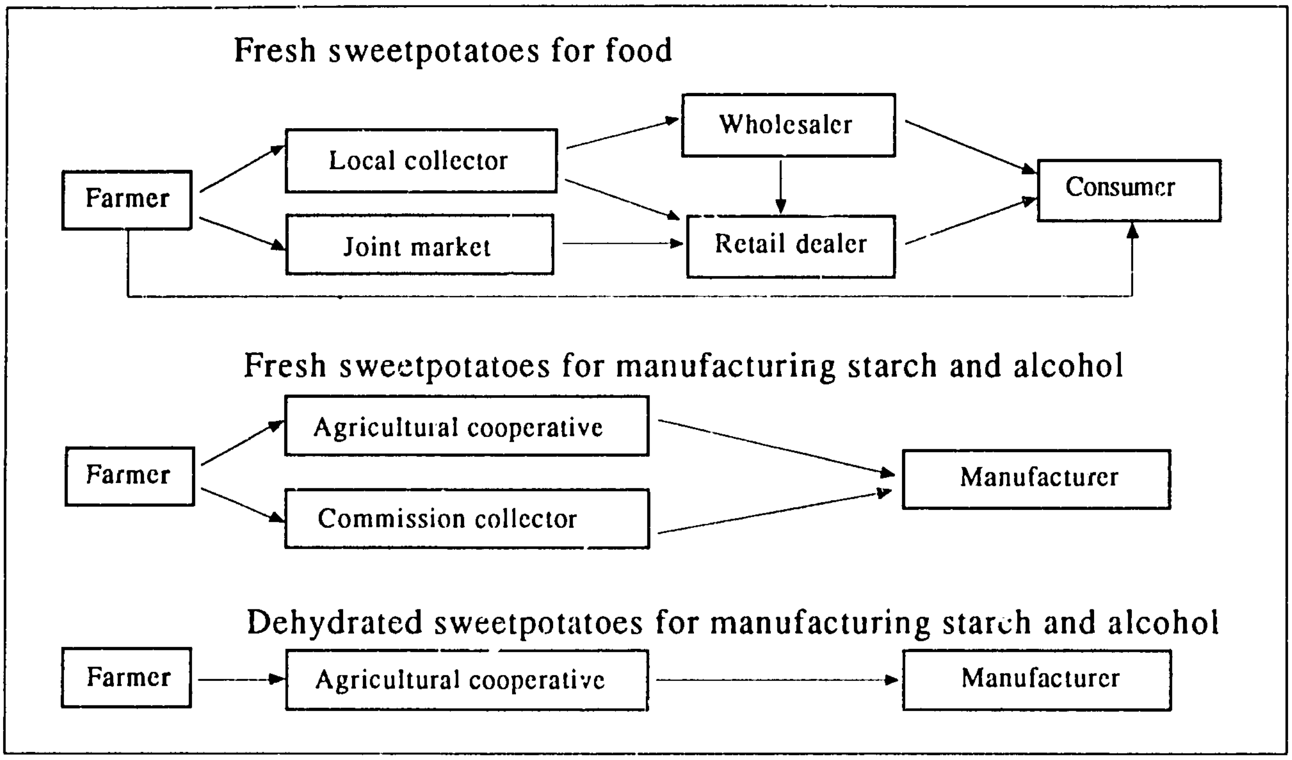


Table 10. Prices and margins of sweetpotato in major marketing channels.

	Farm price (US$/t)	Retail price (US$/t)	Margins (%)
Food	698	1396	50
Industrial			
Fresh	126-139	155-198[a]	19-30
Dehydrated	579	681[a]	15

Source: Muan 1990.

[a]Wholesale prices paid by the factory.

Marketing margins vary from 15-50% depending on the channel (Table 10). In the case of sweetpotato for human consumption sold through local collectors to retail dealers, the marketing margin represents 50% of the consumer price. Marketing margins for sweetpotato for industrial raw material sold through agricultural cooperatives or mediators are in the 19-30% range. The margins in the channel for sliced and dehydrated sweetpotato are estimated to be 15%.

Conclusion

Sweetpotato has played an important role in the development of Korean agriculture. Still, in recent years, it has become a declining crop for the reasons discussed here. Therefore, it is urgent to develop new uses to expand sweetpotato production and area planted. Searching out new uses for food processing and preparation are considered to be the basis of research necessary for increasing sweetpotato consumption in the future.

Sweetpotato Production and Utilization in Taiwan

W. Chiang[1]

Abstract

Taiwan is located in the subtropics with abundant rainfall and solar radiation so that sweetpotato can be grown year round. Sweetpotatoes have contributed to the Taiwan diet as a supplemental staple food, especially before the 1950s. Current utilization patterns are not different from those in the past. However, total production of sweetpotatoes in recent years has been only about 6% of its peak level.

This report summarizes the production, consumption, and utilization, and research and development of sweetpotatoes in the last decade. In order to increase human consumption, high value products need to be developed. As an example of such products, this paper uses french fry-type sweetpotato and sweetpotato flakes. This would create an entirely new image for sweetpotato.

Key words: flakes, french fries, response suffice methodology, rheology, sweetpotato, Taiwan.

Production

Soil and climatic conditions in Taiwan are suitable for sweetpotato production. During the period 1955-80, yields per hectare increased steadily (Table 1), but since the early 1970s hectareage has declined rapidly so that total production shows a steep decline. The drop in sweetpotato production has three main causes: (1) the people in Taiwan prefer other foods as their incomes rise; (2) hog raisers use imported corn instead of sweetpotato for animal feed; and, (3) sweetpotato itself generates a relatively low income compared with many other crops that became competitive after the development of water resources. In 1989, about 206,000 t of sweetpotatoes were produced on approximately 12,300 ha. These totals represent 5% of the peak levels for area harvested and 6% of total production.

Sweetpotatoes are grown everywhere in Taiwan (Map 1). The main growing areas are located in the central and southern region of western Taiwan, at Yunlin (20.6%), Tainan (17.6%), and Taichung (16.1%). Since the 1970s, a large amount of corn has been imported for preparing processed feed (Table 2). Sweetpotato has been replaced by production of rice, corn, sorghum, wheat and other competing crops in Taiwan since 1965 (Table 3) because farmers get much more income planting these other crops.

Consumption and Utilization

Before the 1950s, sweetpotatoes were mainly used as human food and animal feed. At that time, sweetpotato was cooked alone or with rice and served as a supplemental staple food. Yang et al. (1975) reported that most sweetpotatoes contain higher lysine and threonine than rice and wheat, and recommended that sweetpotato be eaten with rice or wheat flour to improve nutrition in the Taiwanese diet. However, as shown in Table 4, the net consumption per capita per year of all food materials, except rice and sweetpotato, increased during the period of 1978-88. The importance of rice and sweetpotato as human food has been replaced by imported wheat. In addition, increasing consumption of animal products, fruits, and vegetables also influenced

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Table 1. Area, production, and yield of sweetpotato in Taiwan, 1955-89.

Year	Area harvested (000 ha)	Production (000 t)	Yield (t/ha)
1955	245.5	2,437	9.9
1960	235.4	2,979	12.7
1965	234.1	3,131	13.4
1970	228.7	3,440	15.0
1975	156.7	2,403	15.3
1980	62.5	1,055	16.9
1985	23.2	369	15.9
1989	12.3	206	16.7

Source: PDAF 1990.

Table 2. Imported quantities (000 t) of cereals and soybean in Taiwan, 1965-89.

Year	Wheat	Corn	Soybean	Sorghum	Barley
1965	377	44	161	--	--
1970	603	602	618	--	238
1975	543	1389	827	152	163
1980	686	2605	939	417	382
1985	755	3017	1469	546	337
1989	865	4854	1810	148	236

Source: PDAF 1990.

-- = Data not available.

Table 3. Production (000 t) of cereals and soybean in Taiwan, 1965-89.

Year	Rice (husked)	Corn	Soybean	Sorghum	Wheat
1965	2,348	41	66	--	--
1970	2,462	57	65	6.8	3.7
1975	2,494	138	62	19.0	3.0
1980	2,354	115	26	9.3	2.8
1985	2,173	226	12	86.6	2.1
1989	1,865	329	11	76.5	3.0

Source: PDAF 1990.

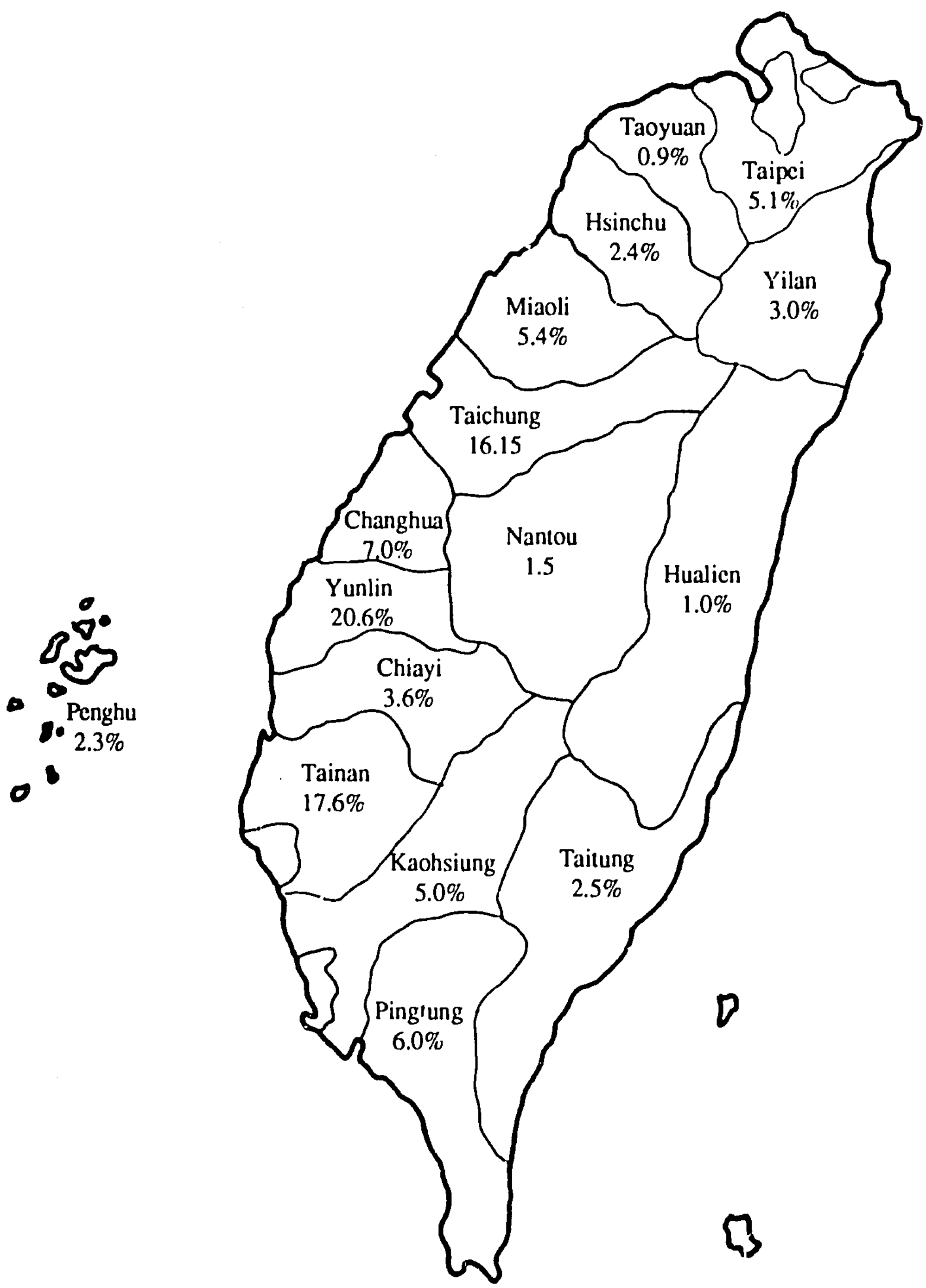
-- = Data not available.

the decrease in consumption of rice and sweetpotato. One other reason for the lower consumption is the strong belief in Taiwan that sweetpotato is poor people's food.

In the past, sweetpotato was the main energy source for animal feed; but, since the 1970s, imported corn has become the main source due to its higher protein content and feed efficiency. Recent utilization patterns of sweetpotatoes (Table 5) have not changed compared with those in the past. Most of the sweetpotato produced in Taiwan is still used for animal feed, but the quantity is much less. Farmers have little interest in growing sweetpotatoes because the market price is very low—fresh roots US$ 110/t and sun-dried sweetpotato chips US$ 300/t (PDAF 1990).

In Taiwan, about 20% of sweetpotato is prepared by baking, boiling, steaming, or frying. There are a variety of products such as starch, preserves, candies, cookies, composite bread, sweetpotato fillings, flakes,

Map 1. Sweetpotato production in Taiwan, 1989.[a]



Source: PDAF 1990.

[a]Percentages are of total national production (206,000 t).

Table 4. Changes in food consumption in Taiwan, 1978 versus 1988.

Category	Net consumption per capita per year (kg) 1978	1988	Increase or decrease (%)
Rice	114.0	73.6	-35.4
Wheat flour, etc.	32.5	37.0	13.9
Root and tuber crops	10.7	6.0	-43.9
Sugar	24.3	25.2	3.7
Legumes, nuts, etc.	45.0	55.5	23.3
Vegetables	114.9	122.1	6.3
Fruits	54.3	104.3	92.1
Meat	36.1	57.8	60.1
Eggs	7.6	10.9	43.4
Fish	36.5	45.8	25.5
Milk	5.4	13.2	144.4
Oils and fats	10.5	18.5	76.2

Source: PDAF 1990.

Table 5. Production and utilization of sweetpotato in Taiwan, 1950-88.

Year	Production (000 t)	Utilization (%) Animal feed	Manufacture	Food	Waste and seed
1950	2201	45	15	25	15
1960	2979	46	15	25	14
1970	3440	62	20	8	10
1979	1225	63	20	7	10
1988	254	63	20	7	10

Source: PDAF 1990.

french fry-type sweetpotato, and alcoholic beverages produced at home or in cottage industries. Among these products, sweetpotato starch has been very important in the past. Currently, however, due to high labor costs and an unstable supply of fresh roots, a few factories are importing crude sweetpotato starches from mainland China and countries in Southeast Asia. This crude starch is purified in Taiwan to make it suitable for local consumption.

Research and Development

There are two possible approaches for expanding sweetpotato production in Taiwan. One is to use more sweetpotato in processed feed formulas, but this is not likely to become government policy in the near future. The other approach is to create an entirely new image for sweetpotato. Using modern food technologies to improve or develop high value products may be effective in expanding the demand for sweetpotato. Given existing food habits in Taiwan, composite bread, sweetpotato flakes, fillings, and chips, and french fry-type sweetpotato could be considered as products with market potential.

Chen and Chiang (1984, 1985a) have reported that by reducing the amounts of sugar and salt and adding carboxymethylcellulose in the recipe of composite bread which contains 30% sweetpotato flour, the problems of less fermentation and staling of the bread could be solved. Lee (1985) reported that when fresh sweetpotato paste was used instead of sweetpotato flour, the composite bread had good quality, even better than the bread made from 100% wheat flour. Table 6 shows the specific gravity and chemical compositions of fresh sweetpotatoes. Table 7 shows that sweetpotatoes having a higher content of beta-carotene and total sugars and a lower starch content were suitable for producing flakes (Chen and Chiang 1985b).

These results could be useful for breeding sweetpotatoes. In order to improve the quality of sweetpotato flakes, Chiang and Chen (1987a) used response surface methodology to find out the optimal preheating condition of sweetpotato strips. They found that if sweetpotato strips were preheated at 78°C for about 35 min before steaming at 100°C for 20 min, bulk density of the flakes was increased and dispersibility of rehydrated sweetpotato pastes was improved. This may result from the action of starch hydrolysis by the residual amylolytic enzyme. The textural characteristics of mashed sweetpotato would be different depending on varieties and processing conditions. The mealiness or moistness of mashed products might be predicted by the amount of the water-soluble solid content (Chiang and Chen 1987b; Chen and Chiang 1988).

Sweetpotatoes with higher beta-amylase activity produced a lot of maltose during preheating and this resulted in mashed products being moist. Sweetpotatoes with lower beta-amylase activity, resulted in the mash being mealy (Chiang and Chen 1988). Hualien pastry, a famous local processed product, was made from mashed sweetpotato and bean paste. Its quality and packaging material has been improved by the Hualien Agricultural Experiment Branch Station.

French fry-type sweetpotato has been sold by some fast food restaurants in recent years, but it is still not very popular due to difficulties in quality control.

According to experimental results (Chiang and Kao 1989), the procedure for producing a better quality french fry-type product is as follows. The sweetpotato strips are first blanched with 1% sodium acid pyrophosphate solution at 100°C for 2.5 min, then partially dehydrated by forced air at 120°C for 5 min, then frozen at -30°C, and finally, fried directly at 145-175°C for 2-6 min (Table 8).

The human consumption of sweetpotatoes in Taiwan will expand only if high quality and added-value products are developed.

Table 6. Specific gravity and chemical composition of sweetpotato varieties.

Variety	Specific gravity	Moisture content (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Ash (%)	NFE (%)	Total sugar (%)	Starch (%)	Beta-carotene (mg/100 g)
TN-57	1.067	67.7	1.47	0.24	0.37	0.83	29.4	2.47	26.9	0.97
TN-64	1.015	74.9	1.37	0.28	0.50	0.82	22.1	3.47	18.6	10.44
TN-66	1.027	69.7	1.68	0.43	0.44	0.74	27.0	3.22	23.8	8.33
64-4	1.059	65.8	1.21	0.33	0.37	0.88	31.4	2.27	29.1	trace
65-46	1.041	63.8	1.20	0.48	0.45	0.70	33.4	1.72	31.7	trace
66-73	1.065	63.3	1.42	0.36	0.39	0.90	33.6	1.83	31.8	trace
69-11	1.039	69.7	0.89	0.40	0.67	0.88	27.5	1.75	25.7	trace
69-12	1.068	63.8	1.02	0.39	0.56	0.82	33.4	1.86	31.6	trace
70-203	1.069	63.9	0.91	0.55	0.68	0.78	33.2	2.16	31.0	0.80
70-220	1.056	65.2	·1.24	0.61	0.69	0.82	31.4	2.08	29.4	0.29
70-245	1.032	68.3	1.04	0.34	0.76	0.90	28.7	1.77	26.9	trace
70-298	1.072	64.8	1.15	0.54	0.56	1.12	31.8	2.04	29.8	0.60
71-5	1.073	64.5	1.52	0.51	0.56	1.06	31.9	1.95	29.9	trace
71-66	1.030	68.6	1.89	0.36	0.51	0.81	27.8	0.94	26.9	1.53
71-92	1.098	59.1	1.28	0.53	0.38	0.77	37.9	1.19	36.7	trace
71-96	1.081	61.3	1.58	0.41	0.49	0.90	35.3	1.38	33.9	trace

Source: Chen and Chiang 1985.

Table 7. Correlation coefficients for composition of sweetpotato and quality of sweetpotato flakes.

Compositions	Bulk density (g/ml)	Dispersibility (%)	Viscosity (c.p.)
Specific gravity	0.004	-0.757[b]	-0.568[a]
Moisture (%)	-0.068	0.740[b]	0.668[b]
Crude protein (%)	0.471	0.252	0.056
Crude fat (%)	-0.301	-0.243	-0.397
Crude fiber (%)	-0.504[a]	-0.069	-0.135
Ash (%)	-0.288	-0.437	-0.158
NFE (%)	-0.333	-0.829[b]	-0.753[b]
Total sugar (%)	-0.101	0.717[b]	0.695[b]
Starch (%)	-0.274	-0.854[b]	-0.783[b]
Beta-carotene (%)	0.150	0.923[b]	0.814[b]

Source: Chen and Chiang 1985a.

[a]P<0.05 significant level.
[b]P<0.01 significant level.

Table 8. Comparison of oil content, color, and sensory evaluation of french fry-type sweetpotato products.

Frying temp. (°C)	Frying time (min)	Oil content (%)	Hunter color values			Sensory evaluation[a]	
			Brightness	Greenness	Yellowness	color	mouth feel
145	6	17.6a[b]	73.2b	2.00ab	33.4a	4.67a	3.44a
160	4	16.1b	76.0a	2.88bc	31.7b	3.28b	2.72ab
175	2	13.4d	76.7a	3.57c	33.4a	3.59b	3.12ab
175	4	14.8c	70.4c	1.48a	29.0c	1.35c	2.29b
190	2	13.0d	72.6b	1.65ab	29.5c	1.72c	2.50b

Source: Chiang and Kao 1989.

[a]Rated by a ten-member panel on a scale of 5=best and 1=poorest.
[b]Means within a column followed by the same letter do not differ at the 5% level by Duncan's multiple range test.

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Root and Tuber Processing, Marketing, and Utilization in the South Pacific

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Abstract

This paper describes the status of root and tuber processing, marketing, and utilization in some selected Pacific countries. The relative importance of various root crops grown is given. The small amount of processing is noted. The main reasons cited are small markets, limited supplies, long distances between production and consumption centers, and poor communication. Marketing of root crops is hampered by difficult transport. Export is mainly of fresh produce to New Zealand. The root crops are utilized for human food, usually baked, boiled, or roasted. The present root crops project is supporting postharvest operations in addition to advising on increasing yields.

Key words: South Pacific, cassava, sweetpotato, ariods, production, marketing.

Introduction

The South Pacific covers a vast area of ocean with many scattered islands. These islands vary considerably in population and size. The islands basically are of either volcanic or coral (atoll) origin. Among their common features are long distances between islands, expensive fares, and occasional disasters, e.g., cyclones. Some basic data on populations and land areas are given in Table 1. As can be seen from these figures, most of the countries are small to very small (with the possible exception of Papua New Guinea), both in terms of population and size.

Food and Agricultural Organization of the United Nations (FAO) has supported root crops projects in the Pacific since 1973 (Fiji); a regional project conducted in 1980-82 (14 countries); and a follow-up project in 1983-86. The current regional root crop project, RAS/86/034, started in 1988 and will end in 1991. This latest project has as its objective to "support the governments in the region to further develop and promote the production, utilization, and marketing of root crops within the context of sustainable cropping systems, so as to reduce trade deficits and so improve the socioeconomic welfare of small farmers..." (SPRIN 1990).

In Table 2 are listed seven of the twelve countries participating in this project, and the various root crops grown. As can be seen from the table, there is variation in the importance of the different crops grown. Emerging from the table, however, is the fact that aroids play an important role in almost all the countries.

Some countries show almost no diversification at all concerning root crops, e.g., W. Samoa and Niue seem to rely heavily on a sole crop *Colocasia esculenta*. Other countries, like Cook Islands and Tonga, have more variation in their cultivation of root crops, but the available data are limited.

Processing, Marketing, and Utilization

Utilization and Processing

Very little processing is carried out in the countries concerned, both in industrial plants and on the village/household level. Moreover, converting root crops into more storable forms, e.g., by dehydration, is seldom carried out in homes today. The absence of seasonal

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Table 1. Countries of the South Pacific: Populations and land areas.

Country	Population (000)	Area (km^2)
Cook Islands	17.2	238
Fiji[a]	714.0	18,333
Federated States of Micronesia	105.0	700
Kiribati	75.0	684
Marshall Islands	43.0	181
Nauru[a]	8.0	21
Niue	2.3	259
Palau	14.8	494
Papua New Guinea[a]	3,000.0	462,840
Solomon Islands	225.0	30,303
Tokelau	1.6	10
Tonga	95.0	670
Tuvalu	8.0	24
Vanuatu	142.0	12,000
W. Samoa	160.0	2,831
Total	4,610.9	529,585

Sources: Censuses and statistical abstracts 1986-89.

[a]Indicates not participating in present Root Crop Project.

Table 2. Percentage of root crop land devoted to the different root crops in seven project countries.

Crop	Country						
	Cook Is.[a]	W. Samoa[a]	Tonga[b]	Sol Isl.[c]	Vanuatu[b]	Niue[a]	Tuvalu[d]
Aroids							
Colocasia	29	78	10		33	96	52
Xanthosoma	3	--	31	n.a.	1	--	--
Alocasia	--	17	1		--	--	--
Cyrtosperma	--	--	--	--	--	--	40
Total aroids	32	96	42	31	34	96	92
Cassava	43	3	35	13	22	1	--
Sweetpotato	10	--	12	36	15	1	8
Yams	15	1	11	20	28	2	--
Total	100	100	100	100	100	100	100

Sources: [a]1989 Census; [b]1985 Census; [c]Smallholder Project; [d]1990 Statistical Abstracts.

variation in production, with no definite harvest season, seems to account for the absence of processing.

In earlier days, root crops could be grated and left on banana leaves to sun dry, forming a storeable powder. This powder could later be mixed with water or coconut milk to form an edible dough. Large scale processing is not carried out to any degree. The reasons for this are, among others, that many of the communities are too small and the production too low to sustain the raw material demands of a plant. Also, many of the countries that on the whole could sustain a factory have transportation problems so that most of the crops would spoil before reaching the plant. In some of the larger countries that theoretically should be able to sustain plants, lack of capital, knowledge, and traditions seem to hamper the development of these industries. Finally, difficulties in land-ownership reduce the incentives.

A little processing occurs in medium-sized plants. This consists of snack foods and is carried out by local entrepreneurs. A favorite among the W. Samoan producers is making chips of *Xanthosoma sagittifolium*, although the supply of raw material is limited. The technique applied is simple. Tubers are thinly sliced, deep fried in oil and then packaged in plastic bags. Similar operations are also carried out in Tonga and the Solomon Islands.

The bulk of the root crops are consumed by the grower and his family. Normally they are prepared by boiling in water, baking, or roasting in the traditional earth ovens. A little is used for animal feed in some countries or processed at the village level. To get information on how the root crops are prepared, the current project has had a consultant in agro-processing, Dr. D. Ampratwum, travelling in Federated States of Micronesia (FSM), Tonga, Vanuatu, W.Samoa, Kiribati, and Tuvalu. The following is based on his findings (Ampratwum 1989).

The traditional ways of preparing the aroids (*Colocasia, Xanthosoma, Alocasia, Cyrtosperma*) are boiling, baking, or roasting. For boiling, the corms are peeled, sliced into 2-2.5 cm thick slices, and boiled in water. The slices are served together with fish, meat, or vegetables, hot, or more often, cold.

Baking/roasting is carried out in the traditional earth oven. Corms are peeled, wrapped in leaves, and put into a pit in the ground on top of stones already heated from a fire. The pit is then covered with leaves and soil or sand, and the contents are cooked. Other uses of taros include peeling, grating, and mixing with coconut milk and/or banana or papaya, wrapping into leaves, and baking in earth ovens (*sawapiaia* in FSM, *buatoro* in Kiribati, *laplap* in Vanuatu, or *takihi* in Niue).

Sweetpotatoes are generally boiled or baked/roasted. Boiled, peeled tubers may be mashed and mixed with sugar and flour into small balls and then fried (FSM). Grated sweetpotato, mixed with coconut milk, and sometimes green leaves and/or fish, are baked in earth ovens (*laplap* in Vanuatu).

Cassava tubers are peeled and boiled; also baked/roasted in earth ovens. In FSM, peeled, sliced tubers are dried in the sun and pounded into tapioca flour. In Cook Islands and Vanuatu, starch is extracted by grating, adding water, and draining/drying. No fermentation takes place.

Yams are generally prepared boiled, baked, or roasted. In order to facilitate more village level processing and introduce new foodstuffs to the area, e.g., *fahrina* and *gari*, a food technologist and a household consultant will be posted in the field.

Livestock

In order to determine the uses of locally grown foods for livestock, the project has had a consultant in four of the project countries. The following is based on the work of these consultants (Ochetim 1990).

The consultant has also developed feed formulations for these countries based on their locally available resources. Root crops make up 20-30% of these feed formulations. The formulations are available for chicken (broilers/layers) and pigs.

The livestock sector in the Pacific consists mainly of two types. First is the traditional type, where chicken and pigs roam about more or less freely. These animals are used for the family's own consumption, not for sale. Second, there are a few units practicing commercial/semi-commercial pig/poultry farming, but these are generally small-sized enterprises.

The traditional system of pig and poultry farming gives little attention to feeding. The animals will have peels and leftovers and sometimes help themselves in the root crop farms. In the Cook Islands, Solomon Islands, and Vanuatu, cassava is cooked and fed to the pigs. In Tonga, raw (often overmature) cassava is fed to pigs.

In Tonga, there is also one feed mill operating which uses sun-dried cassava chips as part of the diet. A sun drier for cassava (and other) chips exists at the Vaini research station, but it is little used. A feed mill (now closed down) in the Cook Islands used to operate using imported cassava chips.

In the Solomon Islands, dried cassava is purchased by the Livestock Development Authority for compounding pig and poultry rations. In Vanuatu, boiled taro is being used as a pig feed.

The commercial/semi-commercial farms rely heavily on imported feeds (cereal rich). To substitute these by making formulations based on locally available produce has been one of the current project's aims.

Marketing

With little processing being carried out, most marketing consists of fresh produce. The domestic marketing varies from country to country. In W. Samoa, there are two large markets, one on each of the two large islands. Almost all produce to be sold is brought to these two markets. Very few village markets/roadside markets exist. The produce (mainly *Colocasia*) is brought to the markets in coconut baskets. It is displayed in piles, each costing approximately US$ 4.3. The size of the piles will be adjusted according to the supply, with the price per pile being constant. Since nobody weighs their piles, the price per kg varies from pile to pile, from seller to seller, from time to time. Sometimes the variation is so big that the whole system loses its meaning completely.

Under the current project, a study was made of the Samoan domestic market (Lauina 1990). It was found that the supply of taro was at its peak in the first quarter of the year, gradually declining through quarters II-IV. Prices ranged from US$ 0.27 kg to US$ 0.98 kg.

Lauina (1990) also found that transportation (from plantation to main road and from main road to market) was the main obstacle towards marketing according to the sellers contacted.

Supply fluctuations in the Samoan taro market are not uncommon, and as a result prices fluctuate. These fluctuations reflect planting procedures; most taro is planted in the rainy season (November-April), and a supply of other crops such as breadfruit, substitute for taro during seasons when taro is not available.

In Tonga there is quite another situation. There is a main market in the capital, but also numerous roadside markets carrying a good selection of root crops. Table 3 shows the volume and prices obtained at the Talahamu market in 1985.

As can be seen from Table 3, *Xanthosoma* and cassava are the main root crops at the market, the lowest priced being cassava. The supply of *Alocasia* has increased quite a lot since these figures were taken.

It should be expected that some of the smaller Pacific countries would have difficulties establishing marketplaces, because of small population concentrations and limited purchasing power. In Tuvalu for instance (population 8,000 on eight islands), sweetpotato is sold through the cooperative store in the administrative center of Funafuti, whereas the production takes place on another island.

In Niue (population 2,300) there exists a small marketplace. This came into function after the Department of Agriculture initiated the construction of a roofed area. Since then there has existed a small, but lively market in Alofi two days a week.

In the Cook Islands, on the main island of Rarotonga, there is no market as such; but, on Saturdays, trucks and pickups park under the large trees by the roadside in the administrative center, offering produce of many kinds.

Export

As with domestic marketing, mainly fresh, unprocessed produce is exported. Only three of the project countries have any serious export: W. Samoa, Tonga, and Cook Islands. Some data on their exports are shown in Table 4.

Nearly 100% of Cook Island's and Tonga's and 75% of W. Samoa's export goes to New Zealand. The buyers in New Zealand are generally Pacific Islanders living there. These buyers have a preference for taro (the most exported crop) grown on their own island. The remaining 25% of W. Samoa's export goes to American Samoa/Hawaii, where the buyers also have ethnic linkages.

It is interesting to note the variation in prices obtained (Table 4). The Cook Islanders get up to 3-4 times as much for their produce as the other two exporters. The reasons for this may be that there is an agent from a New Zealand vegetable firm located in the Cook Islands. This means good market information; set quality standards; the taro is sold at auctions; and it is also backed by promotion from the firm. Further, the taro is grown in paddies and is reported to be of very good quality, clean of dirt and soil, and presented in nice packages. Also adding to the quality is the use of air freight, reducing postharvest losses because the time from harvest to sale is very short.

The two other countries export larger quantities, but of more variable quality. Also the supplies vary because the New Zealand market is flooded with produce periodically, resulting in low prices.

Other countries have started to develop interest in exports of fresh produce. In early 1991, a workshop in Vanuatu was held which focused on yams for export. This was organized by the Root Crops Development Project.

Table 3. Volume of root crops delivered and prices obtained in Tonga, 1985.

Crop	000 kg	Price US$/kg
Yams	323	0.79
Xanthosoma	680	0.20
Colocasia	221	0.28
Alocasia	2	0.30
Sweetpotato	193	0.27
Cassava	866	0.06

Source: Opio 1990.

Table 4. Root crop exports and earnings, average prices per t for Tonga, W. Samoa, and Cook Islands.

	Country		
	Tonga (1987)	W. Samoa (1988)	Cook Is. (1988)
Volume (t)	798	5,857	150
Earnings (US$)	280,000	2,327,000	226,000
Earning/t (US$)	350	397	1,506

Source: Opio 1990.

Some Samoan entrepreneurs are also at this time interested in developing produce for export, based on taro as a raw material. Peeled, blanched, and vacuum packed taro slices have been suggested. A main obstacle, however, is the fluctuation in supply of raw material.

A little cassava starch is exported from Cook Islands; it fetchs quite good prices. In order to determine the situation regarding marketing, the project has also had a consultant travelling to seven of the project countries. Most of the above information is extracted from this report (Opio 1990).

Conclusion

Roots and tubers are important food commodities for the South Pacific islands, although production of specific crops varies considerably from one location to another. Efforts to expand utilization and increase incomes from the sale of these commodities have focused primarily on improvements in local marketing infrastructure and exports rather than on initiatives to introduce large-scale processing. The limited supply of raw material and the logistical problems associated with its procurement and transport are the principal obstacles to the manufacture of processed products. Future efforts in the area of product development for roots and tubers in the South Pacific are likely to be small scale and build on the successes achieved in the fresh market—foreign and domestic.

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Processing, Marketing and Utilization of Cassava and Sweetpotato in India

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Abstract

Area planted and production of cassava and sweetpotato in India started declining recently, while the per acre productivity of cassava has increased. A large variation in cassava and sweetpotato consumption exists between urban and rural areas. Information on consumption patterns for sweetpotato indicate that the bulk of production goes for human consumption. It is estimated that 70% of the total cassava production in Kerala is used for food; whereas in Tamil Nadu only 25% is used for human consumption. The bulk of the production in Tamil Nadu and Andhra Pradesh goes for industrial utilization.

Approximately 17% of the country's total cassava production goes for animal feed. In industry, cassava is used as a raw material for a number of processed products such as starch, *sago*, liquid glucose, dextrin, Vitamin C, gums, and high fructose syrup.

Research has been done to develop technology for the storage of fresh and dried cassava. Sweetpotato could be stored without sprouting and weevil infestation in sand, saw dust, wood ash, earth, and waste carbon paper in earthen pots. A hand-operated and a pedal-operated chipping machine, and artificial drying and peeling machines have also been developed.

Protein-enriched food and feed preparations based on cassava were developed by blending cassava with protein sources and using solid state fermentation Pregelatinized and modified starches were also made. Technology for the production of ethanol from starch and *thippi* was perfected. Current processing techniques of cassava and sweetpotato are described in detail. Research priorities for cassava and sweetpotato are storage techniques, waste recycling, fermented and non-fermented food products, animal and fish feeds, modernization of starch extraction units, and improved technology for the extraction of starch from sweetpotato.

Key words: cassava, sweetpotato, demand and supply, diversification, processing and utilization, constraints, food, feed, industry, India.

Introduction

Cassava (*Manihot esculenta*) was introduced into India either during the 17th century by the Portuguese or brought from South America in 1840. However, it spread as a cultivated crop after a royal proclamation by Shri. Visakhom Thirunal (1882-85), the ruler of Kerala, the then princely state of Travancore. Shri Visakhom Thirunal realized that the problem of rice shortages in Travancore state could be overcome by the introduction and popularization of cassava, especially among the low-income group consisting of small farmers and laborers engaged in hard physical labor. The ability of cassava to supply adequate calories cheaply encouraged its use, especially among vulnerable social groups. When the utilization of cassava as food had attained full momentum in Kerala, it emerged in industrial use in the neighboring state of Tamil Nadu.

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Industrial utilization of cassava throughout India started during the World War II, when the manufacture of starch and flour was initiated to overcome the non-availability of corn and potato starch from the western countries and cassava starch from Indonesia which were used in textile mills. When the Government of Travancore introduced control over the export of cassava products to ensure their availability as cereal substitutes, some areas in Tamil Nadu developed cassava processing plants. At this stage, cassava cultivation crossed the boundaries of Kerala and spread to the states of Tamil Nadu and Andhra Pradesh. The migratory habits of the people of Kerala also helped in cassava's spread to the other regions, like the northeastern hill provinces. Now, India ranks sixth in the total world production of cassava. Cassava is slowly spreading as an industrial crop to many other states.

Sweetpotato is also believed to have been introduced to India by the Portuguese. Unlike cassava, sweetpotato is grown throughout the country as a secondary food crop. Sweetpotato has yet to be used in industry.

Area Planted, Production, and Yield

Kerala and Tamil Nadu contribute 95% of the growing area and 99% of the production of cassava in India (Map 1), while seven other states, Assam, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Orissa, and Uttar Pradesh, account for 89% of the growing area and 88% of the production of sweetpotato (Map 2).

Cassava

The area under cassava cultivation increased steadily and reached its maximum in 1975-76. Thereafter, the area started declining, and the area index dropped to 76.5 in 1987-88. Production indices also exhibited a steadily increasing trend until 1975-76, then fell sharply over the next two years. The indices of area under cultivation, production, and productivity indicate that between 1970-71 and 1987-88 area and production had a decreasing trend while productivity increased. Specifically, while area had a 1.7% and production a 0.6% negative rate of change, the positive growth rate for productivity was 1.2%. However, the wide range of end uses of cassava in the starch and starch-based industries and the potential of cassava as an alternative resource in alcohol production and in animal feed formulations have, in recent years, generated an interest in this crop in some states where cassava has been of little importance. If this interest is translated into actual production, the present declining trend in cassava production could be reversed.

By 1986-87, the area under cassava had gone down to 205,800 ha with a corresponding reduction in production to 3.5 million t. Productivity of cassava per hectare has increased from 15.5 t/ha during 1971-72 to 19.3 t/ha during 1987-88.

Sweetpotato

Unlike cassava, sweetpotato is grown throughout the country. Area planted and production of sweetpotato in India has recently declined. In 1980-81, the country had an area of 0.208 million ha under the crop and production was 1.5 million t. In 1986-87, the area was reduced to less than 0.2 million ha and production had fallen to 1.2 million t. Sweetpotato productivity in India is almost 50% of the World/Asian average (8.16 t/ha). The crop occupies only about 0.11% of the total cropped area of the country. Even though the crop is grown in most states and union territories of India, the bulk of area and production are confined to Orissa, Bihar, and Uttar Pradesh (Map 2).

Current Utilization Patterns of Cassava and Sweetpotato

Cassava in Food

In 1882, immediately after the Royal proclamation about the importance of cassava by the Maharaja of Travancore for supplementing food grain production, there was a slow change in the food habits of the poorer segments of the population. During World War I and II, there was an increased dependence on cassava when rice imports were cut off. But eventually cassava became an important subsidiary food, even in normal years. In a National Sample Survey (1977-78), it was observed that the average 30-day cassava consumption per capita was 5.55 kg in rural areas and 2.59 kg in urban areas. The utilization pattern of cassava indicated that about 3 million t of cassava were used for human consumption in 1981. Comparatively, per capita consumption of rice did not vary much between urban and rural areas. The 28th round of the National Sample Survey indicated that per capita consumption of rice was 845 calories in rural areas and 840 calories in urban areas, while for cassava it was 366 calories in rural areas and 190 calories in urban areas. A food habit survey conducted by a research group indicated that the average daily consump-

Map 1. Cassava production in India, 1986-87.

State	Area (ha)	Production (t)
Andhra Pradesh	3,200	10,000
Assam	1,768	7,535
Karnataka	1,508	14,613
Kerala	146,953	2,576,065
Meghalaya	4,189	23,625
Mizoram	118	535
Nagaland	300	600
Rajasthan	223	518
Tamil Nadu	33,776	913,556
Tripura	478	2,153
Andaman and Nicobar Islands	230	771
Pondicherry	504	9,847
All India	205,800	3,574,900

Map 2. Sweetpotato production in India, 1987-88.

State	Area (ha)	Production (t)
Andhra Pradesh	2,700	21,700
Arunachal Pradesh	300	1,400
Assam	8,558	27,363
Bihar	30,389	293,102
Gujarat	921	13,332
Haryana	703	7,236
Karnataka	6,672	43,999
Kerala	4,001	33,851
Madhya Pradesh	6,733	39,194
Maharashtra	5,400	78,400
Manipur	100	300
Meghalaya	3,900	13,000
Mizoram	312	2,211
Nagaland	40	600
Orissa	58,700	351,270
Punjab	116	673
Rajasthan	1,180	2,120
Tamil Nadu	1,958	42,530
Tripura	1,453	13,533
Uttar Pradesh	29,676	267,410
Andaman and Nicobar Islands	100	800
Pondicherry	14	175
All India	163,926	1,254,179

tion of roots and tubers by adults was 175.3 g; school children, 120.8 g; and pre-school children, 30.9 g.

It is estimated that 70% of the total production in Kerala is used for food, whereas in Tamil Nadu only 25% is used for human consumption.

Cassava in Feed

In spite of the scientific knowledge generated about the possibilities of utilizing cassava as a carbohydrate supplement in animal feed formulations, feed manufacturers do not utilize cassava because of its high cost relative to other carbohydrate sources. But the practice of *in situ* utilization of cassava in animal feeding exists in the villages of Kerala. In a survey conducted in 1977, 70% of the cassava retained by producers was set apart for consumption, 17% was used for animal feed, and 13% was given to wage laborers and servants. Farmers with a land holding of 2.4 ha used 36.6% of their retention for feeding livestock.

Cassava in Industry

Cassava is used as a raw material for a number of processed products such as starch, *sago*, liquid glucose, dextrin, Vitamin C, gums, and high fructose syrup.

The Indian textile bulletin shows that corn starch dominates the starch industry approximately in the ratio of 10:1 for corn and cassava. In 1980 and 1981, cassava starch production was around 10,000 t. The present production of cassava starch in India should be more than 300,000 t (including *sago*), or about 37% of annual cassava production (Ghosh 1984).

Sweetpotato Utilization

The bulk of sweetpotato production goes for human consumption, according to available information. Sweetpotato is processed in different forms and consumed. Only the vines are fed to cattle. Not a single industrial unit functioning in India utilizes sweetpotato. Since the technology for the effective separation of starch from sweetpotato is still in the rudimentary stage, sweetpotato is not in a position to compete with other sources of starch. Very recently sweetpotato flour has reportedly started arriving in commercial markets in India. Its usefulness in pure form or as a blend in various flour preparations has to be explored, and research is under way.

Supply and Demand Projections

Projected Area of Cassava

Realizing the importance and potential of tuber crops, in 1976 the National Commission on Agriculture (NCA) projected the production possibilities of cassava and sweetpotato in 1985 and 2000 (Table 1).

Projected yield increases for cassava and sweetpotato are not beyond the feasible. Already, research results from the Central Tuber Crops Research Institute (CTCRI) indicate that a cassava yield of 40 t/ha can be obtained by a scientific package of practices. Similarly, a few promising sweetpotato cultivars have yielded about 20 t/ha in experimental plots. However, the current position of tuber crops is not as NCA projected. Both area planted and production of cassava and sweetpotato in 1987-88 were much less than NCA's projected levels for 1985. Though productivity during 1987-88 has in-

Table 1. Production projections and levels obtained for cassava and sweetpotato, 1985-2000.

	Average of 1969-70	Estimate of NCA 1985	Obtained 1987-1988	Estimate of NCA 2000
Cassava				
Area (000 ha)	350	650	270	1,000
Production (000 t)	5,300	18,200	5,212	40,000
Productivity (t/ha)	15.5	28.0	19.3	40.0
Sweetpotato				
Area (000 ha)	230	310	163	500
Production (000 t)	1,800	4,300	1,254	10,000
Productivity (t/ha)	8.0	14.0	7.7	20.0

Source: *Report of the National Commission on Agriculture (Part III, 1976). Published by Government of India, Ministry of Agriculture and Irrigation, New Delhi.*

creased in the case of cassava to 19.3 t/ha from 15.5 t/ha, productivity of sweetpotato has declined slightly. Moreover, because of the sharp decline in the area under cassava and sweetpotato cultivation in all states, it may be difficult to achieve the targets set by NCA.

Demand Projections

Changes in demand for cassava for human consumption occur through changes in population, income, relative prices, as well as tastes and preferences (George 1988). Some of the cross section consumption surveys have indicated a negative relationship between cassava consumption and income. While there will be an increase in cassava consumption for the low-income groups, improved income levels of middle class families and changes in income distribution will reduce cassava consumption with an improvement in the availability of rice and other cereals. In Kerala the demand for cassava has been depressed during the last few years. It is also assumed that given no major changes are foreseen in consumer tastes and preferences, population changes will be the major factor influencing cassava consumption.

A detailed study for the supply and demand of cassava in India was made by George (1988). The projected area for cassava for 1990 indicated a lower bound of 288,100 ha and an upper bound of 354,000 ha. The lower and upper bounds of area for 2000 are 257,600 and 406,400 ha. The NCA estimated that by 2000 area planted under cassava could reach 1 million ha. Since the average area during the period 1986-87 was only 205,800 ha and growth rates declined during the 1980s, it may be difficult to achieve the targets set by NCA.

Cassava is predominantly a food crop in Kerala and the Kanyakumari District of Tamil Nadu. With the increased availability of food grains in Kerala, the demand for cassava has decreased considerably. But the population growth rate in Kerala will be a major contributing factor to cassava utilization. It is estimated that the demand for cassava for human consumption would increase at an annual rate of 1.5% so that the quantity demanded in 1990 and 2000 would be between 3.3 and 3.9 million t (George 1988). The current use of cassava for starch preparation is about 1.3 million t.

From the starch manufacturers' point of view, there cannot be a substantial increase in the demand for cassava because corn is preferred. Still, interest shown by industrialists in modified starches, high fructose syrup, Vitamin C, and maltodextrins will open new avenues in the utilization of cassava in India. Moreover, projected demand of ethanol to the tune of 800-900 million liters during 1995-2000, from the existing 600-700 million liters produced from the short supply of molasses, may create a situation that depends on cassava and sweetpotato as alternate sources of ethanol.

But in the animal feed sector, cassava and sweetpotato have considerable potential. It is estimated that the shortfall in animal feed concentrates will be 5.8 million t by 2000. If 25% of this deficit could be made up from cassava and sweetpotato, there is a demand for about 1.4 million t of dried cassava and sweetpotato which is equivalent to 3.9 million t fresh weight.

Current Processing Research

Storage and Preservation

One of the main constraints in the utilization of cassava tubers is their rapid perishability due to biochemical changes and microbial infestation. This often results in an inadequate remunerative price because farmers are forced to dispose of the produce without bargaining. Besides creating utilization problems at the home, village, and industrial levels, transport of cassava is also restricted. Research at CTCRI showed that fresh tubers could be effectively stored in sand or soil pits. Tubers harvested along with a one-foot stem were stored in three layers in the pits and covered with sand or soil. The moisture content in soil or sand was maintained at 10-15% by occasional sprinkling of water (Balagopalan and Padmaja 1985).

Conventional systems of storing cassava products have also been evaluated at CTCRI. Metal containers and polyethylene lined bags were found most effective for storage of chips up to 90 days. High density polyethylene and polyimpregnated bags resulted best for the storage of starch up to 180 days. Recent experimental evidence has also demonstrated the possibility of extending the shelf life of cassava tubers in polyethylene bags after treating with Mertect. These techniques are intended to ensure better utilization of cassava in urban areas.

Approximately 23.8% of sweetpotato is damaged during harvest. This enhances rotting during storage. The affected sweetpotato roots can be easily recognized by their water soaked appearance and mushy decay, sometimes exuding a mildly alcoholic odor. Storage rot is higher in room storage than in ventilated yards. Attempts have been made to reduce such damage during storage. One experiment tested sweetpotato roots stored for 90 days in saw dust, red earth, earthen pots, wood ash, white sand, local earth, and waste carbon paper.

Local earth was found to be the most economical media (Mukerjee and Prasad 1972).

Sprouting and rots are common during the storage of sweetpotato. Storage studies conducted in India showed that the weight loss of sweetpotato roots stored for 30 days could be reduced from 25-73% to 7.94% by storing them in sand. After 60 days storage, the weight loss was 41.9% under ambient conditions and 13.22% by storing in sand. After 90 days the weight loss was 50% under ambient conditions of storage (Dayal et al. 1990).

Sweetpotato weevil, *Cylas formicarius*, is a very serious storage problem for sweetpotato. Harvested tubers may contain any of the life stages of weevil which will damage roots during storage. Such roots are very bitter and unfit for consumption. Loss of water and shrinkage are other changes caused by weevil infestation. Research at CTCRI showed that sweetpotatoes heaped on the floor of a godown and completely covered with 5 cm depth of dried red earth (1:4 wt/wt) or wood ash (1:1 wt/wt) were free from weevil infestation and dehydration for two months (Rajamma 1984). Roots free from weevil infestation selected immediately after harvest and cured in the sun for about 6 hrs are used for such storage.

Primary Processing Equipment

The conventional mode of preparation of cassava chips is slicing the tubers with hand knives. This method is time consuming, labor-intensive, and often leads to uneven and delayed drying. For large-scale preparation of chips, manually operated and motor-driven chipping machines have been found to be highly efficient. A low cost, hand-operated chipping machine was developed at CTCRI. The machine is used to produce round chips of varying thickness. Field tests conducted in different villages showed that the average rate of acceptability was 81.2% (Nanda 1985). CTCRI has also developed a pedal-operated cassava chipping machine which can process 350 kg/hr. A vertical feed-type, power-operated chipping machine was developed at Tamil Nadu Agricultural University (TNAU), Coimbatore, India. The chip thickness can be varied from 1-40 mm and the capacity is 270 kg/hr. TNAU has developed a cassava peeler which consists of a cylindrical rotor fitted with a number of cutting blades. The peeling efficiency of the machine is 83% and it has an average production of 950 kg/hr.

Drying of Cassava Chips

Sliced cassava chips are usually dried in the open air under sunlight on cement floors, bamboo mats, and rock surfaces. Depending on weather conditions, it takes 2-5 days to dry chips. The recovery of chips is usually 38-40%; however, contamination by air-borne dust, dirt, and microbes is common. Moreover, it is difficult to bring moisture down to a safe storage level of 14% or less by natural drying. This can be better achieved by combining natural drying with solar or electrical drying. CTCRI has developed an electrically operated dryer which has a holding capacity of 1 m^3 and is suitable for drying up to 500 kg of fresh chips. Moisture content can be brought down from 65-74% to 12.2-13.8% within 24 hrs of drying.

Processing Techniques for Hydrocyanic Acid in Cassava

Although the toxic properties of cassava are well recognized, cassava is eaten in different ways in India. Research was done at CTCRI to select the best processing technique to reduce cyanoglucosides to the minimum level. Cyanide retention was maximum in the tubers which were baked, steamed, or fried. Dried chips and boiled cassava tubers had low residual cyanide (Nambisan and Sundaresan 1985).

Food Products

Balanced Food

The high incidence of protein calorie malnutrition and nutritional diseases among children in developing countries calls for effective steps to improve the quality and quantity of diets. It is well known that the most vulnerable group to be adversely affected by nutritional deprivation are pregnant and lactating mothers, and children. Among the various strategies that have evolved to combat malnutrition, enrichment of cassava diets with protein has assumed considerable significance. Investigations carried out at the Central Food Technological Research Institute (CFTRI) and Food and Nutritional Laboratory, Hyderabad, India, led to the formulation of the following non-conventional foods. Flours made of cassava (45%), wheat (20%), groundnut (25%), and Bengal gram (10%); and flours made of cassava (70%) and groundnut flour (30%). These food items produce a balanced ration consisting of 15% protein and 10% calories. These protein-rich food formulas are being adopted to replace imported "Care" food by indigenous formulations like *Balahar*. Kerala Indigenous Food's (KIF) *Pushta Atta* is another balanced food mixture of wheat flour, cassava flour, and groundnut flour (Balagopalan et al. 1988).

The Sago Fortification Project of Salem, India, has developed technology for producing fortified *sago* with a protein content of 14-16% and a protein efficiency ratio (PER) of 1:7 to 1:9. The *sago* is further fortified with vitamins and minerals. The project has achieved a fortification level of 1500 I.U. of Vitamin A in the final product which also contains appropriate levels of Calcium, Phosphorus, and Iron. These food formulations satisfy all the requirements for a weaning food (Balagopalan et al. 1988). Enriched noodles and vermicelli containing cassava starch, wheat flour, soya flour, groundnut flour, Vitamin A, calcium, phosphorus, and iron have also been prepared by the Sago Fortification Unit.

Nutritious food mixes have been developed utilizing cassava starch and mixing in locally available cereals like *bajra* and corn. Further enrichment is done using groundnut flour. The cereals, cassava starch, and groundnut flour are roasted and then mixed with *jaggery* (sugar cane juice) in equal proportions. The products have been found to have excellent taste and are readily acceptable to children.

Enriched Gold Finger

In the traditional process of manufacturing ordinary gold finger, 50% wheat flour and 50% cassava starch are used. Successful attempts have been made to substitute the 50% wheat flour with soya flour and edible groundnut flour to make it more nutritious.

Cassava *Rava*

In order to promote the consumption of cassava in urban areas, it is essential to develop instant and modified food products based on cassava suited to the requirements of urban people. Cassava *rava*, a pregelatinized preparation, prepared and modified by CTCRI, is one attempt in this direction. CTCRI has also developed an instant, pregelatinized flour preparation to produce an instant porridge.

Sweetpotato Food Products

Research to develop novel sweetpotato-based food products has not gained the attention of scientists in India. The traditional method of consumption continues in rural and urban areas. However, since sweetpotatoes are an indigenous, inexpensive food rich in calories, an attempt was made to prepare and incorporate sweetpotato flour in South Indian and baked recipes (Arunaseralathan and Thirumaran 1988).

Other Uses

Cassava in Animal Feed

To enhance the protein content of cassava and cassava starch factory wastes, *thippi*, for use in animal feed, microbial techniques have been developed. It was found that *Trichoderma pseudokoningii* could grow profusely on cassava flour. An animal feed containing 6-8% protein was developed by mixing this flour with *thippi* in a 50:50 ratio and converting it in the presence of nitrogen (Bagalopalan and Padmaja 1988). Broiler feeding trials conducted with SCP-enriched cassava feed showed that it could fully meet the requirement of broilers (Padmaja and Balagopalan 1990).

Fresh cassava and sweetpotato can be successfully ensiled and preserved in the presence of suitable absorbants. It was found that cassava tubers ensiled with wilted cassava leaves and paddy straw (80:20) could remain fresh even after 72 days of ensiling.

Cassava in Industry

Although cassava starch and its derivatives are widely used for a number of industrial applications, the unstable viscosity leading to a long cohesive nature often tends to rate it as inferior to corn starch by textile industries. Research at CTCRI could modify the undesirable properties of cassava starch (Moorthy 1985).

Ethanol from Starch and *Thippi*

Viable and economical techniques have been developed by CTCRI and CFTRI, Mysore, for the production of ethanol from cassava flour and *thippi* (Lonsane and Ghildyal 1990).

Treatment of Waste Water

Successful attempts have been made at CTCRI for the effective detoxification and purification of waste waters from starch factories which cause enormous environmental pollution.

Current Processing Techniques

Primary Processing

Since fresh cassava tubers deteriorate within a few days after harvest, they are sliced into small pieces or chips and dried in the sun. The dried chips can be preserved for months and consumed after grinding into flour. They are also used in industry for starch, dextrin, and glucose

Edible cassava chips in India are of two types. White chips are obtained by removing the outer skin of the tubers, slicing, and sun drying. Parboiled chips are obtained by immersing the chips in boiling water for 10 min before drying. Parboiled chips are easier to store than white chips.

There is not much uniformity in the preparation of cassava chips in different localities. The various chips available in the market can be broadly grouped into the following categories, although names may differ in other regions.

Iritty-type	Outer skin is removed.
Vella	Both rind and skin are removed.
Chilta	Both rind and skin are retained.

Vella chips usually obtain a better price when compared to the other chips because of their bright color. *Chilta* and *iritty* are used for the cattle feed industry. Under conventional practices, cassava tubers are sliced with hand-knives, with or without peeling the outer skin and rind. Chips are then dried under the sun. However, this method is tedious and time consuming, and leads to uneven and delayed drying because chips are produced in various forms, sizes, and shapes.

Cassava Drying

The sliced tubers are usually dried in the open air under sunlight by spreading in a single layer on cement floors, bamboo mats, rock surfaces, or sometimes even on bare earth. Chips dry better on rocks because they dry white in color and take less time. Depending upon the weather conditions, it takes 2-5 days to dry the cassava chips. Contamination by air borne dust, dirt, and debris cannot be entirely avoided during sun-drying, especially on windy days.

Secondary Processing

Cassava Flour Preparations

Cassava roots are first boiled in water, then sun dried. The dried roots are then pounded or ground into flour to be used for various preparations.

Traditional Indian foods, such as *chappathis, uppuma, puttu,* and *dosa*, can be made from cassava flour. Cutlets are made by mincing the grated roots and mixing with fried onions, cashew nuts, black gram, and coriander leaves. The mixture is then made into balls dusted with *maida* flour and lightly fried. The flour can also be used for making breads, biscuits, salad dressing, custard powder, ice cream powder, flakes, and vermicelli.

Cassava starch

Cassava starch manufacturing in India is divided into the following stages.

Washing and peeling the roots to remove and separate all adhering soils and as much protective epidermis as necessary.

Rasping to destroy the cellular structure and to rupture the cell walls to release the starch as discrete, undamaged granules from other insoluble matter.

Screening or extracting to separate comminuted pulp into two fractions, waste fibrous material and starch milk.

Purifying or dewatering to separate the solid starch granules from their suspension in water by sedimentation or centrifuging.

Drying to remove sufficient moisture from the damp starch cake obtained during the separation stage so as to reduce the moisture content from 35-40% to 12-14%, which is a level low enough for long-term storage.

Finishing operations such as pulverizing, sifting, and bagging.

Manufacture of cassava starch is mostly carried out in three types of establishments. The first is cottage industry where work is carried out entirely by rudimentary hand tools, usually operated by a single family and producing 50-60 kg of crude starch per member per day. The second type, small-scale enterprise, produces about 5-40 t of tubers per day, mainly because of more efficient rasping. This is done by using a prime mover of about 20 hp that needs little skilled labor. The third type is the large-scale factory which may sometimes operate its own extensive plantations, thus assuring a regular supply of raw materials processed using modern equipment. The third type of mill processes about 100 t of roots or more per day.

Sago

Sago is a processed food starch marketed as small globules or pearls. *Sago* is manufactured in India from cassava starch. For the manufacture of *sago*, wet starch is dried in the sun to a moisture content of 40-45%. This is made into small granules by shaking in power-driven globulators. In small units, globulation is done with 10-15 kg starch. The globules vary considerably in size and are sieved through standard meshes. The next step is partial gelatinization which is carried out on shallow iron pans with oil. These are then heated on fire. The granules are stirred continuously for 15 min and are then dried in the sun or oven. The *sago* roaster developed at Tamil Nadu Agricultural University consists of a feed hopper, drying cylinder, and electrical heating coils. A temperature of 170°C with a retention time of 3 min is enough for obtaining uniformly roasted *sago*.

Liquid Glucose and Dextrose

Liquid glucose, containing products of incomplete hydrolysis of starch, and dextrose are produced in most of the large-scale processing units. The moist starch slurry is directly subjected to acid hydrolysis at pH 1.8-2.0 and a temperature of 160°C. Liquid glucose is used in India by many food and confectionary industries.

Dextrins

Cassava starch is used for producing dextrins of good solubility, neutral flavor, and good adhesive qualities. This is obtained by mildly heating starch with an added catalyst at 80-120°C.

Animal Feed

In India under the Operation Flood Program, 38 feed milling plants have been established in different parts of the country. Also there are about 138 mixing plants in both the private and public sectors. Cassava has already been accepted as a cattle feed ingredient by ISI (Standard No. IS-1509-1972 and IS-5064-1960) and can thus be incorporated as one of the ingredients as a grain substitute. However, the cost of cassava is higher in the animal feed raw material market and hence is not selected in least-cost formulations.

In situ utilization of cassava after cutting into small pieces and boiling or pulping and boiling for feeding the animals is a local practice in Kerala. Feeding cassava along with the proper protein supplement could enable cassava to be used in the least-cost feed formulations.

High Fructose Syrup, Oxidized Starch, and Vitamin C

Recently licences have been issued in India for the industrial production of high fructose syrup, oxidized starches, and Vitamin C utilizing cassava starch.

R&D Areas that Require More Support

The major factors contributing to the slow growth of cassava and sweetpotato are the easy availability of cereals; increased standards of living; lack of an assured market; and, high returns from cash crops. Diversification of cassava and sweetpotato for industrial uses is the major alternative to the existing situation. Therefore, the future research and development (R&D) strategy for cassava and sweetpotato in India will be the exploitation of these crops for non-conventional food, feed, and industrial uses. Some of the major areas are discussed below.

Cassava

Storage Techniques

Fresh cassava roots deteriorate within a few days after harvest due to physiological and microbiological reasons. In order to facilitate the overseas transport and land transport of the produce from the site of production, less expensive treatment technology has to be developed.

Instant and Convenience Foods

The demand for ready-to-eat foods is on the increase in India with people having less spare time and better purchasing power. Food items like cassava *rava*, cassava chips, pregelatinized starches, and instant food mixes, may be able to compete in this market in the near future. Hence, priority could be given to improvising these products and popularizing the food products made out of them.

Fermented Products for Food and Industry

Fermented food products based on cassava could also be developed to help increase the food uses of cassava. The potential for industrial ethanol production needs be effectively tapped to meet the acute shortage of industrial and potable ethanol. Efforts should be made to produce high fructose syrup made from cassava starch on an industrial basis.

Development of Animal and Fish Feeds

Ensiling which ensures the nutritional superiority for cassava over other storage methods can be evolved as a viable model system to promote *in situ* utilization as animal feed. Enrichment of cassava with microbial proteins, in addition to reducing feed costs, will help in sparing a costly proteinaceous human food item, fish. Hence, SCP-enriched feeds can be developed for broilers, layers, cattle, etc.

The primary factor inhibiting the use of cassava in compound feed mixes is its price in comparison to corn and other cereals. This can be solved to a large extent by using *thippi* (flour mixes in animal feeds). Pelleted cassava chips can be transported to distant places due to less chance of damage, and low volume to weight ratio.

As aquaculture has gained momentum in India, there is an urgent need for developing cheap artificial feeds for fish. Cassava starch with its highly adhesive nature is an ideal carbohydrate supplement in fish feeds.

Modernization of Processing Factories

Most of the unit operations for the manufacture of starch/*sago* are obsolete and labor-intensive. There is a need to modernize processing equipment. Development of electronic equipment to indicate starch content will help to protect the interests of producers. Solar drying systems can ensure the production of good quality starch/*sago*. The luster of finished *sago* depends to a large extent on the drying time and method. Sun-drying often imparts color, a bad smell, and microbial contamination to *sago*. These damages can be prevented in solar and electrical dryers.

Liquid Glucose

In the production of liquid glucose, acid hydrolysis of starch is practiced in many industries. This often results in corrosion of machinery and other handling problems. Reversion of end products and high energy consumption during saccharification could be eliminated if efficient enzyme hydrolysis of starch is undertaken. It is, therefore, necessary to develop ancillary industries to produce superior-grade starch saccharifying enzymes.

Waste Recycling

In view of the pollution potential of cassava processing units, effective recycling of waste water needs attention. Efforts have to be made to reduce BOD and COD of the effluents and detoxify the cyanide present in it. Such non-toxic effluents can find use in irrigation and fish rearing.

Sweetpotato

Food

Sweetpotato is directly consumed as a processed food item in India. No attempt has been made in the past to produce secondary processed foods. One of the main constraints faced in the utilization of sweetpotato is the poor extractability of starch. The extractability of starch from sweetpotato very seldom exceeds 50% of the values recorded by chemical means. Phenolic oxidation and its effect on the starch color is another minus point. Novel methods for the maximum extraction of starch and removal of unwanted colors will enable its utilization in various food industries.

Development of sweetpotato-based, home-scale, processed food products will also ensure better utilization.

Animal Feed

Approximately 20-25% of total production is lost either due to damage during harvesting or to weevil infestation. Utilization of damaged tubers after developing a proper ensiling technology could ensure conservation and diversification of this produce for animal feeding.

Fermented Products

Techniques for the production of novel products like citric acid, monosodium glutamate, high fructose syrup, Vitamin C, and ethanol from sweetpotato must be standardized for their utilization in industry.

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III. Assessment of Processing Potential

Perhaps the most critical stage in all of product development concerns the initial evaluation of different possible products and processes. The most appropriate region or area to begin such work and the final market to be targeted are among the principal questions that need to be answered. Often this task is all the more intimidating because little information of this nature is readily available for root and tuber crops in most developing countries. Furthermore, once a decision is made, the resources available must be concentrated on the development of the most promising alternative. Under such circumstances, a user-friendly approach to identify the product or process with the greatest potential can considerably enhance the chances of success.

This section addresses the issues of market, technical, political, and social potential for product development for root and tuber crops in two ways. First, it presents a framework for conducting such assessments. Second, examples of work done on specific products in particular countries provide an indication of what such assessments entail.

As Christopher Wheatley and Gregory J. Scott point out in **Identification of Product Opportunities,** options for processing and marketing products made from roots and tubers often are more numerous then initially realized. They go on to present a systematic approach to opportunity identification considered to be thorough, yet inexpensive and designed for rapid generation of results. Their paper includes an inventory of possible processed products and a checklist for helping to determine those with the greatest potential. An abbreviated version of an evaluation of potato processing in India illustrates the application of the proposed procedure.

A rapid, cost-effective method for analyzing commodity markets is described by Taco Bottema in **Rapid Market Appraisal, Issues and Experience with Sweetpotato in Vietnam.** Bottema indicates that this form of rapid appraisal can be used to identify the position of different participants in both input and output markets. He highlights the use of food balance sheets. In carrying out such appraisals, Bottema recommends giving special attention to linkages between agriculture and industry.

In **Analyzing Sweetpotato Marketing in South Vietnam: An Informal Approach,** Zenaida F. Toquero presents an informal survey method to carry out a rapid assessment of the market structure for root and tuber crops. This method utilizes casual interviews with key participants in the marketing chain and direct observation of the activities and facilities involved. The results indicate that most traders in Vietnam buy and sell a variety of root crops, other vegetables, even fruits to reduce the risks associated with trading in a single commodity and to offset seasonal supply patterns for particular products.

Julieta R. Poa recommends integrating technical and socioeconomic/market research in **Market Research in a Sweetpotato Food Project in the Philippines**. In her view, the need for combining different perspectives manifests itself at each stage of the product development cycle, from idea generation to pilot testing and eventual commercial sale of the product. Furthermore, she observes that socioeconomic/market research may be done by scientists from a variety of disciplines.

Researchers at the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) have developed a procedure for identifying the commercial potential of proposed processed products. In **Evaluating the Potential for Sweetpotato Products in the Philippines: SEARCA's Experience**, Ana G. Abejuela indicates that the procedure consists of three weighted criteria: marketability (40%), technical feasibility (30%), and profitability (30%). She explains that this procedure can identify technologies that are ready for commercial development. She illustrates use of the procedure with a variety of sweetpotato products in various stages of development including snack foods, soy sauce, jam, and catsup.

Problems and opportunities in the market for both fresh and processed sweetpotato products are outlined in **Prospects and Constraints for Sweetpotato in Indonesia** by A. Rachim, H. Malian, M.O. Adnyana, and A. Dimyati. The authors review trends in production; the comparative advantage of sweetpotato; marketing and utilization; and government policy and strategic intervention. In their view, success with sweetpotato will depend on, among other things, improved production technologies to raise yields and lower the cost of raw material. In addition, the national research program must generate technologies to absorb the additional supply potent...y available from further yield increases. Greater utilization of sweetpotato in the form of flour has shown promise.

Identification of Product Opportunities

Christopher Wheatley and Gregory J. Scott[1]

Abstract

Options for processing and marketing products made from roots and tubers often are more numerous than initially realized. This paper reviews the potential objectives, participants, constraints, and opportunities involved with alternative forms of product development for the purposes of determining those with the greatest probability of success. An inventory of possible processed products is presented. The technical aspects of some basic processing operations are reviewed. An initial checklist for final screening of products is described. The paper concludes with an illustory evaluation of village-level potato processing in India.

Key words: product opportunities; processed products; processing techniques; procedures for evaluation.

Introduction

This paper presents methods used to generate and evaluate ideas for new or improved products from root and tuber crops. It deals with how the objectives and constraints of such projects affect the choices made, describes the product possibilities and process options available, and presents a checklist for gathering the information used to select the best option from a range of product ideas. The overriding theme is the importance of the market and consumer in the product development process; in other words, the technical aspects of the exercise cannot be carried out in isolation from the real world.

Definition of Objectives

Before considering which products made from root and tuber crops can be taken through the product development process, it is necessary to define the objectives of the exercise clearly. This is important because product development is, almost by definition, something that involves a number of actors—from farmers to research scientists. It is important that there be some overlap in the objectives of the participants; otherwise, the project is certainly doomed. Three basic types of organizations, each with its own set of objectives, can be identified as national research institutions, local development and extension agencies and farmer groups, and commercial enterprises.

National Research Institutions

Their objectives are to provide solutions to priority problems at a national level, as determined by the government. Examples of these objectives include:

- generate foreign exchange earnings;
- substitute imports;
- slow migration to urban centers;
- increase small farmer incomes;
- develop specific regions;
- improve nutritional status of population; and,
- reduce costs of basic foods (control inflation).

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Local Development and Extension Agencies and Farmer Groups

The objectives of these groups are focused on a particular region or province of a country. They attempt to provide solutions to problems directly affecting the local target population groups; some examples of problems are:

- increase incomes of small farmers;
- provide employment for landless laborers;
- improve markets for traditional crops;
- improve nutrition of rural and/or urban populations;
- improve market efficiency/reduce losses;
- protect environment: control erosion, reduce pollution, etc.; and,
- improve the position of women in agriculture.

Commercial Enterprises

Although the prime objective of a private company in developing products using root and tuber crops is undoubtedly commercial, such firms are also interested in long-term profitability. This implies a concern for the local environment and community, which provides scope for interest in social welfare objectives.

Many of the objectives of these different actors do overlap. For example, provision of employment for landless laborers will slow migration to urban centers. However, the importance given different objectives may vary and could be a source of conflict. If the overriding national priority is the generation of foreign exchange, this may be difficult to reconcile with a development emphasis on small farmers and appropriate processes. It is important for all participants to agree on the main objectives; differences in emphasis and focus can usually be accommodated. The various institutional agendas must therefore be made explicit, for hidden agendas can cause friction later in the process.

Project Assumptions and Constraints

In addition to the objectives of each institution involved in a product development project, the constraints facing each may also play a decisive role in determining the type of projects undertaken. Constraints can exist in the following areas.

Institutional Mandate

- Crop/raw material used (e.g., cassava or sweetpotatoes only).
- Type of processing organization (cooperative, small business).
- Farm size (<20 ha).
- Location (specific province, watershed, irrigation district, etc.).

Financial Constraints of the Institution

- Research facilities available.
- Technical expertise available.
- Cost of research project.
- Process scale.

Financial Constraints of the Farmers and Processes

- Capital investment required.
- Credit availability and conditions.
- Technical complexity of process.

Legal Constraints

- Compliance with government regulations for product nutritional or sanitary standards.
- Licensing requirements.

Certain institutional assumptions are made on be basis of an analysis of these constraints; and, it is important that these also be made explicit from the start of the project. It is possible that some of these constraints can be removed at a later date; for example, an externally funded research project could provide the needed research equipment. Making these constraints explicit at an early stage will help to clarify which market and technological options fall within the framework of manageable solutions to the problems and opportunities presented.

Identification of Market and Technical Opportunities

Based on a clear definition of the problems to be overcome and the constraints that are present during this process, a search for possible product options based on market and technical opportunities can be initiated. These ideas are then screened according to criteria based on project constraints and market- and process-related factors important to the project's success.

In order to identify a range of possible market opportunities for root and tuber crops, the present status and future trends in society's use of food, feed, and other industrial products should be known. Demographic changes over the last 30 years or more have resulted not only in dramatic population increases in many developing countries but also in an ever greater concentration of this population in large, urban centers. In Latin America over 75% of the population resides in urban areas, compared to 30% and 35% in Asia and Africa, respectively. The growth rates of urban areas in Africa are especially high. The combination of migration and urbanization has often led to dramatic changes in food consumption habits due to the more diverse number of foods available in an urban environment. Income increases associated with a move to urban areas can also lead to dietary changes. These changes have often adversely affected root and tuber crops, whose bulky, perishable nature is not well suited to transport and marketing in urban situations. Traditional foodstuffs have therefore tended to lose out to more convenient, non-traditional foods, especially where government subsidies for certain cereals and indiscriminate food aid have artificially reduced the price of imported goods. Nevertheless, this process has led to the development of a local food industry in many countries.

Many governments are now reducing subsidies on foodstuffs and agricultural inputs, and it can be expected that market competition will increasingly be allowed to develop in the food and agricultural sectors of developing countries. Therefore, the withdrawal of subsidies to other crops may provide an opportunity for root and tuber crops to enter into the food industry as a locally available source of starch, protein, and vitamins. The challenge is to foster the use of such raw materials by the local food industry, which developed using other frequently imported, raw materials.

As incomes increase, consumption of animal products also increases. The poultry and pork industries in many countries have shown rapid growth rates. An opportunity exists for root and tuber crops to become an accepted carbohydrate source for a range of animal feeds. This has happened in the case of cassava exported from Southeast Asia to Europe, but with one or two exceptions, (e.g., China) has yet to develop on a large scale in the animal feed industries of tropical countries. Root and tuber crops are used for animal feed in many traditional on-farm feeding systems, especially fresh or ensiled roots, but the increasing intensification and use of purchased feedstuffs will necessitate the use of processed (dried) root and tuber products.

Finally, a range of opportunities exists in non-food industries—for example, textiles, paper, glue, and plywood—which currently use other sources of starch or flour. In Ecuador and Peru, heavy subsidies on imported wheat flour resulted in its use in plywood manufacture as it was the cheapest available flour. This is now declining as subsidies have been withdrawn.

Information required to identify market opportunities often can be obtained using secondary sources. For a specific country or region, the following topics and sources can be considered.

Crop production, yield. Food and Agriculture Organization of the United Nations (FAO), Ministry of Agriculture; regional rural development agency; extension workers; and, growers associations.

Food, feed, and other industries. Chambers of commerce; associations of flour millers; cereal producers; poultry, egg, swine, and cattle producers; animal feed companies, etc.

Consumer information. Census data; household expenditure, food and nutrition surveys of major cities (ministries of planning, agriculture, etc., universities); quick surveys of products available in major shops and supermarkets give a good idea of products currently being made, raw materials used, and the existence of gaps in the market.

Technical Opportunities

The market characteristics outlined above help identify possible areas where root and tuber crops could be used. These must be checked against the technological possibilities of each crop, and the current processes used to transform them. A list of possible products is shown in Table 1.

A wide range of processes are also used to make the different products. Since some processes may be inappropriate in certain situations, summaries only are given in the table.

Table 1. List of possible products using root and tuber crops.

Fresh roots, human consumption: Traditional product improved and value-added by:
- Grade and clean to produce high quality
- Package to increase shelf life
- Pre-peel, to give convenient, fresh prepared product (cold store)
- Chemical treatment to prevent microbial deterioration

Fresh roots, animal feed:
- Non-commercial fresh roots left over from fresh market
- Fresh roots, as main product
- Fresh boiled roots (removes anti-nutritional factor)
- Ensiled roots for use out of usual harvest period

Fresh leaves:
- Human consumption, vegetable
- Fresh or ensiled leaves, animal feed

Fried products:
- Chips, crisps
- Add flavorings

Dehydrated products:
- Sun dried, traditional products (chips, root pieces, slices)
- Flakes, granules, cubes (convenience foods)
- Chips for animal feed
- Leaf meal for animal feed

Flour used as raw material in food industry for:
- Bakery products
- Soup, sauce bases
- Processed meats
- *Pastas*, noodles
- Beverage bases

Flour used in other industries (quality specifications differ):
- Glue and plywood
- Raw material for animal feed rations (flour or pellets)

Starch used in traditional food products and by food industry:
- As for flour, in many products
- As feedstock for derived products (glucose, alcohol, etc.)

Starch also used by other industries:
- Textile
- Paper
- Animal feed (especially fish, shrimp)

Fermented products:
- Whole root; e.g., *tape* (Indonesia)
- Starch; e.g., *almidón agrio* (Colombia), *polvilho azedo* (Brazil)
- Flour; e.g., *gari* (Nigeria)

Frozen:
- Root pieces, often parboiled
- *Purée*

Vacuum packed:
- Root pieces, parboiled and sterilized

Canned:
- Root pieces
- Leaves

Bottled products:
- Jams
- Sauces
- Beverages, juices

By-products from industrial processing:
- Peel, fiber used for animal feed
- Fiber, feedstock for citric acid production

Processes Used in Transformation of Root and Tuber Crops

A discussion of the detailed processes used with root and tuber crops is beyond the scope of this paper. Briefly, the main options are:

Storage

Wound healing or curing processes can be accelerated in all crops, under the correct environmental conditions, to prolong storage life. In addition, treatments such as paraffin wax coating and packing in moist containers can also work well. It is important to differentiate among different objectives for storage when deciding the method to use:

- on-farm storage for seed use;
- on-farm storage for human consumption;
- storage during normal marketing (transport, distribution, sale, and at-home storage (2-3 weeks);

- storage for several months to smooth imbalances in supply and demand due to seasonal harvests;
- storage for export; and,
- storage at processing plants (stockholding).

A comparison of the last two points is worthwhile. Storage for export will require excellent product presentation and raw material quality control; but storage or processing/treatment costs will be high. Storing roots prior to industrial processing must be low cost, yet some loss of yield or quality may be acceptable. These different needs should be reflected in the design of the storage technology.

Selection and Cleaning

Roots may be selected and cleaned before, during, or after storage depending upon their intended use. Selection involves the removal of unacceptable roots (rotting, deteriorated, excessively mechanically damaged, too small, or immature) and also any foreign matter (stones, sand, woody material). The criteria for selection or rejection depend upon the end use. Cleaning is usually carried out by washing or brushing roots. This operation may not always be necessary (harvested roots are cleaner during drier periods). Washing can be manual or mechanical, and may be combined with peeling.

Peeling

It is important that peeling be efficient in order to minimize the loss of raw material. Peeling losses can be very high if roots vary greatly in size and shape. Grading before peeling may help to reduce losses in batch processes. Other factors influencing losses include depth of eyes and length of storage for potatoes. Peeling can be manual or mechanical, by abrasion, lye, or steam.

- Manual peeling, can be inefficient and result in high losses.
- Mechanical peeling, by abrasion in a rotating drum with water added to flush loose peel.
- Lye, roots immersed in solution of sodium hydroxide.
- Steam, roots exposed to steam under pressure.
- Combination of lye and steam peeling.

The end use of the raw material will determine whether costs can be lowered through shorter peeling times. For example, in the case of cassava, abrasive peeling for 3 min is sufficient to remove most of the outer, barky peel while leaving the white inner peel largely intact. For starch extraction this is sufficient; for other purposes longer times for complete peeling may be needed, at a greater cost and with higher losses. In many cases, the peel by-product can be dried and used as an animal feed.

Sulphiting

Potatoes and other tuber crops may be immersed in sodium meta bisulphite to avoid enzymic discoloration if further processing is not carried out immediately.

Size Reduction

Almost all processes involve some type of size reduction of the whole peeled or unpeeled roots and tubers. Some of the alternatives are to:

- slice, for snack food products;
- chip, for french fry cut and for later natural or artificial dry (traditional dried root products may use quite large root pieces cut manually); and,
- grate, for starch extraction and some traditional products (*gari*, *farinha*, etc.).

For potatoes, it is important to keep all chips, slices, etc. under water to prevent discoloration.

A vast array of chipping, grating, and slicing machines have been developed for root and tuber crops, from manually operated chippers (output of 1-200 kg/hr) to the continuous process equipment used in large starch extraction plants, capable of processing 200 t/day.

Blanching

Raw material is subjected to boiling or near boiling temperatures for short periods in order to inactivate enzymes, as well as cook the tissues partially, rendering the cell membranes more permeable to moisture transfer. By blanching, more rapid and complete drying is obtained and the texture of rehydrated products is improved. Partial sterilization is also achieved. The temperature should be above 80°C. Blanching time depends upon the dimensions of the root pieces, the amount of raw material to be added, and the temperature of the water. Blanching is mainly used with potatoes for products destined for human consumption. For potato slices, 3-4 min will suffice. The more complex alternative of steam blanching results in less loss of nutrients.

Additives to improve flavor, appearance, and texture may be added during or after blanching, e.g., sodium bisulphite, citric acid, and pro-phosphate are often used to reduce browning during storage. The blanched product must be cooled before drying can commence.

Drying

Root pieces may be dried either with or without prior blanching. Drying is achieved by the evaporation of moisture from the surface of the pieces and by migration of moisture from the interior to the surface. Adequate air movement around the drying pieces is important to prevent the accumulation of humidity in the surrounding air which slows the drying process. Drying speed depends on the dimensions of the root pieces, rate of air movement, atmospheric humidity, and air temperature. The moisture content of the final product must be low enough to prevent the growth of microorganisms during storage (especially *Aspergillus*) and to eliminate tissue metabolic processes that could affect product quality. This critical moisture content level varies for different crops (e.g., potatoes, 8-10%; cassava, 14%).

Natural or sun drying is the cheapest method. Chips can be dried on concrete floors, trays, or even flat roofs of houses. Drying can only occur during reasonably dry and sunny weather, especially for larger operations. Drying may be carried out by the small subsistence farmer or by a large commercial operation (e.g., 35,000 m^2 drying areas per factory for cassava in Thailand).

Natural drying results in possible contamination of the product by dust and microorganisms during the two days or longer that it takes. A solar collector may be feasible to harness solar radiation to reduce drying times, although few working examples of these have proven feasible thus far.

Artificial drying—which permits the rapid drying of root crops with good hygiene, outside the dry season, or in areas with constant rainfall—does increase costs. Batch driers, which can be constructed simply and cheaply, can be powered by locally available sources of fuel (e.g., coal, diesel, plant by-products, etc.). The drying temperature should not exceed the gelatinization point of the starch contained in the roots, about 50-60°C. For cassava, artificial drying results in a final product with a higher cyanide content than a naturally dried one.

Drying using continuous processes is rarely profitable, except where a high value product is being made in large volumes.

Starch Extraction

After grating, starch can be extracted through a simple process of adding water, mixing well (usually in a rotary system with water injection), and then separating the extracted starch from the fiber and other root components. Separation may be through centrifugal action, sedimentation in tanks, or in a system of channels. The separated starch is then dried, either naturally in small-scale operations or using a flash drier in large-scale plants. *Sago* is a product derived from starch, involving partial gelatinization of small globules or flakes of starch with an intermediate moisture content.

Fermentation

A variety of fermented products are made from root crops, mostly by traditional processes. These are destined to be used in traditional food products. Fermentation may be in the solid state, after grating, or after starch separation (*tapé*, *gari*, and sour starch—traditional cassava products from Indonesia, Nigeria, and Colombia, respectively). Natural fermentation is the rule, except for *tapé* where *rasi* a powdered inoculum consisting of *Amylonices rouxii* is used. Fermentation changes the taste of final products, and in the case of starch, also modifies their baking properties. Natural fermentation, however, may take 2-3 weeks to fully modify starch.

Milling and Grading

Dried root pieces can be processed into flour through milling and grading or sifting stages. Milling can be a large- or small-scale operation. Small-sized cassava chips can be successfully milled in a normal wheat flour roller mill, with very high conversion rates (90% or more). Small-scale hammer mills generally give lower conversion rates. The grading of flour depends on the end use. For pellet production or direct use for animal feed, the entire milled product is used. For a high-quality flour for bakery use, several milling and sifting stages may be necessary to reach the required standard.

Other Processes

These may be used to make products of less general application or to manufacture derived products from the basic flour or starch products described here.

Initial Selection of Products

By considering the range of technological options for root and tuber crops together with the market characteristics discussed earlier, the initial range of product ideas can be selected. These can be summarized as:

- improving the traditional fresh product (better storage, convenience; a fresh prepared product, precooked or parboiled, instant products, fast and snack foods);

- animal feed uses (stable, dried products for marketing; or ensiled/fresh roots for local use.);
- flour for food or industrial uses (substitution of wheat and other flours); and,
- extraction of starch for food and industrial uses (substitution of maize and other starches).

Other possibilities exist but with a less general application; for example, dried chips for human consumption, beverages, and fermented products.

Selection of Region

In order to screen and evaluate the different opportunities that exist, it is necessary to obtain information about the markets, products, and industries already present. This obviously requires that a region where the project is to be developed has already been chosen. The next task is to select the area where the project is to be located. Regional selection needs to consider the following criteria:

Root and Tuber Crop Production

- The region should have sufficient production or potential to permit the establishment of a rural agro-industry.
- Prices should be low enough to permit processing as an option (i.e., no dominant fresh market).
- Production should not be concentrated into one very short harvesting period.
- Institutional support in crop production is necessary (research, extension).

Markets

- A major urban center should be located in or relatively close to the project area (for human food markets).
- Food or feed industries should be within a reasonable distance.

Social Factors

- A rural population with experience in root crop production and with a clear need to improve economic well-being.
- Successful local experience with cooperative or small business organizations.
- Institutional support and financial assistance to such groups should be available.

Clear support for the idea of improving rural welfare through interventions in root and tuber crop production, processing, and marketing should be available from local and regional state and private sector organizations working for rural development.

Idea Screening

The product ideas developed through a consideration of the technical possibilities of the crop, the region in which the project will be focused, and the markets available or potential in that region can now be screened to pinpoint those with the best chances of success. Screening is a two-stage process. First, those products that are clearly incompatible with the objectives of the project or the constraints imposed on it are deleted. This leaves a narrower range of possibilities, which then need to be subjected to further consideration.

Initial Screening

If the objectives of the project are to improve the welfare of small farmers through adding value to root and tuber crops via rural processing, then products that entail processes unsuited to these objectives will be eliminated. For example, freezing, canning, and vacuum packing are relatively high technology processes with a capital-intensive, large-scale processing bias. It is difficult for a small-scale rural industry to develop using this type of technology. Similarly, if project objectives are to improve the nutritional status of low-income urban consumers, this same group of technologies would also be discarded because of their high cost, which would result in a product accessible only to higher income consumers. Using the socio-economic objectives of these projects and the financial limitations within which they must work, the number of possible options can be reduced to a feasible number for more detailed study.

The remaining options will normally belong to those products requiring relatively simple, low-cost processes, resulting in products with a large potential market. These will be in the categories of fresh, prepared or stored products, flour, and starch. Considering that flour includes products suitable for animal feed, human food, and industrial use, it is necessary to subdivide these categories further. Each potential use will require specific quality or product specifications, which in turn affect the process and the cost of the final product.

Final Screening

Each product/market category remaining under consideration can be screened in greater detail using a checklist approach. Such a brief, but systematic consideration of basic facts relating to raw material supply, potential demand, etc., is preferable to a large and costly research project that will certainly be very time consuming. Table 2 gives the points that should be considered.

The time required to obtain answers to these questions will depend on the supporting data that already exist. Secondary data sources will provide much information, and a brief visit to the project region will often help fill in any gaps. It is not necessary to conduct an elaborate formal survey; but, it is important to think carefully about all assumptions made since popular knowledge is frequently mistaken. For example, cassava drying is now commercially successful in areas originally considered to have excessive rainfall.

With answers to the checklist, it is then possible to assess the favorable and unfavorable responses and decide which of the several initial product ideas can be taken for further study and development. The individual researcher must use this checklist with great flexibility. For one product, a single negative response to one crucial question may be sufficient to kill that product. For another product, many negative responses to certain questions may not be critical at all. Given financing, training, or time, such negative aspects can be changed.

An additional benefit of proceeding through the checklist is the generation of alternative product ideas. For example, by considering each of the items on the list, suggestions or observations may surface that can be useful in modifying the original idea; e.g., selling a powder-like potato product to industrial clients rather than a dried wafer or chip directly to consumers. Or, a totally different product may come to mind, e.g., for animal, ***not*** human consumption.

By working through the checklist in Table 3, four product ideas can be evaluated: (1) storage to provide potatoes out of season; (2) snack foods for high-income consumers; (3) chips for animal feed; and, (4) starch for food and other industries. The most favorable option shown is to store potatoes for sale in the off-season when prices are higher. In fact, such a project could develop several processed products for human consumption based on the project objectives, which could be to maximize rural employment, not farmers' incomes. Processing activities generate much labor, and this is considered to be an essential element in any product development activity.

Concept Testing

This is a simple procedure that can be used to define further the product idea. Information from the checklist has provided better knowledge of the market, and consumer characteristics and needs. These can be used to elaborate a series of concepts relating to the way the product will be used by different consumer groups (Table 3). Concept testing involves presenting the different concepts to consumers (or industrial clients) and receiving feedback from them. The advantage is that this can be done without having the product, but through using photographs and text to describe the product and its characteristics. Consumers can then be asked to comment on the concept (if they understand it) as to if the benefits of the product are relevant to them, how they would use the product, tentative purchase intentions, etc. This process is a very cost-effective, rapid method of defining product characteristics based on consumer needs, and it helps to eliminate those ways of presenting or using a product that are unattractive to consumers.

Conclusion

At this stage, a product with potential for benefitting the target population has been identified, as well as the region in which the project will develop. The next stage is to undertake market and technical research required to define the product characteristics, the process to make the product and the marketing strategy to be used.

Table 2. Checklist for final screening of products.

Demand
- Define target market (city, region, etc.).
- How many consumers (total, % who could purchase)?
- How much product per person/yr?
- Is purchasing power increasing or not?
- Are consumption, food purchase habits changing?
- Does product fit these changes?
- If product is novel, will acceptance be good?
- If product is competing against others, will price and quality be better than competitors?
- For industrial markets: What is the volume of purchases and the price of competing raw materials by industries concerned?

Raw material supply
- Volume of production in target region.
- Demand in other markets for this production.
- Seasonality of production and demand in other markets.
- Price fluctuations/cycles.
- Characteristics of both traditional and new varieties (growth cycles, quality, yield).
- Potential for and constraints to increasing production (diseases, erosion, drought, etc.).

Physical factors: Determine harvest times and feasibility of natural drying systems.
- Rainfall (dry and wet seasons).
- Does dry season coincide with harvest time?
- Temperature.
- Relative humidity.
- Is there ready access to clean water (for starch extraction especially)?

Organizational aspects
- Are farmers market- or subsistence-oriented?
- Are farmers willing to experiment?
- Has there been a positive experience with coops?
- Is institutional support available for coops/small businesses?
- Is credit available?
- Are capital requirements manageable?
- Is a separate distribution entity needed? Is technical and financial support available for this?
- Will many institutions be involved? Is inter-institutional coordination satisfactory?

Existence of similar activities
- Is small farmer processing novel or a continuation of existing practices?
- What are the strengths and weaknesses of existing operations?
- How can weaknesses be corrected?
- Are there any existing facilities that can be utilized to reduce capital outlay?

Consumer acceptance
- Is this crop accepted in the diet (fresh processed)?
- Is image good or not?
- Is this product being made already? If not, why not?
- If an existing product, what improvements can be made?
- If a novel product, is this crop accepted in other foods or is it a food accepted with other ingredients?

Capital requirements
- Amount, conditions of loan (interest rate, period of grace, etc.).
- Requirements for collateral (land holdings, etc.).
- Standard banking arrangement or special loan scheme for small businesses, cooperatives.

Labor
- Costs.
- Availability (seasonality).
- Educational level.
- Gender issues: replacing manual operations by machinery often reduces the women's role and can have negative social consequences.

Technology
- Is it already developed, or is further research required; if so, how much and what are the chances of success?
- Imported or local? If imported, are spares, etc., available?
- Can it be managed by farmer group if necessary?
- What training will be required (process operation, business, marketing, etc.); who can provide and finance training activities?
- Can local labor and materials be used in construction?

Benefits
- How well will the product fit project objectives?
- Who will benefit and by how much?
- What is the risk of failure? Who suffers if project fails?
- How much; i.e., economic feasibility?

Table 3. Example of selecting product ideas using a checklist: Potato processing in North India.

Factor	Product: Fresh storage	Dry processed	Chips (animal feed)	Starch
Demand	Good, fills gap in market (out of season); traditional product, good acceptance across incomes	Novel product for high income (10% population)	Depends on price, unlikely to be competitive	Depends on price of raw material & starch yield; uncertain
Raw material supply	Excellent; buy at a low price & sell when high	Limited to June-March, when main harvest/low prices operate		
Physical factors	Need to store during hot season; technology development needed?	Dry season coincides with harvest; good for natural drying		Water availability poor
Organizational aspects	Family level or coop	Small business	Family level or coop	Small business
Existence of similar activities	Storage of other crops carried out	Processing well known & accepted		Not in this area
Consumer acceptance	Good if quality ok	Good at upper income levels	Industrial market; depends on price	
Capital requirements	Moderate	Moderate	Low	Moderate to high
Labor	Little used	Much needed; some skilled	Unskilled only	Much needed; some skilled
Technology	Needs some work, but simple	Needs some work; rather complex	Simple	Known; relatively simple
Benefits:				
Farmers	+++	+	++	+
Processors	none	+++	++	+++
Consumers	++	+	none	+
Economic feasibility	+++	++	+	+

Rapid Market Appraisal, Issues and Experience with Sweetpotato in Vietnam

Taco Bottema[1]

Abstract

Based on a large number of studies throughout Southeast Asia, including Vietnam, this paper argues that crop development and diversification of use reflect development of local, area specific economies, which are in a process of market formation and integration.

Fresh consumption in the local rural economy and nearby urban centers constitute the major market for root and tuber cropsin Vietnam. A variety of stages in market development is discernible.

A rapid, cost-effective adaptation of the survey method, Rapid Market Appraisal (RMA) is presented. This research instrument can be used to identify the place of farmers and entrepreneurs in the developing input and product markets. It is recommended to pay attention to market formation in agricultural planning as well as in agricultural research. Specific attention is drawn to the use of food balance sheets, agricultural linkages to industry and research on quality rewards.

Key words: markets, methods, processing, storage.

Introduction

The Coarse Grains, Pulses, Roots and Tuber Crops Center (CGPRT) has been active in Vietnam over the last years in collaboration with the International Potato Center (CIP), the University of Agriculture and Forest (UAF)-Ho Chi Minh City, the Ministry of Agriculture and Food Industries, the National Root Crop Research and Development Program, and a number of other institutes and organizations. The activities have been directed towards the creation of common ground, necessary for the establishment of the national root crops research and development program. Results are presented in CGPRT 24, "Sweetpotato in Vietnam, Production and Markets" 1991. In this paper CGPRT's (limited) experience in market assessment for sweetpotato and processed products is brought together and illustrated by some facts and figures already generated. Before discussing the specific situation in Vietnam, a methodological device developed by the CGPRT Center is presented. The paper is divided into three sections: a presentation of Rapid Market Appraisal (RMA), a summary of sweetpotato development in Vietnam, and a look at some specific issues recommended for attention.

Rapid Market Appraisal (RMA)

Recent years have seen the emergence of a wide range of uses regarding survey methods. Distinctions between formal and informal surveys are well known. Quick, cost-efficient exercises are sometimes referred to as "*sondeo*" and "rapid rural appraisal". A similar sort of quick survey approach, referred to as RMA, has been developed by the CGPRT Center. This approach provides an overall framework and places an actor, a farmer or a business, in the input and the product market. It is not a business development device, but rather a business-oriented approach to quickly identify various interacting markets.

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Figure 1 depicts marketing channels for agricultural products and farm inputs. In RMA, recognition of the local rural/urban economy is explicit. It basically identifies economic zones, as they are reflected in the length of supply and distribution channels.

Agricultural product marketing consists of various configurations because farmers in Asia typically produce several commodities in one calendar/crop year, with the sequence of food-crop production being determined by the cropping system. It is of vital importance to recognize home consumption and marketed surplus. Figure 1 maps the various market configurations in which producers participate. For example, the simplest situation is represented by the configuration on the far left in which the farmer consumes his own production. Subsequent situations indicate the various marketing channels that may exist for production not consumed by the household. Usually other proportions are marketed at the village or district level. Here again it is of importance to establish the specific proportions.

In Vietnam, sweetpotato is marketed between provinces, which points at yet another proportion of production being marketed through slightly longer market configurations (Ha et al. 1991).

Some authors and researchers refer to the shorter configurations as a "food system," taking into account all commodities produced and consumed. Others refer to the complete set of market configurations as the "food system." In my view, this concept is misleading because we are speaking about producers, traders, processors, retailers, and consumers, in other words the market as a whole. The concept of food system could lead one to expect that a large degree of self-sufficiency is prevalent or desirable. The essential characteristic of any local agricultural economy in Southeast Asia is that there is usually competition between the users/buyers in the different market configurations even for a single crop.

If one depicts developments through time one can usually observe that the number of configurations increases, while the relative proportions among the configurations vary. It can be imagined that a large number of configurations can be discerned based on a relatively small number of commodities produced. Thus, the linkage of a given farming system with a variety of markets can be illustrated, which would also underline those components of a farming system which would be directly affected by government price and trade policies.

Practical application of the market configuration approach lies in conducting a RMA. For example, in focusing on sweetpotato, one could map the different combinations of configurations in different areas. Identifying differences among the various production areas is quite important because their unique local situations determine whether or not it is conducive to business development such as the establishment of sweetpotato processing. Competition, product flows, etc., can quickly be mapped.

A similar use of the various configurations pertaining to the input market is depicted in Figure 1. Farm inputs are of great importance for improving productivity. This issue is of specific relevance to Vietnam where private trade in fertilizers and chemicals was only legalized in 1988. One of the most important, almost universal, developments of the last 40 years is that fertilizer has become well accepted and is widely used. This results in a market configuration starting from the national or even international level (Fig. 1). Although chemical fertilizers are important in sweetpotato production in Vietnam, manure (usually purchased at village level) is also important. Soil fertility is being maintained by supplies from two extremes in the range of configurations in the input market.

Seed is also an important input. In the case of sweetpotato, it is usually obtained at the local level, but also on occasion through provincial trade. Labor likewise is usually supplied by the household; however, as comercialization assumes a stronger pace in the course of time, it is often supplied by village and district-level labor markets.

The case of capital is a story in itself. The attempts of many governments to establish local credit facilities can be interpreted as an effort to create local finance distribution agencies so as to increase access to capital.

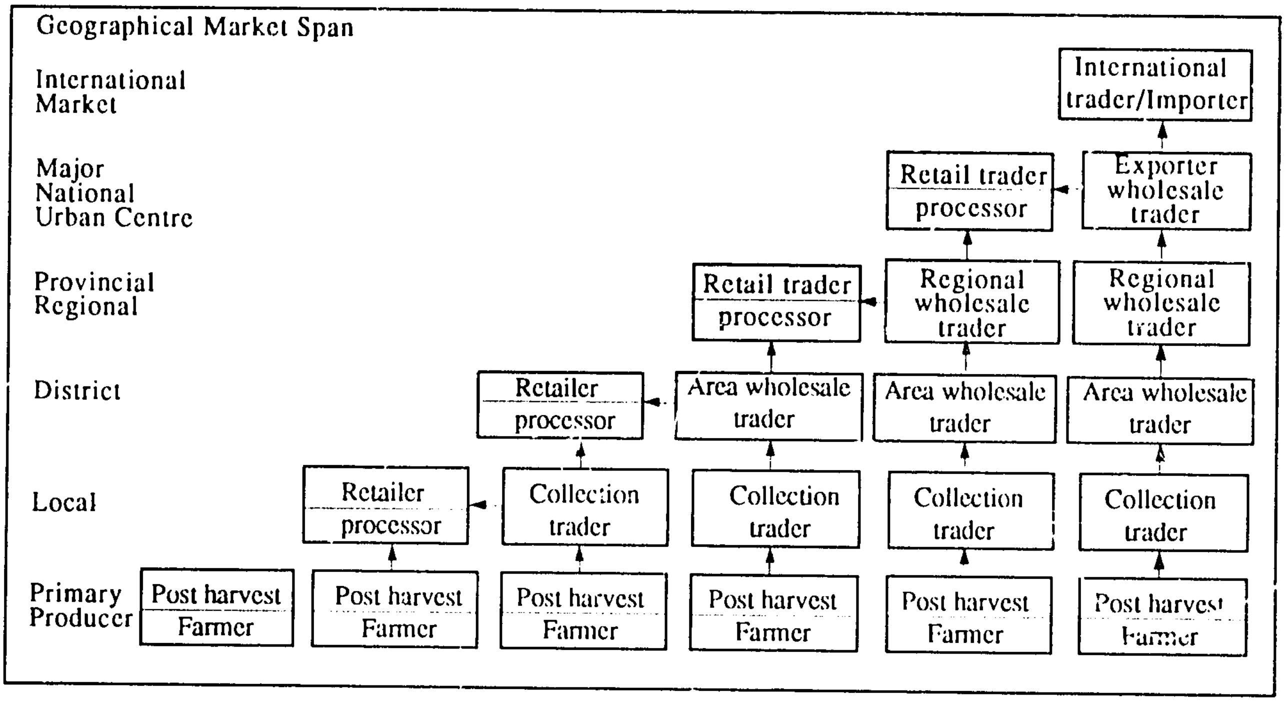
The descriptive device presented here can be applied universally. An RMA maps the area specific product and input configurations pertaining to the commodities under scrutiny. The CGPRT Center has applied this device throughout the region, with quite interesting results. It has been found that substantial comercialization of food crop agriculture takes place within local, area-specific economies. Crop development is connected with the development of the local economy. In holistic approaches which are *en vogue*, such as the farming systems approach, the process of local differentiation can only partly be reflected.

The empirical steps are simple and include identification of:

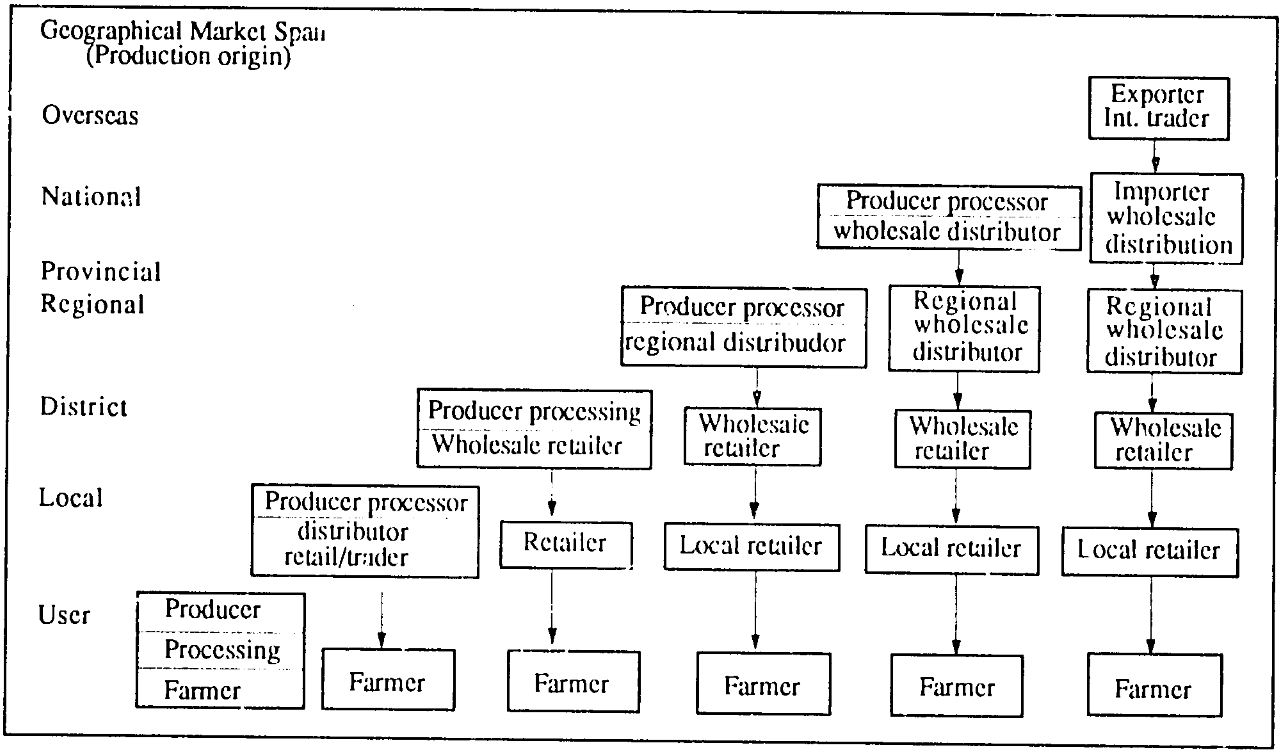
- different marketing channels;

Figure 1. Marketing configurations for agricultural products and farm inputs.

Agricultural products



Farm inputs



- proportions of total production entering the various channels;
- different uses among and within marketing channels;
- actors engaged in business (traders, processors, retailers, etc.) and their practices; and,
- market rewards or premiums paid for specific qualities in both the input and product markets.

If improving (or introducing) processing is a specific goal, one would also look in detail at existing processing technologies, and identify the availability of necessary components.

In short, one needs to visit farmers, traders, processors, and retailers, and establish prices and costs at all these levels of the market. Figures 2 and 3 present two different sets of product market configurations.

In establishing a sweetpotato processing industry, applications of the above mentioned data can be cited. First of all, Figure 1 focuses on farmers and not on the processing industry. Furthermore, sweetpotato is just one input for a processing industry. This is unlikely to present a constraint, except in terms of the seasonal supply of production. Several solutions can be applied to overcome the seasonality problem, either separately or in combination with one another. First, storage is possible, but its costs should be compared with the costs of buying fresh sweetpotato from other production centers. For example, a location could have a year round supply of sweetpotato from different production areas (Ha et al. 1991) (Table 1). Or, one might consider provincial markets or even major urban markets, such as Ho Chi Min City and Da Nang, as a source of year round supply of raw material. A second possibility entails using equipment capable of processing a number of different root crops which are complementary in timing of supply (Nghiem 1989). In Vietnam, sweetpotato, cassava, canna, and potato come to mind. Supply requirements may be more difficult to fulfill through time at the local level, because, assuming cropping systems remain stable, the processing facility would have to purchase its raw materials from the provincial market or from other production areas.

Figure 2. Sweetpotato marketing in the Mekong Delta.

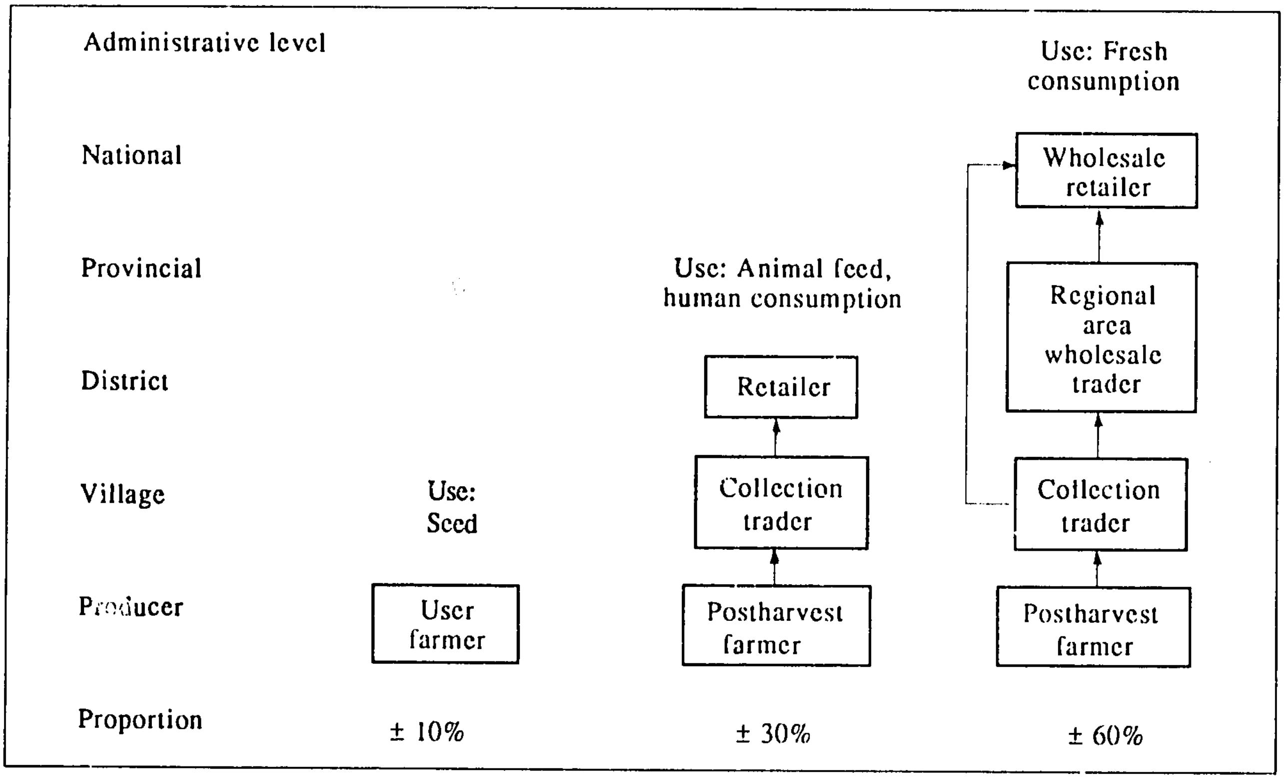
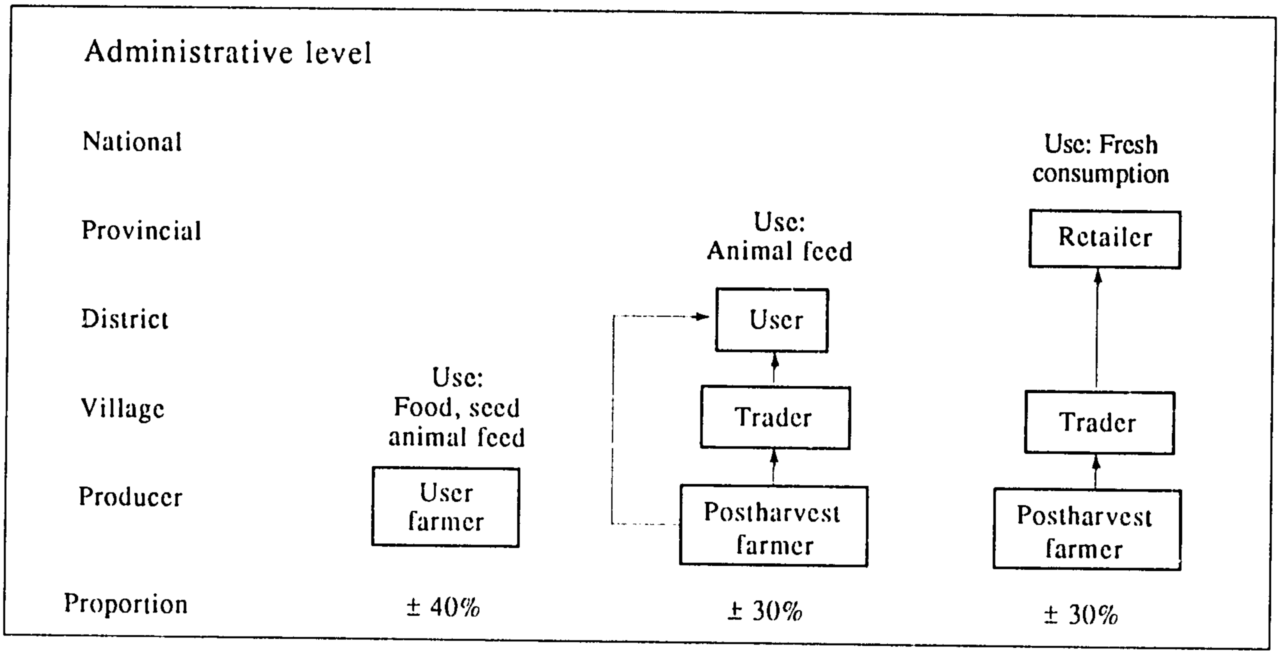


Figure 3. Sweetpotato marketing in Central Vietnam.



Source: Ha et al. 1991.

Assuming that basic processing equipment is available or can be made, a notion also supported by Nghiem (1989), the choice between end product and intermediate product has to be made. In the case of sweetpotato, it seems logical to think of noodles, a highly appreciated food throughout Vietnam.[2] In producing noodles or related products, other inputs are necessary such as certain chemicals, clean water, etc. Availability of chemicals, reportedly specific to the production of sweetpotato-based noodles, may present difficulties for local industry as they may have to be imported. These are more likely to be available in major urban centers.

The size of the target market is more important. The government of Vietnam promotes village-level processing industry. Such industry would have to estimate the local, and possibly adjacent, market for each product. The situation may well be conducive to business in cases where noodles and related products are not yet marketed. In other cases, where a village is located nearer to a major consumption center, village produce would simply have to compete with existing produce on the market. In short, every prospective establishment would have to carefully gauge its unique local setting.

The market configuration approach has been found most useful in describing market integration and the accompanying market diversification process. These two processes are very important in Vietnam at this time.

Recent findings in Vietnam

The following contains a brief summary of major findings of research conducted in the period 1988-91 in North, Central, and South Vietnam.

[2] The cases of soybean and cassava in Indonesia comes to mind. Processed soybean and cassava are consumed widely and as a result literally thousands of successful small industries supply processed produce to rural consumers, the raw material being supplied by traders, in case of local shortage. Thus, the prime condition for success is established local consumption.

Table 1. Delivery schedule from sweetpotato production centers to Ho Chi Minh City.

Production	Month of delivery	Distance to HCMC[a]	Travel time (hrs)
Mekong Delta:		Waterway	
Long Phy (Province Hau Giang)	Jan, Feb, Mar	250 km	25
Mitho (Province Tien Giang)	Feb, Mar, Apr	170 km	17
Giong Rieng (Province Kien Giang)	Apr, May, June, July	380 km	40
Omon (Province Hau Giang)	July, Aug, Sep	320 km	34
Binh Minh (Province Cuu Long)	July, Aug, Sep	280 km	30
Vinh Long (Province Cuu Long)	July, Aug, Sep	220 km	19
Province Minh Hai	Oct, Nov, Dec	380 km	40
Hon Dat (Province Kien Giang)	Sep, Oct, Nov	420 km	45
Southeast zone of Nam Bo:		Road	
Long Dat (Province Dong Nai)	Jan, Feb, Mar, Apr	100 km	
Chau Thanh (Province Dong Nai)	June, July, Aug	90 km	
Long Thanh (Province Dong Nai)	June, July, Aug	50 km	
Phan Thiet	Aug, Sep, Oct	180 km	
Dalat	Aug, Sep, Oct, Nov	250 km	

Source: Ha et al. 1991.

[a]HCMC = Ho Chi Min City.

Vietnam has followed a socialist path, characterized by broad state intervention in the product and input market. However, it was found that non-rice crops, including sweetpotato, were not subject to state intervention and that Vietnam's agricultural economy to a large degree resembles the agricultural economies of more market-oriented countries in Southeast Asia. In fact, in the late 1970s, individualized production became more important through the three-point contract (in North and Central Vietnam), followed by individual land lease in the late 1980s. Since 1988 domestic trading of farm inputs has been liberalized, allowing both cooperatives and private traders to participate in commerce. Price controls for farm products were relaxed in the late 1980s and cooperatives were allowed to apply for export licenses, establishing competition with state trading firms. Public broadcasting of prices for a wide range of agricultural produce began in 1990, contributing to market integration.

International recognition of the slow, but very broad, move towards a market-oriented agricultural economy has been very limited. This is unfortunate in view of Vietnam's wish to become eligible for loans from international development banks, which are subject to the condition of a more market-oriented policy.

Vietnam is characterized by vast differences among North, Central, and South Vietnam, which are climatological, historical, and institutional in nature. The North has a temperate climate, whereas the South has a tropical climate. The North has a relatively long socialist history resulting in the overriding importance of cooperatives in the North and the Northern part of Central Vietnam as the major rural institution. However, in the South, production has remained predominantly individualized since liberalization. These differences effectively prevent "blanket" policy recommendations as regards institutional components.

With regard to sweetpotato growers, differences in resources and access to markets are reflected in farm household incomes in North, Central, and South Vietnam which were 1.7, 1.4, and 2.5 million Dong respectively in 1988 (1988, 3200 Dong = US$ 1). Yields of sweetpotato in North, Central, and South Vietnam range between 10-24 t/ha, which are more than double the nationally reported average of 3.4 t. Statistical information on root crops is notoriously unreliable throughout Southeast Asia including Vietnam. Since the early 1980s substantial intensification of cropping systems has taken place in areas near cities and urban markets, led by vegetables and secondary crops. In more isolated areas, intensification is based primarily on secondary crops, including sweetpotato (Binh and Bottema 1991). These developments closely resemble intensification patterns encountered throughout Southeast Asia.

There is substantial linkage between the production of sweetpotato and pork production. Nghiem (1989) also found a relation between root crop processing facilities and household income in North Vietnam. There seems to be a similar, but more widespread positive correlation between pork production and products and residues of sweetpotato which are used to feed pigs. It seems likely that use of by-products of processing for pig feed would substantially strengthen the viability of local root crop processing facilities, because pork is not only a high value, tradeable commodity, but also in local demand.

Inter-district and inter-provincial markets of sweetpotato have evolved spontaneously (Binh and Bottema 1991; Ha et al. 1991). The low margin accruing to traders, the existence of competition among traders, and the rewards for specific varieties of high quality sweetpotato for human consumption all suggest that these markets are quite efficient. Cooperatives are also taking an interest in pork production and consequently in sweetpotato production in North and Central Vietnam (Bottema et al. 1991; Ha et al. 1991). Significant variation was encountered in the use of inputs and the proportion of production sold for human consumption and for animal feed. In the South, sweetpotato is a cash crop with 90% of production sold for human consumption in urban markets and low-quality sweetpotato sold locally for animal feed. In North and Central Vietnam local averages of 30% sold for human consumption have been reported, and 30% has been reported as used for animal feed, while 40% is consumed by the household. In Central and North Vietnam cash sales vary considerably by location.

In 1988 sweetpotato competed effectively with rice in North and Central Vietnam in terms of net farm income (Hoanh et al. 1991). However, recent increases in the price of rice have made rice the more remunerative crop. The effects of rising prices for rice on derived products such as rice paper and noodles, and on other foodcrops including sweetpotato still need to be determined.

Based on the above findings it is concluded that sweetpotato has five primary markets in Vietnam, varying in proportion, depending on the location (Table 2).

Assuming growing incomes, markets for meats and starch products appear to have the most potential, especially in the vicinity of urban areas. Sweetpotato for direct human consumption will probably expand with population growth in urban markets and will remain important in more isolated areas. Quantitative estimates cannot be made given the shortage of information about changes in the various markets that have taken place over the last ten years. It may be of interest to note that major potential users of starch are the plywood and textile industries, although the latter increasingly uses chemical substitutes. These industries may in the near future develop further in Vietnam. Such a development seems probable in view of the low wages in Vietnam. This would induce intermediate product industry, in other words starch industry producing for industrial end-users.[3] A similar development could take place if feed industries, which already exist around major urban markets, were to increase in scale. Market information still needs to be collected on this issue.

Issues for Research

In this section, three possible issues for future attention are briefly discussed:

Table 2. Primary sweetpotato markets.

Main use	Estimated proportion (%)	Prospects
Fresh sweetpotato for human consumption (cash)	3-60	increasing with population
Fresh sweetpotato for home consumption (feed/food)	3-60	continuing/decreasing
Sweetpotato and tops for animal feed, mainly pork	10-40	potentially increasing
Sweetpotato for starch production	small?	potentially increasing
Sweetpotato for seed	2-05	stable

[3] Again, resemblance to other Southeast Asian economies may be pointed out. In Thailand and Indonesia substantial industrial development led to the establishment of a strong cassava processing industry.

- The need for food balance sheets.
- The need for research on linkages between agriculture and industry.
- The need to identify existing market rewards for using specific qualities of sweetpotato and other root crops.

However, this is only a brief list of the issues pertained to this discussion. Before going into the research issues it should be noted that the Vietnam economy is in a state transition towards market orientation. The essential characteristic of the developing countries in Southeast Asia is the growing importance of intersectorial linkages between agriculture and industry. It could be argued that the wave of recognition in the last two years by agricultural researchers of this classic feature comes somewhat late. Industrial as well as agricultural development depend to a large extent on government policies. However, they depend to a much greater extent on spontaneous processes of market formation of a large range of commodities and products. At this point, Vietnam is in a process of largely spontaneous market formation. This situation needs to be recognized by the government to guide more effectively industrial development with the limited means available. This process will take time and the outcome is not easy to predict.

Food Balance Sheets

One device often used in planning and commodity projection is a food balance sheet. A food balance sheet presents yearly production, losses, use for seed, industrial use, export/import and a residual category of consumption. It is an attractive method of calculating consumption because of its simplicity. It is useful in depicting trends. It should be appreciated that the actual consumption figures are a residual category which only approximate national per capita consumption. A food balance sheet pre-supposes that the proportion of produce sold to the various markets is more or less known, a condition which could be met in Vietnam several years from now. Food balance sheets are of no real use for specific business proportions because they only present national averages. The use for planning agricultural research is self-evident.

Research on Linkages

The concept of linkage between agriculture and industry is of respectable age and it has often been observed that processing of agricultural produce (which is industry) is linked to its production (which is classified as agriculture). Research on this issue more closely approaches the investigation of business and functional relationships between agriculture and business. These are expressed by some in the form of multipliers indicating employment or value added. In the case of Vietnam, this type of investigation could be quite beneficial for several reasons. The feed and starch industry are in a process of development and it may well be that there are factors pushing the industry towards expanding scale which usually point to the need for a stable year-round supply of raw material. Some markets are already in operation and analyzing trends in needs of raw and intermediate produce would be quite useful in local level planning. At the local level, the relation between pork production and sweetpotato (and other root crops) production and processing warrants some investigation. In addition, the feed industry may expand its production for chickens, which would lead to a multi-commodity exercise, including soybean, cassava, sweetpotato, maize, and possibly sorghum.

Quality Rewards

Specific varieties and good quality sweetpotato receive premium prices in the market for human consumption. It is conceivable that starch producers, especially larger scale enterprises, would similarly reward specific varieties of sweetpotato and cassava. Such a development has been observed for cassava in Indonesia resulting in variety-specific market segmentation. It must be emphasized that analysis of rewards given by traders operating in different markets depends on those actors buying from the traders, retailers, or industries. Research would therefore have to focus on identification of rewards at specific market levels, which may not be identical to consumer preference. Such an exercise could possibly help genetic adaptive research, and result in expanded farm incomes. Examples for soybean, maize, and groundnut in Indonesia can be found in Altemeier, Bottema et al. (1989).

Concluding Remarks

Nevertheless, it should be recalled that the success of business depends to a large degree on the abilities of entrepreneurs. Tenacity, patience, creativity, and energy are all necessary in business establishment, a process which is based on trial and error. It so happens that virtually all successful entrepreneurs are good business economists. The reverse is not necessarily true. Aside from stipulating the "potentialities" there is nothing much economics can do for business.

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Analyzing Sweetpotato Marketing in South Vietnam: An Informal Approach

Zenaida F. Toquero[1]

Abstract

The paper discusses the research methodology undertaken by the author in order to have an initial understanding of the marketing structure for sweetpotato in South Vietnam. The two-day reconnaissance survey was part of the International Development Research Center's (IDRC) research initiative in Vietnam which is aimed at providing financial and technical assistance to selected institutions in the country. The paper likewise summarizes the results of this two-day market study, the problems encountered during the survey, and the lessons learned from the exercise.

Key words: sweetpotato, processing, marketing, Vietnam.

Introduction

The International Development Research Center (IDRC) of Canada is now initiating work in Vietnam to provide limited financial and technical assistance to selected institutions in the country. The ultimate objective of this research initiative is to assist selected research and development (R&D) institutions in Vietnam in the pursuit of activities they have identified and prioritized in the socio-economic and technical postproduction fields for some important agricultural crops. Through such an initiative, it is hoped that solutions and/or recommendations can be identified in order to eliminate or minimize these problems. As part of this effort, both the Agricultural Economics (AE) and Postproduction Systems (PPS) Program of IDRC are interested in attempting to define a suitable entry point for their work. The Postharvest Economics Advisor (Asia) is assisting in this attempt by helping in the identification of researchable areas and in the assessment of research resource capabilities (human and facilities) in the country. This is done through a series of field visits, consultations, and discussions with technical and administrative/management staff in various government, academic, and R&D institutions in Vietnam.

Next to rice and corn, sweetpotato ranks third in importance as an agricultural crop in Vietnam. It is planted in every geographic region in the country with the central region accounting for 50% of the total production, the Red River Delta with 20%; Mekong Delta, 9%; and the rest of the country, 21% (Pham and Bottema 1989). Sweetpotato is an integral part of the life in every family in Vietnam (Truong and Vander Zaag 1987). Similar to other agricultural crops, sweetpotato may be faced with postharvest constraints and problems. With the experience and help gained in root crops from IDRC-funded projects in the Visayas State College of Agriculture (ViSCA), Philippines, and elsewhere, there may be some parallel research activities which could be pursued to improve the production and processing of these crops to generate value added income for small and marginal farmers.

This paper is based on the author's field notes as part of her two-time visit (first with a joint IDRC-International Potato Center (CIP) team and last with an all IDRC team) to Vietnam in relation to the IDRC's above-mentioned research initiative in the country. The root crop informal market survey is an integral part of IDRC's socio-economic and technical evaluation of the potentials and problems confronting the different major agricultural crops in the country.

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Research Methodology in Assessing the Market Structure of Sweetpotato in South Vietnam

Based on available literature and discussions with the technical and research staff of the University of Agriculture and Forestry (UAF), Ho Chi Minh City, South Vietnam, it was apparent that there is very limited information about the flow, processing, marketing, and utilization of sweetpotato in the country. The limited studies done in this area were either location- or time-specific, based on the availability of the funds and the interest of the person or agency conducting the study. There was no centralized planning, careful preparation, nor adequate focus in the conduct of some market studies on root crops due partly to limited funds, technical expertise, and the closed market economy that have prevailed in the country until late 1987 (Vietnam followed a socialist path characterized by broad government intervention in the production, processing, and marketing of agricultural cr. ps especially staples such as rice and corn until 1987). To better understand post-production system for root crops, a quick reconnaissance survey was, therefore, initiated.

Planning of the Market Survey

Through the assistance of the research staff from the UAF (headed by Professor Hieu and two members of his staff, Messrs. Hung and Ngai), a quick and dirty survey was conducted to understand the market structure of sweetpotato in South Vietnam. This was done by tracing the flow of harvested sweetpotato from farmer-producers in the southern part of Vietnam to the retailer's level. A sample of two to three respondents in each market intermediary group, e.g., trader-distributor, big wholesalers, small wholesalers, wholesaler-retailers, and retailers, were interviewed informally, i.e., without any structured questionnaires, regarding their marketing operations, practices, and problems. Due to the lack of a list of names of market intermediaries involved in sweetpotato trade, compounded by time and resource constraints, no formal sampling scheme was used in this market assessment. A sample of two to three respondents per market outlet was considered sufficient for the survey.

Implementation of the Market Survey

Respondents were contacted on the spot when the harbors and markets in Ho Chi Minh City were visited during the two and one-half day market study. They were selected on the basis of availability and willingness to answer questions. The two UAF researchers who accompanied the Advisor made the necessary introduction to selected respondents regarding the purpose of the visit and the kind of questions that would be asked. In their introduction, it was always emphasized that the Advisor was from the Philippines doing a quick study of the market to serve as a basis for future IDRC research initiatives in the country. Being a foreigner may have helped in eliciting the respondent's willingness or eagerness in entertaining our inquiries. In some instances, however, non-familiarity with the language also posed a constraint. The taking of pictures to document these market visits and observations also proved to be effective in establishing rapport and gaining the interest of respondents. These different market intermediaries were eager to be in pictures and even their relatives and hired laborers were very willing subjects during the photo session.

There was no structured questionnaire used during these market visits but a list of questions was prepared for referral to guide the interviews. The questions or issues asked about were either expanded or shortened depending on the information volunteered and the willingness or knowledge of the respondent.

Advantages of Informal Survey Method

The absence of a formal questionnaire helped make the respondents more relaxed and at ease in answering the questions. Interviews were conducted impromptu and the pace of the inquiry depended on the ease or difficulty on the part of the respondents as well as UAF interpreters in understanding the issues or questions raised. And, since the interviews were conducted in a very spontaneous manner, the majority of the respondents voluntarily shared information on their marketing experiences, practices, and problems. The on-the-spot selection of respondents limited the size of the sample to only those who were willing or knowledgeable about the questions raised. Although some respondents were initially unwilling to provide information on costs, incomes, and pricing practices, an assurance that it was just for information purposes and had nothing to do with tax considerations helped in gaining the respondent's trust and willingness to divulge such figures.

Problems Encountered and Solutions Taken

Several problems were encountered in the course of the informal survey due partly to the following factors.

- Author's unfamiliarity with the language resulted in complete dependence on the knowledge and efficiency of the Vietnamese researchers in translating the questions correctly to the sample respondents. Literal translations of some of the questions resulted in a need for re-phrasing in order to ensure that the questions were interpreted correctly by UAF staff and understood by the respondents. Consequently, more time was required per interview thereby reducing the total number of respondents included in the survey.
- Limited grasp of the English language by the Vietnamese translators sometimes distorted the idea or questions being raised, often resulting in erroneous answers. The author, therefore, had to be very alert and discreet in accepting the interpreted answers given by the translators.
- Unfamiliarity of the UAF research staff regarding the principles of capitalism and perfect competition restricted or constrained their interpretation of the issues on supply-demand relationships, price discounts, or incentives due to quantity and/or quality differences, etc. To partly solve the problem, the Advisor resorted to sample cases or situations to effectively illustrate the meaning of price differential, discounting, and the like.
- The interview session attracted a lot of kibitzers and curious passerbys, which sometimes distracted the attention of the sample respondents and affected the smooth conduct of the survey. In some instances, these kibitzers were not satisfied to just watch and listen to the interview but even volunteered unsolicited answers or coached the respondents on the kind of replies to give. These sometimes affected the nature and quality of responses by sample interviewees. For the purposes of an informal assessment of the sweetpotato market, these interruptions can be tolerated and even useful (sometimes, depending on the information being volunteered) to get a better feel of the market. [However, in actual research surveys, the interviewer should try and keep his/her respondent away from the kibitzers or request them to cooperate by not interfering during the interview session. A more diplomatic way to do it is to assure them that their ideas or opinions will also be solicited after the sample respondents have been interviewed].
- Answers on prices, costs, and income were noted to be inconsistent or the range of values given were quite large in some market outlets under the same category. This can be attributed either to trade secrets, unreliable memory of respondents, confusion or limited understanding of the question, or the respondents' nagging fear of additional taxes. To partly solve the problem, the respondents were always assured that the information shared would only be used for planning and research purposes and not for tax computation. When the cost figures given were really extreme values (too high or too low) compared with what had been obtained from previous interviewees, additional questions were posed to the respondents to assist them estimate as accurately as possible the data being asked for.

Market Structure of Sweetpotato in South Vietnam

Due to the limited number of sample respondents who were included in this informal and unstructured sweetpotato market study, the discussion in this paper is by no means conclusive. As stated earlier, the limited market analysis was done only to have an initial understanding of sweetpotato marketing in South Vietnam as one of the preliminary steps in assessing the state-of-the-art situation in root crops so as to identify the potential entry point for IDRC in supporting research on these commodities.

Market Flow of Sweetpotato Roots in South Vietnam

The pattern of distribution of fresh sweetpotato tubers in South Vietnam starts from the farmer-producer who hauls his produce to the river banks, where trader-distributors with their boats (either owned or hired for a fee) collect and combine these small lots of produce for shipment to the Ho Chi Minh market. At Ho Chi Minh Harbor, these boats are met by big wholesalers from the different central markets in the city using different modes of transport to haul their purchased product. These transportation facilities vary in size, shape, and capacity depending on the volume of sweetpotatoes purchased. These include big trucks, small trailer vehicles (e.g., *Landro* which is similar to Thailand's *Tuktuk*), pedicabs, or tricycles. These big wholesalers usually have permanent stalls in the market where they operate their businesses. Big wholesalers sell their sweetpotato to small wholesalers, wholesaler-retailers, and retailers. Root crop consumers, especially individual householders, buy their sweetpotato from these different market intermediaries, usually the retailers (Fig. 1).

Marketing Practices at the Trader-distributor Level

Source of Sweetpotato

According to the trader-distributors interviewed, they get their sweetpotato from farmers in the provinces of Hau Giang, Cuu Long, Rach Ghia, Long Anh, etc. These traders are either informed by the farmer-supplier of the impending sweetpotato harvest 2-3 days before actual operation so they will know when to come to the area, or they just come into the area during harvest months. Through experience, these traders already know the schedule of harvest in the different sweetpotato producing areas where they usually operate.

Seasonality of Purchases

These respondent traders reported some seasonality in their buying operations. Their reported peak purchase months were April to August for sweetpotatoes grown in Rach Ghia, while peak months were September to December for sweetpotatoes grown in Minh Hai.

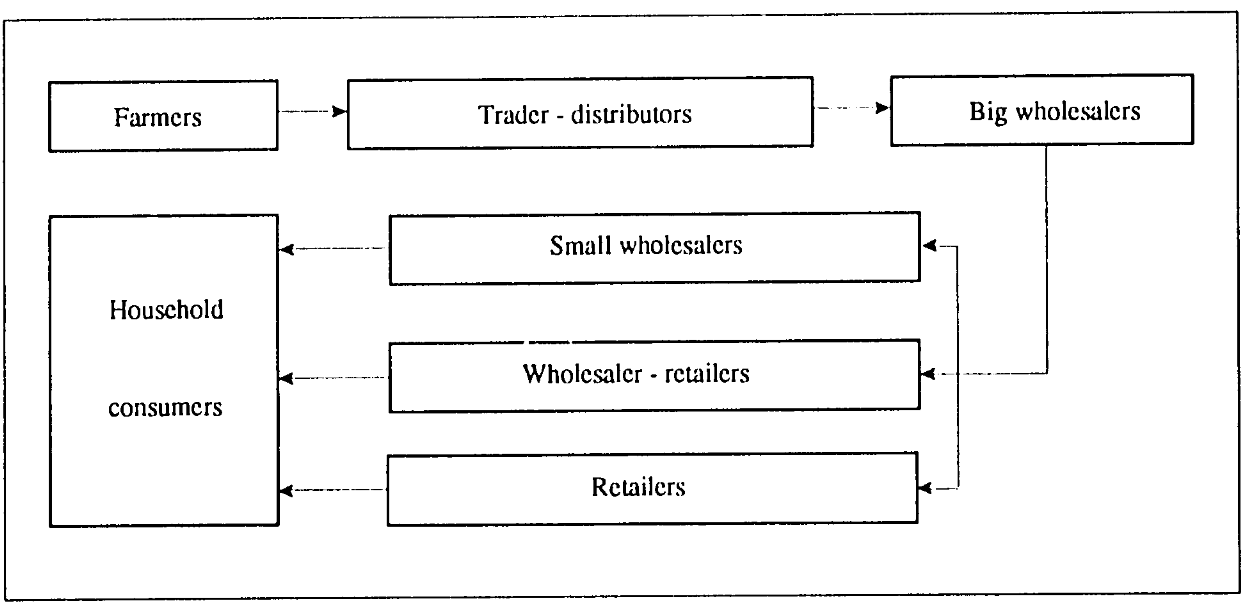
Boat Capacity and Cost of Transportation

The boats commonly used by trader-distributors have outboard motors with capacities ranging from 8-40 t depending on the kind, size, and shape of root crops purchased. The boats used for procurement consume about 30 liters of diesel and a liter of oil per trip. At the time of the interview, the price per liter was about US$ 0.27 for diesel and US$ 0.87 for oil. The sweetpotato purchased from the farmers is priced either in bulk or it is sorted into small- and big-sized categories. According to the respondents, the price per kg of big-sized sweetpotato was US$ 0.07 while it was US$ 0.04 in the case of small-sized ones. When they are purchased from farmers according to size, the sweetpotatoes are already classified and sorted when dumped inside the boat using sectioning partitions.

Mode of Payment at the Farm Level

Two modes of payment were reported by the sample trader-distributors. First, if the volume purchased from farmers was less than 15 t of sweetpotato, the trader-distributor gave only 10% of the value of the product to the

Figure 1. Marketing system for fresh sweetpotato in South Vietnam.



farmer-producer as advance payment with the balance to be paid after all the root crops had been sold to the market which took about 4-10 days. Second, if the volume purchased was equal to or greater than 15 t, the farmer-producer received about 20-25% of the total value of the crop with the balance given after the crop had been sold by the trader-distributor in the market. According to some respondents, some trader-distributors just have run off with the money without reimbursing the farmer for the remaining value of his crop. Thus, many farmers are very selective and careful in trusting their produce to trader-distributors.

Mode of Payment at the Wholesale Level

When trader-distributors sell the sorted sweetpotato to big wholesalers, a price mark-up of US$ 0.01 kg is usually charged. Thus, big-sized sweetpotatoes were sold to wholesalers at US$ 0.08 kg while small-sized ones were at US$ 0.05 kg.

In terms of market arrangement, trader-distributors do not provide price discounts to big wholesalers regardless of volume purchased. However, these big wholesalers can get sweetpotatoes from the trader-distributor on credit for about 4-5 days or until the trader-distributor had disposed of all the sweetpotatoes brought to Ho Chi Minh City.

Marketing Practices at the Wholesalers' Level

Sources of Sweetpotato

According to the wholesalers interviewed, their major suppliers of sweetpotatoes are trader-distributors operating in Cantho, Dalat, and the Mekong Delta area (i.e., Long Anh, An Ghiang, Minh Hai).

Peak and Lean Months of Sale

May to August are the reported peak months of sale for sweetpotatoes. During this period, the average volume sold ranged from 0.7 to 5 t per day at a price ranging from US$ 0.09 to US$ 0.11 kg. Conversely, the lean months of sale are January to March when the volume of sales ranged from 0.3 to 1 t per day. The price of sweetpotato during these months varies from US$ 0.05 to US$ 0.07 kg.

Quality Preferences for Sweetpotato

According to the sample wholesalers, their sweetpotato buyers (composed mostly of small wholesalers, wholesaler-retailers, and retailers) expressed preference for sweetpotatoes grown in Dalat because of their sweet taste, fine texture, smoothness, and generally cleaner skin. In terms of skin/flesh color, buyers prefer purple and orange color which enhances the soup and other food recipes which use sweetpotato.

Pricing Scheme

The average selling price of sweetpotato varied according to the month of sale. From April to August, the average selling price was US$ 0.067 kg while it was US$ 0.106 kg the rest of the year. A price discount of US$ 0.003 kg is likewise given to buyers if the volume purchased is greater than 100 kg. Moreover, there is a price difference in sweetpotato sold to different market outlets—US$ 0.073 to US$ 0.11 kg for small wholesalers and US$ 0.08 to US$ 0.13 kg for retailers.

In terms of price differentials according to tuber size, the following information was obtained from the sample of big wholesalers: small–US$ 0.04 kg; medium–US$ 0.08 kg; and, large–US$ 0.106 kg. Therefore, from the trader-distributors who classify their sweetpotato tubers into only small and large sizes, the big wholesalers reclassify the tubers into three size categories—small, medium, and large. Thus, through re-classification, the big wholesalers can increase their profit from the sale of sorted tubers.

Stall Rental

The wholesalers interviewed have different types of stalls where they conduct their business. The bigger wholesalers have permanent stall structures measuring about 12 x 12 m^2 where they sell their products and which at the same time serve as their living quarters.

Small wholesalers and wholesaler-retailers on the other hand, have designated corners or spots in the market where they conduct their business under temporary roofs such as canvas, umbrellas, clothing materials, and plastic sheets. At the end of the market day (which runs from 4 a.m. to 8 p.m.), the unsold tubers are left in these temporary stalls and covered with sheets. Some wholesaler-retailers request their family members or hire/contract a watchman to guard the remaining sweetpotato. The monthly stall rental paid by big wholesalers amounts to US$ 93 while that for small wholesalers and wholesaler-retailers US$ 12-13, depending on space allotment and type of roofing materials used. Not one of the big and small wholesalers as well as wholesaler-retailers interviewed could tell whether the monthly rental fee was based on permanency of stall facilities, measurement of the stall space, volume and/or value of sales, capitalization or net worth, or any combination thereof.

Other Crops Sold

All the wholesalers interviewed include other crops in their trading business in addition to sweetpotato. This is done as part of their market strategy to solve the problem of seasonality of production and to spread out the risk of low prices and unpredictable or limited supplies of the different crops they sell. Among the other agricultural crops sold by wholesalers are other root crops such as cassava, yam, taro, and turnips, as well as fruits such as watermelon, melon, mango, and banana.

Marketing Practices at the Retailers' Level

Sources of Sweetpotatoes

According to the surveyed retailers, the majority of the sweetpotatoes they sell comes from big wholesalers, wholesaler-retailers, and small wholesalers in big markets around Ho Chi Minh City, such as Cau Moi and Cho Lon.

Peak and Lean Months of Sale

December to January were the peak months of sale at the retail level. During this period, the average volume sold per day amounted to 50 kg. Conversely, during the lean periods which occur during February to November, the average volume sold per day ranged from 5 to 6 kg.

Stall Rental and Other Marketing Arrangements

Sweetpotato retailers usually occupy small spaces to carry out their trade (generally just the table or cart where they display their goods for sale) and mostly without the benefit of permanent or even temporary roofing. Thus, they can be found generally selling their goods in open spaces within the market premises. Their stall rental amounted to only US$ 6.67 per month. Similar to the small wholesalers and wholesaler-retailers, the retailers surveyed were not aware how their monthly rental rates were determined.

Retailers usually sell their sweetpotatoes to regular costumers on credit for two to three days. Regardless of volume purchased, no price discount is provided to their customers.

Similar to trader-distributors, wholesalers, and wholesaler-retailers, the sweetpotato surveyed retailers include other root crops and vegetables in their trading operation.

Conclusion

The informal market survey in Ho Chi Minh City, South Vietnam, was done by the Advisor with the assistance of two research staff from UAF to gain an initial understanding of the market structure of sweetpotato. The informal, unstructured market study combined casual interviews of different market agents and direct observation of the processes and facilities involved in the sweetpotato food system. Several problems were encountered in conducting the study. In spite of this, however, the reconnaissance market study provided a relatively quick and efficient general understanding of sweetpotato marketing and processing in South Vietnam. Through the casual, impromptu, but guided questioning (unlike the usual "interrogative," formal interviews using questionnaires) the respondents were more relaxed and at ease in providing answers, some of which may be considered "confidential" and not commonly divulged during formal interviews.

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Market Research in a Sweetpotato Food Project in the Philippines

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Abstract

Failed efforts to sustained adoption of technologies has pushed discipline rigidity to an outmoded stance in agricultural development research. In came attempts at blending various client/beneficiary-researcher perspectives in multi-disciplinary, integrated research. This paper recounts the manner by which technical and socioeconomic/market research is integrated for the development of sweetpotato food products and subsequently their transfer to potential technology users in a International Potato Center (CIP)-funded Visayas State College of Agriculture (ViSCA) project in the Philippines. Interdisciplinary research interfaces are attempted in all the stages of the product development cycle —from idea generation to the transfer of technology.

Key words: integrated approach, market research, product development.

Introduction

This presentation largely deals with various market research efforts integrated into the International Potato Center (CIP)-supported Visayas State College of Agriculture (ViSCA) sweetpotato food project. ViSCA's goal is to develop relatively cheap and nutritious food products for low- to middle-income households in urban areas. The issue that may immediately come to mind is the role market research plays in product development *vis-à-vis* a purely technologically-driven research that produces innovative ideas anyway.

A little bit of homework immediately brings us to several cases which were costly, wasteful, and even failures both in terms of time and resources. These cases were significantly numerous, in fact, to warrant the holding of a workshop in mid-1986 organized by the International Development Research Center, and spearheaded by its Postproduction Systems and Agricultural Economics Programs. Some of the workshop's noteworthy conclusions strongly highlight the need for market research to be integrated into the research process starting right at the onset by setting attainable objectives and defining food technology research. Experiences in research design and idea generation should, therefore, be strengthened through group discussion of lessons learned from successful and failed research projects. The documentation further led to the conclusion that market research traditionally has not been part of the food technology process in developing countries. Technological and market research was generally taken up on a fragmentary and compartmentalized manner. Sometimes in a way in which the food technologist worked independently in the first phase only for the market analyst or economist to provide an analytical evaluation of the product's market performance in the end. It is necessary that market research and economic analysis be combined in the same project (Young and MacCormac 1986).

The following discussion that uses the CIP-ViSCA project as a case in point holds the basic principle of a consumer-oriented or market approach to sweetpotato food technology research. Such an approach is premised on the expectation of improved utilization of research output and the increased likelihood of successful adoption of technology. Incorporating a market research

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component in a development project entails added costs, but, in the long run, would be more cost effective in terms of implementation and delivery of research results. Oftentimes, food technology research independently carried out without due consideration to user factors entails considerable opportunity cost and lag time between technology generation to sustained adoption, if successful at all.

The Integrated Approach

A Sketch

Long before the sound and fury of technology and market research theorizing, traders, retailers, financiers, and wholesalers have gone about the business of catering to consumer needs and wants. In their own practical ways, these business people have tried to innovate and sell products that fit demand. They made a living through market mediation and flourished through practical, common sense. Yet, innovations were never wanting. That pragmatism without the sophistication of bookish theorizing brought about the commercial revolution of the Eighth Century in the Mediterranean Crescent. These early traders, in fact, were practitioners of the integrated approach.

Almost a millennium later, the demands of professionalizing specialization to improve efficiency and to meet the needs of modern science and industry led to polarizing the technical and social fields of science. Consequently, with feeding booming populations as a major concern after the initial successes of the Industrial Revolution, agricultural development research followed a technical-heavy production orientation and brought about researcher-biased methods. Documented cases of failed technology adoption, especially in less developed countries poured in, starting in the 1970s; the top-down approach proved to be ineffective. Social scientists clamored for change and ushered in the bottom-up, holistic, participative approaches with such popular catch phrases as the "farming systems" perspective; "farmer-back-to-farmer" model (Rhoades and Booth 1982), "user ' perspectives" (Rhoades 1988). Technology and its application have become both the art and science of concrete articulation of "what exists" and drawing from this set of conditions the appropriate mix of interventions or strategies.

From such a backdrop, the integrated approach became a guiding principle in developing methods for technology generation and transfer. To integrate, by dictionary definition, means to bring the parts together or to make whole. The nuance conveyed here is to view a process in its totality, looking at all its parts or aspects—a systems or holistic view. To fail to have this perspective is to lose the subtle synergies that result from a concerted action of all parts. In this sense, the integrated approach calls for interdisciplinarity, the substance of which refers to more than one component, dimension or aspect, and thus, more than one discipline to carry out a research or development project (Castillo 1990). The practical application of the approach differs because there are diverse ends or goals, different levels of complexity, and various types or natures of projects.

The Technical and Market Research

Skillful and shrewd entrepreneurship in small or big enterprises is a practical, glowing example of dexterous handling of technicalities and the human agenda. Business success is measured in several way., ergo, profitability, and contribution to welfare. The analogy in government or externally-funded product development research is the appropriate blending of technical and market research with a continuous interface at various stages of development. This can be illustrated in the following example.

In an attempt to approximate integration, the project team (i.e., technical and socio-economics) emphasized team planning, team discussions of methods and results, and consensus decision-making. The inputs of collaborating CIP scientists served as important catalysts in forming a holistic framework and user-oriented methods. Thus, a market-oriented approach in developing sweetpotato food products was adopted in the hope of ensuring a relatively cost effective process in the long run, despite the increased cost outlay for market research. The final test, after all, of a product idea or innovation is whether a product sells in the market, or a technology is adopted and has impact. Consider the schema in Figure 1. The discussion draws from this project's experience.

Idea Generation

For getting ideas to develop product concepts or prototypes, the market needs to be explored. In the case project, market opportunities of where sweetpotato products could fit were identified through consumption and marketing surveys. These, in addition to technological literature research and review of experiences in food technology research, formed a wider range of possibilities to choose from for a better product market fit.

Figure 1. Stages of product development with research interfaces.

Stage	Technical Research		Market Research
Idea generation	Technological literature research/review of experiences	⟷	Consumer surveys Market inventory Informal farm-market surveys
↓ Screening/evaluation	Brainstorming		
↓ Product/process development	Experimentation product; concept tested continuously at lab (product-process-raw materials)	⟷	Product profile and raw materials specific actions from consumer/farm market survey
↓ Product testing	Shelf life test Packaging tests Lab. acceptability test (sensory evaluation/taste panel)	⟷	Market research: distribution competition consumer testing
↓ Pilot testing	Skills/hands-on training of technology beneficiary Pilot runs	⟷	Consumer test-feedback modifications Final market test Feasibility preparation
↓ Commercialization	Final product developed and commercialized	⟷	Market launching; product promotion market monitoring

The result of technical research alone could be quite similar to that of the combined approaches but one never knows when and where the two could be similar unless the process is complete. Can it, therefore, be argued that technical research alone suffices? Not without the greater risk of a mismatch. A wider-based range is better than a narrower one. Besides, the generation of product ideas is just one of the service outputs of market research. Other information would be useful in later stages, from screening ideas to formulation of marketing strategies.

The surveys confirmed that low income urban consumers are largely consuming junk food such as chippies as a leisure food or hunger-filler in an already deficient diet. The food budget is only about ₱50-70 for a household of six and is, in real terms, lower compared to the same budget in the rural areas where produce from household gardens or farms greatly supplements the diet. The product inventory is nowhere advantageous to this target market because nutritious products are usually costly. And where poor households have to utilize fully time for work to afford living in cities, food convenience is a highly desired. These people know the importance of nutrition and would have decided to buy nutritious food, but the range of affordable choices is very limited. Their preferences and consuming and buying patterns were also noted. Thus, the opportunity of providing for this substantial food gap for low-middle income households in urban areas is present. The food technologist, then, is presented objective information, not just casual observation in developing the product prototypes. Product possibilities include chips, hotcake mix, soup mix, instant variable powder, and noodles.

Screening/Evaluation

To screen and evaluate product ideas, the target market must be described. Characterization of users by various categories, such as income, difference in preference patterns by age or sex, or other consumer differences helps greatly in screening ideas and refining products. These help in determining the need for product differentiation, what type, how and to what extent, and in marketing strategies, i.e., size of pack, price guide. Reliance on purely technical brainstorming is rather limited. There is nothing like really understanding the market as a guide for evaluation. A consumer survey, as in the example cited above, is ideal if the characteristics of the target market have not been defined. Secondary data from other similar surveys or relevant official statistics should be explored so that primary data gathering, if needed, will be more focused and defined.

Product/Process Development

Product profiling and raw material specifications based on consumer and market surveys are essential inputs into the experimentation in order to develop the screened product as having market potential. Farm-market surveys provide information on raw material availability and their production and market conditions, noting seasonalities and prices. Various widely grown sweetpotato cultivars, e.g., Bureau, Miracle, Leyte, Central Luzon, Karingkit, and Samar-Leyte, were included with the VSP's in screening for desired product traits. The supply of root crops could be a constraint to processing as in the case of cassava starch. It is, therefore, important that at the early stage of product development, supply and cultivars' performance—both in production and processing, be assessed. Experimentation is an iterative process of testing for the fit of process and raw materials to several product options. Shelf life and packaging tests are part of the experimentation. Several packaging materials are being tried out to get a longer shelf life for the product at a reasonable cost. Based on supermarket inventories of similar products, for example, the prototypes should attain a shelf life of at least six months. Sources of packaging materials, their availability, and prices are other details which need attention. Packaging affects costs and this can be taken for product differentiation to cater to various types of markets—the low to middle income continuum is of several shades by age, sex, income, or even food habits.

Important parts of process development are the design and fabrication of tools and equipment and the standardization of the process. Simple processing equipment such as the adjustable gauge slicer were designed and fabricated for the making of sweetpotato chips. The Lorena stove which economizes on fuel was recommended for expanded operation. A prototype chip processing assembly was set up which can be modified to fit other products to utilize rejects/waste and/or to optimize the time or equipment capacity.

Product Testing

When the product/process mix is complete, acceptability tests are conducted at the lab level by a trained sensory/taste panel. Consumer tests were undertaken in identified target markets with products being evaluated as acceptable at the lab level. Feedback from consumer tests led to further product improvement. The description of the target market determines the different ways of stratifying the market. A carefully designed consumer test is helpful in the formulation of marketing strategy.

Take the chips. Sensory evaluation showed a high acceptability rating in crispiness, texture, aroma, and flavor for VSP-1 and VSP-4 with the standard thickness at 1.5 mm. These were then tested by a sampling of consumers in the cities of Manila, Cebu, and Tacloban. A high favorable rating showed again for VSP-1 and VSP-4 with both sweetened and flavored chips as having potential markets. Consumers, too, suggested affordable pack price and preferred packing. Results, therefore, led to modification of ideas about the standard product and process. At this early stage, even before introducing at pilot sites, the product profile has been made.

Pilot testing

A lab-scale pilot is most useful in product-process development, but realistic hard facts to determine viability can only be through pilot testing the technology with identified target clientele. While technical skills are transferred by hands-on training, the output is tested continuously for quality to be ready for consumer tests where feedback again provides inputs for refinement. Testing and equipment verification under local conditions provides the basis for a realistic feasibility study.

The farm-market surveys at the early phase of the project already provided information that helped assess for potential pilot sites and technology beneficiaries. Potential supply and competitiveness of prices of fresh sweetpotato roots, *vis-à-vis* processing, were critical information which was also gathered. Knowledge gained of the sweetpotato production system made for a clear understanding of the supply-processing linkage. Thus, the interface of marketing research (early phase), with the later stage of the product development cycle (piloting), is seen in this example.

Commercialization

The final test is the commercialization of the product. The various types of market research and the different technological processes combined to develop the final product—screened, tested, and refined to really fit market demand. A clear-cut market description is an important step to promotion strategy. A certain level of market assurance based on the research done in various stages increases the likelihood of sustained adoption of the technology.

Product development, however, does not end here. While human behavior changes and is modified so does the market. The process of market research feeding information for technical changes in the product to fit changing demands is a cyclical process.

Conclusion

Some scientists and researchers still are uncomfortable with the proposition that market research should always be part of any product development effort. This can arise partly from a misunderstanding that market research always involves huge financial resources, large, sophisticated, long formal surveys, and overdue results. These do not necessarily have to be the case. Market research design will depend on goals and available resources. An intensive exploration of secondary information and cost-effective informal surveys can give a comprehensive view of the market and consumer behavior in a timely manner. The availability of resources, in some cases, gives the researcher the option to design for optimum market information. Many projects doing this have made substantial contributions in terms of generating information useful in other related projects beyond their spans while serving their own ends. These positive externalities are part of the beneficial returns to investment in market research while increasing the likelihood of consumer acceptance of the product, and thus, improving the likelihood of sustained technology adoption. Substantial investments in market research tended to result in long-run cost effectiveness of technology development.

In whatever form and degree of sophistication market research takes, the basic idea is that product development be geared to satisfy the real needs and wants of the end-user. Depending on the project, types of information gathered may differ, but the basic principle of understanding users remains. Simply put, market research involves getting information about people so that research results are fully utilized. In a looser context or in less than ideal situations (which much product research is), this may be carried out by different people (or disciplines) with the proper orientation, but the work needs to be coordinated and results available at each stage of the development cycle.

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Evaluating the Potential for Sweetpotato Products in the Philippines: SEARCA's Experience

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Abstract

In line with the Southeast Asian Regional Center for Graduate Study and Research in Agriculture's (SEARCA) thrust of accelerating research results utilization, the Research Utilization Project (RUP) with funding support from the International Development Research Center (IDRC) of Canada developed a procedure for identifying research results with potential for commercialization. The procedure is composed of three weighted criteria namely: marketability (40%), technical feasibility (30%), and profitability (30%).

The results of the evaluation revealed the following: (1) the procedure can discriminate among the technologies that are ready for commercial use i.e. ability to distinguish between marketable and non-marketable products as shown by only one out of four evaluated processed sweetpotato products recommended for commercialization; and, (2) to determine the marketability of the product is the most expensive part of the evaluation in terms of money and time spent.

SEARCA's experience emphasized the marketability or substantial demand for a product/technology as a major pre-requisite to commercial utilization of research results.

Key words: research results, commercialization, utilization.

Introduction

"Research, to be of value, must contribute to technology that could positively affect the lives of the people and their economic position. The ultimate test, therefore, of the value of any research activity is the extent with which its result has been utilized on a sustained basis" (Gomez and Abejuela 1988). These two basic statements became the creed that SEARCA has been promoting through its Research Utilization Project (RUP) in the past three years.

SEARCA emphasized the importance of research result utilization by making this one of its major thrusts in its five-year plan which started in 1989. RUP, then, was conceived with the main objective of hastening and increasing the frequency of commercialization of research results. In order to achieve this objective, the project was charged with developing a procedure for evaluating the potential commercialization of research results.

A research result is defined as a product that embodies an innovation; and its commercialization is said to have happened when the number of users adopting the innovation is large enough to have a significant impact on their well-being.

This paper will discuss the development of this evaluation procedure in which research results on sweetpotato played a major role.

RUP's Evaluation Procedure

With some funding support from IDRC-Canada, RUP developed a procedure to evaluate the potential of a

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research result for commercialization—a procedure that can identify research results ready for commercial utilization.

There are three primary criteria used in this procedure and these are: marketability, 40%; technical feasibility, 30%; and profitability, 30% (Table 1). Thus, to determine a research result's potential for commercialization, it has to undergo three types of evaluation: marketability evaluation to determine potential commercial demand; technical feasibility evaluation to determine if the research result is technologically workable; and profitability evaluation to determine financial and economic gains, if utilized.

Marketability

This is the heart of the procedure. The basic issue addressed by this criteria is: "Is there a demand for this certain technology?" Evaluating all other aspects of the technology, such as the technical and profitability aspects, is useless if there is no demand for the technology. What propels a technology to be utilized commercially or otherwise, is that there is a need for it. An accurate reading of the market is very important before pushing a product or technology for commercialization. Under this criterion, the technology's demand is determined, its competitive edge over alternative technologies is assessed, and the technology's potential market share is estimated.

Technical Feasibility

A research result is technically feasible if its technical performance is acceptable and can be mass produced easily. The technical feasibility evaluation looks into the technical soundness of the technology. This means looking into if the technology or research result does what it is designed to do. The cost and availability of production factors required for mass production are also determined in this evaluation.

Profitability

The profitability criterion looks into the financial gains the technology will generate for the end user as well as the economic benefits utilization activities will give to the community, country, or society. The financial evaluation uses the basic financial ratios used traditionally in determining financial profitability. These are the Net Present Value (NPV): the Internal Rate of Return (IRR); the Return on Investment (ROI); and the Payback Period (PP).

Using these criteria, the research result is rated from 1-5 with five as the highest rating. Ratings are then multiplied by the assigned weight to get the weighted rating. An overall weighted rating of four to five indicates that the research result is ready for commercialization.

This procedure has been used to evaluate the potential of six root crop-based research results for commer-

Table 1. Criteria for evaluating commercial potential of research results.

Criterion	Weight (%)	
Market feasibility	40	
Substantial demand		10
Competitive edge over alternative technologies (products)		20
Potential market share		10
Technical feasibility	30	
Technical soundness of the technology		20
Availability of production factors		10
Profitability	30	
Financial		20
Economic		10
Total	100	

Source: Abejuela et al. 1989.

cial utilization. These research results are Delicious Sweetpotato; sweetpotato catsup; sweetpotato jam; sweetpotato soy sauce; *cacharon*, and cassava flour. For purposes of discussion, only the evaluation of sweetpotato research results will be presented here.

Evaluation Activities

The sweetpotato research results previously mentioned are root crop processing technologies which the Visayas State College of Agriculture (ViSCA) has developed. All four sweetpotato processed products underwent the three types of evaluation mentioned in the preceding section.

As expected, the most critical and time consuming portion of the procedure is the evaluation of the product's marketability, i.e., the determination of demand.

Market Research for Sweetpotato Processed Products

A major activity of the marketability evaluation is the conduct of market research through a Usage, Attitude & Image (UAI) survey on four product categories where the sweetpotato processed products belong. The survey was done in seven key trading areas and in areas where root crops are grown in the Philippines, covering Luzon, Visayas, and Mindanao. These product categories are: soy sauce for sweetpotato soy sauce; jam/jelly for sweetpotato jam/jelly; catsup for sweetpotato catsup, and dried fruit for Delicious Sweetpotato. In the case of Delicious Sweetpotato, a taste test was also done together with the UAI survey.

The identified respondents were homemakers or those who take charge of the households' products, i.e., soy sauce, jam/jelly, and catsup; and, individual consumers aged 12-60 years old from the same household for the dried fruit-snack item, i.e., Delicious Sweetpotato. A total of 700 homemakers and 700 individual consumers were interviewed. The individual consumers were also the taste test respondents.

The UAI survey gathered data on market size/growth/shares; usage, consumption, and purchase habits of consumer-respondents; product needs/satisfaction; product positioning; pricing; product awareness, and the source of awareness.

Market Research Results and Findings

The UAI survey results showed that consumers are not particular about what these processed products are made from. What matters to them is the quality of the final product; whether their preferences are met by the product; and, if the attributes they look for in a particular product are present. Thus, the fact that they are made from sweetpotato does not bother them, especially if before trying or using the product, they do not know that it is a processed product from sweetpotato.

To support these findings using the gathered data, RUP made a product-market fit analysis for each of the evaluated products. This analysis was really a process of determining how a product fit market needs. A summary of this analysis is shown in Table 2.

The household products, i.e., sweetpotato soy sauce, jam/jelly, and catsup do possess the basic attributes the market looks for (Table 2). These products also satisfy the needs of consumers in the same way as the currently available products in the market. These products were rated to have parity product-market fit.

Delicious Sweetpotato was noted to have a superior product market fit, i.e., it satisfies the needs of the target consumers more than the currently available products in the market. The basic attribute the market looks for in a dried fruit snack food is sweetness. Delicious sweetpotato is not only sweet, but also delicious, nutritious, and cheaper than its main competitor, dried mango.

Result of Evaluation Activities

Of the four processed sweetpotato products, only one is recommended to have very high potential for commercialization (i.e, a score of 4.10). One was recommended for commercial utilization with reservation, while the two others were not recommended for commercial utilization at that time. Table 3 shows the ratings for each of the four sweetpotato products. These results can be summarized as follows:

- Technical feasibility, as expected, is satisfied by the four products (research results). Marketability and profitability, however, are the two criteria failed by the three products (research results) that were not recommended for commercial utilization.
- The quality of the product which is already in the market and is to be substituted for by the product

Table 2. Product/market fit for root crop-based food products.

	Delicious Sweetpotato	Soy sauce	Jam/jelly	Catsup
Market side:				
Minimum requirement the market needs	Dried fruit-like snack food that is **sweet**	Soy sauce that adds **flavor to cooking**	Jam/jelly that is **nutritious**	**Must complement** taste of any fried food
Other attributes required	Munchy Reasonable in price Has pleasant smell Always available Attractive color	Delicious dip Must complement taste of any fried food Good marinade Reasonable price Always available Has pleasant smell	Can be used with any kind of bread or biscuits Reasonable price Not too sweet Has a pleasant smell Economical to use Always available	Adds flavor to certain food like spaghetti, pizza, etc. Reasonable price Fine texture Not too sweet Availability
Selling price (top brand)	₱ 22.0/100 g Dried mango	₱ 4.70/320 ml bottle Silver Swan	₱ 14.10/215 g Lady's Choice guava jelly	₱ 5.45/320 g bottle UFC
Product side:				
As per research brief	Delicious SP is **cheap, delicious, sweet,** and **nutritious**	Soy sauce is a **delicious dip**	Jam is a **nutritious** and **delicious** sandwich spread or filling	Catsup is a **cheap food** flavor enhancer and a **delicious dip**
As per taste test done: Like attributes (voluntary answers)	Delicious Sweet A bit sour Sweet/sour taste Tastes like dried mango	Tasty Delicious Smells good Taste like other brands	Not too sweet Delicious Sweetness is just right "Balanced" taste Tastes like other jam/jelly	Very delicious Red color Better than banana catsup Not sweet nor sour Comparable with other brands
Overall rating	**Very good**	**Good**	**Good**	**Good**
Average cost	₱ 9.72/100 g pack	₱ 7.52/320 ml bottle	₱ 13.82/215 g bottle	₱ 9.07/320 g bottle
Prognosis	**Superior** product-market fit	**Parity** product-market fit	**Parity** product-market fit	**Parity** product-market fit

Source: Abejuela et al. 1989.

Note: Prices and costs are based on 1989 canvassed prices.

(research result) is clearly an important determinant of the commercial potential of a new product (research result). Excellent competing products make it more difficult for a new product (research result) to be commercialized.

- The procedure was able to discriminate among technologies with respect to the potential for commercialization. For example, only one out of the four sweetpotato products (research results) was considered ready for commercial utilization.

Table 3. Weighted ratings on potential for commercial utilization of four root crop-based products.[a]

Criterion	Delicious sweet-potato	Sweet-potato catsup	Sweet-potato jam	Sweet-potato soy sauce
Market Feasibility				
Substantial demand	0.35	0.40	0.25	0.40
Competitive edge over alternative technologies/ products	1.00	0.60	0.60	0.60
Potential market	0.35	0.40	0.30	0.35
Technical Feasibility				
Technical soundness	0.80	1.00	0.80	0.80
Sources and cost of production factors	0.20	0.20	0.20	0.20
Profitability				
Financial	0.90	0.40	0.20	0.20
Economic	0.50	0.30	0.30	0.30
Total weighted rating	4.10	3.30	2.65	2.85

Source: *Abejuela et al. 1989.*

[a]Research results are based on the evaluation criteria given in Table 1.

Post-evaluation Activities

During the course of RUP's evaluation activities, some groups came to know about what the project was doing and expressed interest in RUP's work and the transfer of some sweetpotato research results. RUP, for its part, acts only as a bridge between the prospective user and the researcher. A few of these experiences are cited here.

San Pablo Choice Foods. This company is engaged in the export of processed coconut and other fruit products, e.g., coco candy, jam, and sweetened tamarind. Their interest in sweetpotato processed products began when the provincial government of Laguna sponsored a trip to ViSCA for some farmers and processor/entrepreneurs from the Province. Delicious Sweetpotato was the product they were interested in. They inquired about the whole process and about the feasibility of commercializing it. A series of meetings transpired between them and RUP together with the researcher. After some product tests and market scanning abroad, the company requested some modification of the product. This was relayed to the researchers. During these meetings, interest in other sweetpotato processed products was also generated and the company bought samples of the other sweetpotato products, e.g., sweetpotato powder and sweetpotato chips to test the product acceptability in local and foreign markets. Feedback from the market was given to us or to the researcher. These activities gave the researchers information and knowledge of what the market wants and they were able to so some reformulation or adjustments on the product to suit market requirements.

Alta Products and Machinery Works, Inc. This company is involved in the processing of sweetpotato (VSP-3) as a cheap, partial substitute for corn in animal feeds. RUP got to know them through the Sweetpotato Producers and Processors Association which was headed by one of the people involved in running the company. RUP got interested mainly because they were using a ViSCA variety and RUP researchers wanted to know how effective their activity was. RUP also referred them to persons and institutions engaged in sweetpotato research for feeds, such as the Institute of Animal Science of University of the Philippines at Los Baños (UPLB), ViSCA, International Potato Center (CIP), and Southeast Asian Program for Potato Research and Development (SAPPRAD).

Project staff also had the chance to visit a feed plant in northern Philippines. RUP came to know later that the company had some problems in procuring raw materials as well as with financing for operating the feed mill. Though initial production catered to backyard hog-raisers in the province where the plant is located, the company wanted to target large-scale hograisers as well so as to boost its credit standing with the banks. Initial feedback from the company, however, was that they were reluctant to adopt the technology since the long-term effect of the use of sweetpotato feed ingredients in a large-scale hog enterprise in the country has not yet been established. They did not want to risk financial losses because of low productivity due to changes in the feed formulation. The other question posed by the company to RUP staff concerned the regular and sustained supply of root crops, which would be required by them, because such supply is known to be erratic.

The Philippine Department of Science and Technology (DOST). DOST embarked on a comprehensive technology transfer and commercialization program in 1990 and tapped RUP to do feasibility studies on research results it has evaluated. From the sweetpotato research results, a feasibility study was done of Delicious Sweetpotato as an export commodity. Market research aimed to determine the preferences of foreign consumers for dried fruit snack foods. It was found that foreign consumers prefer natural foods with no artificial additives. The current trend in the market is that of "health foods." Some foreign importers signaled their interest to test market the product in their own countries. RUP staff have left DOST personnel to do the matching of importers and interested processors.

Proposed project on sweetpotato production and processing for agrarian reform beneficiaries. A research institution is currently studying the possibility of a multi-million peso project for agrarian reform beneficiaries on sweetpotato production and processing. SEARCA's input to this project proposal was the market information on sweetpotato processed products it had gathered over the two-year research period. The idea behind this project (i.e., that massive planting of sweetpotato by the farmer-beneficiaries), will only be achieved if there is an assured market for this produce and that there are processing facilities in place.

This exercise with the institution concerned is a realization of one of RUP's proposed recommendations, namely, that proposals for funding should show that the results of research and development (R&D) activities have high potential for commercialization in order to warrant financial support from donors.

Conclusion

SEARCA's activities involving sweetpotato research and utilization are limited. This is due to the fact that the sweetpotato research results were incidental participants in our development of the evaluation procedure. This exercise, however, demonstrated several points.

- The need for the input of user's/entrepreneur's/investor's criteria in the evaluation process of new technology to enhance subsequent utilization.
- The gap that existed between generators of research and the target users. This gap showed a major weakness in processing research, i.e., that most research done in the past was technology driven. Intended beneficiaries/users were thought of only when the results of research were ready for dissemination and researchers found out that these research results were not really needed by the target beneficiaries. The outcome then is that most research results end up only in journals and are not fully utilized.
- The importance of doing a needs assessment of the identified target users/beneficiaries or doing market research prior to any research activity (ex-ante evaluation).
- The importance of having a comprehensive and balanced procedure for evaluating a research result's readiness for commercialization. This procedure should evaluate all aspects affecting the commercialization process, e.g., market, technical, and economic and financial.
- The importance of the target user's participation or input throughout the research process from project conceptualization to utilization.

The above conclusions highlight the importance of doing market-driven research. With funding for research getting more scarce, especially in the developing countries where R&D for science and technology are not priority areas of governments, it has now become imperative that these activities focus on market needs so that results are commercialized. Though a market-driven research process entails a larger initial funding requirement than traditional (i.e., technology-driven) research, this process comes out to be more economical in the long run. Not only will this type of research process prevent costly mistakes, as well as financial losses, it will also facilitate faster transfer of technology to the intended beneficiaries. Applying this logic to sweetpotato R&D will surely boost the chances of success in the commercialization of sweetpotato research results and in so doing enable market researchers to help improve the lives of sweetpotato farmers. Understanding identified target users/ beneficiaries (the market) of technical research results through marketing research is one such step which will help achieve this objective. We at SEARCA would like to think that our project activities we have contributed something towards that end.

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Prospects and Constraints for Sweetpotato in Indonesia

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Abstract

This paper illustrates the strengths, weaknessess, opportunities, and threats to sweetpotato in Indonesia. It evaluates trends in production; the comparative advantage of sweetpotato (production cost and return analyses); marketing and utilization; and, government policy and strategic intervention.

Sweetpotato is more profitable than any other major *palawija* (secondary) crop, such as maize, soybean, groundnut, or cassava. Over the past decade, demand for sweetpotato as a food (fresh root) has declined. Demand for feed and industrial products is still limited, especially compared to the demand for cassava products. Government policy and strategic intervention over the past *Pelita* (five-year development plan) has given less priority to sweetpotato than soybean or maize. Most recently, however, the Government of Indonesia (GOI) has given top priority to the crop diversification program. The strategy for implementing sweetpotato production will depend substantially on improved production technologies, soil and land suitability, and socio-economic conditions.

Key words: production, yields, utilization, marketing, costs and returns, processed products.

Introduction

Agriculture plays a major role in the Indonesian economy. In 1986, about 26% of the Gross Domestic Product (GDP) was generated by the agricultural sector, and 61% of this originated from food crops. In the same year, the estimated contribution of sweetpotato was about 0.7 percent of the total food crops' contribution (Pakpahan et al. 1990). More than two-thirds of the population live in rural areas where more than half of the population depends on agriculture.

The role of sweetpotato for human food is still dominant. Food balance sheet data for 1987 show that 1.77 million t or 88% of sweetpotato production was used for human consumption, while utilization for feed was only 40,000 t or 2% of total supply (Central Bureau of Statistik 1987).

Sweetpotato is a crop of considerable unrealized potential. Its popularity is due to high productivity, suitability in mixed cropping systems, and relatively low labor inputs. Also, sweetpotato has a high nutritional value. It is a good source of carbohydrates, carotene, ascorbic acid, niacin, thiamin, and minerals. In addition, it is rich in Vitamins B2, C, and crude protein (FAO 1988).

This paper is based on a study designed to assess the strengths, weaknesses, opportunities, and threats to sweetpotato in Indonesia. The study focuses on evaluating production trends; the comparative advantage in terms of sweetpotato costs and returns to production; marketing and utilization; government policy, and strategic intervention for a sweetpotato research program. The study was carried out through a literature reviews and analyses of Central Bureau of Statistik (CBS) data.

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Trends in Sweetpotato Production

Changes in Harvested Area of Palawija Crops

On Java and several other major islands, sweetpotato is mainly grown in paddy fields (*sawah*) in the post-rainy or dry season following the rice crop. The land planted to sweetpotato is in both lowland and rainfed areas. Additional growing areas are in upland areas (*tegalan*). The altitude ranges from almost sea level to the frost line, but, due to competition from vegetable crops (Manwan et al. 1989), sweetpotato is less important at altitudes above 700 m.

Changes in the area harvested of the six major *palawija* crops (maize, cassava, sweetpotato, mungbean, groundnut, and soybean) from *Pelita-1* (the first five-year development plan, 1969-73) to *Pelita-4*, (the fourth five-year development plan, 1984-88) are presented in Table 1. Area harvested for root crops (cassava and sweetpotato) are declining, while maize is rather stable and legume crops (mungbean, groundnut, and soybean) have tended to increase. In proportional terms, maize accounted for about half of the total *palawija* area while root crops and pulses each accounted for about one-fourth of the *palawija* area.

Area harvested of *palawija* crops and sweetpotato from 27 provinces in Indonesia are shown in Table 2. Over the past decade (averages from 1977-79 to 1987-89), total area harvested of *palawija* increased by 12%, while sweetpotato declined by 23%. Out of 27 provinces, five provinces (Central Sulawesi, Bengkulu, Jambi, Central Kalimantan, and East Kalimantan) showed an increase in the sweetpotato area of more than 100%. These provinces are located outside Java and few surveys have been carried out there. In contrast, the five provinces (West Java, East Java, Central Java, Irian Jaya, and North Sumatra) with major areas of sweetpotato showed a negative trend, with area harvested declining by from 7% to 48%. Therefore, changes of area harvested in these ten provinces need special study in relation to the characteristics of market demand for food, feed, and industry.

Changes in Sweetpotato Production

Over the past two decades, from 1969 to 1986, the total area of harvested sweetpotato decreased from 369,000 ha to 229,000 ha or by 38%, while production decreased

Table 1. Changes in area harvested of *palawija* crops from *Pelita-1* to *Pelita-4*.

Crops	Average *Pelita-1* 1969-73	Average *Pelita-2* 1974-78	Average *Pelita-3* 1979-83	Average *Pelita-4* 1984-88
		('000 ha)		
Cassava	1,434	1,40[illegible]	1,357	1,267
Maize	2,719	2,56[illegible]	2,669	2,940
Soybean	674	709	715	1,057
Mungbean	111	161	243	301
Groundnut	380	463	486	561
Sweetpotato	360	314	268	250
Total *palawija*	5,677	5,610	5,737	6,378
		(%)		
Cassava	25	25	24	20
Maize	48	46	47	46
Soybean	12	13	12	17
Mungbean	2	3	4	5
Groundnut	7	8	8	9
Sweetpotato	6	6	5	4
Total *palawija*	100	100	100	100

Source: Processed Central Bureau of Statistik data 1969-88.

Table 2. Total area harvested of *palawija* crops and area harvested of sweetpotato, 1977-79 and 1987-89 averages.

Province	Total *palawija* area harvested (ha) (average)[a] 1977-79 (1)	1987-89 (2)	Decrease or Increase (%) (3)[c]	Sweetpotato area harvested (ha) (average)[b] 1977-79 (1)	1987-89 (2)	Decrease or Increase (%) (3)[c]
West Java	445,029	484,682	8	48,446	45,019	-7
East Java	2,167,080	2,036,110	-6	48,046	24,810	-48
Central Java	1,252,568	1,202,416	-4	34,707	24,399	-30
Irian Jaya	40,250	42,023	4	31,170	24,296	-22
North Sumatra	114,330	177,152	35	22,478	15,868	-29
East Nusatenggara	312,055	336,291	7	25,042	14,362	-43
Central Sulawesi	46,327	54,105	14	3,728	10,946	194[d]
Bali	115,664	117,737	2	17,458	9,023	-48
South Sulawesi	409,806	451,362	9	11,790	8,442	-28
West Nusatenggara	126,562	191,180	34	12,555	8,104	-35
South Sumatra	42,434	98,902	57	5,248	6,419	22
North Sulawesi	120,263	134,614	11	8,523	4,438	-48
Bengkulu	7,732	29,040	73	1,232	4,178	239[d]
West Sumatra	19,199	55,178	65	2,324	3,951	70
Southeast Sulawesi	79,639	83,007	4	6,016	3,797	-37
Jambi	7,490	37,304	80	1,218	3,255	167[d]
West Kalimantan	32,610	40,470	19	1,856	2,854	54
Maluku	49,112	34,068	-44	8,852	2,779	-69
Central Kalimantan	12,560	22,201	43	1,232	2,600	111[d]
Lampung	168,046	457,527	63	2,548	2,573	1
East Timor	NA	51,327	NA	NA	2,478	NA
East Kalimantan	9,794	25,121	61	1,030	2,453	138[d]
Riau	19,904	35,975	45	1,649	2,355	43
Aceh	25,620	150,151	83	1,497	2,261	51
South Kalimantan	18,899	36,918	49	3,484	2,258	-35
Yogyakarta	189,595	211,338	10	2,176	1,267	-42
Jakarta	1,017	209	-387	250	22	-91
Indonesia total	5,833,583	6,596,408	12	304,552	235,204	-23

Source: Processed Central Bureau of Statistik data.

[a]Total area harvested of *palawija* crops (maize, cassava, sweetpotato, soybean, peanut, and mungbean).
[b]According to the average size of sweetpotato area harvested by province in 1977-89.
[c]$(3) = \frac{(2)-(1)}{(1)} \times 100\%$
[d]Increased more than 100%.

from 2.3 million t to 2.1 million t. During the same period, average sweetpotato yields gradually increased from 6.1 t/ha to 9.3 t/ha, or 52%. Productivity off Java was lower, 8.6 t/ha, than on Java, 10.3 t/ha (Tables 3 and 4).

Farmers near Bogor estimate that sweetpotato yields grown in fertilized rainfed lowlands are about 13-20 t/ha. In Kuningan, farmers calculate that the productivity of sweetpotato ranges from 15-28 t/ha in irrigated fields with fertilizer inputs. In Karanganyar, average yield estimates range from 16-27 t/ha for late maturing varieties. Farmers also estimate that sweetpotato intercropped with maize yields 25-33% less than when monocropped (Watson et al. 1991).

Production Constraints

Manwan and Dimyati (1989) have identified the following production constraints to sweetpotato.

Limited Number of Improved Varieties

Two introduced cultivars, Southern Queen (SQ) 27 and Puerto Rico, were released by Bogor Research Institute for Food Crops (BORIF) and are widely grown by farmers in the Bogor area. The most recent releases from BORIF—Daya, Prambanan, and Brobudur varieties—were not adopted by farmers, probably because of taste and texture preferences. The three cultivars have high yields as well as high carotene and moisture contents, but both farmers and consumers prefer varieties with a dry texture.

Crop, Soil, and Water Management

Soil and water management are the most important cultural practices according to farmers. Fertility is maintained by traditional procedures which are sufficient to sustain the current level of productivity. Many farmers

Table 3. Sweetpotato area harvested and production, 1969-89.

		Area harvested (000 ha)				Production (000 t)			
Plan	Year	Java	Other Islands	Total	Index[a]	Java	Other Islands	Total	Index[a]
Pelita-1	1969	188.0	181.5	369.4	100	1076.8	1182.9	2259.7	100
	1970	185.4	172.2	357.6	97	1073.3	1102.0	2175.3	96
	1971	174.8	182.0	356.9	97	946.5	1264.8	2211.4	98
	1972	160.5	177.3	337.8	91	905.5	1160.8	2066.3	91
	1973	202.6	176.1	378.7	103	1170.4	1216.3	2386.8	106
Pelita-2	1974	165.4	164.9	330.3	89	1181.0	1288.2	2469.2	109
	1975	157.6	153.3	310.9	84	1266.2	1166.5	2432.6	108
	1976	140.6	160.4	301.1	81	1121.6	1259.6	2381.2	105
	1977	151.7	174.6	326.2	88	1134.5	1325.8	2460.4	109
	1978	131.5	169.1	300.5	81	921.8	1161.0	2082.8	92
Pelita-3	1979	117.7	169.2	286.9	78	879.9	1314.5	2194.4	97
	1980	117.2	158.8	276.0	75	870.6	1208.2	2078.8	92
	1981	110.2	164.7	274.9	74	839.7	1253.9	2093.6	93
	1982	95.3	124.4	219.7	59	729.6	946.0	1675.7	74
	1983	117.3	162.8	280.2	76	908.0	1305.1	2213.0	98
Pelita-4	1984	109.0	155.8	264.9	72	875.2	1281.3	2156.5	95
	1985	96.5	159.6	256.1	69	871.4	1290.1	2161.5	96
	1986	99.2	153.8	253.1	68	940.1	1150.5	2090.6	93
	1987	91.4	137.7	229.1	62	892.2	1120.7	2012.8	89
	1988	97.7	150.1	247.8	67	960.7	1198.0	2158.6	96
Pelita-5	1989	97.5	131.3	228.7	62	1004.7	1121.7	2126.4	94

Source: Processed Central Bureau of Statistik data.

[a]1969 = 100.

Table 4. Sweetpotato yields, 1969-89.

Plan	Year	Yield (t/ha)			
		Java	Other Islands	Indonesia	Index[a]
Pelita-1	1969	5.73	6.52	6.12	100
	1970	5.79	6.40	6.08	99
	1971	5.41	6.95	6.20	101
	1972	5.64	6.55	6.12	100
	1973	5.78	6.91	6.30	103
Pelita-2	1974	7.14	7.81	7.48	122
	1975	8.03	7.61	7.82	128
	1976	7.97	7.85	7.91	129
	1977	7.48	7.59	7.54	123
	1978	7.01	6.87	6.93	113
Pelita-3	1979	7.47	7.77	7.65	125
	1980	7.43	7.61	7.53	123
	1981	7.62	7.61	7.62	125
	1982	7.66	7.61	7.63	125
	1983	7.74	8.01	7.90	129
Pelita-4	1984	8.03	8.22	8.14	133
	1985	9.03	8.08	8.44	138
	1986	9.47	7.48	8.26	135
	1987	9.76	8.14	8.79	144
	1988	9.83	7.98	8.71	142
Pelita-5	1989	10.31	8.55	9.30	152

Source: Processed Central Bureau of Statistik data.

[a]1969 = 100.

do not apply any fertilizer. For those who use fertilizer, single and double applications are common.

Pests and Diseases

The most important pests and diseases are root weevil and scab. Weevil has been reported from production centers in Java and Irian Jaya, while scab disease has been recorded in Java, Irian Jaya, Lampung, and Sumatra. Viruses have been reported in Lampung and South Sumatra, but these are not considered to be important diseases for sweetpotato production.

Storage and Marketing

For commercial farmers in Java and other islands, storage of sweetpotato is not important. All farmers sell the roots before or just after harvest. Only a small portion, around 50-200 kg per harvest, is brought home for family use. Distribution and marketing will be explained in subsequent sections of this paper.

Comparative Advantage and Cost and Return Analysis

Production decisions taken by farmers are based on expectations about prices, yields, and input requirements, as well as other economic, biological, and social considerations (Longmire and Winkelmann 1985). Analysis of the comparative advantage of agricultural commodities is useful in planning and policy decision making processes concerned with the efficiency of production systems. Comparative advantage analysis can also help the policy maker, the planner, and the researcher when setting up projects pertaining to agricultural diversification, agroecological zones, or technology to be generated and adopted (Manwan et al. 1990).

The Central Research Institute for Food Crops (CRIFC) (Manwan et al. 1990) has developed a simple analysis of comparative advantage for a certain crop by comparing the minimal yield that can be produced by the crop which gives a net profit of at least the same amount as other crops.

In Java, sweetpotato should give minimal yields of: 4.7 t/ha, 6.7 t/ha, 6.4 t/ha, and 6.1 t/ha, to have a net income comparable to maize, cassava, soybean, or groundnut, respectively. These figures reveal that sweetpotato, with a yield of 9.8 t/ha, has a high comparative advantage with other *palawija* crops. Outside Java, however, where sweetpotato productivity is lower (8.2 t/ha), its comparative advantage is lower or higher.

In relation to cost and return analysis, Table 5 shows that sweetpotato contributed more to net income than any other *palawija* crop, both in Java and outside Java. In terms of return on investment (ROI), farmers outside Java can obtain an ROI of about ten times, while farmers on Java can obtain an ROI of only 3.6 times.

Farmers in Kuningan estimated that their sweetpotato productivity ranged from 15-28 t/ha in irrigated areas with fertilizer inputs and, in Karanganyar, average yields are estimated to range from 16-27 t/ha for late maturing varieties.

Marketing and Utilization of Sweetpotato

Remarks on marketing and utilization are based on the study conducted by the survey team of CRIFC and International Potato Center (CIP).

Marketing

A study was conducted in seven villages located within three centers of commercialization in West and Central Java. The team selected the two provinces in Java based on the criterion that the area has had the highest production of sweetpotato. Three districts (Bogor and Kuningan districts in West Java; Karanganyar district in Central Java) were selected based on the hectarage under sweetpotato.

Two major methods of marketing sweetpotato were identified. The first method, sweetpotato sold directly after harvest to village collectors. The second method is the contract harvester or *tebasan* system. In the *tebasan* method, a middleman purchases a standing crop, harvests it, and arranges its transportation and marketing. Farmers prefer the *tebasan* system because: (1) it is well established, so the sales are easy; (2) it minimizes risks of damage or weight loss in yield; and, (3) it saves the cost of monitoring labor for harvesting work.

Farmers receive around 50-60% of the consumer price according to this study. This proportion varies depending on the transportation cost, sweetpotato supply, and market demand.

Market segmentation differs among regions and for different sweetpotato cultivars. The Lampeneng cultivar from Kuningan District is generally marketed in Jakarta, while Gitok and Ceret varieties are mostly sold in Bandung. Bestak and Mangkokan cultivars from Karanganyar District, are marketed in the subdistrict market Tawangmangun or sold in Solo, Central Java. In general, village collectors are eager to sell sweetpotato in Jakarta because prices in the Jakarta market are higher than in other areas.

Farmers in Central Java reported that during the peak harvest season, farm gate prices can drop substantially. In the dry season, farmers could avoid the predictable low price by harvesting earlier or later. They point out, however, that the price of sweetpotato is more stable than that of perishable vegetables. Most of the farmers noted that sweetpotato is more profitable than rice. This primary information is entirely consistent with the secondary data from CBS (Tables 5 and 6).

Utilization

Sweetpotato is typically consumed in boiled form. It is eaten as a breakfast snack, as a side dish vegetable, and is also cooked with bananas in sweetened coconut milk and eaten as a *kolak* (dessert) or sliced, uncooked, into fruit salads (*rujak*). Different sweetpotato cultivars are used to produce different food products, especially snacks.

Another important role of sweetpotato is as a supplementary food and side dish in the diet of farmers who produce sweetpotato for sale and is, as such, an important dietary suplement. Sweetpotato is usually eaten as a "filler" food—particularly for breakfast, and its consumption is seasonal.

Women farmer respondents stated that children generally eat the largest amount of sweetpotato, usually in boiled form. Adults consume relatively little sweetpotato.

The preferences for sweetpotato differ according to age. Children prefer the yellow or orange skinned, soft,

Table 5. Minimum yield of sweetpotato required for equal returns compared with other *palawija* crops, 1988.

Commodity	Yield (kg/ha)	Price (Rp/kg)	Gross income (Rp/ha)	Production costs (Rp/ha)	Net farm income (Rp/ha)
Java					
Maize	2,078	168 (B1)	349,104	138,127 (D1)	210,977 (E1)
Cassava	12,250	59 (B2)	722,750	170,811 (D2)	551,939 (E2)
Soybean	1,126	639 (B3)	719,514	197,122 (D3)	522,392 (E3)
Groundnut	948	799 (B4)	757,452	257,926 (D4)	499,526 (E4)
Sweetpotato with respect to:		82 (B5)		172,430 (D5)	
Maize	4,676 (F1)		383,432		211,002
Cassava	6,731 (F2)		551,942		379,512
Soybean	6,371 (F3)		522,422		349,992
Groundnut	6,092 (F4)		499,544		327,114
Other islands					
Maize	1,755	160 (B1)	280,800	67,154 (D1)	213,646 (E1)
Cassava	11,407	65 (B2)	741,455	96,244 (D2)	645,211 (E2)
Soybean	1,012	552 (B3)	558,624	123,677 (D3)	434,947 (E3)
Groundnut	1,007	853 (B4)	858,971	176,849 (D4)	682,122 (E4)
Sweetpotato with respect to:		106 (B5)		79,179 (D5)	
Maize	2,763 (F1)		292,878		213,699
Cassava	6,089 (F2)		645,434		566,255
Soybean	4,103 (F3)		434,918		355,739
Groundnut	6,435 (F4)		682,110		602,931
Indonesia					
Maize	1,961	166 (B1)	325,526	112,458 (D1)	213,068 (E1)
Cassava	11,911	61 (B2)	726,571	140,805 (D2)	585,766 (E2)
Soybean	1,091	614 (B3)	669,874	174,594 (D3)	495,280 (E3)
Groundnut	971	820 (B4)	796,220	226,535 (D4)	569,685 (E4)
Sweetpotato with respect to:		96 (B5)		115,942 (D5)	
Maize	3,427 (F1)		328,992		213,050
Cassava	6,102 (F2)		585,792		469,850
Soybean	5,159 (F3)		495,264		379,322
Groundnut	5,934 (F4)		569,664		453,722

Source: Processed Central Bureau of Statistik data.

Note: F1 = (E1+D5)/B5; F2 = (E2+D5)/B5; F3 = (E3+D5)/B5; F4 = (E4+D5)/B5.
Exchange rate: US$ 1 = Rp 1,694 (1988); US$ 1 = Rp 1,999 (1991).

watery, very sweet, and wet cultivars such as Ceret. On the other hand, adults prefer white skinned, white and firm fleshed, sweet, and dry cultivars such as Lempeneng.

In terms of fresh root consumption, the respondents in the study areas reported that they consumed more than the national average. In Peusing, Puntuk Rejo and Karanglo, Kuningan, West Java, average consumption is 68 kg/month/family, while in Wargajaya, Bogor, respondents reported about 60 kg/month/family. National Socio-economic Survey (*Susenas*) and CBS recorded that consumption of sweetpotato (fresh root) in rural areas in 1987 was 159 gr/week/capita.

Table 6. Cost and return analysis of *palawija* crops, 1988.

Items	Sweetpotato	Maize	Cassava	Soybean	Ground-nuts
Java					
Yield (kg/ha)	9,842	2,078	12,250	1,126	948
Price (Rp/kg)	82	168	59	639	799
Gross income (Rp/ha)	807,044	349,104	722,750	719,514	757,452
Total costs (Rp/ha)	172,430	138,127	170,811	197,122	257,926
Net income (Rp/ha)	634,614	210,977	551,939	522,392	499,526
ROI (%)	368	153	323	265	194
BE yield (kg)	2,103	822	2,895	308	323
BE price (Rp/kg)	18	66	14	175	272
Other islands					
Yield (kg/ha)	8,234	1,755	11,407	1,012	1,007
Price (Rp/kg)	106	160	65	552	853
Gross income (Rp/ha)	872,804	280,800	741,455	558,624	858,971
Total costs (Rp/ha)	79,170	67,154	96,244	123,677	176,849
Net income (Rp/ha)	793,634	213,646	645,211	434,947	682,122
ROI (%)	1,002	318	670	352	386
BE yield (kg)	747	420	1,481	224	207
BE price (Rp/kg)	10	38	8	122	176
Indonesia					
Yield (kg/ha)	8,868	1,961	11,911	1,091	971
Price (Rp/kg)	96	166	61	614	820
Gross income (Rp/ha)	851,328	325,526	726,571	669,874	796,220
Total costs (Rp/ha)	115,942	112,458	140,805	174,594	226,535
Net income (Rp/ha)	735,386	213,068	585,766	495,280	569,685
ROI (%)	634	189	416	284	251
BE yield (kg)	1,208	677	2,308	284	276
BE price (Rp/kg)	13	57	12	160	233

Source: Processed Central Bureau of Statistik data 1988.

Note: ROI = Return on investment; BE = Break-even.

Exchange rates: US$ 1 = Rp 1,694 (1988); US$ 1 = Rp 1,900 (1991).

Analysis of CBS data on domestic utilization of sweetpotato from 1977 to 1987 shows that demand for food declined (-1.6% annually), while demand for feed remained stable. In the case of cassava, annual demand increased for food by 2.6%, feed by 2.1%, and industry by 30.2% (Table 7).

Industrial Processing

Utilization of sweetpotato for industrial processing has not been recorded. CRIFC observed that sweetpotato is used for sauce and chips and is processed by small- and medium-scale industries. The commercial farmers in Java considered sweetpotato more profitable, since it does not require a lot of inputs and it has low risk when compared to other *palawija* crops and most vegetables.

The number of industrial processing units for tapioka flour in Central Lampung was 71, Ciamis, 83, and Bogor, 49. Processing units in Ciamis and Bogor are small- and medium-scale, while in Lampung they are mostly large-scale (Irawan 1990).

Greater utilization of sweetpotato in the form of flour has potential. This can improve storability and the stored product can be used for making many kinds of food (Suismono et al. 1990).

Table 7. **Total supply and domestic utilization (000 t) of *palawija* crops in Indonesia, 1977-87.**

Item	Year											CGR
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	(%)
Sweetpotato												
Total supply	2,460	2,083	2,194	2,079	2,094	1,676	2,213	2,157	2,161	2,091	2,013	-1.2
Utilization:												
for food	2,214	1,875	1,975	1,789	1,801	1,440	1,904	1,855	1,859	1,798	1,732	-1.6
for feed				41	42	34	44	43	43	42	40	0.5
for industry												
Waste	246	208	219	208	209	168	221	216	216	209	201	-1.2
Cassava												
Total supply	12,016	12,049	11,779	12,653	12,265	12,372	11,355	13,046	12,496	12,094	14,356	2.1
Utilization:												
for food	10,356	10,359	9,734	10,382	9,686	9,853	8,978	9,695	9,660	8,573	12,203	2.6
for feed	240	241	234	253	245	247	227	261	250	242	287	2.1
for industry	218	244	287	373	740	664	674	1,394	962	1,707	--	30.2
Waste	1,202	1,205	1,524	1,645	1,594	1,608	1,476	1,696	1,624	1,572	1,866	5.0
Maize												
Total supply	3,142	4,034	3,787	3,942	4,520	3,284	5,068	5,231	4,375	5,984	5,373	8.1
Utilization:												
for seed	73	64	65	65	69	63	0	66	62	74	62	
for food	2,943	3,808	3,458	3,443	3,638	2,630	4,156	4,372	3,531	4,870	4,720	7.7
for feed	63	81	75	237	271	197	304	314	262	359	322	29.2
for industry					316	230	355	217	301	382	--	10.8
Waste	63	81	189	197	226	164	253	262	219	299	269	22.1
Soybean												
Total supply	612	747	847	754	703	531	768	1,142	1,143	1,602	1,411	11.5
Utilization:												
for seed	30	31	35	32	35	34	34	44	34	47	42	4.8
for food	551	679	770	684	633	470	696	1,041	1,052	1,475	1,298	11.9
for feed												
for industry[a]												
Waste	31	37	42	38	35	27	38	57	57	80	71	11.2
Groundnut												
Total supply	387	423	424	479	483	500	502	556	545	676	366	1.4
Utilization:												
for seed	36	34	33	35	34	34	35	33	32	37	33	
for food	328	364	367	443	441	466	456	523	513	605	311	1.8
for feed												
for industry	23	25	24	1	8	0	11	0	0	0	4	42.0
Waste										34	18	-4.7

Source: Central Bureau of Statistik.

[a]Utilization of soybean grain for tempe, tofu and other soybean processed products are included in the utilization for food.

Cost and return analysis for sweetpotato and cassava flour (Table 8) shows that if the selling price of the product is Rp. 450/kg and price of raw materials is Rp. 106/kg for sweetpotato and Rp. 65/kg for cassava, respectively, the net profit for sweetpotato flour is Rp. 32/kg, and for cassava flour Rp. 125/kg.

Since the price of sweetpotato and cassava as raw materials fluctuates, the minimum price of sweetpotato roots is Rp. 96/kg in order to obtain a positive net profit for sweetpotato flour whose selling price would range from Rp. 400/kg to Rp. 500/kg. Similarly, the minimum price of cassava roots is Rp. 75/kg (Table 9).

Government Policy and Strategic Intervention

The *palawija* crops intensification program started in 1972-73. However, among the *palawija* crops, only maize and soybean were selected as major components

Table 8. Cost and return analysis of sweetpotato and cassava flour.

Item	Cassava	Sweetpotato
(1) Conversion factor (%)	0.25	0.30
(2) Price of raw material (Rp/kg)[a]	65	106
(3) Total value of raw material (Rp)[b]	260	353
(4) Production cost of root flour (Rp/kg)	65	65
(5) Selling price of root flour (Rp/kg)	450	450
(6) Profit (Rp/kg)[c]	125	32

Source: Processed from Adnyana et al. 1991.

[a]CBS data, average price of outside Java, refer to Table 6.
[b](3) = (2)/(1).
[c](6) = (5)-(4)-(3).

Table 9. Net profit assuming different prices for cassava and sweetpotato flour, and raw material.

Price of raw material (Rp/kg)	Price of flour 400	425	450	475	500
Sweetpotato					
76	82	107	132	157	182
86	48	73	98	123	148
96	15	40	65	90	115
106	-18	7	32	57	82
116	-52	-27	-2	23	48
126	-85	-60	-35	-10	15
136	-118	-93	-68	-43	7
Cassava					
35	195	220	245	270	395
45	155	180	205	230	230
55	115	140	165	190	215
65	75	100	125	150	175
75	35	60	85	110	135
85	-5	20	45	70	95
95	-45	-20	5	30	55

Source: Derived from Table 8.

of the program. Consumption of soybean is increasing steadily, due to an increasing demand for soybean as a raw material for animal feed, and the strong demand for soybean products (CGPRT 1988).

More recently, the government has given top priority to the food diversification program. Strategic implementation of sweetpotato production will depend substantially on the availability of improved production technologies for different soil conditions (Manwan and Dimyati 1989). The national research program must generate appropriate technologies to meet the demand for further yield increases in sweetpotato.

The national sweetpotato research program is designed to address the most critical constraints and to achieve the objectives of the agricultural development plan. The CRIFC has outlined the following objectives.

- Sustaining self-sufficiency in food and improving the national diet.

- Improving farmers' and rural laborers' incomes and welfare as well as increasing employment opportunities.
- Increasing export earnings and reducing imports of agricultural commodities while supporting national industries.
- Optimizing the productive utilization of natural resources.
- Stimulating more integrated and more harmonious rural development.

The CRIFC is the main organization responsible for coordinating research activities on food crops, including cereals, legumes, and root crops. Collaborative work has been undertaken by Malang Research Institute for Food Crops (MARIF) in East Java, Maros Research Institute for Food Crops (MORIF) in South Sulawesi, Brawijaya University, and Cendrawasih University. Root-crop research, including sweetpotato, has been supported by International Development Research Center (IDRC), Southeast Asian Program for Potato Research and Development (SAPPRAD), and CIP.

Conclusion

Over the past decade, the five major sweetpotato producing provinces (West Java, East java, Central Java, Irian Jaya, and North Sumatra) showed a decline in areas harvested of 7-48%. In contrast, areas outside Java (Central Sulawesi, Bengkulu, Jambi, Central Kalimantan, and East Kalimantan) showed a considerable increase in area planted with sweetpotato. The reasons for this increase/decrease in area merit further study.

Analyses revealed that sweetpotato has a high comparative advantage compared to other *palawija* crops like maize, soybean, groundnut, and cassava. In addition, the ROI of sweetpotato is considerably higher than that from other *palawija* crops. Therefore, sweetpotato is more profitable than the others.

Macro (CBS) data analyses of domestic utilization of sweetpotato from 1977 to 1987 indicate that the demand for sweetpotato as food has declined, while the demand for feed has remained stable. In cassava, the demand for food, feed, and industry increased by 2.6%, 2.1% and 30.2% per year, respectively.

Farmers in the two major producing areas in West Java and Central Java received around 50-60% of the retail price. Farmers reported that the price of sweetpotato is more stable than that of perishable vegetables and that sweetpotato is more profitable than rice or other *palawija* crops. These results are consistent with the analysis of secondary data from CBS.

The government of Indonesia has launched a *palawija* crops intensification program over the last *Pelita.* Maize and soybean, rather than sweetpotato, receive high priority in this program. More recently however, the government has placed considerable emphasis on crop diversification.

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IV. Products and Processing Research

Having analyzed the recent trends in production, marketing, and utilization in the case of a particular commodity in a given country, the alternatives for new product and process development then could be assessed. Results of that assessment enable researchers to focus on particular products or processes that have the greatest probability of success. This section begins by outlining procedures to do this type of research. Experiences acquired with different products and processes made from potatoes, sweetpotatoes, and cassava are presented in the subsequent papers.

In order for a specific product or process to realize its full potential, a systems approach calling into consideration a number of interrelated factors provides a useful framework. In **Research in Support of Process and Product Development**, Rupert Best, Gregory J. Scott, and Christopher Wheatley describe procedures for analyzing consumers' tastes and preferences, market structure in terms of the number of buyers and sellers, and the supply patterns for raw materials as well as for conducting technical product and processing research. Some specific methodological tools like creating an idealized system for converting the .aw material into the desired product, and the use of project briefs are also explained. Examples based on potato processing in Peru and Colombia illustrate the application of these procedures.

Research on equipment, organizational structure, marketing, and financing as well as technical work on processing different products are highlighted in **SOTEC Village-Level Potato Processing Development: Organization and Marketing** by Robert W. Nave. Nave observes that establishing the procedures for making solar-dried chips, strips, and potato powder by small, village units of 10-15 people in India required more finances, time, and effort than initially estimated. He nevertheless contends that the most difficult and expensive part of the program proved to be setting up and operating an organization to coordinate small, scattered, village-based processing units.

Based on his experience in the Philippines, Truong Van Den analyzes three modes of transfer for processing technology: direct extension and exclusive and non-exclusive contracts. He then goes on to identify a series of key factors factors involved in the process depending on the user of the technology (i.e., commodity-based project, private company). His paper, **Transfer of Sweetpotato Processing Technologies: Some Experiences and Key Factors**, also characterizes commercial sweetpotato products according to use, processing steps, and suitability for home or industrial use.

Henry C. Samar, Sr.'s paper, **Product Development at the Local Level: Mayon Brand Sweetpotato Catsup and Jam,** briefly reviews the history of launching these products and processes in the Bicol area of the Philippines. The paper includes a series of recommendations including a plan of action to sustain such initiatives, dissemination of information about the importance of sweetpotato, and establishment of commercial advertising for processed products.

In **Sweetpotato Processing in the People's Republic of China with Emphasis on Starch and Noodles**, Siert G. Wiersema briefly reviews the evolution of sweetpotato utilization in China over the last 20 years. Wiersema points out the tremendous growth in sweetpotato processing at the household level both for human consumption and animal feed. This now accounts for some 75% of total output, or roughly 75 million t per year. He then describes sweetpotato processing for starch and noodles in Sichuan Province. Wiersema concludes by noting that a detailed technical and socioeconomic analysis of current processing methods is required before specific changes to upgrade the existing system can be recommended.

Winston H. Timmins, Alan D. Marter, A. Westby, and June E. Rickard provide a more detailed look at sweetpotato processing in **Aspects of Sweetpotato Processing in Sichuan Province, People's Republic of China.** They describe the basic processes employed for the extraction of starch and subsequent manufacture of transparent noodles for human consumption. In particular, they offer an account of an unusual traditional process known locally as the "sour-liquid method." Preliminary work carried out on the characteristics of the starch and microbiology of the fermentation operation used to prepare the sour liquid also are reported.

Recent **Sweetpotato Starch and Flour Research in Thailand** has included the bio-chemical analysis of 34 varieties for moisture content, fiber, ash, dry weight, and dry matter. Saipin Maneepun, Suparat Reungmaneepaitoon, and Montatip Yunchalad also report on the starch content of these varieties, three of which were used for flour production. Based on their research results to date, the authors observe that sweetpotato flour has promising potential for commercial development as a substitute for rice flour in snack foods.

Several types of equipment have been developed at Visayas State College of Agriculture (ViSCA) in the Philippines for processing cassava into a variety of products (e.g., dehydrated cubes, fried strips) that do not pass the flour stage. Felix J. Amestoso and Agustin L. Dignos describe the operation and performance of this equipment: a cuber-sorter, a strip cutter, a slicer, and a grater-pulverizer. In **Small-scale Equipment for Processing Food Products from Cassava,** the authors note that these equipment now require pilot testing to improve their usefulness.

The Philippine Root Crop Research and Training Center (PRCRTC) has developed various pieces of small-scale equipment for root crop flour processing at the rural level. In **Cassava Flour Processing: ViSCA's Experience,** Alan B. Loreto describes the process for producing the flour. He then briefly reviews two attempts to transfer this technology to local entrepreneurs. In his concluding remarks, he notes that the potential for substituting cassava flour for wheat flour still needs a thorough economic analysis.

Bakery products made from wheat flour have become a widely accepted part of the Filipino diet. As considerable wheat flour is imported, recent research has focused on ways to develop local substitutes with acceptable quality characteristics. L. S. Palomar's paper, **Formulation and Evaluation of Sweetpotato and Cassava Chiffon Cake,** reports results of experiments to evaluate sensory and consumer acceptability of these products and to determine their shelf life. The findings indicate considerable potential for both forms of substitute flour.

In Indonesia, growers have little incentive to produce more cassava. Production has grown from 9.3 million t in 1972 to over 17 million t in 1989. As a result, the domestic market for fresh roots is saturated. The export quota to the European Community (EC) has already been filled. In **Development of Cassava Processing at the Village Level in Indonesia**, Djoko S. Damardjati, S. Widowati, and Abdul Rachim describe the cassava flour processing industry. They then present an economic analysis of three alternative models for developing this sector both to increase farmers' incomes and to reduce wheat imports in the future. Their results indicate that domestic cassava flour production is technically and economically feasible.

Vietnam produces 2.6-2.8 million t/yr of cassava. Improvements in village-level processing are needed because: (1) poor infrastructure requires that most processing be done in the countryside; (2) fresh cassava spoils rapidly after harvest; and (3) losses of up to 30% occur utilizing traditional processing and storage techniques. In **Development of Milksap-free Cassava Half-product in Vietnam**, Quach Nghiem describes a technology developed by the National Institute of Agricultural Sciences (INSA) that permits the farmer to process a large amount of fresh roots under any climatic condition and without drying. Transfer of this technology to the farm level has now begun. Economic analysis of its impact on farmers incomes will also be undertaken.

Research in Support of Product and Process Development

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Abstract

Consumers' tastes and preferences, market structure in terms of the number and size of participating firms, supply patterns for raw materials, and the state of existing processing technology are all key areas for product development research. This paper describes procedures for realizing the potential for new products and processes based on a systematic review of these factors. Market and consumer-oriented research methods are discussed first given that demand-driven processing endeavors have demonstrated the greatest probability of success. Farmer-level investigations are considered next so as to not overlook potential supply-side obstacles to product development. Product and process research is then outlined i some detail. The paper includes two appendices that illustrate the use of the procedures presented.

Key words: markets, consumers, farmers, processes, methods.

Introduction

Having identified a product that appears to have commercial potential, and knowing where a processing project could be located—an assertion based on the present and potential production of the selected commodity in a particular region, four critical questions need to be answered:

- What is the demand for the product?
- What are the key characteristics of raw material supply?
- Is there a suitable processing technology available for producing the product to the desired quality standards?
- Will it be profitable to produce the product?

Some information may already be available to formulate partial answers to these questions. However, before continuing to the next product development step/pilot scale operation, it is often necessary to undertake research to generate additional information on which to base a sound decision as to whether or not to continue with the project idea as originally proposed.

Two types of research are required:

Market and consumer research to characterize the existing production, marketing, and consumption patterns of the selected commodity and of products that could compete with the contemplated product. The information provided by these studies will highlight many of the socioeconomic, cultural, and technical constraints that will have to be taken into account in order to achieve success.

Technical research to develop the product idea according to consumer tastes and preferences, and to design processing technology that is appropriate to the scale of operation envisaged.

A Systems Approach to Research Planning

The first step in research planning is to create an idealized system for converting the raw material into the desired product by breaking the system down into those different components that will have to be linked if the

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project is to be a commercial success. The system components will include:

- production of the raw material;
- processing to transform the raw material into an end product. Often more than one processing component will be involved, with the raw material being transformed into a primary product, such as flour or starch, which is then used as a raw material to manufacture the final product through a secondary processing stage;
- marketing to make the product available to the consumer or client. Marketing, is often carried out at different levels, involving, for example, wholesalers and retailers; and,
- consumption of the product by consumers and clients. For the purpose of this approach, "consumers" refers to the ordinary man or woman who buys food products for consumption; and "clients" refers to industries that purchase primary products derived from roots and tubers as raw materials for the manufacture of products for human and animal consumption or for industrial use. Consumers are a heterogeneous group who show markedly different food preferences and habits depending upon their socio-economic status. Clients are much more homogeneous in their requirements for a particular product.

Many of the components of this ideal system already exist. For example, the geographical region where the project will be carried out will almost certainly have farmers that are cultivating the chosen commodity. Also, the potential consumers or clients of the new product have tentatively been identified. What may be missing, according to the particular circumstances in the selected region or country, are the processing and distribution components. Even these components may be present if the project contemplates expanding the market of an already existing product through reduced production costs and improved quality or diversified end uses.

Once the ideal system has been created it is a fairly straightforward exercise to enumerate the socio-economic, market, and technical issues that will need to be confronted for the system as a whole to be viable. An example of this approach is shown in Figure 1 which refers to a research project in Colombia on the production and utilization of a wheat-cassava composite flour. In this case, the objective was to link small-scale cassava farmers to the urban bakery product market through rural processing of cassava into flour. To facilitate the production of the composite wheat-cassava flour, it was proposed that wheat mills do the mixing for subsequent sale to bakeries using the wheat mills' own distribution channels. The missing component in this system is the processing of cassava into flour. However, as can be appreciated from the description of the issues to be researched, they were not restricted to those directly related to the supply of cassava, its processing into flour and the sale of the flour to the wheat mill. This holistic, systems approach is helpful in identifying possible constraints that may not be immediately removable but should be taken into account and investigated during the research phase.

Characterizing the System Components

Once the various components that make up the system for producing the desired product have been defined, an analysis of the socio-economic and technical conditions under which the individual components operate will help to quantify and qualify the restrictions to establishing the proposed processing industry.

Market and Consumer Research

Processing—particularly new processing initiatives—frequently raises many technical and economic questions concerned with the production of these products. Perhaps for that reason, a tendency often develops to focus on solving these types of problems first and to worry about the marketing and eventual use of processed products later. The danger of this approach is in forgetting that the commercial success of processing depends more on what people will buy and how it will be used than on whether it can be made. A clear understanding of market/consumer requirements at the earliest phase of product development is therefore essential. This involves two complementary tasks:

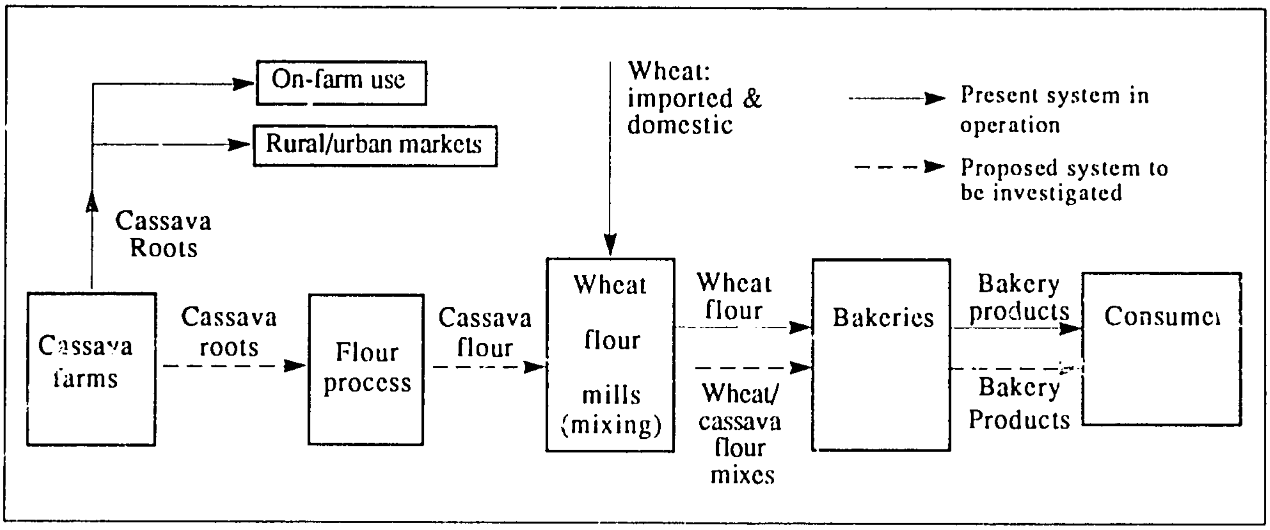
- an inventory of processed products already available in the market; and,
- an assessment of consumer attitudes towards these products.

Market research

The three essential components of market research are:

- identifying the types of processed products for sale and their characteristics, including where they are sold (e.g., marketplace, supermarket, shop, etc.);

Figure 1. Composite wheat-cassava flour (CF) system and the major issues for an integrated research program.



Socio-economic and market issues

Costs of production with & without new technology. Output prices in traditional cassava markets. Potential for production increase with new markets. Changes required in system to meet requirements of processing plant. Evaluations of increase in farmer incomes due to development of flour market.	Investment costs of alternative processing methods. Evaluation of alternative organization and management schemes. Calculation of per unit costs of flour processing.	Model of price determination for wheat & bread demand. Evaluation of cost increase for CF production. Determination of price differential between cassava & wheat flour to motivate CF production. Evaluation of difference in social benefits due to government legislation vs market prices in CF production.	Price differential required to motivate use of CF.	Consumer preference for different bread types. Evaluation of whether a price differential is necessary to motivate consumer acceptance.

Technical issues

Evaluation of varieties for flour quality at different planting and harvesting dates. Evaluation of improved production technology.	Development & evaluation of selection, washing, peeling, drying, milling & storage methods for producing cassava flour. Quality control of product.	Determination of additional equipment needed to produce CF. Storage characteristics of CF.	Determination of local bread types & quality parameters. Evaluation of different % mixtures on bread quality. Effect of variety, harvesting age & processing on flour characteristics and bread quality. Adjustment of breadmaking techniques for CF.	

- estimating the most important processed products by the volume and value of products sold; and,
- determining what factors impede expansion of sales.

This information is intended to answer certain basic questions about the proposed processing activity. For example, will the processing create a totally new product (because there are no others like it currently in the market place)? Will it be a modified, improved version of existing products (e.g., appearance, package, size of unit of sale)? Is there already a considerable volume of similar products being sold? Or, is there currently little interest in this type of product? According to wholesalers, retailers, and consumers what factors are most important in discouraging greater sale/use of this type of product (e.g., price, appearance, use)?

It is fairly easy to prepare a list of processed products produced from a particular food crop based on visits to representative markets in a given place. There are simply not that many products available for each of the major food crops. Still, one may be surprised to find more than one had imagined or was familiar with. This list of products should also include information about their respective characteristics, e.g., color, size, shape, type of package, size of unit of sale, price. "Representative markets" refers to the types of places people shop (e.g., store, streetmarket, covered market, supermarket), not to a particular location where people shop. It is also wise to visit intermediate users (e.g., bakeries, restaurants) as well as industrial concerns (e.g., flour mills, confectionary companies) to complete the identification of existing products.

Casual conversations with retailers, wholesalers, and industrial users can serve to clarify opinions about the marketability of different products. For example, could traders sell more if they could be supplied more? Is price the key factor influencing sales? Appearance? Packaging? Such questions should be posed in a manner that reflects empathy, rather than aggressive curiosity. The parties interviewed are also less likely to be put off by people who don't write down what they say in front of them. A possible solution is to record these conversations immediately after leaving the premises. In the course of this exercise, it can be extremely useful to compare the different opinions expressed to clarify apparent contradictions, to identify common points of view, and to isolate genuine discrepancies.

While there is no substitute for firsthand information of this type, it may also prove useful to consult specialized libraries or documentation centers to check for additional facts and figures. For example, an agro-industrial institute may have feasibility studies that focus on the type of processed products in question. The School of Food Technology at a local agricultural university may be another source. The relevant offices of the Ministry of Agriculture or the Agrarian Bank may also have useful data or be aware of similar attempts in the past that could be looked into.

A word of caution is in order here about who should collect this type of information. Many food technologists and agricultural engineers (even social scientists) have a certain phobia about information gathering in offices and markets. These locations often require the ritual procedures of appointments, written explanations of what is required and why, or, in the case of the market place, they represent a noisy, dusty, and congested contrast to the relative tranquillity of a farmer's field or a science lab. Nevertheless, people who work on processing-related, agricultural research have special qualifications for this type of information gathering. They bring with them their accumulated knowledge about farm commodities and processing techniques. Finding out, for example, how the market works (e.g., who buys what, at what price, in what quantities) may be mundane; but, why it works in such fashion can be positively enlightening. The specialized knowledge of these individuals puts them in a much better position to evaluate the reasons offered and perhaps probe areas less well-trained interviewers might never have asked about. Results of the market survey provide the basis for conducting interviews with consumers.

Consumer Research

Consumers are key decision makers in the development of simple processing. Their tastes and preferences influence the type and quality (color, shape, size) of the products most likely to find ready acceptance. Their purchasing power helps to determine the quantity of such products that can be sold. Hence any prospective processor would do well to take consumers' opinions into consideration prior to launching full-scale production. After a brief statement of the objectives and justification for consumer research, this section describes some simple procedures on how to go about this. Ideally, the same individual(s) who carried out the literature review and market survey would also undertake this research. Knowledge acquired in prior activities is then directly incorporated into this component of the study, sharpening the focus while extending the coverage.

The objective of consumer research is to establish the level of consumer awareness of processed products; whether they are consumed and if so, with what frequency; how consumers characterize the products, positively and negatively; and what the consumer would like in a new product. Product description includes form, flavor, preparation time, storage characteristics, and price. It should be noted that the type of consumers interviewed will depend on the product. For example, processed products for restaurants or industrial use would require contacting restaurants and industrial buyers, not household consumers.

There are various reasons for consumer research. This process aims to distinguish those types of products that have the greatest—or least—potential because they are/are not desired on the basis of one or more attributes such as taste, appearance, or use. Similarly, it attempts to discover those that are the most/least affordable. Such research also seeks to identify those characteristics that are most desirable in existing products or that because of their presence, e.g., poor quality control or unattractive appearance, discourage greater consumption. For example, a prospective processor wants to produce industrial starch, but contacts with possible future clients point to the inexpensive price of currently available substitute products due to a cheap raw material price. Most people can readily think of an example of a new product that was supposed to be widely accepted, but then turned out to be a complete failure.

Consumer interviews may be carried out in an informal fashion, i.e., without a written questionnaire; with or without a list of topics to be covered; or utilizing a survey form. The latter facilitates collection of quantitative responses, e.g., by imposing standard units of measure, and more extensive amounts of information. The former is by definition more flexible. Whether one procedure is more appropriate than the other will depend, among other things, on the number of processed products that questions are to be asked about, the amount of information already available in the literature or through the market survey; and the experience of the researchers in conducting informal interviews.

Both procedures involve considerable advance preparation to specify the questions to be asked or topics to be addressed and the way they should be phrased to avoid confusing the persons interviewed. Table 1 presents a list of questions for consideration in this regard (see also Appendix A). Prior to launching the data collection process, it is particularly important to consider how the data will be processed and written up (e.g., are there too many questions to enable ready analysis?). Pre-testing of the questions both on actual consumers and on members of the research team can also be extremely useful in minimizing problems of misinterpretation or repetition.

One of the most important aspects of consumer interviews is to remember that it is a pilot survey. In other words, the results gathered are intended to be indicative, rather than definitive. This characteristic is particularly relevant when considering size and composition of the sample of consumers to be contacted.

Table 1. Questions for consumer research.[a]

Key questions for consumer research (by type of processed product under consideration) include the following:

- What is the current level of annual food crop, e.g., rice, wheat, potato, consumption per capita?
- Does it vary by income group?
- What is the level of consumption for processed products?
- Does consumption of processed products vary by income group?
- Does consumption of processed products vary by season?
- What are the principal types of processed products purchased by consumers?
- Where do they purchase processed products? In what form? and at what price (per weight)?
- Do consumers consider such products nutritious?
- Do they consider these products filling?
- Are processed products considered tasty?
- Do consumers feel that processed products are of attractive, hygienic quality?
- Are the available processed products of the desired size, color, weight (units of sale)?
- In the consumers opinion, do processed products keep well?
- Are processed products easy to utilize in cooking or preparation?
- Do available processed products have different uses, e.g., can they be utilized in various dishes?
- Are such products considered inexpensive? With reference to what substitutes?

[a]This list is by no means exhaustive. See also Austin (1981:29-30) for additional ideas.

Rough guidelines in this regard would be no more than 200 consumers and no less than 50. Any more than 200 raises a series of questions about the time available to do the interviews, analyze the data, and write up the results, as well as the infrastructure required for processing the data. A sample that is too small raises doubts about its representativeness and also preempts much meaningful comparison between the different types of consumers interviewed.

It is essential that the consumer interviews be done with a cross-section of individuals reflecting difference in incomes or a proxy for incomes such as place of residence. For example, obvious distinctions between low-, middle-, and high-income housing areas are easy to identify in most cities in developing countries. The literature should also provide some help in this regard. By interviewing different types of consumers, not only are the current consumption patterns of different groups identified but also some appreciation of the potential for change (e.g., should incomes rise) can be detected.

How does one actually select the consumers to be interviewed? One procedure that was used successfully in Lima, Peru, was to interview people who were in the act of buying processed products. In other words, those contacted probably consumed the articles in question and hence had some opinions to express about them. Furthermore, if questions are to be asked about several items, a simple display of the products to be discussed can both arouse curiosity (hence make consumers eager to be interviewed) and ensure that the names and products that they refer to are not confused. Once the interviews have been conducted, it becomes a question of reporting the results. The example in Appendix A illustrates the use of a market survey and consumer interviews to evaluate the market potential of processed products.

Farm-oriented Research

In addition to having to know who might buy the processed product, the processor has to be sure that the raw material can be obtained for processing and at a reasonable price. One objective of farm-oriented research is to establish what supply patterns exist and whether price movements are such that growers will be interested in selling to a processor or consider processing themselves as an alternative outlet for some/all of the crop. Another is to ascertain whether processors can easily procure sufficient quantities of raw material to justify establishing a processing facility. At this stage, such issues as the quality and uniformity of supply, as well as assembly and transportation costs, must be considered.

Agricultural supply is naturally cyclical while the demands of a processor are stable. Thus processors have to balance the seasonal availability of supply with the steady raw material requirements of their plant and facilities. In some cases, depending on operating costs and returns per production unit, processing can profitably be undertaken during only a few months a year; in others, year-round operation may be needed to earn a profit. Alternatively, growers may already have a ready outlet for their produce even in the peak harvesting period; or they may have only occasional difficulty selling their crop.

The purpose of farm-oriented research is to determine commodity-supply patterns by seasons, varieties planted, experience of producers, and postharvest practices such as grading for size and quality, and the typical uses for these grades. This research also establishes producer preferences for varieties and the reasons why, thereby acquiring information from farmers on varietal characteristics and performance. The potential processor also has interest in the type of varieties available (or potentially available) in order to obtain desired processing characteristics. Growers' marketing habits are also closely examined: marketing channels, their seasonal stability, typical buyers, and traditional arrangements for payment. Once present conditions are mapped out, then the research explores the potential for change to include/expand processing. Finally, constraints that the producers may have in producing or marketing a processed product may also be analyzed.

In carrying out farm-oriented research, it is particularly important to interview different types of representative growers. Small, subsistence growers may have minimal surpluses to sell and hence a limited interest in commercial processing. Just the opposite may apply to growers who seek to maximize profits. The research should aim to measure the interest of both types.

Methods for farm-oriented research include a synthesis of secondary data, a review of available literature, and primary data collection. Information on the annual volume of crop production in a particular region, department, or province can usually be obtained from the Ministry of Agriculture or the National Bureau of Statistics. Commodity programs usually have data on planting and harvesting dates. The size of different types of farmers and their importance as a group in accounting for total production can be estimated from the agricultural census or by synthesizing the results of previous formal farm surveys. Producer prices for specific crops by calendar year (or month-to-month) are often available from the Ministry of Agriculture. Analyzing this information may be sufficient in itself to identify or eliminate certain crops or areas as the most likely current possibilities for processing. For example, perhaps Region "X" produces very few sweetpotatoes and prices for this commodity are always quite high. It is thus unlikely that there would be much immediate interest on the part of growers in sweetpotato processing.

In the event that this analysis suggests strong possibilities for particular foodstuffs in a given location, then it is advisable to check relevant research centers, e.g., university libraries, agro-industrial institutes, to review the available documentation on previous, farm-level attempts to introduce (or improve) processing activities. This search may well uncover ongoing experiments or pilot projects that have proven unsuccessful that merit closer examination to comprehend their operating rationale, track-record, and any major constraints encountered.

A third component of farmer-oriented processing research is contact with growers themselves. The purpose of this exercise is to sound out growers' opinions and listen to the reasons for their stated views. Methods for obtaining this type of information may be formal or informal. The larger the number of possible alternatives, the more precise the quantitative information required, then the more likely that a formal survey may be necessary. The extent to which the range of processing possibilities has been narrowed to one or two, e.g., through analysis of secondary data, may make formal interviews unnecessary.

If the informal approach appears most appropriate, given the time and resources available, several recommendations are in order. Consult the literature on how to carry out such appraisals (see e.g., Rhoades 1982; Khon Kaen University 1987) and to be aware of their strengths and weaknesses (see e.g., Holtzman 1986). For the relatively less-experienced researcher, it is probably advisable to memorize a list of specific topics (if not questions) to pose to growers in the course of these casual conversations. Carefully recording the results of these interviews and contrasting them with the opinions of technical specialists, owner-operators of existing processing facilities may serve as a check/point of comparison to the views expressed by growers.

A formal farm survey is another option. Horton (1982) suggests a framework for evaluating the appropriateness of this approach as well as some practical suggestions on how to implement it. A few words of caution are in order here. Sample size should be kept below 200. Half that number may be sufficient, depending on the number of locations to be visited and the type of farmers to be contacted. Minimize the amount of information requested, i.e., check through the proposed questionnaire to be sure what is being asked is what you need. Be sure to pre-test the questions so that you are certain that they are readily and correctly understood. Finally, think through the process of data analysis as well as data collection so that completed survey forms can be processed rapidly and the results written up in the minimum amount of time necessary. The example in Appendix B illustrates the use of a formal questionnaire to evaluate processing potential.

Developing the Product and the Process for Its Manufacture

This section looks into aspects related to technical research that will ensure that the product meets the expectations, in terms of price and quality, of the consumers or clients that are going to buy it. Two closely related activities are involved: research on the product itself and research on the process that will be used to make the product. At this point it is worthwhile differentiating between two types of product: first and second generation products.

The term "first generation product" refers to a product resulting from what may be described as primary transformation or from a process of selection, treatment, and packing. Examples of first generation products derived from roots and tubers would be flour and starch and also fresh roots that have been selected, treated, and packed in order to improve their presentation and prolong their shelf life.

In the case of flour and starch, these products are often used as raw materials in secondary transformation processes, which give rise to second generation products. These secondary processes may include the addition of other ingredients, as in the case of balanced animal feed rations or the production of composite flour for example, while maintaining the same physical characteristics of the ingredients or involve biochemical or physical modifications to the raw materials through cooking, extrusion, fermentation, etc.

The Project Brief

With the information that has been gathered thus far, it is now possible to draw up a detailed project brief, giving a well-defined specification of the product and its physical attributes, the raw material, the processing and packaging requirements, and the intended marketing methods and consumers to be targeted. Examples of two project briefs are illustrated in Table 2. The project brief, as well as giving a short summary of the project in its entirely, helps to identify the areas that require in-depth research or experimentation. As can be observed, a number of technical options exist and these options will need investigating to decide which is the most appropriate.

Product and Process Research

Product and process research can be broken down into two stages.

- Developing a prototype product on a lab- or bench-scale.
- Producing the product with prototype equipment under experimental conditions.

Table 2. Project briefs for two cassava products.

	Dry cassava for animal feed	Fresh stored cassava for direct human consumption
The product	A carbohydrate source in the form of dried cassava chips for incorporation into balanced feed rations to compete with traditional carbohydrate feeds such as sorghum and maize.	A fresh cassava root product of high quality with a storage life of up to two weeks.
The raw material	Cassava roots with high dry matter and low/intermediate cyanide content.	Cassava roots, selected by size and eating quality.
The processing	The roots will be washed, chipped and dried by either natural or artificial means. The processing will be carried out by farmers' cooperatives or small- to medium-scale agro-entrepreneurs.	The roots will be treated to suppress physiological and microbial deterioration. Treatment and packing will be carried out by farmers' coop., or assembly agents.
The packaging	The dry root chips will be packed in 50-kg sisal or polypropylene sacks. Closure of the sacks will be performed manually or by machine.	The roots will be packed according to type of market outlet. Polyethylene bags, plastic crates and wooden boxes are options.
The marketing	The dried chips will be sold directly to animal feed concentrate companies or to livestock producers. Promotion emphasizes high starch digestibility, availability and relative cost.	The stored cassava will be sold through supermarkets and local neighborhood shops. Promotion will emphasize freshness and storability.
The consumer	See marketing above.	Consumers will be families from all socio-economic groups, favoring those with poor market access.

Source: Adapted from Anderson and Earle 1985.

In the first stage, the focus is on trying to achieve an acceptable product in terms of its physicochemical properties and, in the case of foods, organoleptic characteristics. For foods, therefore, a taste panel is an essential element for checking the product's acceptability. In the second stage, the focus is more on selecting and developing suitable prototype equipment that will then be incorporated into the pilot plant. The following are some of the most important areas that need to be taken into account.

Characterizing the Small-scale Agro-industrialist

One other vital piece of information may still be lacking at this stage; that is who is ultimately going to invest in the process to manufacture the chosen product? In most situations there will be a number of options depending on the circumstances, and at this stage it may not be possible to select any one of them. In a situation where the purpose is to improve the marketability of an existing product through reduced production costs or improved quality, this does not pose a problem. However, where it is necessary to establish a new product, there are the following options:

- an existing agro- or food industry takes on the manufacture of the new product. This possibility would come to light during the market research. This option would be most appropriate for second generation products that will require a certain level of skill and experience to achieve the desired quality characteristics;
- an entrepreneur, not necessarily with previous agro-industrial experience, invests in the process for manufacturing the product. If entrepreneurial groups can be easily identified (associations of food manufacturers or growers' federations, for example), then through them it may be possible to identify interested parties. Also, their involvement from an early stage would be important; and,
- processing is undertaken by farmers' organizations such as associations or coops. If these organizations already exist and have many years of experience, they are an ideal alternative given that they will have a direct control over the supply of raw material and will also have the required managerial and administrative capability for taking on a new venture. On the other hand, it may be necessary to form a farmer organization around the establishment of a processing activity. In this case first generation products are normally the most appropriate, at least in the initial stages.

A tentative idea about which of these alternatives will be the most appropriate is important because this may markedly influence the selection of technology for the manufacture of the product.

Raw Material Characteristics

The physical/mechanical characteristics and the chemical constituents of root and tuber crops were presented earlier (Scott 1991). The type of processing technology used will depend to a large extent on these characteristics, and the end product will be the result of this interaction between raw material and processes. To take a simple example, a root crop with a high dry matter content (40% +) can be successfully dried at low cost (natural drying, etc.); whereas a root with only 15% dry matter will obviously take longer, require more sophisticated drying conditions and equipment, and/or be of poorer final quality. In general, the economics of processing improves with increasing dry matter or starch content; that is, fewer tons of raw material make a ton of end product. The presence of toxic or anti-nutritional factors may necessitate extra processing steps or increased process time to eliminate/reduce them to acceptable levels.

The non-uniformity of size of some roots and tubers, especially cassava, poses problems for initial processing, especially peeling, which is very inefficient. Roots can be graded by size before peeling, but this represents an additional labor cost. Hand peeling is highly labor intensive and uneconomical in some areas, although it can be a useful source of employment in others.

The specifications for raw materials that must be available at the end of this stage will be those that, when combined with the processes as developed here, give a product of the required quality. If the specifications are such that only a small percentage of the harvested roots and tubers fall within them, then either a good market must exist for reject roots or a sufficiently attractive price must be paid to farmers to encourage sales to this, for them, difficult market.

Product Quality

A clear idea of the end product, its characteristics and quality will be available from previous consumer and market studies, summarized in the product brief. In addition, there may be legal standards (e.g., for foods) that must be met.

Both raw material and the process determine end product quality, and it is important to identify those aspects of both that are crucial to meeting the quality requirements at an economic cost (Table 3).

During initial experimentation, it is important to monitor end product quality as well as process efficiency. Those quality characteristics to be evaluated will be those that will affect the product's appearance, organoleptic properties, hygiene, and performance in use; that is:

- chemical composition;
- functional properties; and,
- "use" characteristics (storage time, etc.).

In order to obtain satisfactory end product quality, it will be necessary to adjust process conditions and select appropriate raw material.

Determination of Technology and Equipment Selection

If the objective of the product development project is to benefit small farmers through market expansion and employment generation, the equipment chosen for root crop processing must be appropriate for use by such groups. In a research situation, it is tempting to opt for technologically sophisticated processes even though simpler options are frequently available. However, the latter have the advantages of local construction (generating more employment); few if any imported parts, which can cause bottlenecks later if spares are required; and, are straightforward for farmer groups to operate and perform basic repairs and maintenance on. The scale of technology is also important: small-scale equipment is most suitable to farmer groups. It is important to identify the capacity of each piece of equipment/operation in order to identify bottlenecks in the process. The plant should, however, be designed with future capacity expansion in mind; for example, the distribution of equipment, size of initial infrastructure, and capacity of certain key items of equipment.

For equipment design and testing, it is useful, initially, to consider similar equipment in use locally for other agricultural products. These will need adapting to the specific characteristics of root and tuber crops; but the local materials used, the sources of power employed, and the design of the equipment made locally can be helpful in defining some of the process options.

Equipment design is a specialized activity, and projects will need to include capable people in this field. Frequently, this specialization (mechanical engineering) is not found within the national agricultural or development institutions. It will be necessary to include in the project an institution that does have this capacity (e.g., university, industrial research center).

The design and prototype testing of small pieces of equipment (chippers, driers, mills, etc.) has proved to be an excellent subject for student theses.

Finally, a wide range of small-scale processing equipment has been designed in the recent past for root and tuber crops, by both international and national research and development (R&D) institutions. It is important to thoroughly review the available literature in order not to re-invent the wheel in each project.

Table 3. An example of assessing product quality requirements.

End product quality	Process	Raw material
Dry matter < 14%	Drying natural? Artificial?	High dry matter content needed
Low microbial counts	Hygienic conditions, water treatment, rapid drying	Absence of pre-harvest roots, etc.
Fiber content < 3%	Peeling, sifting	Age at harvest, variety, environmental conditions
Protein content > 5%	Fermentation	Variety
White color	Sulphiting, rapid drying, removal of impurities, water treatment, rapid postharvest processing	Variety

Taste Panels

Lab analysis of the experimentally produced end product can indicate if the product meets the quality specifications desired. However, only tests carried out with "real people" can tell if the more subjective aspects of quality are satisfactory. The perception of taste, aroma, feel in the mouth, texture, etc., are all crucially important in determining consumer acceptance of food products. It is essential to obtain some evaluation of these quality aspects during the research phase to ensure that an acceptable product is being developed.

Two types of situations can be used to evaluate organoleptic quality: taste panels in controlled conditions and consumer panels (at-home use tests).

In the lab situation taste panels provide a "scientific," controlled environment in which the subjective nature of this testing is made as objective as possible. The panelists can be highly trained people with sensitive organoleptic capabilities, who meet on a regular basis to evaluate samples. A special environment with controlled lighting and samples presented in random order permits the reduction of human and other errors. However, it is not essential to construct a special facility. Any quiet, well-lit area will suffice. It is important to select the panelists carefully. This requires more than just gathering the lab workers for half an hour every week, but selecting a group of people who are both representative of the local or target population and who have a good sense of taste, smell, etc. (This can be tested with preliminary screening based on presentation of sweet, salt, bitter, and acid solutions of differing concentrations for identification and ranking.) Preliminary group discussions can help to reach a consensus on the quality characteristics to evaluate. The scales used for evaluation should be clear and simple to understand.

Many examples exist in the literature which can be followed (see e.g., Watts 1990). The statistical analysis of results is important; the method used will depend on the evaluation scale chosen and the experimental design.

Taste panels can be used to evaluate:

- intensity of different quality characteristics of a food; e.g., sweet taste—little ... very intense;
- intensity of quality characteristics relative to a standard; e.g., much sweeter than X;
- acceptability of a food; e.g., very acceptable ... not acceptable;
- preference of a food, relative to standard; e.g., prefer X to Y; and,
- hedonic evaluation; e.g., like ... dislike.

Consumer testing of products. Although food products can be evaluated in a lab setting, in the end they will be prepared and consumed by ordinary consumers at home. At later stages in the research process (and certainly during pilot scale operations), the product must be tested in these more varied environments. Consumers' methods of preparation (use of other ingredients, cooking times, etc.) will vary greatly, as will their perception of foods and their individual preferences. The results of this sort of evaluation will, therefore, be the summation of a series of factors, for example, giving an overall like/dislike acceptability rating, or a purchase intention.

Because variability is so high, it is important to include a relatively large number of consumers. The sample should be representative as regards income level, rural/urban areas, family size, etc., to ensure that the composition is similar to that of the overall target population. In urban areas, census data can be useful to guide this operation. Consumer tests that take place in an at-home environment can be very time consuming to organize and run. Repeated visits may be necessary, drop-out rates high, and instructions (e.g., dates for food preparation) may not be followed. In some countries, it can be difficult to obtain adequate participation by upper income households. The number of different samples that can be tested in this way is very limited, and it should only be contemplated at the end of the research phase.

Packaging and Shelf-life Studies

Again, once the product is nearing the end of the research process, packaging and shelf-life studies will be needed. Consumer and market research should provide information on the storage time necessary (i.e., shelf life in shops and homes for consumer goods; storage time before further processing for industrial goods). Other relevant information from consumer studies are:

- package size; and,
- storage conditions, at home and in store, etc.

Some initial storage trials in a range of package materials in typical storage conditions can then be evaluated for:

- changes in chemical composition, functional properties;

- changes in appearance, especially color;
- changes in organoleptic characteristics (use taste panels); and,
- signs of insect infiltration, microbial contamination.

These results can then be used to design the best package, considering stability of the product over time and the cost of the materials involved. Packaging costs should enter fully into the pre-feasibility study and should include those of printing logos, instructions, etc., on the package rather than using a plain box or sack, if this is envisaged.

Feasibility Studies

Reference is made here to two types of feasibility studies: the pre-feasibility study and the feasibility study. The objective of both types of study is to provide the technical, economic, and commercial information necessary to make an investment decision. These studies should define the production capacity of the proposed plant, the proposed technology or technologies to be used in processing, the raw material inputs and the total investment cost, the production costs, and sales revenues and returns on investment (Wilkinson 1985).

The essential elements of a feasibility study are:

- production specifications;
- raw material compositions, quantities, and costs;
- processing methods;
- project engineering development;
- development costs;
- plant capacity;
- plant equipment: specifications and costs;
- plant layout;
- building design and costs;
- total investments costs;
- processing operations including manpower;
- plant organization and overhead costs;
- operating costs and total product costs; and,
- financial evaluation.

The market and consumer studies and the research carried out on the product and the process should have provided sufficient information to be able to prepare a pre-feasibility study along the above guidelines and, depending on the results, take a decision on whether or not to set up a pilot-scale operation in the region where the selected commodity is grown.

Conclusion

Research in support of product and process development involves market and consumer research, and technical studies. Based on the authors' experience, sketching out an idealized system for converting raw material into the desired product(s) and its subsequent sale to a set of interested buyers can serve as a guiding framework for this research. It permits the researcher to breakdown this system into its various components for subsequent detailed analysis. A strategic consideration in this set of studies is to recognize from the outset the paramount importance of not only the technical feasibility but also the commercial viability of root and tuber processing.

Once the market for the proposed product has been assured, research can focus on technical product and process research on a prototype or pilot scale. Lab or engineering success then leads to taste panel evaluations as well as packaging and shelf-life studies. Promising results from this work sets the stage for a feasibility study of a specific pilot plant in terms of product, process, scale, location, costs, and returns. Once this study has been completed, the product development process can focus on the operation of the pilot plant itself—the subject of the following selection of papers.

Appendix A

Consumption of Processed Potato Products in Lima, Peru

The Problem. Research on various aspects of potato processing has gone on in Peru for years: simple processing technology (Keane, Booth, and Beltran 1986), traditional potato processing in the highlands (Werge 1979), prospects for increased consumption of traditional processed products in Lima (Benavides and Horton 1979), and the feasibility of introducing certain types of processed potato products into low-income diets in the capital (Benavides and Rhoades 1987). Nevertheless, basic information on the consumption of various processed potato products by different income groups in Lima simply was not available. Thus a team of social scientists at the Universidad del Pacífico addressed this topic during 1987 (Gomez and Wong 1988).

The Method. This study incorporated a variety of research procedures (Gomez and Wong 1988): a literature review; participant observation; informal interviews with potato processors and traders; and a pilot consumption survey utilizing a structured questionnaire. The sample (n = 199) consisted of high- (n = 19), medium- (n = 81), and low-income (n = 99) consumers interviewed in supermarkets, shops and stores, and markets. In addition, the preliminary findings were presented to a group of processors and traders as part of the information gathering.

The Results. The principal findings of this study follow.

1. A variety of different processed potato products are available including potato starch, dehydrated (traditional) potato (*papa seca*), instant potatoes (imported), potato bread, potato crisps, bleached and dehydrated (traditional) potato (*papa chuño*), and peeled and pre-cut potatoes for restaurants. The estimated total fresh potato requirement annually for the Lima market alone is 36,000 t.
2. Many consumers were unaware that one or more of these products exist; they professed considerable interest in knowing more about different uses for these products.
3. Particular attributes (and defects) of these products, as noted by the consumers, were identified (Appendix Table 1).
4. Products with practical use, e.g., crisps, instant potatoes, were found to be more responsive to simulated declines in price than those with specific uses, e.g., potato starch, dehydrated (traditional) potatoes.
5. Marked differences were detected in the knowledge of particular processed potato products by income group. High-income consumers had much less knowledge of traditional bleached and dehydrated potatoes than the middle- or low-income consumers interviewed.

Impact. Results of this survey were utilized by one processing group to improve the color (make more yellow-gold) of dehydrated potatoes and to exercise more quality control in packaging such as making sure the product has been properly washed, that the package contains no extraneous material (e.g., sand, small stones). These improvements led to successful contracts for the test marketing of the improved product in two major supermarket chains in Lima. The expanded volume of sales raised questions about the sources of supply for raw material, the subject of the next step (see Appendix B).

Appendix Table 1. Attributes and defects of potato products in Lima, Peru.

Product	Attribute	Defect
Potato starch	Good taste	Tends to go lumpy
Potato crisps	Practical, readily available	Greasy, salty, spoils
Instant potatoes	Easy to prepare	Acidic taste
Dehydrated potatoes	Filling	Bitter taste; uneven quality
Bleached & dehydrated potatoes	Nutritious	Small pieces

Source: Adapted from Gomez and Wong 1988.

Appendix B

Potential for Potato Processing in Northeast Colombia

The Problem. Colombian policy makers concerned with rural development as well as researchers in the National Potato Program are interested in developing alternative uses and markets for potatoes in an effort to stabilize prices and improve grower incomes. They considered simple potato processing as one potential means of bringing this about. The Pamplona region in northeast Colombia seemed an ideal location for establishing such facilities because it is an area where potatoes are the principal crop and is noted for its small-farm population and geographic isolation from the rest of the country. The first initiative was to set up a small pilot plant in order to demonstrate that processed potato products using simple technology could be produced utilizing local varieties, infrastructure, and technical personnel. Subsequently, a research project began to assess the socio-economic feasibility of such technology. A key component of this technology assessment was an attempt to determine the needs and interests of local potato producers with respect to simple potato processing.

The Method. Research methods for this project included a review of available studies and secondary data on potato production, prices, and marketing in the Pamplona region; a gathering of producers to show them the types of dishes that could be prepared with processed potato products (e.g., crisps, cakes, soups); and a formal survey of 81 growers, selected from five different farming localities in the region. Recent agricultural census data and farm production statistics were consulted to determine the location of potato production in the various localities and the number of potato producers in each. Furthermore, since the survey was conducted by personnel of the Colombian Institute for Agricultural Research (ICA), the exercise was intended to collect information not simply about potential interest in simple potato processing, but also about technical aspects of potato production of interest to the National Potato Program.

The Results. Highlights of the producer survey findings were (Mantilla 1988):

1. Of the farmers interviewed, 63% have produced potatoes for over 20 years; in 1986, average potato production per farmer was 52.7 t, 9% of which went for sale; and, 60% of the production is harvested during the second half of the year.
2. Most potato sales take place from September to January when supplies are abundant in the market; 40% or less is sold in April-May, when growers prefer to sell because supplies are lower and prices higher; sales occur at harvest time with little storage for delayed sale.
3. Of the growers interviewed, 52% reported selling potatoes at very low prices in 1984 and 9% in 1985 and 1986.
4. Family labor is employed all-year round by 73% of farmers; in fact, 68% have difficulty hiring labor at harvest time.
5. Many (72%) are familiar with potato crisps, but 28% were unfamiliar with any processed potato product.
6. Of the 81 growers interviewed, 80 are interested in processing part of their production in order to improve prices, diversify the family diet, and provide employment for household members.
7. Products the growers are interested in producing include potato chips, potato flour, and french fries.

Impact. Results of this survey were decidedly mixed. Nearly all growers expressed interest in processed products and a disposition to conduct such activity in cooperation with other farmers. However, they also reported no particular difficulty in selling their harvest at remunerative prices. In fact, the last time prices were disastrously low was several years ago. Thus the economic incentive to process was not as compelling as in the case of India (see Nave and Scott 1991), where severe seasonal fluctuations in potato prices occur every year. The labor shortage at harvest time also raises questions about the feasibility of introducing a labor-intensive technology to operate at a time of year when manpower is already scarce. While these findings have not prompted abandonment of processing, they have led to a reconsideration of the economic rationale for this activity.

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SOTEC Village-level Potato Processing Development: Organization and Marketing

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Abstract

This paper describes the development of a potato drying process. This process includes processing equipment, an organizational structure, and marketing of dried chips, strips, and powder produced in small village units of 10-15 people. Assumptions had to be made for each aspect of the process and tested in pilot projects before introducing the process to village units.

This paper concludes that a viable potato drying project is possible wherever there is a large, seasonal fluctuation in potato prices; the harvest season is followed by a 3-4 month dry season; rural wages are relatively low; and, there is an existing or potential market for this type of product.

Key words: India, plant and equipment, applied research, economic feasibility.

Background

Every few years there is a glut in the major potato growing region of North India. This excess generates wide price fluctuations resulting in severe economic losses for small farmers. Excessive profits are often captured by those who were able to buy up potatoes and store them in refrigerated storage.

Even during normal years there is a wide variation in potato prices. Only about 70% of the crop can be put into cold storage. Hence, the Society for Development of Appropriate Technology (SOTEC) Village-level Potato Processing Project was developed to provide an alternative to distress selling and refrigerated storage, and to bring additional income and employment opportunities into suitable villages.

With the help of Compatible Technology, Inc. (CTI), Minneapolis, MN, USA, and the International Potato Center (CIP) Region VI Office, New Delhi, SOTEC undertook to develop and establish this program. It is now embarking on an ambitious five-year development and replication program with the assistance of Appropriate Technology International (ATI), the Food and Agricultural Organization of the United Nations (FAO), and others.

Currently, there are seven regular village units, one small unit at a village women's training project and a new women's unit at the SOTEC Rural Training and Village Development Center. Each year SOTEC has conducted general training programs to which any interested person is welcome as well as special training programs for groups or individuals on request. In addition to the above-mentioned units, SOTEC has helped establish 7-8 more. Since these units operate completely independent of SOTEC and are far away from the project's area of operation, no information can be presented here on their functioning.

When the SOTEC program started, it was difficult to locate people willing to set up units who fit the definition of the project's target population. Therefore, it is not surprising that most of the units which were organized during the first three years have stopped functioning, while all the units started during the next three years are operating. This latter group of units is from the target population for which the program was designed. The five-year goal of SOTEC is to see 90

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full-sized village units (two units belonging to women) in operation in 1991, an additional 15 units in 1992, and 100 new units in 1993-95. About one-third of the new units will be women's units. By the end of this period, SOTEC expects this village industry to be self-replicating.

Since the potato drying season lasts only for four months, SOTEC, along with CIP and other institutions, are experimenting with sweetpotato, vegetable, and fruit drying to extend the processing season and the use of the existing equipment. The peeling and slicing equipment has been successfully tested on small quantities of cocoa yams, cassava, carrots, and onions, though only cocoa yams and carrots were peeled in the peeler.

Basis for Undertaking the Project

Before deciding to go ahead with the project, certain trials were undertaken and assumptions made over a two-year period. From this experience a training manual was written and a rudimentary plan was developed.

The project could go ahead only if potatoes could be stored without refrigeration until needed. To test this, about 2,000 kg of fresh potatoes were stored in a deep pit. Each week about 50 kg were removed. About half were processed and the remainder cooked in the boys' hostel kitchen. By the 10th week the spoilage and weight loss was quite high, but the product made from these potatoes was as good as that made earlier. After the 10th week, rapid deterioration made further storage impractical.

Processing was done using equipment available in the bazaar and with lab quality potassium meta bisulphite. Sometimes the results were good and sometimes poor, but they were good enough to encourage SOTEC to try again during the following year. It soon became apparent that a substantial increase in worker output and a very consistent product quality were necessary to make this industry viable.

During the second season, several simple machines for peeling and slicing were fabricated and tried. Also several designs for racks and blanchers were tried. The first prototypes of all the equipment now in use were developed during this time. However, it has taken another four years to firm up the equipment designs. We are still making improvements and exploring the possibilities of improved or less expensive designs.

Often the desired potato varieties for processing were not available. Even when they were, other varieties were usually mixed in. Also potatoes of the same varieties from different areas, different cultivation practices, and different times of the season resulted in different product qualities. The challenge was to develop a process which worked on almost all varieties of potatoes and could be done by illiterate people without using any testing or measuring equipment. The process which SOTEC has developed comes close to meeting this ideal. During the third year, 39 combinations of chemicals and timings were tried; the better results were kept sealed in 200-gauge polythene bags for one year. Several retailers, wholesalers, and others who sell similar products were asked to choose the product most acceptable to them. The process that corresponded with the sample selected by wholesalers and others was chosen for the project.

Storage for Processing

The profitability of the village units is greatly reduced or eliminated unless potatoes for processing are purchased at the peak of the harvest and stored for the drying season. Therefore, it was necessary to design an inexpensive, practical way to store 60 t of potatoes to be processed over 90-120 days. Practical experience showed that about 20 t could be stored in any reasonably cool and ventilated room or shed for processing during the first 20-30 days.

A passive evaporative storage building, which we call a "rustic store," was designed based on the design developed by CIP Region VI for bulk storage of up to 20 t of potatoes piled one meter high on a slatted floor. The walls are made of mud and the roof of thatch. These are typical village construction materials and techniques for this region. The base of the building is a flat, cement plastered, brick platform, with a 4 in high rim around the outside edge so that it will hold water. Bricks are placed on this platform in a way that allows ventilation in all directions and that will also support a split bamboo floor. A fine chicken wire mesh is stretched over the bricks but under the bamboo floor and another from wall-to-wall at ceiling level to keep rodents out. The cost of constructing a 20 t rustic storage is about 1.5 times the cost of storing 20 t of potatoes in a commercial cold storage for one season. Maintaining and operating costs are about 20% as much as storing in a cold store. Potatoes from the rustic store process better than those from the cold store. During the off season, the store can be used for other crops, equipment, or as living quarters.

Equipment and Processing

The complete operation and processing can be done manually without any conventional energy, except for fuel to heat the blancher. Units have operated using hand pumps and in one case, using buckets to draw water from an open well. A 3,000-liter tank can hold enough water to process 2 t in two days. To process 500 kg or 1,000 kg in one day takes almost the same amount of water.

The processing steps can be summarized briefly as follows:

Store Fresh Potatoes

About two-thirds of the anticipated quantity of potatoes to be processed during the season should be stored in a rustic store as described above. Only good quality potatoes should be stored. Every few days the area under the floor should be filled with water. This is especially important if the potatoes are stored for over a month. When potatoes are being used from a store, it should be opened only once each day, preferably early in the morning.

Wash and Peel

The SOTEC peeler washes and peels at the same time. Water is fed into a drum through its axle. If running water is not available, it may be siphoned from a container placed 5 ft high. The drum is coated inside with a coarse carborandrum grit. Potatoes are peeled by rotating the drum manually. Thirty to fifty kg may be peeled at one time. Peeling may take from 2-15 min depending on the quality of potato, the condition of grit, and the speed of rotation. Potatoes should be peeled as little as possible but enough to process well and be acceptable to customers. Seventy percent peeling is sufficient for processing. Peeled potatoes must be covered by water at all times to prevent darkening.

Rectifying

Cuts, green areas, rotten spots, deep black eyes, and other discolorations are removed with a knife before chipping. We have experimented with several designs of knives and have found that some shapes and lengths result in much quicker work. Rectifying is done in small processing units by women squatting around tubs of potatoes. The most efficient arrangement is one women at each tub. Four or more women around one tub reduces the output by almost 50%. Rectifying is the most expensive step of the process when making julienne strips. There is a tendency to rectify too much or too little. Village women in the project area are not used to using paring knives and have to be taught.

Slicing

This is done on a slicer which can be operated by either a foot-operated cycle or a 1/2-hp electric motor. Blades can be fitted to cut chips (wafers) or julienne strips. The thickness of chips or strips can be adjusted without tools. The slicing rate varies from about 200-500 kg per hour. The rate depends on the speed and uniformity of operation and thickness of the slices. Any relatively firm fruit or vegetable such as carrots or onions can also be sliced on this machine. The only drawback, at present, is that both the blades and blade holders are imported. Sliced potatoes fall directly into a 0.05% solution of sodium meta bisulphite. Once enough machines are in operation in India, they will be manufactured here. This can be done with a 10 t press, and milling and grinding machines.

Rinse

After slicing, the chips are packed into nylon mesh bags for easy handling. They are then rinsed in tubs of plain water 2-4 times to remove surface starch which has been freed by the slicing. Starch in the slicing and rinsing tubs is accumulated, rinsed, and put out to dry at the end of each day. A hook is placed above each tub where chips should be drained before being taken to the next step. Another hook is also placed through the drawstring of the bag to speed hanging and handling. Tubs can be of any convenient size and shape. Two sizes are used. Each have an 11.5 in height. One has a 60-liter capacity and the other has a 160-liter capacity. Stainless steel tubs would be ideal, but are much too expensive. Now black sheet metal tubs are used and painted with the most durable finish available. The tubs generally have to be repainted each year. Galvanized iron sheet tubs do not hold up either, unless they are painted. The possibility of heavy duty plastic tubs are now being explored. Common plastic tubs and buckets last only a few weeks.

Blanching

The blanching tub is 15 in high, 18 in wide, and 36 in long and made of 26-gauge stainless steel sheet. A very thin sheet is used because stainless steel is very expensive in India. Therefore, the tank must be supported from underneath and no outlet should be made in the bottom or sides. The tub is emptied through a siphon made of galvanized iron pipe. The tub is placed in a mud and brick structure with a fire box at one end and a chimney at the other. A space is left between the tub and the structure all around to improve heating. More than 1,000 kg of potatoes can be blanched in one day.

Chemical Bath

After blanching, the bags of chips are placed in a solution of 0.1% sodium meta bisulphite for about 5 min. This water becomes very hot, but we have not tried to keep it cool or to pre-cool the potatoes before putting them in the solution. The chips are drained over the tubs before spreading. This step has made product quality better and more consistent.

Drying

The racks are made of electric conduit pipe with a 1/2 in mesh chicken wire stretched over the top. They have 6 in legs and can be stacked up to 10-12 in high. The potatoes are spread on nylon mosquito netting placed over the racks to keep the chips from touching the wire mesh and to make handling easier. Only one person is required to spread julienne strips. They are spread and later turned over 3-4 times during the day simply by running one's fingers through the layers of potatoes. Wafer-type chips require at least five times as much labor because each chip has to be separated on the netting. Wafers also require about five times as much rack space.

Drying is done in open sunlight. It takes from a minimum of 6 hrs to a maximum of three days. When drying takes more than one day or the weather threatens, the racks of chips are stacked in a well ventilated shelter. We have not been able to design a solar drier which is more efficient than open air drying. Being able to stack the racks has been very beneficial and convenient.

Originally bamboo racks were made at about one-third the cost of the conduit racks. However, they did not last, were bulky, and did not stack well. In the long run, they were more expensive.

Grinding

At present, a large market exists for dried wafers and strips. And, the market is growing for powder and granules. These are made by grinding chips or strips on a locally available stone mill normally used to grind wheat or on a screen mill. Some customers want a uniform granule size. To provide this, sieving is done between two sieves. So far this has been done manually. This results in considerable dust, which is both unpleasant to work in and represents a considerable financial loss.

The irregular, broken, and slightly discolored chips are used to make powder. Potato starch can be added to the powder but not to the granules. Some customers require a high starch content which can be obtained only by adding the starch collected during processing.

Space for Processing, Drying, Grinding, and Storing

Processing can be done in an open shed with a thatched roof over a plastered floor of about 15 x 20 in with a good slope for draining. The processing water should be drained into a field or vegetable patch in such a way that the water can be emptied into different plots each day. This keeps unpleasant odors from developing and also utilizes the nutrients which are in the water.

The drying area can be any open area on a roof or in a field as long as the area is not excessively dusty and is close to the processing area. About 3,150 ft^2 of area is required to dry 1,000 kg of potatoes per day during good drying weather. About 50 racks are sufficient for strips and 70-100 racks are needed for chips (wafers). After the product is no longer sticky and begins to curl, the contents of several racks may be combined onto one rack.

Grinding should be done in a room and requires about 300 ft^2 of space. Grinding and sieving can be done in the same room, but packaging and storage is better done in an area without dust. Only one grinding unit is needed for 8-10 production units.

Storing finished product to be sold during the year is a major problem. To store 20 kg of chips (wafers) takes about 6 ft^3. If 75% of a year's production of one village unit is stored as a mix of wafers, strips, and powder and stacked 6' high, it will take a floor space of about 15 x 25 ft. Rustic stores can also be used to store the finished product.

Organization

It was clear from the beginning that a project of this nature would have to consider a number of factors including finances, raw material purchasing, process development, equipment development and supply, ongoing consultancy, training, mobility, collection, and storage of raw materials and finished products, legal requirements, environmental factors, sales, and marketing.

Village units cannot deal with all these matters on their own. Several forms of organization were considered. A three-tier system was eventually decided on. In this system, the tiers are divided on the basis of such things as skills, educational level, experience, and mobility required. Legal requirements, and how they could be dealt with, were also considered.

Tier I

Tier I is composed of the village production units. Their job is to process the potatoes and deliver them to a central Tier II unit. This should not be more than about 30 km away. Unfortunately, some of the units are as much as 80 km away which makes transportation costly, and meetings and supervision difficult.

While all Tier I units are registered societies, they are essentially owned by one person. The project is now working to establish some units which are true coops or associations of equal persons all of whom will share in the profits of the unit. This region of North India has been notoriously unsuccessful in establishing coops. To establish a successful coop here will require a long period of guidance and training.

Tier II

Tier II collects, stores, grinds, packages, and checks product quality. Originally, this tier was planned to be an independently owned business. However, this would put the Tier II unit in the position of "middleman" with many opportunities for exploiting the village units. After trying several approaches, it was decided to form a coop-type association of all the production units and the sales organization to function as the Tier II unit. SOTEC is also a member of this Association. The Association is still very new, but the concept seems to be promising. The Association is now in the process of taking over the responsibilities of obtaining operating loans, developing and providing machinery, providing consultancy, and many of the other activities now done for the potato project by SOTEC.

Tier III

Tier III is composed of the sales and marketing units. These are privately owned registered companies and are members of the Tier II Association. The possibility of selling through established marketing agencies was investigated but their charges were found to be very high. In addition, this sort of project needs people who are dedicated to its concepts and social goals and in developing long-term benefits for the village units.

Financing

The unit holders need loans to purchase potatoes for a full processing season and for fixed capital. The unit owners are expected to put as much of their own money into the project as possible. In some cases, such as a recently started women's unit in which most of the women are widows or the sole earning adult in the family, little or no money can be invested by the owners.

So far it has not been possible to obtain financing from banks. They require collateral in the form of real estate or guarantees backed by bank deposits. Until now, SOTEC has had to finance units using grant and loan funds from a variety of donors. Under this program SOTEC has provided the equipment, which is debited against the unit, funds to buy potatoes or the potatoes themselves, and has made payments for processing after the product has been delivered to the Tier II Association.

All loans are repaid in the form of product. Cash loans are repaid in one season and fixed capital loans over a five-year period. So far the farmers have been very responsible in this matter.

Each year the cost of producing one kg of dried product is calculated. At present, labor, chemicals, fuel, maintenance, repayment of equipment, use of facilities, use of the rustic stores, and profit are included in the calculations. Profit is calculated at 20% of the processing costs. On an average, the dry product is 17% of the weight of the fresh potatoes processed. Deductions for equipment payments and any loans given are made each time the product is delivered and payments are calculated. However, the payment of profit may be deferred until later in the year when sales improve the cash flow position.

Interest has not been charged on the loans given through SOTEC. However, when bank financing is finally available, interest between 4-12.5% will have to be added. SOTEC believes this can be included and still leave the business profitable.

Marketing and Sales

A market for dried chips existed before the project was started. The demand is greatest at the time of certain festivals. People deep fry chips and sprinkle with salt and spices. Chips being marketed earlier were generally of very poor quality and in limited supply. The market is growing and is responding well to the introduction of a better quality dried chips. However, we felt the SOTEC village process would eventually saturate the market and a new product should be introduced. For this, we chose potato powder.

SOTEC intended the potato powder to be used in homes and roadside restaurants; therefore, a large number of potato powder recipes were developed. Quite a few demonstrations were given in stores, clubs, and institutions. The response was good, but the project has yet to take advantage of this market. One reason was the lack of funds to develop and buy the quality of packaging materials necessary to introduce a new food concept. The other was the relatively high cost of distribution.

While exploring the market for powder-based products, a great deal of interest was detected in extruded snack products made from powder and granules. The powder made by the village units has been costing about 25% less than that from large factories and, the project was told, has a better flavor. Since the project has sold all its product to this market, developing the home market has been put off until the program is better established. SOTEC believes the home-use market will eventually be larger than the snack manufacturing market.

Some bulk users insist on 30-45 days credit and then they often delay payments for months. This has caused serious cash flow problems. Project staff are now trying to get payments in advance or have letters of credit opened in SOTEC's favor. When neither is possible, small quantities of product are now given with full payment insisted on for the previous shipment before the next delivery.

The marketing of powder provides a way to use broken and slightly discolored chips. Powder also provides a way to utilize the starch which is collected as a processing by-product.

Marketing and Sales System

There is a sophisticated and well developed marketing system for food commodities in India. Most sales agencies, wholesalers, and distributors handle several product lines. If a product is to be given equal treatment, it must be equally profitable to the dealer. When the product is new, it requires special effort and higher mark-ups.

SOTEC found it far too expensive to contract any well-known sales agency. The less expensive ones were not willing to give SOTEC's products the kind of attention they needed, nor assume any of the risks. Therefore, project staff looked for some young persons interested in marketing and sales who wanted to build a business for themselves. This also fit in with the project's relatively low production and need to build up the industry slowly while the units were learning.

Although SOTEC has not given anyone exclusive rights to its products, the project has given priority to two young men who have established registered sales companies. As they market the project's products, SOTEC helps them build their companies. This fits with the Society's social goal of establishing independent business and industry among low-income people.

It will still take two years for the project's marketing and sales system to reach the level of stability already achieved by the processing and machinery programs.

Shelf Life

The product, whether it is wafers, strips, or powder, keeps well for two years or more if it has been properly processed, is kept dry, and is protected from outside infestation by insects or rats. Several tons have been stored sealed in 20-gauge polythene bags inside polythene woven outer bags. Before packaging, SOTEC tested the contents for moisture by sealing a small amount in a plastic bag and leaving it in the sun for about an hour. If no moisture collected on the bag while it was still in the sun, it was dry enough to store.

The climate in North India is usually hot and very dry for three months, hot and very humid for three months, and temperate with moderate humidity for six months.

The project has kept product stored for two years in a shed with three walls and a thatched roof. Product was stacked on logs and bricks to keep it about 4-6 in off the floor. No cereal grains or other infested materials were allowed in the storage building. Rats or mice did some damage, especially during the monsoons.

Pricing

The price depends on the purchase price of potatoes, storage costs, processing costs, transportation costs, finished product storage costs, overhead, and mark-ups. Several of these factors, such as transportation and mark-up, have to be considered at several stages in the marketing process. SOTEC's experience has been that it is best to consider (and allow for) all the steps and marketing costs found in the traditional marketing system used by the established processed food industry. It is essential to include all these costs in pricing even if some of the steps can be subsequently eliminated. Such savings can add to profitability or be used to lower prices. At first, the project tried to bypass some of the steps and did not make allowances for them. Later it was necessary to incorporate some of these steps and costs, which created confusion in the marketing and sales program.

The pricing process was based on the best estimates for potato prices plus the accumulative costs at each pricing point. The pricing points are: (1) delivery at the collection center; (2a) sale to a marketing agent who is a member of the Association, or (2b) sale to an agent who is not and Association member; (3) sale to a wholesaler or local distributor; (4) sale to a retail store, and (5) sale to customer. There are only three pricing points for bulk users instead of five as required for a sale through retailers.

Two considerations which SOTEC feels are important in pricing are that the price must be within acceptable limits for the final customer, and that the price should be the same throughout the year as far as possible. This means that costs of storage are prorated on product throughout the year.

Conclusion

SOTEC underestimated the cost, the effort, and the time required for establishing this processing industry. Initially, it was envisaged that developing a suitable process would be the most difficult task. However, this was done rather easily and quickly. Although there is room for improvement, the process works well, and is reliable under a wide variety of conditions.

The overall processing system was more difficult and costly to develop. The financial and technical help which SOTEC received from CTI and CIP made it possible to develop a good processing system and very successful and practical processing equipment.

The rustic store design has proven itself suitable for the project requirements. It can be easily replicated in a tropical or sub-tropical area wherever short duration storage is required. The problem of storing finished goods is one of sufficient space. No special technology is involved Sufficient storage space is a matter of constructing or renting suitable storage buildings.

The most time-consuming, difficult, and expensive part of the program is to establish and operate an organization which coordinates the small, scattered, independent village-based units and undertakes such responsibilities as training, setting up new units, providing consultancies, controlling quality, collecting product, and marketing.

In any replication program, either in India or abroad, a lot of attention must be given to the problems of financing and marketing. Without a committed source of funds to sustain the supervisory organization during the development period and to provide risk capital for developing the units and keeping them going during the initial period of 2-3 years and to provide a reasonable marketing strategy, a lot of time will be lost and unnecessary mistakes will be made.

A viable village-level potato drying project can be established any place where there is a considerable increase in potato prices following harvest and where the harvest season is followed by a 3-4 months dry season, where farm labor is in surplus during the dry season, rural wages are relatively low as compared to urban wages, and where a market for dried potato products or some type of snack industry exists into which this product could fit. It is, of course, possible to introduce a completely new product into the market; although this would probably require greater effort and time and may require a different marketing approach.

The experience of SOTEC during the past eight years and the results achieved can be used as a sound foundation for planning and implementing a replication program in any suitable area.

Transfer of Sweetpotato Processing Technologies: Some Experiences and Key Factors

Truong Van Den[1]

Abstract

The paper presents some experiences in the transfer of processing technologies for fruity-sweetpotato products, dried sweetpotato with a sweet and sour taste, sweetpotato catsup, sweetpotato jam, and sweetpotato beverage. Three modes of technology transfer to the private sector are highlighted including direct extension, exclusive, and non-exclusive contracts. The key factors in the technology generation and pilot testing phase which accelerate the process of technology transfer are analyzed.

Key words: fruity-sweetpotato products, technology transfer.

Introduction

One of the criteria used to assess the viability of a processing technology is its successful transfer to end-users and eventual commercialization. The complete process of research for development should start from idea identification and development of the technology to technology transfer and commercialization of the results which are proven feasible. While technology development has been given much emphasis in academics and government research institutions, not many of the available technologies are known to the private sector for possible commercialization. The link between the two sectors is weak and, thus, only limited numbers of developed technologies are successfully transferred to potential users.

The whole process is of utmost importance for sweetpotato which is often branded as a "survival" or subsistence food and which traditionally has a low status in the food industry. Therefore, in order to change the status of sweetpotato from a subsistence to a commercial commodity, efforts should be devoted not only to development of processing technology to convert raw sweetpotato roots into appealing processed products, but also to the process of technology transfer.

Technologies for processing sweetpotato roots into non-traditional food products which are competitive with fruit-based products have been developed (Truong et al. 1990a). Among the five fruity-sweetpotato products, dried sweetpotato with sweet-sour taste (Delicious Sweetpotato), sweetpotato catsup, sweetpotato jam, sweetpotato beverage, and sweetpotato leather, technologies for processing the first four products have been transferred to the private sector. Large-scale production of these products would benefit the following target clientele:

- farmers: for having better markets for their fresh sweetpotato and/or participating in an integrated production-processing-marketing system to increase the value added to their produce;
- food processors: for the advantages that sweetpotato is relatively cheap and non-seasonal as compared to fruits, and a nutrient-rich raw material; and,
- consumers: for having low priced and nutritious products.

This paper presents some experiences in the transfer of sweetpotato processing technologies to the private sector and analyzes the underlying key factors.

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Background

Product Idea Generation and Conceptualization

Several steps were undertaken during the initial phase of the project.

Inventory on Existing Sweetpotato Food Products

Existing sweetpotato food products in the Philippines and other countries were documented through informal surveys and desk research.

Traditionally, sweetpotato is consumed fresh after boiling, frying, or cooking with other ingredients for snack or vegetable dishes. At the commercial scale. sweetpotato has been processed into various products; their uses, the processing techniques, and existing scales of operations are presented in Table 1. In the Philippines, processed sweetpotato products such as fried chips, fried chunks, candies, flour, and native delicacies are produced at the household level (Alkuino 1983; Alkuino et al. 1986; Truong and del Rosario 1986).

The inventory points to the need for strengthening the sweetpotato processing industry in the country through improvement of existing products and processes, adoption of technologies from other countries, and development of new products with good marketability and growth potential. While the first two approaches had been used in other research, the third was the choice for the project under discussion here.

Examination of the Chemical Constituents of Sweetpotato

Sweetpotato has been recognized for its high nutritive value. However, for a starchy commodity such as sweetpotato, development of new food products that are different from traditional food items which are starch-based, would require a thorough examination of the chemical constituents of sweetpotato.

A tabulation of reported data from various published works indicated that the vitamin and mineral content in sweetpotato roots are comparable with various fruits (Table 2). One hundred grams of fresh roots can supply 25-50% of the Recommended Daily Allowance (RDA) of Vitamin C (Anonymous 1980). The orange-fleshed sweetpotato root also contains B-carotene (pro-Vitamin A) which is as high as that of carrot and superior to other common vegetables and fruits (Bureau and Bushway 1986; Dignos et al. 1990).

The analogy between sweetpotato and fruits, in terms of B-carotene, ascorbic acid, and mineral content, provided a basis for a hypothesis that sweetpotato can be processed into products which are traditionally made from fruits. Nevertheless, the high starch content of sweetpotato roots would be a problem in the processing. Selection of varieties with a low starch content and/or application of certain processing treatments could probably solve this problem.

Observations on the Commercial Fruit Products in the Markets

Various locally processed fruit products are available in the market. These are dried mango, dried papaya, dried pineapple, and other dried fruits, jam and jelly, canned fruits, and fruit juices and drinks in cans, bottles, and aluminum foil or tetrapacks. These products have good marketability and have been available in the market for years. However, due to high cost and seasonality of fresh fruits, these products are expensive and mainly targeted for high-income local consumers and export.

Sweetpotato is a cheap commodity which is non-seasonal and less prone to the damage caused by adverse weather. If sweetpotato can be processed into products with a taste and appearance similar to fruit products, the production cost would be low enough to make it competitive with fruit products. Given this analysis, the development of fruity-food products from sweetpotato proceeded ahead.

Product Development

Initially, a dried sweetpotato product with an appearance and taste similar to that of dried fruits was developed. Results of the consumer acceptability tests on the product were very encouraging (Truong 1989) and some local entrepreneurs expressed interest in adopting the developed technology This finding, then, proved positively the stated hypothesis. Therefore, other fruity-sweetpotato products were then developed.

Generally, the common activities in product development—including standardization of product formulations and processing technologies and sensory evaluation of the products—were undertaken. Formulations with high sensory scores were used in the preparation of samples for consumer acceptability tests. The comments and suggestions of consumers on the accept-

Table 1. Characteristics of sweetpotato products.

Product	Use	Processing steps	Suitable (x) for Home-scale	Intermediate-scale	Large-scale
Fried chips/strips	snack food	peeling, trimming, slicing, blanching (optional), deep frying, packaging	x	x	x
Dried chips/strips	food preparations	washing, peeling (optional), trimming, slicing, drying, packaging	x	x	x
Dried cubes	food preparations	washing, peeling, trimming, cubing, blanching, drying, packaging	x	x	x
Dehydrated flakes	breakfast food food preparations	peeling, trimming, blanching, pureeing, flaking with drum dryers, grinding, packaging	x	x	x
Flour	baked products food preparations	grinding of good quality chips/strips, sieving, packaging	x	x	x
Starch	food (noodles, baked products, food preparations, etc.) industrial products (glucose syrup, alcohol, medicines, chemicals, textiles, etc.)	washing, grinding in lime water (pH 8.6), sieving, setting, centrifugal dehydrating (large scale), drying	x	x	x
Canned/bottled products	food preparations baby food	peeling, sorting, trimming, blanching, grinding and formulating (for bottled products), filling, sealing, sterilizing			x
Frozen products (chunks, cubes, slices)	food preparations	peeling, trimming, size reduction, blanching, freezing			x
Fermented products	alcoholic drinks fuel alcohol	hydrolysis of starch by acid or enzymes, yeast fermentation, distillation	x	x x	x x
Specialty products (candies, sembei, "cracker", pies, paste, roasted, etc.)	snack food food preparation ice cream	various, depending upon the product	x	x	x

Sources: Bouwkamp 1985; Duell 1990; Edmond and Ammerman 1971; Truong and del Rosario 1986; Winarno 1982.

Table 2. Nutrient composition of sweetpotato as compared with various fruits (per 100 g edible).

Crop	Moisture (%)	Total Carbo-hydrate (gm)	Fiber (gm)	Ash (mg)	Ca (mg)	P (mg)	Fe (mg)	Vit. A (I.U.)	Ascorbic acid (mg)
Sweetpotato									
Yellow (boiled)	68.1	29.4	0.6	0.9	66	58	0.8	1,025	31
Orange (baked)[a]	n.a.	n.a.	n.a.	n.a.	45	n.a.	1.0	9,184	25
Apricot[b]	85.3	12.8	n.a.	n.a.	17	23	0.3	2,700	10
Banana	73.2	24.4	0.6	0.8	23	36	0.9	340	32
Grapes	79.2	19.7	1.7	0.4	6	24	0.4	n.a.	3
Lemon-Philippines (Kalamansi)	89.8	8.3	Tr	0.5	18	12	0.8	00	45
Mango	83.9	15.0	0.4	0.4	8	17	0.5	2,580	45
Orange[b]	86.0	12.2	[illegible]	n.a.	41	20	0.4	200	50
Papaya	86.4	12.2	0.6	0.6	23	10	0.7	425	89
Pineapple	86.0	13.0	0.4	0.4	19	9	0.2	15	21
Strawberry	91.3	7.2	1.6	0.5	34	21	1.2	15	107
Tomato	94.1	4.1	0.8	0.6	18	18	0.8	735	29

Sources: Food and Nutrition Research Institute (FNRI) 1980; [a]Anonymous 1980; [b]Salunkhe et al. 1974.

Tr = Trace; n.a. = No data available.

ability and cost of the tested products were incorporated into the refinement of product formulation.

Detailed information on fruity-sweetpotato products is reported elsewhere (Truong 1989; Truong et al. 1990a). The following is a brief description of the features of the technologies which have been transferred to the private sector.

Dried Sweetpotato with Sweet-sour Taste

The product was originally named Delicious Sweetpotato. The processing technique is as simple as that involved in preparing dried fruits. Orange-fleshed sweetpotato roots (e.g., VSP-1 variety) are washed, peeled, sliced uniformly at 3 mm thickness, soaked in a 2% meta bisulfite solution, and cooked in acid containing syrup. The cooked slices are dried in a mechanical drier and packed in plastic bags (Truong et al. 1988).

Consumer acceptability tests of Delicious Sweetpotato revealed that the product is highly acceptable with 11% of respondents rating it "like extremely", 60% "like very much", and 23.5% "like moderately". Nutritionally, the total soluble solids, carbohydrate, protein, fat, fiber, and ash contents of the dried sweetpotato product were within the value range of dried mango and dried apricot. The dried sweetpotato contained 13,033 I.U. of Vitamin A per 100 g which is higher than that of the two fruit products.

Sweetpotato Catsup

The process was developed following a modification of the procedures of tomato and banana catsup processing. The roots are washed, trimmed, chopped into chunks, and cooked. The cooked chunks are blended with water, vinegar, spices, and food colors, and boiled to the desired consistency before bottling. Compared to commercial products, sweetpotato catsup has similar values of viscosity, total soluble solids, and pH, as well as Vitamin A content (intermediate between that of tomato and banana catsup). In consumer acceptability tests, sweetpotato catsup was rated equal to the leading brand of banana catsup (Truong et al. 1990b).

Sweetpotato Jam

The initial step in the preparation of sweetpotato roots was similar to that for sweetpotato catsup. The steamed chunks are blended with water, sugar, and optionally with ripe fruit pulps or juices or artificial flavors. The slurry is then cooked until a total soluble solids of 68° Brix is obtained. Toward the end of the cooking process, citric acid is added to the slurry. The hot sweetpotato jam is poured into clean jars which are allowed to cool with covers in place and sealed.

Sweetpotato Beverage

The processing steps involve washing, peeling, trimming to remove damaged parts, steaming, extracting, and formulating with 12% w/v sugar, 0.20% w/v citric acid, and 232 mg/l ascorbic acid as a Vitamin C fortification (Truong and Fementira 1989). The formulated beverage is bottled in 150 ml glass containers and pasteurized at 90-95°C.

The addition to sweetpotato beverage of juice or pulp of different fruits, e.g., guava, pineapple, or Philippine lemon, at concentrations of 0.6-2.4% w/v significantly improved the aroma scores of the product. Likewise, incorporation of artificial orange flavor also enhanced the aroma of sweetpotato beverage.

Results of the consumer acceptability tests indicated that over 85% and 96% of the respondents rated "like" to both the plain and guava (0.6% w/v)-flavored sweetpotato beverage. Likewise, about 73% of the respondents commented that the sweetpotato beverage with guava flavor and 54% without guava flavor, was better than the commercial fruit juices which they commonly drink. Nutritionally, the sweetpotato beverage prepared from the orange-fleshed roots (e.g., VSP-1 variety) is comparable or even superior to various commercial fruit juice drinks in terms of Vitamin A, Vitamin C, and mineral content (Truong and Fementira 1990).

In recognition of the originality of the processes developed for the dried sweetpotato with sweet and sour taste and the sweetpotato beverage, two patent applications were filed at the Philippine Patent Office, Department of Trade and Industry. The technologies were awarded with the Philippine Patent Number 22242 for dried sweetpotato (Truong et al. 1988) and 23269 for sweetpotato beverage (Truong and Fementira 1989). As legal documents, the patents protect the institution's rights to the developed technologies and serve as "bargaining power" with private companies.

Some Experiences in Transfer of the Developed Technologies to the Private Sector

A strategy of technology transfer was framed for these emerging technologies. The first step was dissemination of information to the public through scientific reports, announcements in newspapers, seminars, and investment forums held in various provinces of the Philippines. Displays of actual products were made at science and technology fairs organized by government and non-government organizations.

The case experiences (the cited cases are true stories; however, the names of the companies are withheld to avoid possible complications) presented below highlight the three modes of technology transfer: (1) direct extension to entrepreneurs and farmers, (2) exclusive contracts, and (3) non-exclusive contracts with private companies. The decision on which would be the most appropriate mode of technology transfer depended on the originality of the technology, capability of the potential users, and technology level. The technology level was defined by its suitability for village-level operations, small-, medium-, or large-scale, because the technology developed for the products aiming for rural consumers may not be viable in urban settings, and vice versa.

Direct Extension to Farmers/Entrepreneurs

Through various forms of information dissemination, local farmers and food processors have been informed about the development of sweetpotato catsup processing technology. Training sessions were conducted for interested participants. The sweetpotato catsup technology has been adopted by farmers' organizations, small-scale food processors, and catsup processing companies in Leyte, Bicol, and Manila. Products with sweetpotato as an ingredient or a brand name of Sweetpotato Catsup are presently available in domestic markets. A banana catsup company which has a factory with a production capacity of 10,000 bottles of catsup per day, adopted the sweetpotato catsup technology and made a substantial profit in 1990. For sweetpotato jam, the technology has been adopted by a farmers' organization in Bicol and integrated with sweetpotato catsup processing.

The cited case can be considered as an example of the successful transfer of developed technologies through direct extension. The rapid adoption of the technology by catsup manufacturers can be attributed to the cost effectiveness of the process and product quality. Indeed, several advantages of sweetpotato over banana in catsup making have been recognized. Sweetpotato is cheaper than banana: Its supply is less susceptible to adverse weather. Due to the favorable chemical properties of sweetpotato, addition of a stabilizer, as commonly practiced in banana catsup making, is not required. Sweetpotato catsup has a higher Vitamin A content than banana catsup (Dignos et al. 1990; Truong et al. 1990b).

Exclusive Contract

The technology developed for processing dried sweetpotato with sweet and sour taste was transferred to a group of businessmen who were establishing a food processing company in Tacloban City. The technology was recommended for commercialization in an evaluation conducted by the Research Utilization Group of the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) (Abejuela et al. 1989).

Inasmuch as the product was new and the company was being established, it was mutually agreed that the technology would be transferred on an exclusive basis for five years and that the company would pay 1.5% of gross sales to Visayas State College of Agriculture (ViSCA) as royalty. The exclusive terms of the contract created criticism because it appeared to be contradictory to the mandate of a public institution like ViSCA.

The product was wrapped with attractive plastic packaging material and named Tropical Delights. However, due to inadequate facilities and lack of experience in marketing of food products, the company encountered difficulties in producing a good quality product and in market development. A fire destroyed the company's processing facilities and the agreement was made void by mutual consent of the two parties. Recently, an association of sweetpotato growers and processors in Jaro, Leyte, has adopted the technology for small-scale production of Delicious Sweetpotato. For the benefits of the farmers, the technology was transferred through direct extension. The association received financial support from the Department of Trade and Industry to begin commercialization of the product.

Non-exclusive Contract

The problems encountered in the transfer of the Delicious Sweetpotato technology helped us recognize some limitations in the technical capability of the technology users and the terms of agreement. As a result, transfer of the patented sweetpotato beverage process to a large food and beverage company was done on a non-exclusive basis.

Initially, the company preferred exclusive rights to the technology. However, negotiations for mutual agreement on the non-exclusive transfer of sweetpotato beverage technology took into consideration the "dominant" position of the company in the market and ViSCA's desire for wider dissemination of the developed technology.

The company became interested in the sweetpotato beverage because of its high Vitamin A content. The product fits very well with the company's campaign to utilize local raw materials for processing of nutritious, low-priced food products and to contract small farmers to produce the raw material. Interestingly, the company's objectives match those of the project. More importantly, the project's targeted clientele, root crop farmers, could also benefit from production of the raw materials. Adoption of the technology by a large company would also enable the sweetpotato beverage to penetrate different markets.

With common interests in mind, ViSCA agreed in principle to transfer the know-how for processing the sweetpotato beverage to the company for commercialization. In return, the company donated equipment to ViSCA for research and development (R&D) in food processing. ViSCA and the company also agreed to undertake a joint project for scaling up the process for commercialization. The implementing team was composed of company personnel (a food product development specialist, process development engineer, marketing specialist, fruit processing plant manager, agricultural extension specialist) and the ViSCA inventor. The company provided the budget and its fruit juice factories for pilot testing of the beverage.

Translation of ViSCA Process to Pilot-scale Operations

Pilot-scale operation began with the following activities:

Product refinement and diversification. The sweetpotato beverage was prepared in the company's laboratory, following the process developed at ViSCA. The formulation was adjusted to meet company standards and the process was modified to make it fit existing company facilities. Other beverages using sweetpotato were also explored.

Trial runs at company factories. Trial runs were conducted at the company's factories with the use of the commercial sweetpotato purchased from the market and VSP-1. Various factors affecting the process operations and product quality were identified. Samples of the sweetpotato beverage were evaluated for sensory attributes and product shelf-life.

Product costing. Data obtained during the trial runs were used in costing the whole process. Production costs of the sweetpotato beverage were analyzed in relation to fluctuations of the local price of sweetpotato roots.

Product testing and market plan. Beverage samples were subjected to consumer evaluation for market analysis. Several planning activities related to projected production, profit estimates, product naming and positioning were carried out.

Production of raw material. Because VSP-1 is a new sweetpotato variety, the company sought assistance from ViSCA regarding the supply of planting materials and information on cultural management, postharvest handling, and grading of the roots. To ensure regular supplies of the propagules to contracted farmers, the company collaborated with a local agricultural school to propagate VSP-1 cuttings. However, due to the need for scheduling the use of the company factories for sweetpotato processing only when there is no fruit processing, timing the production of VSP-1 roots by contracted farmers appears to be problematical.

No major technical problems emerged in trial runs for the sweetpotato beverage at the company's facilities. However, launching of the product in the market has been delayed due to the unexpectedly inadequate supply of VSP-1 roots and other managerial matters.

Key Factors Accelerating the Transfer of the Generated Technologies to End-users

The potential for commercial use of a developed technology should be incubated at the project conceptualization stage and nurtured along the way to ensure its successful transfer and sustain its viability in the commercialization phase. Kefford (1984) stated that a systems approach to a project from idea to market is the likely way to success.

Based on the experiences cited and the problems encountered in the transfer of sweetpotato processing technologies, the three "actors" in the scenario, i.e., government-researcher-private sector, have to perform in concert to bring the fruits of research to the target clientele. The key factors for accelerating the transfer of generated technologies to end-users will, therefore, be discussed in relation to two phases (technology generation and transfer), and the expected roles of the government, researcher/research institution, and private sector.

Technology Generation Phase

Essential steps involved in product development are well described elsewhere (for example, Earle and Anderson 1985). These include: (1) definition of project goals and target clientele; (2) product idea/opportunity identification through idea generation and screening, product concept testing, analysis of potential market demand, and profitability; (3) product and process development; (4) consumer acceptability testing; and, (5) final planning of production and marketing.

In reality, the product idea/opportunity identification is often bypassed. In most public research laboratories, the idea usually emerges from institutional thrusts, literature, researcher's perception, etc. The researcher then pursues it in the laboratory and pilot plant before investigating its market potential. Consequently, research results will not reach the target clientele if market potential eventually proves negative.

Alternatively, the product idea can be generated through consumer and market research (Truong et al. 1990c). This may reduce the risk of failure. But, it also may stifle the researcher's innovativeness. Researcher's observations of existing products and their marketability, raw material characteristics (physico-chemical and nutritional), and cost can point to a potential product idea as well. As previously mentioned, the perceived analogy between sweetpotato and fruit in terms of Vitamin A, Vitamin C, and mineral content spurred development of fruity-sweetpotato products. Hence, an acquired understanding of the market and creativity on the part of the researcher are two key factors in determining the commercial potential of new products.

Rigorous evaluation of the commercial potential of a developed technology should be done before it is recommended for transfer to end-users. Abejuela et al. (1989) have developed an evaluation procedure which takes into account three criteria: technical feasibility, marketability, and profitability. Based on these criteria, Delicious Sweetpotato and sweetpotato catsup technologies were favorably rated for commercial utilization. Reduction of the input costs for sweetpotato catsup was suggested (Abejuela 1991). The comments were useful. Subsequently, raw materials costs for sweetpotato catsup were reduced 50%. This improved the economic attractiveness of the technology and thus accelerated its adoption by end-users. Evaluation of the commercial potential of a developed technology therefore should be incorporated in research planning and budgets.

Technology Transfer Phase

Habito (1991) identified various barriers to the commercial use of research results. Among these, inadequate information on available new and promising technologies as well as "immaturity" of available technologies are considered to be direct impediments to the process of technology transfer.

Information Dissemination

More efforts should be geared toward disseminating the information on promising technologies to a wider, more popular audience, i.e., the potential end-users, to complement the extensive, technical literature in the form of reports produced in universities and government research institutions. Government can play an important role in this aspect by linking potential investors with the generators of technology through provision of appropriate opportunities for interaction between the two.

Technologies for fruity-sweetpotato products were widely disseminated through the various investment forums organized by the Department of Trade and Industry, and the national/regional science and technology fairs. These helped create an awareness for farmers, food processors, and companies of new products made from sweetpotato and, thus, accelerate the adoption of the developed technologies.

Pilot Testing

A pilot project aims to generate information needed to confirm the "maturity" of the developed technology in terms of technical and economic feasibility for commercial production. This step is often not performed and the generated technology is sometimes publicized prematurely.

Depending on the technology level, pilot testing of a developed technology can be carried out in a community-based project or at a pilot plant/factory of the research institution or corporate cooperator.

Community-based project. Due to location-specific factors in community-based projects, it is necessary to evaluate the technology's adaptability and socio-economic parameters, as well as to integrate production, processing, and marketing. Truong (1991) pointed out that if pilot projects were not set up in villages, valuable lessons in the transfer of cassava flour processing technology would not be learned.

The following key factors in setting-up community-based projects for pilot testing of village-level technologies have been identified:

- *Farmer organization.* Farmer associations and cooperatives are existing in many villages. Orientation and strengthening of the cooperatives toward new ventures (i.e., processing and marketing) are needed.
- *Financial support.* Despite the existing credit schemes from government and private financiers, the lack of capital is usually the constraint which keeps farmers from engaging in agricultural production and processing. Furthermore, the release of approved loans is usually delayed.
- *Entrepreneurship development.* Small farmers usually have little experience in operating a processing unit and marketing processed products. Training needs have to be assessed to develop skills in management, accounting, processing techniques, quality control, and marketing. This process may be costly and take time. Nevertheless, it is the only way to help small, start-up enterprises survive in the business environment.
- *Material inputs.* Purchase of packaging materials requires a substantial capital investment. This is usually a major constraint at the start of the operation. Without attractive packaging materials, the product may not be able to compete effectively with other products in the marketplace. The cost of equipment is another limiting factor.
- *Market development.* Product name and package design can increase marketability, especially in consumer goods. However, no matter how good the product is, its promotion through published advertisements, television, radio, leaflets, etc., is essential to catch the attention of consumers. Guerrero (1984) reported that a lack of funds for promoting products through the mass media was one of the major con-

straints of a pilot project for commercialization of an extruded, high protein supplementary food. Farmer organizations and small-scale processors cannot afford to conduct promotional campaigns for the distribution of their products. This is an area which needs strong support from local government, even during the commercialization phase.

- *Commitment of the parties involved.* Commitment of all parties involved, e.g., cooperators, researchers, institutions, and government/non-government organizations, should be institutionalized to ensure the continuation of the pilot project until the research results are converted into commercially successful products. A strong commitment by farmers to sustain the operations beyond the pilot phase not only depends on the potential profit of the venture, but also on whether the researcher can prove to farmers that their involvement in the undertaking is really for their long-term benefit, rather than as a means for the researcher to gain credit. Likewise, financial support from the government should be extended until results of the pilot testing are obtained. "Seed money" and/or "facilities-for-rent" should be provided at the initial phase of commercialization. Commitment by researchers/institutions for technical assistance to the cooperators should also be sustained, even beyond the pilot phase.

Pilot project at company's factory/pilot plant. For technology which has industrial potential, government research institutions may not have the facilities required to undertake complete pilot testing. Collaboration with private companies interested in the technology can accelerate the commercialization of the research results. The following factors need to be considered when deciding on collaborators.

- *Capability of the company.* This determines the pace of commercialization. Difficulties encountered by the company which adopted the Delicious Sweetpotato technology illustrate this point. For start-up companies, commitment, entrepreneurship development, material inputs, and market development strategies are essential factors required for successful commercialization. For companies with established processing and marketing capabilities and tested products belonging to the same category as the newly developed products, the pilot project can move directly into the commercialization phase.

- *Partnerships between private companies and public research institutions.* Such partnerships should be promoted for mutual benefit. The company may be updated with new technological developments. The institution may get feedback about the adopted technology that would be useful for refining the direction of its R&D programs. Usually, conflicts of interest between entrepeneur and researcher do not encourage this type of partnership. The businessman counts on private profits from the investment, while the researcher is oriented toward professional advancement in terms of scientific publications which may benefit the general public.

  Private companies making profits from the research results of public laboratories should be willing to contribute (in cash or in kind) to the institutions generating the technology for partially supporting the R&D activities. This is a part of their social responsibility.

- *Supply of raw materials.* When the market for the product is established, there is a corresponding increase in the demand for the raw material needed in the processing. This necessitates a good production plan to ensure an adequate and regular supply, particularly in the case of new varieties not widely grown in the locality. This is the experience with the sweetpotato beverage previously cited.

  Raw materials can be supplied either by contract growers or from the private company's plantation. The former scheme is more complicated, but it is often preferred by the researcher and the public institution because it benefits small farmers if the price is right. Production of sweetpotato catsup at the commercial scale as mentioned in the previous section is a good example of this scheme. Again, the commitment between growers and the processing group should be mutually complied with.

Conclusion

The experiences cited illustrate examples of the smooth transfer of the technologies developed for sweetpotato catsup, jam, beverage, and Delicious Sweetpotato to the private sector. Sweetpotato catsup has been commercialized at both a small- and large-scale. The other products are still at the pilot stage. Regardless of how much effort is put into bringing research results to end-users, a reasonable lag time prior to commercialization must be expected. This is particularly true for sweetpotato, because tactful marketing strategies are needed to gain acceptance of the products by consumers, and thus, accelerate their market penetration.

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Product Development at the Local Level: Mayon Brand Sweetpotato Catsup and Jam

Henry C. Samar, Sr.[1]

Abstract

A number of sweetpotato processed products are currently being produced in the Bicol region by a local self-help organization. This paper briefly reviews the history of product development for sweetpotato in the Bicol area. Favorable circumstances and key constraints for sweetpotato product development in Bicol are noted before concluding with a short list of recommendations for extending such work in the future.

Key words: Philippines, processed products, farmers, researchers.

Introduction

Sweetpotato catsup and jam are presently manufactured by the BIADS Foundation, Incorporated. The machines used to manufacture the products were procured through a grant from the Australian Direct Action Program (ADAP) of the Australian Embassy in Manila. Present production output is only 50% of the plant's capacity of 16,128 320-gram bottles per month of finished product. The same machines can be used for the manufacture of sweetpotato jam and can pasteurize the root-soy sauce. However, due to a lack of working capital, these two food items are not produced on a commercial scale yet. The catsup now is in the market, but sweetpotato jam is produced in small quantities on an on-and-off basis. The BIADS immediate market outlet is small farmer organizations. The product is distributed to members with a certain commission given by BIADS for sales. Other market outlets are the cooperatives, the City Public Market at Legazpi, and the public market at Daraga, Albay. Profits are being distributed proportionately to the direct and secondary beneficiaries through a profit-sharing scheme. BIADS members used their shares for building capital. Each member has an individual bank savings account for this purpose.

Sweetpotato jam and sweetpotato soy sauce will be produced on a commercial scale at the soonest possible time. BIADS is presently waiting for a delivery van and the provision of substantial working capital. The market demand for sweetpotato catsup is gradually increasing because it is popular and commonly used by farm children. Some customers use it as a sandwich filling and on cooked sweetpotato. Most of the farm children in the farthest *Barangays* in Legazpi City and Albay Province use sweetpotato catsup as a substitute for fish and meat because their parents cannot afford the high price of fish and meat in the market.

One selling point for sweetpotato catsup is its nutritive value and the presence of Vitamin A. Albay is now the most depressed area, second to it is Camarines Norte. Malnutrition is more prevalent in the cities of Legazpi and Albay than in other areas of the Bicol region. BIADS Foundation believes that development of sweetpotato in the Bicol region is one way to contribute to the alleviation of poverty through the utilization of sweetpotato as a food extender.

Because the tuber production of VSP varieties is always higher than that of traditional varieties, the BIADS Foundation singled them out as the only varieties that should be propagated in the Bicol region. The most serious problems that our members are encountering are the following:

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- lack of working capital to set-up processing centers in every province of the Bicol region;
- no storage facilities to store sweetpotatoes so that there will be a continuous daily supply of fresh tubers to the processing plants;
- technicians with the Department of Agriculture in the region are not helping the farmers to propagate root crops, specifically sweetpotato; and,
- there is always a good market even for the fresh tubers, but sweetpotato developers like the BIADS Foundation do not have the capital to buy a delivery truck.

Project History

The following is a personal history of how VSP sweetpotato varieties became so popular in the Bicol region and how sweetpotato catsup and jam came to be identified as food items with commercial potential in the area.

On October 27-29, 1986, I first visited the Visayas State College of Agriculture (ViSCA) with 39 farmers who cultivated small areas of marginal land in the Bicol region. We attended a special training session on root crop production, processing, and utilization. The session was sponsored by the Department of Agriculture, Region V, the Philippine Root Crop Research and Training Center (PRCRTC), and the Philippine Training Center for Rural Development in ViSCA. From November 1-7, my special training on root crop processing and utilization was extended with sponsorship from the Agricultural Training Institute (ATI) through the efforts of Federico Flores and Truong Van Den of ViSCA. From September 27 to October 2, 1987, I came to ViSCA for the second time with a group of leading farmers and entrepreneurs from the Bicol region for special training on sweetpotato technology under the sponsorship of the Department of Trade and Industry. On October 12-26, 1987, I came again for a short course on Root Soy Sauce Production and Feed Formulation with three leaders from our farmers' organization; this course was under the sponsorship of the Department of Agriculture, Region V.

Through this special training extended to me by the PRCRTC and ViSCA, I came to know that sweetpotato can be an important industry in the country, particularly in the typhoon-prone Bicol region; provided, however, that processing, marketing, and utilization is given more emphasis and intensive attention by sweetpotato developers.

The BIADS Foundation has succeeded in its program for the development of sweetpotato in the Bicol region primarily because of continued support through monitoring activities by the PRCRTC and ViSCA. Some of its researchers have conducted field visits to our area. These have been coupled with the active participation of the Department of Trade and Industry in extending substantial funding support to the extension of technology transfer, seminars, and skills training on sweetpotato production and processing, utilizing the services of the author, as trainer/resource person. In addition, this has been complemented by the BIADS Foundation's total determination to bring into reality its vision that in five years time, sweetpotato can be identified as one of the important industries in the Bicol region. We want it to be primarily a food product that can contribute in the acceleration of uplifting the living standard of its farmer-members and alleviating the poverty which is presently being suffered by the majority of Bicolanos.

There are some circumstances that can encourage farmers to upgrade the production of sweetpotato so that there will be a steady supply of sweetpotato raw materials to the catsup manufacturing plant. Among these are the presence of the most famous, worldwide known, beautiful and perfect cone-shaped Mayon volcano which has contributed to the steady soil fertility in Albay, and the occurrence of moderate rains, even during summer. There is also the Tiwi Geothermal Plant which generates electricity not only for the Bicol area, but to some parts of Luzon; and land and sea transportation are very accessible in the region, particularly in Albay. However, some constraints which hinder the development of sweetpotato include the following:

- lack of concern for extending financial support and technology on sweetpotato processing, utilization, and marketing to the farmers;
- uncertainty of marketing outlets and nondevelopment of processing centers and utilization schemes, which results in indetermination by farmers to venture into producing more sweetpotato to provide a steady supply of raw materials to the processing plant;
- except for the low-income group who buy sweetpotato catsup and other products, the middle-income group, especially those that are in the upper bracket, are criticizing sweetpotato products, particularly the catsup, because of its sweetpotato-aroma. According to them, it is of poor quality because it is made from sweetpotato;

- awareness and creation of greater market demand are not properly developed because of lack of information dissemination on the nutritive value of sweetpotato products;
- some of the customers, especially the upper-class group, prefer to buy multi-national products. This results in a very slow increase of manufacturing output by entrepreneurs and food processors; and,
- some of the customers are ashamed of buying sweetpotato products because of their belief that sweetpotato is a poor man's food.

Conclusion

Based on this experience, recommendations to develop sweetpotato processing in the future are as follows.

1. Formulate a plan of action and adopt strategies for sustainability in implementing policies for addressing constraints.
2. Establish linkages and close coordination between government agencies and non-governmental organizations that are involved in the development of sweetpotato.
3. Formulate short- and long-term plans/policies for an effective and systematic approach to disseminating information on the importance of sweetpotato.
4. Establish a sweetpotato advertisement or commercial in the programing, coordination, and implementation of programs relative to the development of the sweetpotato industry.

Sweetpotato Processing in the People's Republic of China with Emphasis on Starch and Noodles

Siert G. Wiersema[1]

Abstract

Annual sweetpotato production in China is about 100 million t. Although utilization patterns vary across provinces, about 45% of national production is processed into a wide range of food and industrial products. Sweetpotato utilization for animal feed is of increasing importance, while use of fresh roots for human consumption is decreasing. Starch and noodles are mainly processed at the village level using a range of methods and equipment resulting in varying product quality. The use of residues for pig feed is an important component of village-level processing. There is considerable interest in upgrading traditional processing methods through the use of small-scale equipment. Further technical and socio-economic analysis of current processing systems is needed as a basis for improving village-level processing.

Key words: noodles, starch, processed products, equipment, research.

Introduction

Sweetpotato (*Ipomoea batatas*) was introduced in China approximately 400 years ago. Since then, the crop has spread to most provinces. Presently, China has the largest sweetpotato production in the world. In recent years, area planted has varied greatly with a peak of 9.6 million ha in 1963. This peak occurred just after several years of severe food shortages. With the expansion of rice, wheat, and corn, area planted with sweetpotato gradually decreased to 6.1 million ha in 1986. National average yields in 1986 were 16.2 t/ha and total sweetpotato production was about 100 million t per year. The main sweetpotato growing provinces are Sichuan, Shandong, Henan, Anhui, and Guangdong (Table 1). Average yields in these provinces range from 11-24 t/ha.

Sweetpotatoes are mainly grown on marginal soils and a further decrease in growing area is not expected. Since 1986, total production has increased slightly, mainly as a result of increases in yield per ha. Sweetpotato plays a significant role in food security for the rural population.

Utilization of Sweetpotato in China

Although exact figures on utilization of sweetpotato are difficult to obtain, it is estimated that 15% of total sweetpotato production is used as fresh roots for human consumption, 15% as raw material for the processing of food products, 30% as raw material for industrial processing, 28% as animal feed, and 12% as planting material. The data in Table 2 present the variation that exists in the utilization pattern of sweetpotato across provinces.

Major changes in sweetpotato utilization have occurred, as indicated by data from Sichuan Province (Table 3). Compared to the 1970s, the figures for the 1980s show a drastic increase in utilization for animal feed, particularly pig feed, and a decrease in the use for human food. Fresh roots and fresh or dried vines, as well as residues from starch processing, are all important sources of pig feed.

Processing sweetpotato into starch and noodles is particularly important at village and household levels.

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Table 1. Sweetpotato production and yield in China, 1986.

Province	Planted area (000 ha)	Yield (t/ha)	Total output (000 t)
Sichuan	1,230	15.5	19,100
Shangdong	818	24.5	20,015
Henan	783	11.4	8,910
Anhui	658	21.0	13,860
Guangdong	580	12.0	6,930
Hebei	352	16.0	5,625
Jiangsu	275	24.2	6,650
Hunan	265	13.4	3,350
Guangxi	237	4.9	1,170
Fujian	217	15.3	3,305
Total	6,175	16.2	100,165

Source: National Year Book.

Table 2. Sweetpotato utilization (%) in selected provinces of China, 1988.

Province	Fresh root Consumption	Animal Feed	Processing	Others
Sichuan	20	65	10.0	5.0
Henan	15	15	60.0	10.0
Shandong	10	24	51.0	15.0
Anhui	10	20	49.5	20.5
Hebei	10	30	55.6	4.4
Hunan	30	50	10.0	10.0
Jiangsu	10	30	58.1	1.9
Average	14.2	28.2	47.4	10.2

Source: Survey results from Tang Zongfu et al. (unpublished).

Table 3. Sweetpotato utilization (%) in Sichuan province, 1970s versus 1980s.

Use	1970s	1980s
Fresh root consumption	60	20
Animal feed	30	65
Processing	5	10
Planting material	5	5

Source: Survey results from Tang Zongfu et al. (unpublished).

Industrial processing of sweetpotato into products such as citric acid, calcium citrate, monosodium glutamate, organic solvents (butanol, alcohol), and glucose syrup is of decreasing importance due to small profit margins. In recent years, many sweetpotato processing factories have stopped production or have modified their processing facilities to facilitate the use of other raw materials, particularly corn.

Supply of Raw Material for Processing

Due to different climatic conditions, two distinct systems for supplying fresh sweetpotato roots to processing units can be distinguished. In one system, sweetpotato roots are processed soon after harvest, due to poor storability of fresh roots. In the other system, fresh roots are first transformed into dried chips (slices). The chips are then stored for year round processing.

In areas such as Anhui and Shandong Provinces where climatic conditions allow field drying of sweetpotato chips, the roots are sliced by hand after harvesting and left to dry in the field for periods of up to ten days. The dried chips have a moisture content of 12-14% and can be stored at ambient temperatures for long periods with little loss. The ratio of fresh roots to dried chips is about 2.5:1. The dried chips are usually stored in bags in the open air. Large quantities of bags are stored at processing factories to permit continuous processing throughout the year. Due to low transport costs for dried chips, raw material is obtained from large distances. Therefore, most processing factories in Anhui and Shandong provinces have a large processing capacity.

In contrast, in areas such as Sichuan Province where climatic conditions do not allow field drying of sweetpotato chips, fresh roots are processed into starch within two months after harvest. The starch can be stored for some time and is subsequently processed into noodles, alcohol, and other products. Since fresh roots cannot be transported over long distances, processing units in Sichuan Province are generally small.

Processing of Starch and Noodles in Sichuan

Sichuan Province with a population of approximately 100 million is one of the poorest provinces in China. Of the provinces, it has the largest annual production of sweetpotato. The annual cultivation area is about 1.2 million ha with an output of 20 million t. Although average figures for Sichuan Province show that only 10% of the sweetpotato production is processed (mainly into starch and noodles), in some areas more than 50% of the annual production is processed. Sweetpotatoes are harvested in October and November. Starch processing is mainly carried out in November and December, while noodle processing may continue until April.

Various levels of specialization related to the organization of processing activities can be observed in rural processing. Some families take their washed and cut roots to other more resourceful families for grinding the roots by machine. The pulp is taken home for starch processing. In other cases, families neither grind nor process their sweetpotatoes themselves, but take the roots to a farmer/entrepreneur for processing into starch and noodles. The entrepreneur then returns the processed noodles to his clients. The payment for this service is in the form of noodles that are withheld by the entrepreneur. This payment may be as high as 50% of the total amount of noodles produced for a client.

Starch Processing Methods

The methods applied for starch processing are the natural precipitation method and the "sour liquid method." Processing steps applied in the "natural precipitation method" are as follows:

Wash (fresh roots) → grind → sieve → precipitate in water (5-10 hrs) → remove water and add fresh water →stir → precipitate (5-10 hrs) → remove water → remove starch → dry the wet starch ⇒ dry starch.

Washing of the roots is usually done manually. A variety of different grinders are used for grinding. For sieving, an 80-mesh screen is used. In small processing units, sieving is done by hand, while in larger units sieving is carried out mechanically. For precipitation of starch, round wooden barrels are used by small processing units. Large processing units often use long water troughs (approximately 35 m each) to allow starch to settle. Small processing units sun-dry the starch, while in larger units the starch is centrifuged and artificially dried.

The natural precipitation method is clearly a low-cost method and is labor intensive. The recovery rate is low (50-70%) and the starch is often of poor quality due to its impurity and grayish color. Typical yields of sun-dried starch, following this method, are 12-18%, depending on cultivar and on the skill of individual families.

The "sour liquid" method gives better recovery rates and starch quality. Typical yields of sun-dried starch are 17-20% following this method. Processing procedures are as follows:

Wash (fresh roots) → grind → put slurry in wooden barrels → add "sour liquid" (*Streptococcus lactis*) and water → stir for 10-20 min → remove floating material → filter through 80-mesh filters → add water and sour liquid → precipitate (12 hrs) → remove water and add fresh water → stir and filter through 80-mesh filter → add fresh water to the wet starch → precipitate (3-4 hrs) → wet starch → dry the wet starch ⇒ dry starch.

The sour liquid method is carried out manually except for the grinding. The method is rather complicated and only a few families/processing units have mastered it. Further analysis of this method is needed.

Residues from Starch Processing

Residues from starch processing are used for pig feed. Typically, the yield of sun-dried residues from starch processing is about 35%. The nutritional value of the residues for pig feed is an important aspect of the overall system of starch processing. Increasing the efficiency of starch extraction by using more effective processing equipment will reduce the value of pig feed. An economic analysis needs to be carried out to determine which parts of the processing system, including utilization of residues and waste, might be improved.

Starch processing is a potential threat to the environment due to the disposal of waste water. For washing roots, sieving, and precipitating starch, about 5 m^3 of water are needed per ton of sweetpotato. This water is disposed of in an untreated form. Techniques to treat waste water are available, but their economic application in village-level processing needs to be analyzed.

Noodle Processing Methods

Processing starch into noodles is carried out by individual families as well as by rural entrepreneurs. Processing by individual families is almost entirely done manually while small entrepreneurs apply semi-mechanized methods. Noodle processing at the household level is labor intensive with a processing capacity of 250 kg of noodles per day with five or six laborers.

The process of noodle making at the household level is as follows:

Starch → add cold water while stirring → slurry → add boiling water and stir → add more starch and hot water → slurry → manual "extrusion" → noodles pass through boiling water → rinse in cold water → dry on bamboo-matted floor (1-2 hrs) → sun-dry noodles (8 hrs) ⇒ dry noodles.

Many variations in noodle processing methods exist. Some families start with pea starch and add boiling water to gelatinize the starch before sweetpotato starch is added. Other families mix sweetpotato starch with corn starch. Considerable skill and experience is needed to produce noodles following manual methods. The "extruder" used in the process is basically a pan with holes in the bottom. The slurry or dough is pounded by hand to force it through the extruder. The thickness of the noodles is determined by the size of the holes in the extruder and the distance of the extruder to the surface level of the boiling water.

Noodles made following traditional methods are generally of acceptable quality for the local market, except, perhaps, for the color which is often too dark. The market pays a higher price (about 10%) for light-colored noodles. Dark colored noodles result from impurity of the starch and are caused by enzymatic reactions. Peeling roots would reduce enzymatic reactions and is likely to result in lighter noodles. Also, the use of sulphite would improve noodle color due to its neutralizing effect on enzyme activity. Noodles made from starch that is produced following the sour liquid method are generally of lighter color and are, therefore, of better quality.

Various degrees of mechanization in noodle processing can be observed at the village level. In some cases, pounding by hand to force the dough through the holes of the pan has been replaced by a motor-driven "pounder." Also, the mixing of starch and water is done by using a mechanical mixer rather than manually. Small extrusion machines with a capacity of up to 500 kg of noodles per day have been developed by the local machinery industry. To process noodles, the extruder is filled with a slurry of sweetpotato starch. The extruder is heated electrically and the starch is gelatinized in the machine. When the gelatinized mash is pressed through the extruder, the noodles are formed. The noodles are immediately cooled and partly dried by means of an electric fan. The quality of noodles obtained from these extruders, particularly the texture, is considered to be poor by the local market. In fact, some families in Sichuan Province with a long tradition of manual noodle processing have abandoned the use of extruding machines and returned to the manual process. More research is needed on the particular properties of sweetpotato starch related to extrusion techniques. This will allow the development of improved designs for extrusion equipment.

Conclusion

Sweetpotatoes are processed into a variety of products at both village and industrial levels in China. Industrial sweetpotato processing is of decreasing importance due to small profit margins. Starch and noodles are mainly produced at household and village levels and are an important source of income for rural families. The use of residues from starch processing for pig feed is an important component of the processing system.

A range of different equipment is employed for processing sweetpotato into starch and noodles resulting in varying product quality. There is considerable interest in upgrading traditional processing methods through the use of small-scale equipment with low power consumption. A detailed technical and socio-economic analysis of current processing methods is required before specific changes leading to overall upgrading of the current system can be recommended. In such an analysis, particular attention needs to be paid to the economic value of residues for pig feed. Economic methods of treating waste water at the village level also need to be developed.

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Aspects of Sweetpotato Processing in Sichuan Province, People's Republic of China

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Abstract

In the rural sector of Sichuan Province sweetpotato processing is principally directed toward the extraction of starch, and the subsequent manufacture of transparent noodles for human consumption. This paper describes the basic processes employed and, in particular, gives an account of an unusual traditional process known locally as the sour-liquid method. Preliminary work carried out by the Natural Resources Institute (NRI)on the characteristics of the starch and the microbiology of the fermentation operation used to prepare the sour-liquid are reported. The paper concludes with general observations on future research needs for sweetpotato processing in China. A brief appendix describes the sour-liquid method.

Key words: China, sweetpotato, processing, research, noodles, starch.

Introduction

Sichuan Province produces about 19 million t of sweetpotato a year, which is roughly equivalent to the combined outputs of all non-Chinese producers of the crop in developing countries. The bulk of sweetpotato production in Sichuan is located within the Red Basin region. Production has expanded in recent decades, partly through expansion in area and more recently through higher yields, but there is considerable scope for future growth, primarily through improved yields. At present the yields vary between 10.3-20.5 t/ha, and average around 16.3 t/ha.

In recent decades the pattern of utilization and processing of sweetpotato in Sichuan Province have undergone significant changes (Table 1). The recent dramatic decline in direct food use of fresh roots is a common theme for China as a whole, partly as an outcome of growing incomes and the improved availability of preferred staples such as rice and wheat. The growth in importance of use for animal feed and the relatively modest role of processing are however in contrast to patterns in most other major sweetpotato producing regions where processing is far more important (Table 1).

The pattern in Sichuan partly reflects the growth in importance of livestock products—especially pork—generated by rising incomes and with a corresponding growth in livestock feed requirements. In contrast, climatic factors, particularly the difficulty of producing dry chips for subsequent processing in large-scale centralized plants, appear to act as a major constraint to processing. Almost 60% of processing is reported as household- or village-level starch extraction, principally for the production of noodles (Tang 1989), while an additional 20% is for Chinese wine. A number of large-scale plants exist for the production of starch and other items, but these only account for a little over 20% of the total amount processed.

Processing

Economic Context

There appears to be little recent socio-economic research within Sichuan in the sweetpotato sector. As a consequence, the material for this section is based upon

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Table 1. Production and utilization of sweetpotato in major producing provinces in China.[a]

Province	Production[b]	Utilization (%) Food	Feed	Process[c]	Other
Shandong	20.0	10	24	51	15
Sichuan	19.1	20	65	10	5
Anhui	13.9	10	20	50	20
Henan	8.9	15	15	60	10
Jiangsu[d]	6.6	10	30	58	10
Hebei	5.6	10	30	56	4
Hunan	3.6	30	50	10	10
Rest of China	31.0	n.a.	n.a.	n.a.	n.a.
All China[e]	108.7	14	34	40	11
Historical use in Sichuan:					
1930s		80	10	--[f]	10
1970s		60	30	5	5
1980s		20	65	10	5

Source: Adapted from Tang et al. 1990, Buch 1937, and Tang 1989.

[a]Unless otherwise indicated, data refers to late 1980s.

[b]Million tons per year.

[c]Processed products include food items.

[d]Data for Jiangsu are incorrect in the original source, allowance has been made for the error in calculating the all China average.

[e]Percentage breakdown refers to named Provinces only, based on provincial percentages weighted by production.

[f]Marginal levels of processing may be included under food use.

n.a. = Data not available.

a limited range of sources and the conclusions are somewhat speculative. Major information sources include a limited number of field interviews within the Red Basin region as part of a one-month visit to Sichuan in 1990.

Small-scale processing in Sichuan is primarily a household-based enterprise, although some larger cooperative village-based factories exist. At the household level, processing has an extensive history, but commercial production on a significant scale appears to be a relatively recent phenomenon. Specific localities have developed within Sichuan as concentrated areas of commercial processing partly as a consequence of historical tradition and also of access to transport infrastructure. A much larger number of households produce starch essentially to provide for their subsistence needs, and some of these also make noodles for their own use. Commercial production is geared principally to the sale of noodles in urban areas, with only small volumes of starch traded. This feature may be partly explained by the difficulty of producing noodles in the home.

Field observation and interviews indicated that only a small number of households process sweetpotato commercially on a significant scale. Limiting factors appeared to be access to (household) labor, available financing, knowledge of the process, access to water, and access to transport infrastructure.

Households interviewed indicated a required labor force of 6-8 adults to successfully undertake commercial production. All households actually processing had four or more adults, and labor hire or collaboration between households appeared relatively uncommon. Traditionally, processing is carried out by the men of the household.

Financial requirements for establishing processing appear quite significant; for example, a powered rasper costs in the region of Y 1,000 and a powered noodle extruder Y 2,000 (Approx.: Y 5.2 = US$ 1.0). These figures may be compared with average per capita income of Y 500 in the areas visited and with costs of agricultural equipment, e.g., plows, at Y 34. Field observation indicated that processing households were among the most wealthy in local communities.

Knowledge of the process appears to be a necessary, but not sufficient condition for processing (constraints of labor or finance, in particular, may prevent uptake). Access to water (notably for the starch extraction stage) was generally not a problem in those areas visited, although problems may arise especially in upland areas of the Red Basin. Access to transport may be of considerable importance. Historically, access to river transport was fundamental (Buch 1937), while in recent decades constraints are still imposed by the relatively limited development of the feeder road network and hilly topography of much of the Red Basin.

Storage

Perishability of fresh sweetpotato is of fundamental significance to its subsequent utilization and processing. In Sichuan, ambient temperatures are such that storage periods of up to seven months were reported as feasible. With well constructed stores and chemical treatm nt, losses over this period were said to be as much s 10%, although this may well refer only to quantitative losses.

Notably an abundance of fruit flies (*Drosophilia spp.*) was observed in and around stores which suggests the presence of soft rot (*Rhizopus stolinifer*) in the roots (Moyer 1982).

Although root storage in Sichuan may be less problematic than in some other regions, the strategy preferred by most household-processors appeared to be to process all roots to starch which is then stored. This material is then mostly processed over the ensuing six-month period, although some processors operate on sweetpotato starch over the whole year. This approach reflects the greater ease of storage and lower storage losses reported for dry starch in comparison to fresh roots.

In some locations processors kept the starch under water for periods of up to six months, in preference to immediate drying. This practice was said not to alter the quality characteristics of the starch.

Although it is reported that processors can produce noodles with a storage life of up to one year, in practice they appear to be produced with a moisture content which limits the shelf life to a few weeks. The latter is sufficient to allow time for transportation and sale and enables a higher return per unit of starch.

Starch Extraction

The basic process used for household and village-level starch extraction from sweetpotato is shown in Figure 1. There are three fundamental stages: extraction, purification, and final preparation. At the rural level, the process is not standardized and is confined to processing between 100-2,000 kg of roots per day.

Industrially, the process operations are similar to those shown in Figure 1, but they do differ in terms of the techniques and plant used to carry out the operational stages involved; plant capacities varied between 10-100 t/day.

At the small-scale level, freshly harvested roots are washed and then ground to produce a mash. Typically roots are ground, either with or without water, using a pin mill, hammer mill, or a traditional root crop rasper. The choice of mill depends on the scale of operations and whether an alternative use for the mill exists. Water, when used, is not treated, being drawn either from shallow wells or directly from flooded paddy fields. Its quality is not potable and this would be expected to influence the microbiological quality of the starch produced.

After grinding, the mash is washed on a synthetic screen in order to separate free starch from the fibrous residue. The starch slurry is allowed to sediment and the residue is sun dried or ensiled to be used as animal feed. Sedimentation marks the end of the extraction phase and the start of purification.

Historically, purification of sweetpotato starch has proven a difficult and complicated process. The presence of polyphenolic compounds, ascorbic acid, and carotene make production of good white starch difficult (Yanamura et al. 1959). Industrially in Japan (and previously in the USA), purification is under alkaline conditions using saturated lime water (Brautlecht 1953; Winarno 1982). In rural Sichuan Province, variations on two basic procedures were observed. In both methods, starch sedimentation was done three times. The principal distinction between the procedures is the nature of the liquid used to wash the starch. In some areas, fresh water was used to purify the sedimented starch prior to final recovery, but the starch so produced was invariably discolored. In other communities, an interesting and unique process, known locally as the "sour liquid method", was employed (Fig. 1 and 2). As far as is known, this method has not been investigated and has not been reported in the international literature. The sour liquid is an aqueous acidic fermented extract from dried peas, faba, or mung beans and is prepared as described in the

Figure 1. Sweetpotato starch extraction process (rural process: Sichuan Province, China).

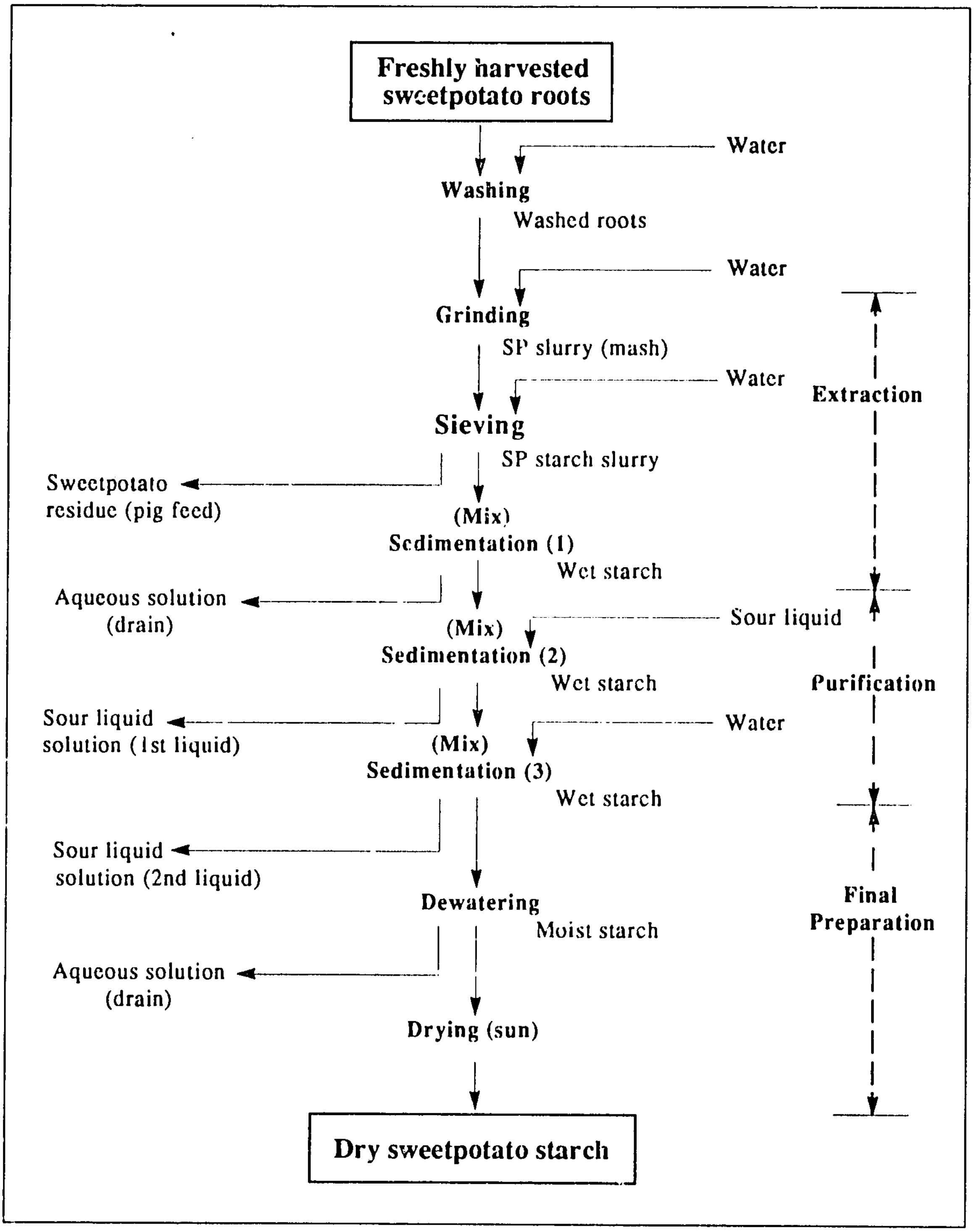
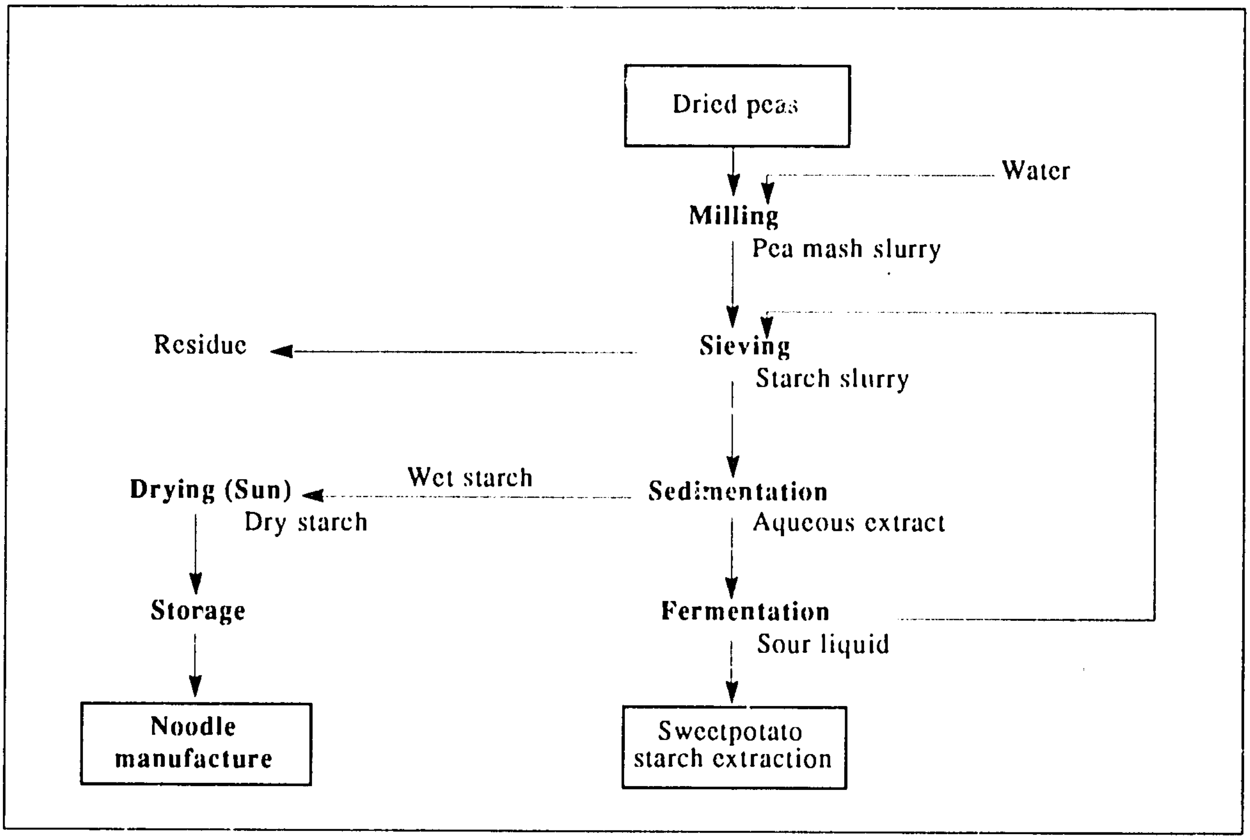


Figure 2. Preparation of "sour liquid" (rural process: Sichuan Province, China).



Appendix. As observed and discussed with farmers, there are two important features regarding use of the sour-liquid method:

- Following initial preparation and subsequent use of the original sour liquid, the aqueous solution obtained from the third sedimentation stage of starch extraction (2nd liquid -Fig. 1) is used as the fresh sour liquid for future processing. Its use is dependent upon its ability to promote starch sedimentation, which is checked visually. If it is not strong enough, it may be strengthened by the addition of some of the more potent first liquid (Fig. 1).

- The sour liquid must be added and mixed immediately with the wet starch following the first sedimentation otherwise the final starch will be discolored. The quantity of sour liquid added is carefully monitored by, prior to processing, evaluating its effect on the rate of sedimentation of a small sample of wet starch cake. The addition of too much sour liquid results in flocculation and associated separation difficulties. Too little sour liquid results in an excessively long sedimentation period and a less white product.

After the third sedimentation, the final stage of product recovery begins. Following decanting, the wet starch cake is further dewatered by allowing it to drain overnight in a suspended nylon screen. The dewatered starch cake is carefully broken up and sun dried on concrete floors or suitable woven matting. Drying to a safe moisture content (approximately 12% wb) was reported to take between 6-8 hours in good weather and between 2-6 days under inclement conditions.

Noodle Manufacture

As observed, there are three key stages in manufacturing "transparent" noodles from sweetpotato starch: (1) preparation of starch dough, (2) formation, gelatinization, and retrogradation of the moist noodles, and (3) drying of the noodles.

The first step involves preparing a small quantity of gelatinized pea or corn starch to act as the binder, or macromolecular network, for the sweetpotato starch. At the household or village level of operation, this is usually carried out in a prewarmed ceramic vessel of around 100 liters capacity. Boiling water is added to the pea/corn starch and the mixture stirred vigorously to give a gel containing 5-7% (w/w) starch. Initially the gel temperature was 78°C and stirring was continued until the temperature had fallen to 50°C. The sweetpotato starch is then added progressively to the gel and mixed continuously until the desired dough consistency is reached. Typically, the amount of sweetpotato starch in the dough at this stage is about twice the weight of the pea/corn starch gel and the dough temperature has decreased to about 40°C. Notably, at the correct consistency, the dough loses its earlier stickiness and can be molded easily by hand.

The dough is then loaded into a saucepan-type "former" which is held at a distance of about 30 cm above the surface of boiling water contained in a heated vessel. The dough is then tapped firmly to force it through the holes of the former and into the boiling water in the form of noodles where gelatinization occurs. Following gelatinization, the noodles are immediately washed in cold water to promote retrogradation of the starch and attendant transparency of the noodles. The noodles are then cut to size and hung on bamboo cross pieces to dry. Under good sun-drying conditions, drying takes about one day; and under poor conditions around 3-4 days are required to bring the noodles to safe storage moisture levels.

The basic quality problems associated with sweetpotato noodles involve their poor color and cooking strength. Color of noodles varies between light and dark brown. Discoloration was considered by villages to be related to the variety of sweetpotato processed. For example, Xushu 18, a preferred variety for industrial use, was reported to produce a dark colored noodle; whereas Chuanshu 27, a variety widely grown by villages, was reported to produce a light colored noodle. In addition to varietal considerations, however, noodle/starch discoloration is most probably related to the chlorogenic acid content of the roots, and to enzyme/iron-catalyzed oxidative reactions more generally (Arthur and McLemore 1956; Hoover 1964). Noodle cooking strength and texture is enhanced by incorporating Potash Alum (Aluminium Potassium sulphate, $KAl(SO_4)_2{:}12H_2O$) at levels up to 0.8% (w/w) into the starch dough.

Research Work at NRI

The studies carried out to date are of a preliminary nature and encompass the quality of starch samples obtained from Sichuan and the microbiology of the sour-liquid preparation procedure.

Starch Quality

To evaluate the noodle making quality of the starch samples, paste viscosity during processing (heating and cooling) was measured at the National Resources Institute (NRI), using a Brabender viscograph (Fig. 3 and 4). Starch characteristics which are considered to be required to produce good quality transparent noodles are high and stable paste viscosity during processing.

The results obtained indicate that fresh starch samples (1, 3, 4, 6, and 8) had better pasting characteristics for noodle production than stored starch samples (two and five). Dough prepared for noodling gave the lowest viscosity values obtained indicating that adverse changes had occurred during production. Reduction in viscosity may have been due to the use of old (stored starch) or discolored starch (sample nine) with poor pasting properties. Pea starch collected during the survey did not give a measurable viscosity value (5% concentration) on the Brabender viscograph indicating a significant reduction in the expected gelatinization properties of a legume starch. Addition of pea starch to the sweetpotato starch dough could also have been responsible for the low values obtained for sample seven.

Proximate analysis (sugar and fats) to date at NRI have not indicated any reasons for the pasting differences obtained with these samples.

Microbiological Analyses of Samples of Sweetpotato Starch Prepared by the Sour Method

The microbiological compositions of a sample of sweetpotato dough and a sample of sweetpotato wet starch, both prepared by the sour-liquid method, were determined. The samples were collected on October 26, 1990, from Shaungnong Village and freeze dried on November 16, 1990. The long storage time before stabilization should be borne in mind when these observations are considered.

In each of the samples, lactic acid bacteria (LAB) were the principal group of microorganisms enumer-

Figure 3. Brabender viscograph of Chinese sweetpotato starch samples.

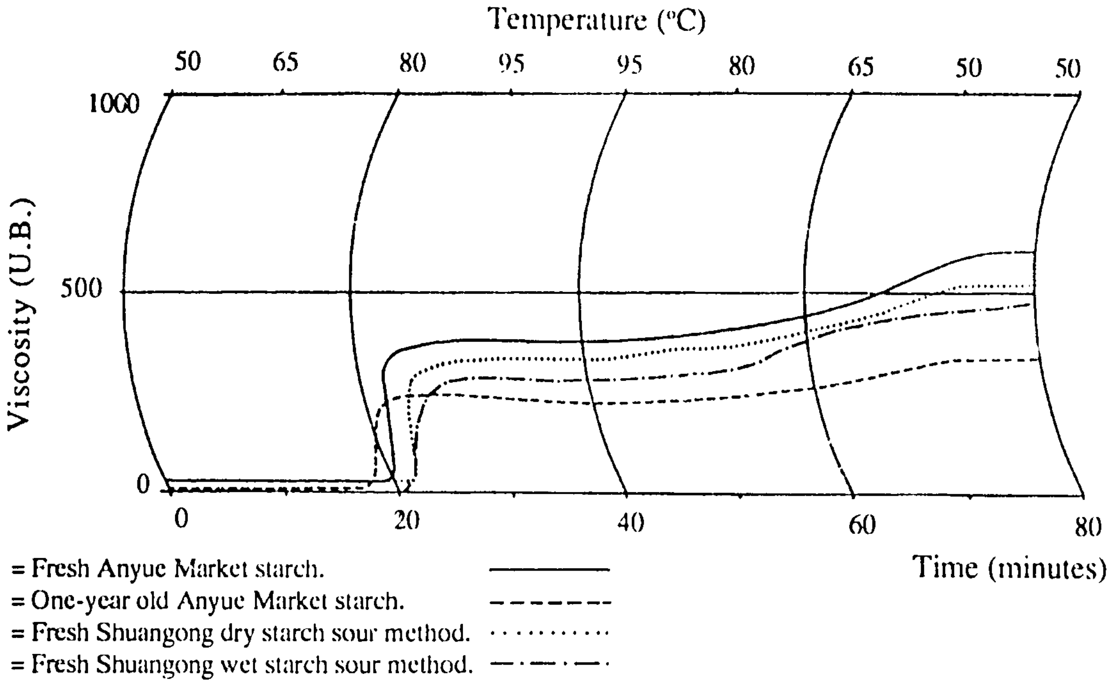
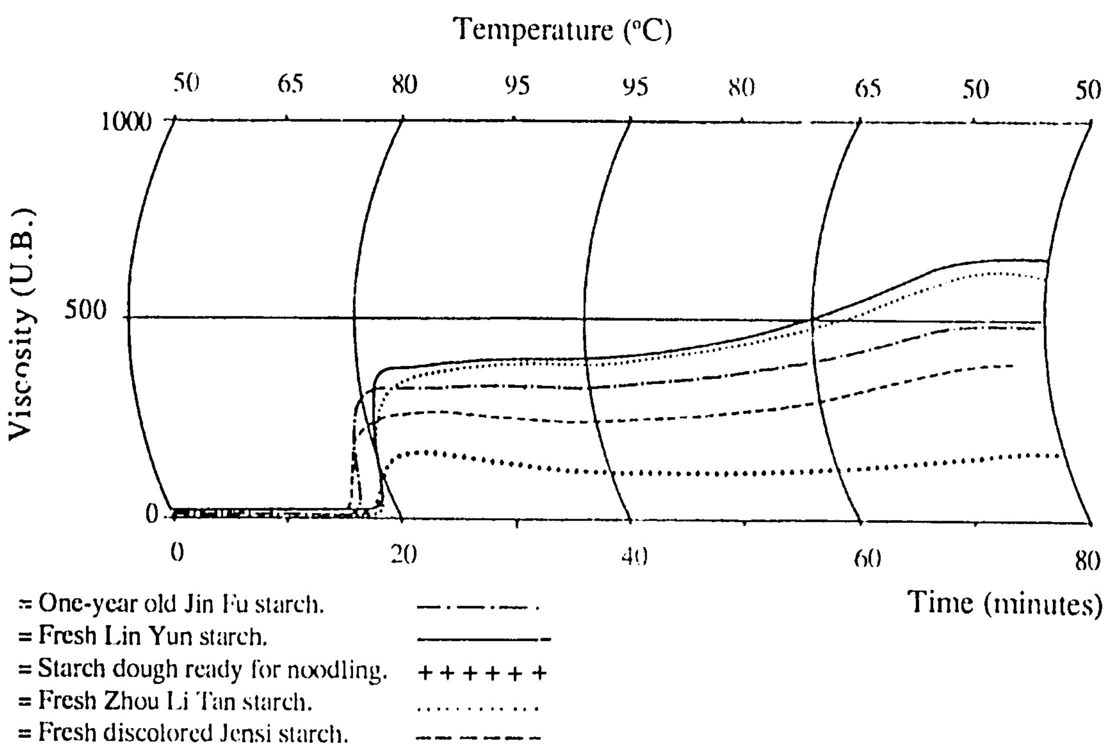


Figure 4. Brabender viscograph of Chinese sweetpotato starch samples.



ated with counts of 1.0 x 10^6 cfu/ml in the dough and 7.2 x 10^3 cfu/ml in the wet starch. A number of isolates were subsequently identified (Table 2). The dough was dominated by a mixed population of *Leuconostoc dextranicum* and *Leuconostoc mesenteroides*. The wet starch had a more varied population of homo- and heterofermentative lactobacilli which included *Lactobacillus brevis, Lactobacillus casei, Lactobacillus acidophilus*, and *Lactobacillus buchneri*.

Laboratory Studies on Preparation of Sour Liquids

The preparation procedure for the production of sour liquids was repeated at NRI laboratories in the U.K. using a sample of peas returned from China, split pea, broad bean, mung bean, and mung bean with 1.5% sweetpotato wet starch added on the first day of preparation. Microbiological changes and changes in pH value were monitored. Each of the sour liquids produced, with the exception of mung bean, was active for the decolorization of sweetpotato starch (on either day 12 or day 15 of preparation). With the exception of mung bean, changes in microbiological composition (Fig. 5 shows broad bean as an example) and pH values (Fig. 6) were similar.

During the fermentation of liquids from peas returned from China, split pea, broad bean, and mung plus added sweetpotato wet starch, LAB were the dominant group of microorganisms. *Enterobacteriacae spp.* grew in the early stages of each of the fermentations reaching peak concentrations between 50 and 100 h of between 1.4 x 10^5 and 2.5 x 10^9 cfu/ml. They then decreased in number to less than 102 cfu/ml after 200 h. The decline in numbers of *Enterobacteriacae* was probably as a result of the low pH due to acid production by LAB. Filamentous fungi and spore forming microorganisms played no role in any of the fermentations. Yeasts were detectable in only the split pea sour liquid reaching a count of 6.4 x 10^6 cfu/ml after 12 days.

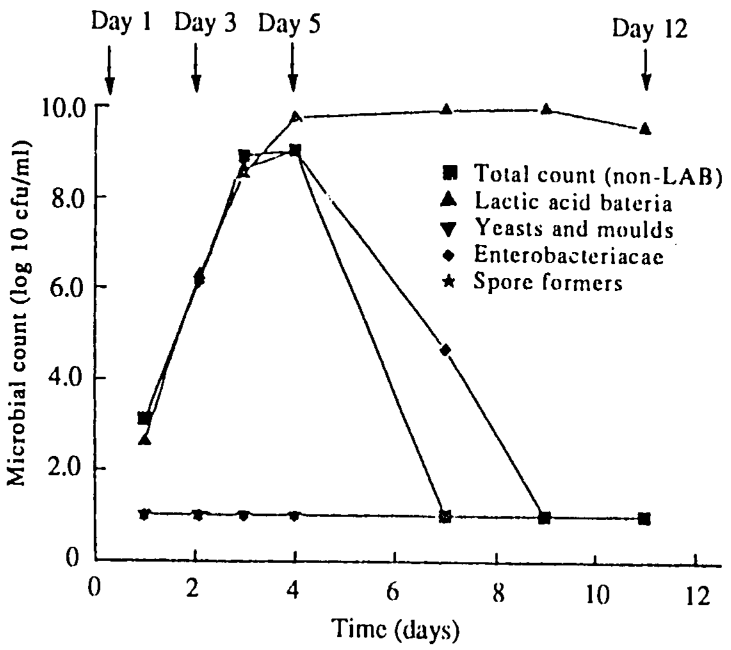
Mung bean sour liquid was dominated by *Enterobacteriacae spp.* and LAB with counts of 5.4 x 10^9 and 7.6 x 10^9, respectively. The rate of growth of the LAB was slower than that of the *Enterobacteriacae* at the start of the fermentation (Fig. 7). Yeasts, molds, and spore forming microorganisms played no role in the fermentation. The faster growth rate and initial numerical advantage of the *Enterobacteriacae spp.* may account for their importance in this fermentation. During village processing, such an outcome is unlikely since the environment would be expected to be contaminated with high numbers of LAB and a typical fermentation, such as that observed with broad bean or mung bean with added sweetpotato wet starch, would be expected.

Isolations were made from the sour liquid on day 12 of preparation. The principal isolates of LAB are listed in Table 2. Each of the principal LAB were heterofermentative, which is in contrast to other fermented foods, such as sauerkraut, where there is a succession of microorganisms with heterofermentative LAB dominating at the beginning and homofermentative LAB

Table 2. Principal isolates from starch samples returned form Sichuan Province and sample of sour liquids prepared from a number of legumes.

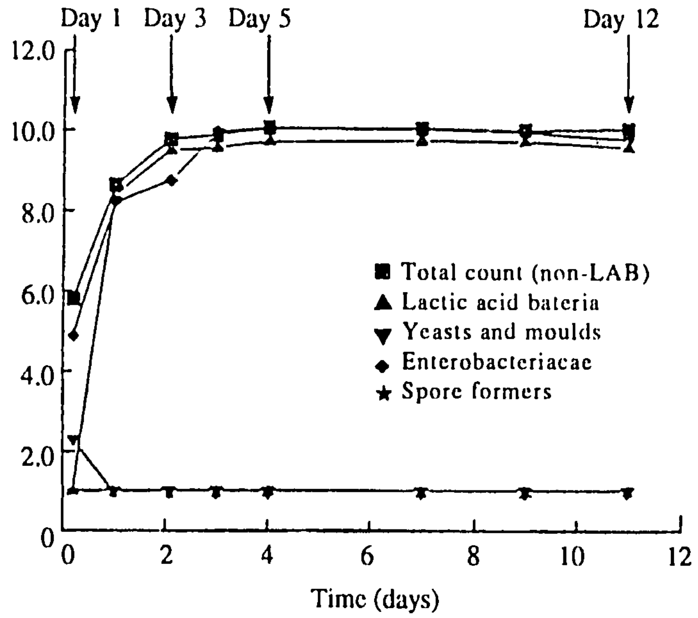
Sample	Principal isolates
Sweetpotato dough ready for noodling	*Leuconostoc mesenteroides* and *Leuconostoc dextranicum*
Sweetpotato wet starch	*Lactobacillus brevis, Lactobacillus casei, Lactobacillus acidophilus*, and *Lactobacillus buchneri*
Chinese pea and broad bean	*L. mesenteroides* and *L. dextranicum*
Split pea and mung bean plus sweetpotato wet starch	*L. mesenteroides* and *L. brevis*
Mung bean	*L. mesenteroides*

Figure 5. Changes in microbial populations during the preparation of sour liquids from broad bean.[a]



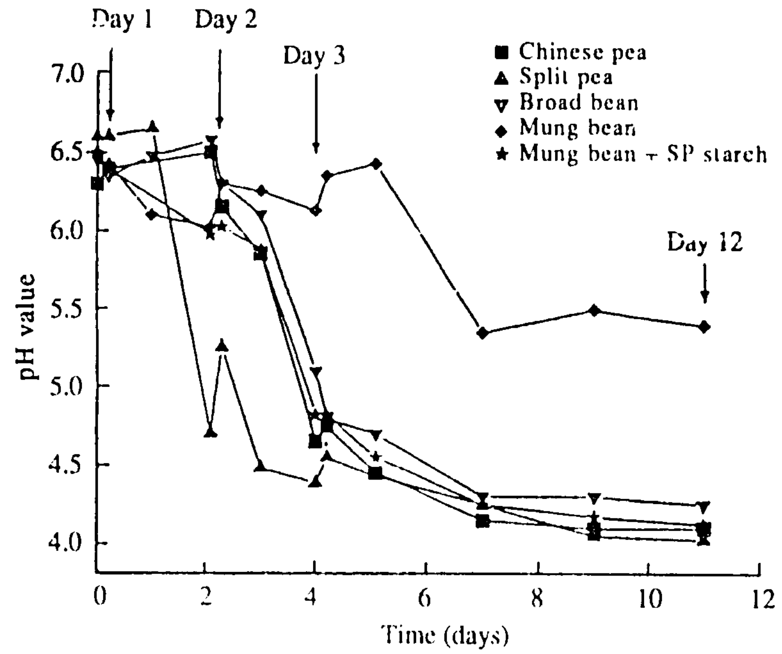
[a]Liquids were prepared according to the method detailed in the Appendix and incubated at 15°C.

Figure 6. Changes in microbial populations during the preparation of sour liquids from mung bean.[a]



[a]Liquids were prepared according to the method detailed in the Appendix and incubated at 15°C.

Figure 7. Changes in pH value during the preparation of sour liquids from a number of legumes.[a]



[a]Liquids were prepared according to the method detailed in the Appendix and incubated at 15°C.

dominating later (Vaughn 1985). The isolates from each of the beans were similar to those isolated from sweetpotato dough ready for noodling that had been prepared by the sour-liquid method (Table 2). Although we have some reservations about the samples of starch returned from China, it would appear that *L. mesenteroides*, *L. dextrancicum*, and *L. brevis* are the dominant organisms in the sour-liquid fermentation. The dominance of heterofermentative LAB is significant since the principal products of their metabolism are lactic acid, acetic acid (or ethanol), and carbon dioxide. Homofermentative LAB principally produces lactic acid (Kandler 1983). The nature of the end products may determine whether or not a sour liquid is active.

Discussion

Enhanced utilization of sweetpotato—in particular, aspects relating to starch extraction, animal feed, and noodle manufacture—is being energetically pursued by local authorities, villages, and individual households through much of Sichuan Province. Production of noodles is viewed as a practical means of raising incomes in the rural sector and earning foreign exchange through export. In order to expand the possible income generating effects of processing, it may be desirable to investigate the potential for labor saving within the process stages involved, since labor appears to be a major constraint affecting the uptake of the activity. Similarly, there may also be scope for reducing equipment costs and/or the need for ensuring that the introduction of mechanized components, such as noodle equipment, is not premature. The International Potato Center (CIP), in close collaboration with the Sichuan Academy of Agricultural Sciences (SAAS), among others, is providing significant scientific and socio-economic assistance to the development efforts involved.

For environmental reasons, starch extraction appears well suited to the small-scale operations found in the rural sector. The quantities of water used during the extraction process vary between 5-10 times the weight of fresh roots processed. The waste waters arising from the sedimentation operations are relatively easy to dispose by direct drainage to field irrigation channels. This situation contrasts strongly with the much larger factory-scale operations. Typically, in these situations, the quantities of water used are twice that employed in the small rural operations. In addition to containing soluble components such as dissolved sugars, protein, and vitamins, the waste waters also contain a suspension of very fine starch granules. Often, due to the lack of proper effluent treatment facilities, the waters are discharged directly into adjacent water courses, where high BODs ranging from 3,000-8,000 ppm (Honbo 1980) can generate severe pollution problems.

Evaluation—and subsequent optimization of the traditional processes used for manufacturing starch and noodles—represents a key component in the development of the Sichuan sweetpotato industry. An important objective should be the standardization of these processes with particular emphasis on product quality considerations. The process optimization studies should include *interalia* work aimed at reducing water requirements in order to minimize subsequent environmental pollution by the waste streams. On the processing side, research on the relative merits of the traditional "sour-liquid" and alkaline, commercial processes, appears a worthwhile area for further study. Regarding the former, the mechanism(s) involved in removing discoloration from the starch and the acid/bacteria interactions are of interest and should be elucidated. In view of the importance of sweetpotato residue for animal feed purposes, studies aimed at maximizing starch extraction from the fresh roots, should pay due regard to the overall energy levels required for the product by the animal feed sector. Given the inter-relationship between feed and food use, there is a strong case for closer investigation of future market trends for food items (noodles) and livestock products (pork). These may serve as a context within which more technically-orientated research can be developed.

The functional properties of starches extracted from different varieties by various means also require careful study. Regarding the manufacture of noodles, it would seem prudent to determine sweetpotato varieties high in amylase; and perhaps investigate the practicability of incorporating high amylase starches and desirable nutrients from other plant sources into the sweetpotato dough. The aim would be producing better quality noodles with high nutritive value.

Acknowledgment

The opportunity to observe sweetpotato processing in Sichuan Province was afforded by kind invitation of the SAAS and by CIP; our grateful thanks are afforded to both of these organizations.

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Appendix

Preparation of "Sour Liquid"

Raw Material

Dried peas/faba beans/mung beans/water

(The researchers were informed that the above legumes could be used either separately or mixed together to produce the sour-liquid; however, from impressions gained, it appears that peas were the preferred starting material).

Method

Day 1

1.1. Wet grind the peas with water producing an aqueous pea mash (Peas: water 1:2 (w/w)).[1]

1.2. Sieve the mash (80-100 mesh screen) separating it into an aqueous starch slurry (collected) and a pea residue (discarded).

1.3. Allow the starch slurry to sediment (5 hrs)[2]; decant/collect the aqueous layer, subsequently allowing it to ferment for two days.[3] (In Sichuan, the pea starch layer is usually dried, and stored for future domestic use).

Day 3

3.1. Repeat (1.1) with a fresh batch of peas and then use part of the fermented liquor from (1.3) to wash the mash during the sieving operation (1.2).

3.2. Sediment the starch slurry arising (5 hrs).

3.3. Decant/collect the aqueous layer, and bulk with the remaining fermented liquor from (1.3); allow the bulked liquor to continue to ferment for a further two days.

Day 5

Repeat Day 3 procedure up to and including (3.2); decant/collect the aqueous layer and mix with all remaining fermented liquor; allow the mixture to ferment for a further seven days.

Day 12

The fermented liquor is now ready for use in the "sour-liquid" process for purification of sweetpotato starch.[4]

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[1] As practiced, the farmers use 5 kg peas to 10 kg water.

[2] Assumed (since the researchers were informed that sedimentation time was similar to that used during the sweetpotato starch extraction process).

[3] Average ambient temperature daily, between 12-17°C; going down to around 6°C at night.

[4] The sour-liquid so prepared must be used within four days of manufacture, after which time it is discarded, and a fresh batch prepared.

Sweetpotato Starch and Flour Research in Thailand

Saipin Maneepun, Suparat Reungmaneepaitoon, and Montatip Yunchalad[1]

Abstract

Thirty-four sweetpotato varieties were grown in 1990 to study their chemical composition. The results were in the range of 57-71% moisture content, 3.19-12.06% dry weight, 4.96-12.83% fiber, 1.37-4.15% ash, and 28.6-43.1% dry matter. Based on these varieties, analysis of dry matter could be classified into three groupslow, medium, and high. Five varieties had below 31% for low; 19 varieties had 31-36% for medium; and ten varieties had over 36% for high. The starch content was below 20% for the low group (four varieties); 20-25% for the medium group (19 varieties); and over 25% for the high group (11 varieties). Starch extraction yield was in the range of 47.17-61.90%. The amylase content of sweetpotato starch ranged from 25.45-3.48%. Fractionated amylase was tested from the high amylase variety, Mae-Jo. Successful separation of amylase from sweetpotato starch was obtained by forming an amylase complex with 1-BuOH and diluted HCl. This mixture of starch and solvent was heated to 85°C for 35 min, then cooled to room temperature and kept for 24 hrs. The fractionated yield was 36.16% and contained 49.07% amylase. The fractionated amylase was also characterized by the Scanning Electron Microscope (SEM).

Three varieties of sweetpotatoes were used for flour production. These were shredded and dried in a cabinet air dryer at 50°C. The shreds dried sufficiently in about four hrs. Weight change, moisture content, and yield were analyzed. The percentage of yields after drying, based on whole roots, was 20.7-21.52%. This uncooked flour was substituted (up to 40%) for rice flour in snackfood processed by using a cooker extruder and village texturizer. These processing experiments have a promising potential for development at the commercial level.

Key words: Thailand, sweetpotato, starch, flour, research.

Introduction

Sweetpotatoes have been grown for domestic consumption in Thailand for many years. The crop can be cultivated in almost every part of the country and is suitable to the tropical climate. Home- and cottage-scale processing units have supplied products to local markets on a daily basis. These processed products must be consumed within 1-2 days due to their short shelf life. Caloric contribution by sweetpotato in the diet is quite small because people consume sweetpotatoes as a dessert and as a processed snack food. Commercial production of sweetpotato has been introduced with government support since 1987 in the Sixth National Agricultural Policy Plan (1987-91) (Tuntithum 1989). Therefore, industrial uses of sweetpotato should be developed to utilize the anticipated increase in production.

Marketing of simple, processed sweetpotato products has been conducted by home- and cottage-scale processing units in various food outlets. However, these small- and medium-scale processing industries have to develop the technology to process more sophisticated products with a longer shelf life and to meet consumer preferences. Since sweetpotatoes are known to have a high nutrient content, as evaluated by Yang (1982), the processes used should be designed to retain this high quality nutrient value.

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The Experiment Station of the Horticultural Center has developed a breeding program for sweetpotato varieties which can be used in industrial processing. Selected varieties are studied for both quality and quantity to meet industrial requirements. Two aspects are mainly studied: starch extraction (and its characteristics for industrial uses) and flour as an intermediate raw material for processing.

Materials and Methods

Starch Extraction and Analysis

Materials

The materials used for this process were:

- thirty-four varieties of sweetpotato,
- peeler and disintegrator for chopping into fine particles,
- vibro-separator for separating starch slurry,
- decanter Centrifugal (Alfa-Laval Type NX 207 S-31) for extracting starch,
- brabender amylograph for starch viscosity determination, and
- Scanning Electron Microscope (SEM) for starch crystal determination.

Methods

Chemical Analysis

The two processes necessary for chemical analysis were to:

- analyze the sweetpotato samples by using the Association of Official Analytical Chemists (AOAC) standards to determine moisture, protein, fat, ash, and fiber content, and
- determine the starch content and reducing sugar from fresh roots by the Lane and Eynon method.

Starch Extraction

Sweetpotato roots were washed, chopped, and disintegrated by using a grinder to extract with water at a ratio of 1:10. The process is shown in Figure 1. Slurry was separated by using a Vibro-Separator (Kason, Australia) with 150 and 200 mesh sieves to remove fiber and skin. Fiber was washed with water until clear water was obtained.

Starch was extracted from the slurry using a decanter centrifuge (Alfa-Laval Type NX 207 S-31) to remove starch. Starch was suspended with water three times and then centrifuged. Clean starch was dried at 50-60°C in the dryer to reduce moisture from 40% to 12%.

Analysis of Starch

The following methods were used:

- protein determination by Kjeldhal Method,
- fiber determination by AOAC standards,
- amylase content by using the method of William et al. (1970),
- brightness of starch examination with an Elrepho refractometer, and
- gelatinization temperature taken by hot stage microscope and viscosity with a Brabender amylograph.

Fractionation Study

Fractionation method. Using the liquid phase separation in $MgSO_4$, the salt solution was adjusted to the optimal condition (Thumyamangkol 1983) as shown in Figure 2.

Using the solid liquid separation technique by selective precipitation with a complexing agent (BuOH), it was possible to effect complete dissolution of starch at a temperature below 100°C. Bauer and Pacsu (1953) recommended using a diluted acid solution adjusted to the optimal condition as shown in Figure 3.

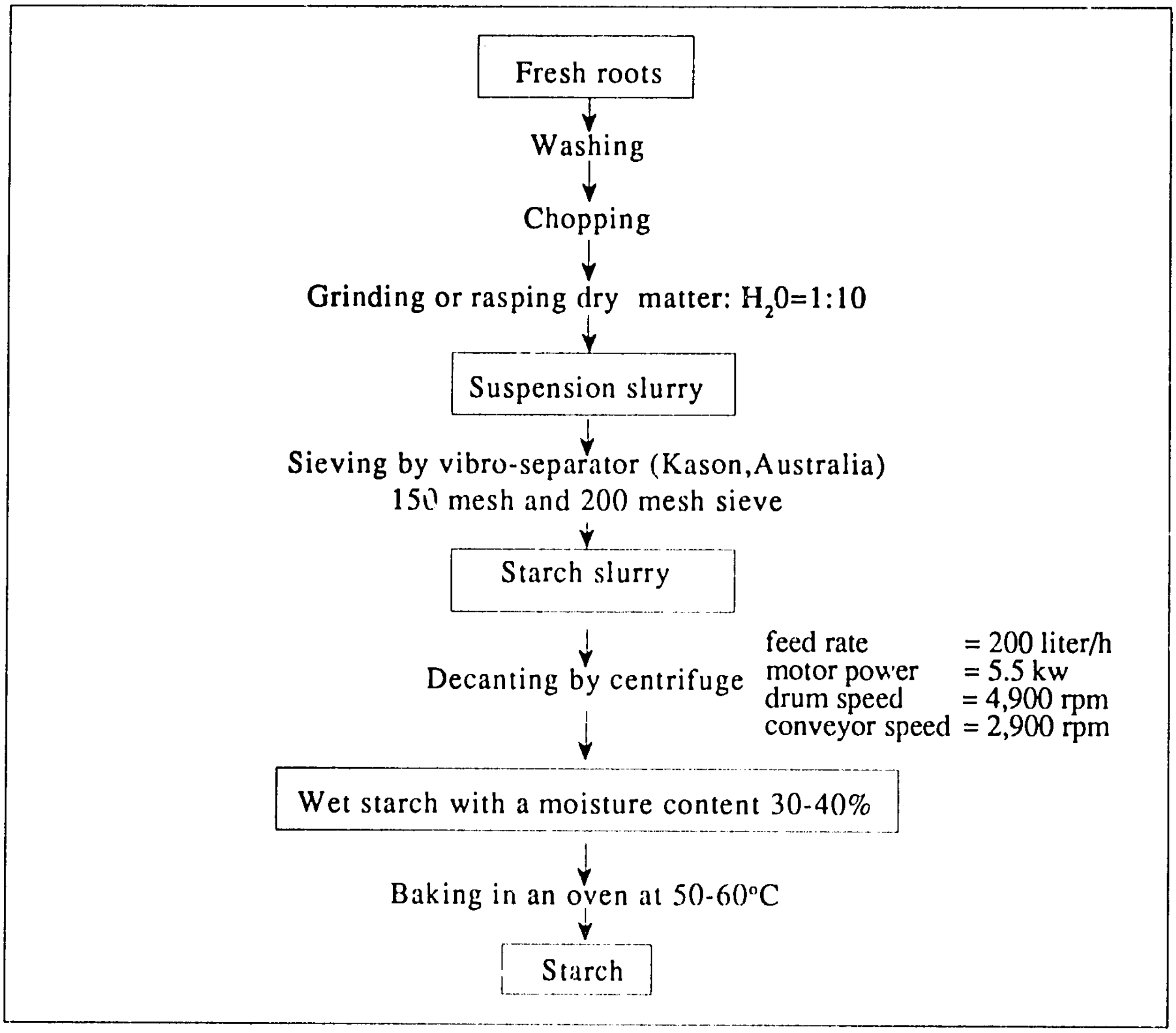
The appearance of fractionated products and characteristics of their crystals were observed under a scanning electron microscope. The amylase content was analyzed by using a simplified assay.

Flour Studies

Materials

- Three varieties of sweetpotatoes were used
- Cabinet air dryer
- Slicing machine
- Pin mill (Alpine Ausburg 160 Z 1979)

Figure 1. Flow chart for the processing of sweetpotato starch.



Methods

- In preparing shredded sweetpotatoes, the Mae-Jo variety was selected for the process because of its high solid matter and starch content, and white flesh color. E-Kaa variety has orange-yellow flesh color. Kaset variety, commonly available in the market, has a yellow flesh color. The process of preparing sweetpotato flour is shown in Figure 4.

- The drying rate of flour was studied by using four aluminium trays for weighing a prepared sample. Hourly recording was done to obtain the drying rate. Temperature and relative humidity were also recorded.

- Proximate analysis was carried out on sweetpotato flour for moisture, protein, ash, fat, and fiber by using AOAC standards (AOAC 1989).

- The yield of sweetpotato flour was determined after drying. Both skin and flesh were weighed separately.

- A preliminary experiment was done to process sweetpotato flour by using a cooker extruder (Wenger X-25) and a local village texturizer.

Figure 2. Optimal condition for amylose fractionation using a liquid phase separation.

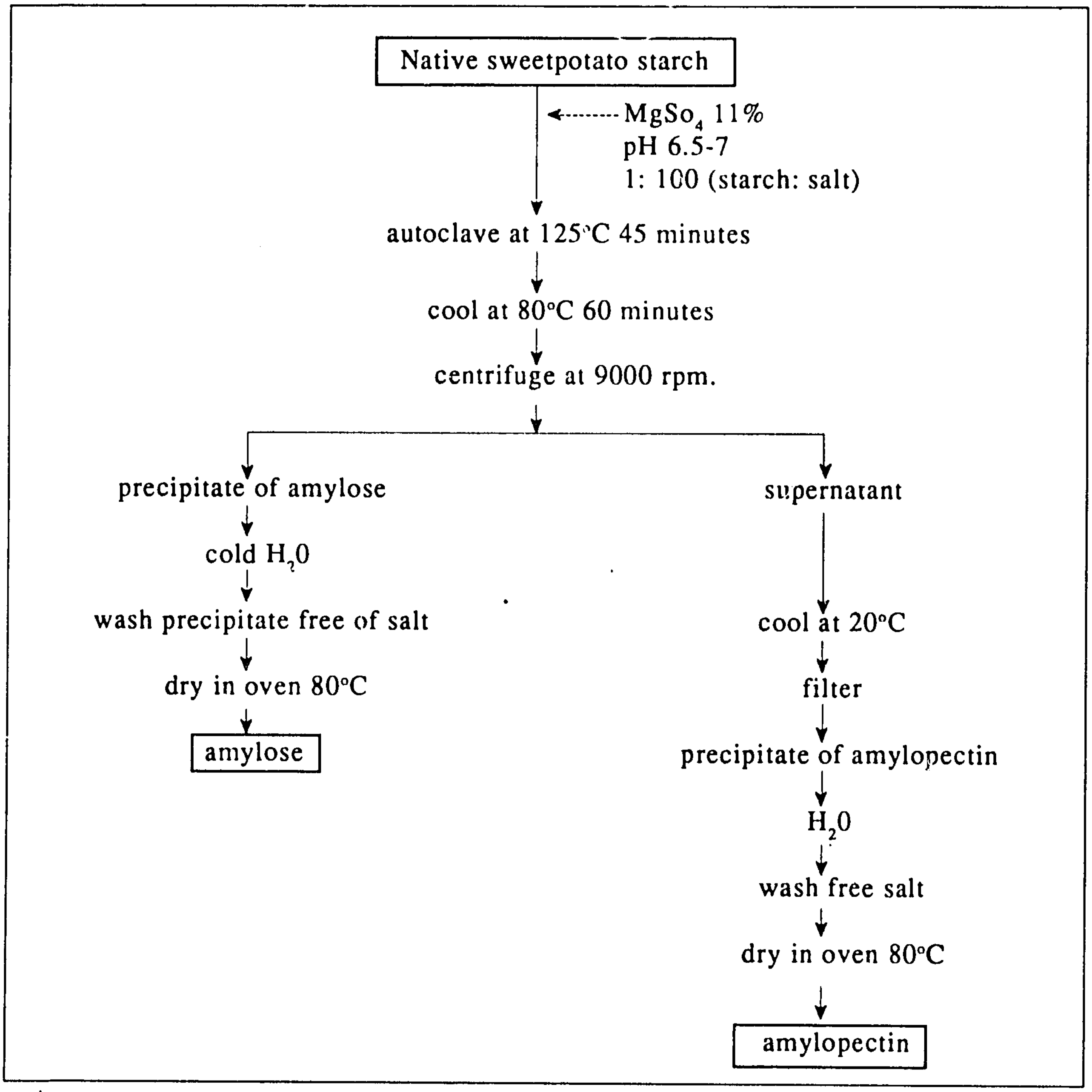
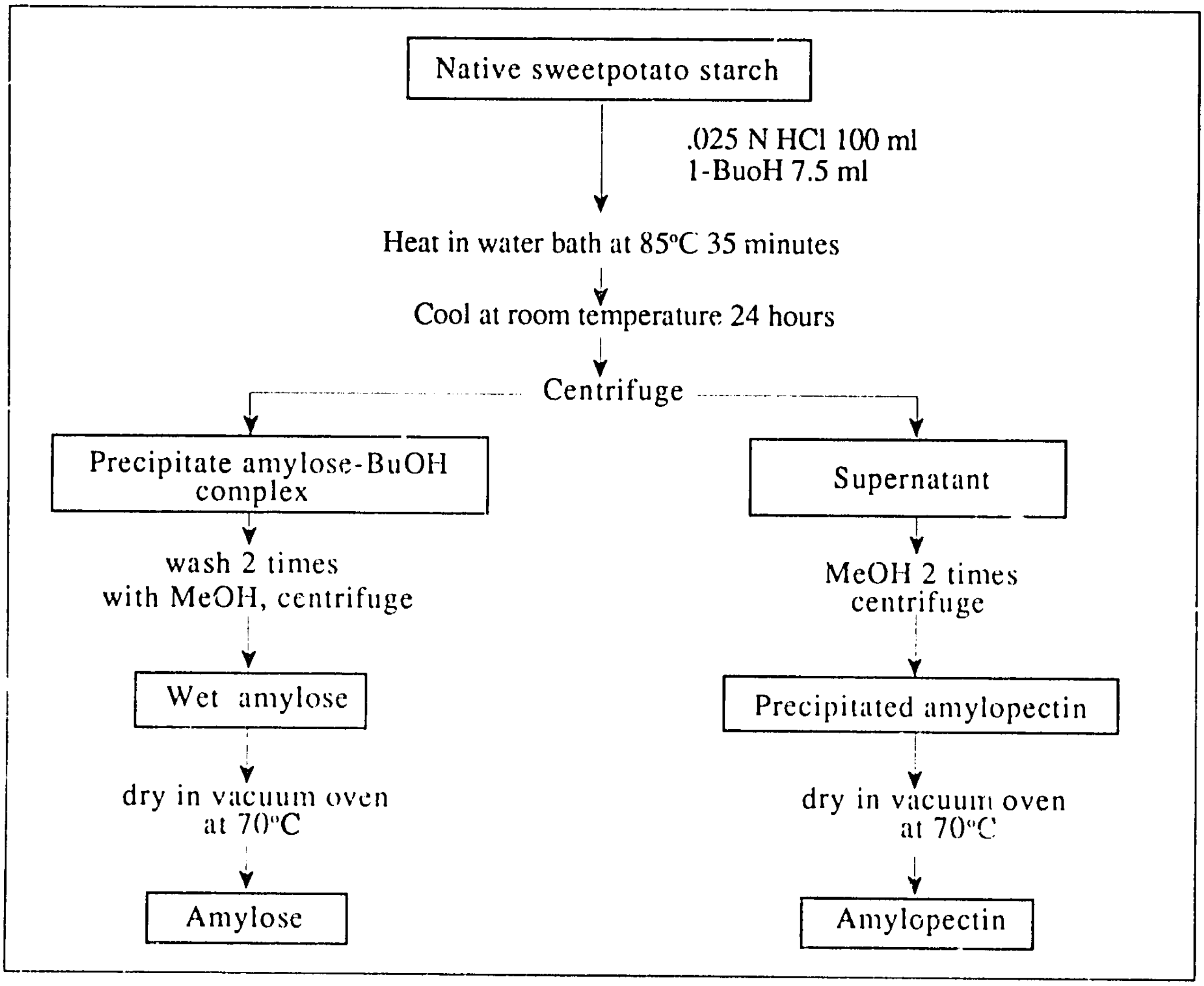


Figure 3. Optimal condition for amylose fractionation using a diluted acid solution.



Results and Discussion

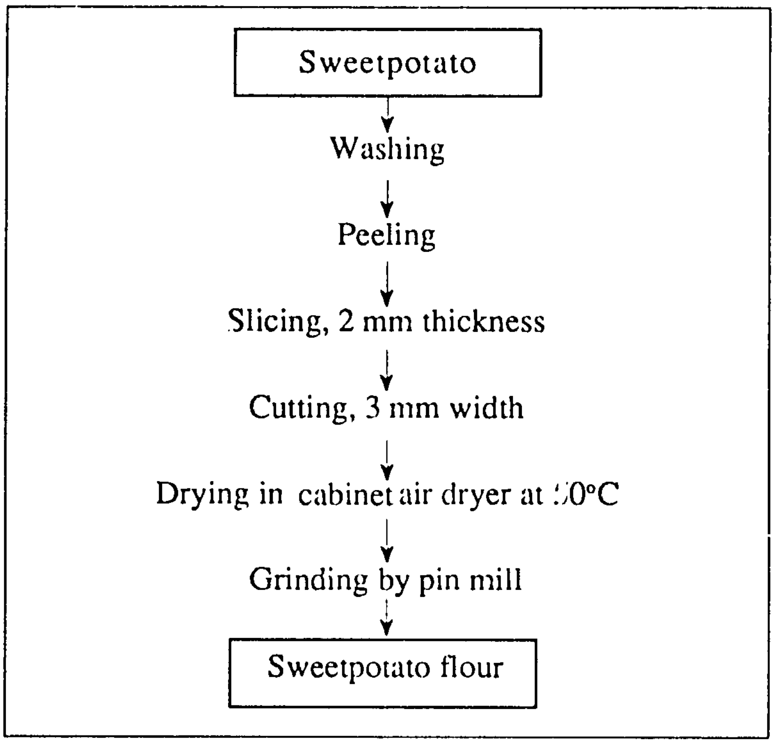
Starch Analysis

Thirty-four varieties of sweetpotatoes were analyzed. The moisture content in tubers ranged from 56.92-11.40%. Protein content was from 3.19-12% on a dry weight basis. The results of protein content fell within the average reported and published by Collins et al. (1982). Various breeding genotypes in a 1980 evaluation ranged from 3.1-13.1% on dry weight; generally, the average protein content was 9.40%, and most varieties contained between 5.57-9.38% protein on a dry weight basis. The protein quality of sweetpotato was found to have a good biological value for human food (Yang 1982). Consumption as a staple food should be promoted where malnourished people need to include nutritious food in their diets. The fiber content was 4.96-12.83%; ash content was 1.37-4.19%. Fat content was very low less than 1%.

Starch Content and Dry Matter

The dry matter content of sweetpotatoes is presented in Tables 1-3. Dry matter content of the 34 varieties grown in 1990 ranged from 28.6-47.12%. These were classified into three groups: below 31% for the low group had five varieties, 31-36% for the medium value had 19

Figure 4. Flow chart for the processing of sweetpotato flour.



varieties, and higher than 36% for the high value had ten varieties. The average dry matter content was 34.72%. The reducing sugar content of the 34 varieties was in the range of 5-9.63% on a wet weight basis.

The starch content of sweetpotatoes is also classified. Four varieties had the low value, 20% wet weight or 63% dry weight; 19 had the medium value, 20-25% wet weight or 63-70% dry weight; and, 11 varieties had the high value, over 25% wet weight or 70% dry weight. The results of the percentage of dry matter ($\bar{x}$) and the percentage of starch is shown Y = 0.689x - 0.405 (r = 0.777).

The 11 sweetpotato varieties which had a high percentage of dry matter and starch are Mae-Jo, Heartegold, Negro-2, Tainung-69, Hao-Dang-Jai-Kao, Pis 57-28, Negro-Ayuthaya, Hao-Kao-Jai-Mung, Hom-Mali, Munkao-Sukothai, and Malaysia.

Starch Extraction

Pilot scale was used for starch extraction. Results are shown in Table 4. Yields of about 10-15% on a dry basis were obtained. More than ten kg of sweetpotato were used for batch extraction. The average yield of starch extraction was 12.66%, but the starch content of sweetpotatoes by chemical analysis was from 20.02-27.04%. The recovery of starch content of sweetpotato varieties ranged from 37.27 to 61.90%. Average recovery percentage was 52.43 with a standard deviation of 6.33. This low recovery was obtained due to starch loss during screening fiber from the starch slurry and in the centrifugal step. Table 5 shows starch quality: fiber content was less than 1.0% on a dry basis. Ash was less than 0.85%. Protein content was 0.01-0.49%. Average amylase content was 25.45 with a standard deviation of 3.48. There are six varieties which had an amylase content of over 28%, Mae-Jo, Po.Mo.Po.Jo-2, Malaysia, Sree-Varndhini, Kao-Chine-Patalung, and Mun-Don-

Table 1. Analysis of starch in raw material from sweetpotatoes which had been harvested in March 1990 at Phichit Horticultural Research Center, Phichit, Thailand.

No.	Varieties	Moisture (%)	Dry matter[a] (%)	Reducing sugar (%)	Starch[b] (wet basis) (%)	Starch (dry basis) (%)
1.	Mac-Jo	60.24	39.76 H	9.47	31.14 H	78.31
2.	Ais 057-4	68.82	31.18 M	8.15	21.29 M	68.28
3.	Heartegold	64.41	35.59 M	5.66	26.24 H	73.72
4.	Pis 091	66.08	33.92 M	7.67	21.92 M	64.62
5.	Pis 094	68.24	31.76 M	5.20	22.26 M	70.08
6.	04-Roi-Et-7	67.57	32.43 M	7.20	22.68 M	69.93
7.	Tis 8250	65.95	34.05 M	7.10	23.70 M	69.60
8.	Centenial	68.12	31.88 M	7.30	22.00 M	69.00
9.	E-Kaa	69.67	30.33 L	7.08	20.55 M	67.75
10.	Huay-Si-Thon	65.14	34.86 M	7.32	23.15 M	66.41
11.	Negro-2	60.47	39.53 H	7.39	28.35 H	71.72
12.	010-1	64.81	35.19 M	7.59	22.60 M	64.22
13.	Norin-03	69.38	30.62 L	5.00	21.08 M	68.84
14.	Tainung-69	60.64	39.36 H	7.30	27.71 H	70.41
15.	V20-429	66.41	33.59 M	8.72	23.12 M	68.83

[a] Dry matter content of varieties is classified as low (L) for values below 31%, medium (M) 31-36%, and high (H) for values over 36%.

[b] Starch content is classified as low (L) for values below 20%, medium (M) for 20-25%, and high (H) for values over 25%.

Table 2. Analysis of starch in raw material from sweetpotatoes which had been harvested in April 1990 at Phichit Horticultural Research Center, Phichit, Thailand.

No.	Varieties	Moisture (%)	Dry matter[a] (%)	Reducing sugar (%)	Starch[b] (wet basis) (%)	Starch (dry basis) (%)
16.	V16-12	70.19	29.81 L	5.64	20.36 M	68.30
17.	Hao-Dang-Jai-Kao	62.48	37.52 H	6.19	26.62 H	70.94
18.	Hom-Mali	59.88	40.12 H	8.29	28.70 H	71.54
19.	Pis 57-28	63.83	36.17 H	9.39	27.52 H	76.08
20.	Negro-Ayuthaya	63.32	36.68 H	6.83	27.85 H	75.92
21.	Pakchong-Ayuthaya	64.49	35.51 M	9.56	23.26 M	65.51
22.	Philippines	71.40	28.60 L	7.46	16.79 L	58.71
23.	Ob-Cheuy	67.91	32.09 M	8.35	22.74 M	70.86
24.	Hao-Kao-Jai-Muang	56.92	43.08 H	7.31	30.78 H	71.45
25.	Mun-Kai-Sukothai	68.75	31.25 M	7.35	21.54 M	68.93
26.	Mun-Soy	63.76	36.64[c] H	8.62	17.52 L	47.82

[a] Dry matter content of varieties is classified as low (L) for values below 31%, medium (M) 31-36%, and high (H) for values over 36%

[b] Starch content is classified as low (L) for values below 20%, medium (M) for 20-25%, and high (H) for values over 25%.

[c] Small roots.

Table 3. Analysis of starch in raw material sweetpotatoes which had been harvested in May 1990 at Phichit Horticultural Research Center, Phichit, Thailand.

No.	Varieties	Moisture (%)	Dry matter[a] (%)	Reducing sugar (%)	Starch[b] (wet basis) (%)	Starch (dry basis) (%)
27.	Mun-Kaset-Nakorn	70.82	29.28 L	7.54	20.19 M	69.19 M
28.	Po.Mo.Po.Jo.2	68.23	31.77 M	7.90	19.52 L	61.44 L
29.	Munkao-Sukothai	64.06	35.94 M	6.68	25.83 H	71.87 H
30.	Malaysia	64.63	35.37 M	8.55	25.26 H	71.41 H
31.	Sree-Varndhini	62.90	37.10 H	7.55	19.80 L	53.36 L
32.	Taiwan-Munkao-Chiangmai	66.55	33.45 M	7.34	22.10 M	66.06 M
33.	Mun-Don-Nakorn	66.80	33.20 M	7.78	21.90 M	65.96 M
34.	Kao-Chine-Patalung	64.01	35.99 M	9.63	24.28 M	67.46 M
Mean (x)		65.49	34.72	7.53	23.54	68.07
Standard deviation (s)		3.44	3.96	1.15	3.51	5.93

[a]Dry matter content of varieties is classified as low (L) for values below 31%, medium (M) 31-36%, and high (H) for values over 36%.

[b]Starch content is classified as low (L) for values below 20%, medium (M) for 20-25%, and high (H) for values over 25%.

Nakorn. The Mae-Jo variety was used for further analysis in a fractionation study. The brightness of Mae-Jo variety starch was 90.3% (% MgO) which was rather high because the flesh of raw sweetpotato was white.

A view of the starch grain was obtained by photomicrography and enlarged to a final magnification of 1,000. The variable shapes were oval, round-faceted, round, and polygonal; and they were generally non-aggregated. Under hot stage microscope, the gelatinization range was 72.5-82.5°C with the mean value of gelatinization temperature at 77.5°C. The viscosity of starch paste and pasting temperature was at 78°C.

Fractionation Study

The amylase fractionation from sweetpotato starch was precipitated by using magnesium sulfate. Results are shown in Tables 6 and 7. Yield obtained was about 47.3%. The amylase content could not be analyzed because of undissolved fractionated amylase in the NaOH solution. The experiment was adjusted to use an amylase-forming complex technique.

Summarized results of amylase separation by forming an amylase-butanol complex from sweetpotato starch are shown in Tables 8 and 9. The maximum yield of fractionated amylase was about 45.8% at 0.01 N HCl, but this condition caused incomplete gelatinization of cooking starch. Therefore, the optimum condition of amylase separation has to be at 0.025 N HCl, 12.5 gm and 7.5 ml BuOH, which obtained a 30.16% yield with an amylase content of 49.07% (Tables 8 and 9).

The appearance of fractionated amylase was opaque and dense, but amylopectin was clear and transparent. The visual characteristics of amylase and amylopectin crystals by SEM could be distinctly differentiated. These results from fractionated amylase could be used to develop another product. This product is a thin layer of edible film which can be consumed with a packaged food product without disposing of the package (Gannadiasne and Weller 1990).

Sweetpotato Flour

The study of three varieties of sweetpotato flour processed as in Figure 4 determined the drying rate. Dryness was recorded every hour for 5 hrs as shown in Table

Table 4. Yields of starch extracted from sweetpotato (pilot plant at IFRPD).

No.	Varieties	(%) Starch analysis	Raw material		Starch		Yield
			Sweetpotato kg	Moisture (%)	Starch kg	Dry basis (%)	recovery (%)
1.	Mae-Jo	31.14	18.10	11.96	3.081	14.98	48.10
2.	Ais 057-4	21.29	13.30	5.45	1.642	11.67	54.81
3.	Heartegold	26.24	35.20	13.88	6.438	15.74	60.02
4.	Pis 091	21.92	8.10	8.04	1.129	12.82	58.48
5.	Pis 094	22.26	47.00	8.52	6.446	11.41	51.25
6.	04-Rol-Et-7	22.68	27.40	4.46	3.178	13.74	60.58
7.	Tis 8250	23.70	13.60	5.50	1.610	11.18	47.17
8.	Centenial	22.00	10.20	--	--	--	--
9.	E-Kaa	20.55	41.90	4.16	4.781	10.59	51.53
10.	Huay-Si-Thon	23.15	12.50	5.75	1.145	8.63	37.27
11.	Negro-2	28.35	21.60	9.66	3.810	15.93	56.19
12.	010-1	22.60	22.80	9.95	3.542	13.99	61.90
13.	Norin-03	21.08	4.70	--	--	--	--
14.	Tainung-69	27.71	21.20	5.64	3.070	13.66	49.30
15.	V20-429	23.12	17.10	6.11	2.467	13.54	58.56
16.	V16-12	20.36	8.65	9.90	1.013	10.55	51.81
17.	Hao-Dang-Jai-Kao	26.62	6.70	9.46	0.996	13.46	50.56
18.	Hom-Mali	28.70	10.35	11.63	1.748	14.92	51.98
19.	Pis 57-28	27.52	4.45	--	--	--	--
20.	Negro-Ayuthaya	27.85	17.88	10.00	2.853	14.37	51.60
21.	Pakchong-Ayuthaya	23.26	10.38	9.35	1.000	8.73	37.53
22.	Philippines	16.79	5.13	--	--	--	--
23.	Ob-Cheuy	22.74	10.00	8.87	1.203	10.96	48.19
24.	Hao-Kao-Jai-Muang	30.78	17 20	9.11	2.912	15.39	50.00
25.	Mun-Kai-Sukothai	21.54	14.70	9.04	1.962	12.14	56.36
26.	Mun-Soy	17.52	0.78	--	--	--	--
27.	Mun-Kaset-Nakorn	20.19	23.00	7.68	3.031	12.17	60.28
28.	Po.Mo.Po.Jo.2	19.52	12.60	7.94	1.400	10.23	52.40
29.	Munkao-Sukothai	25.83	2.30	--	--	--	--
30.	Malaysia	25.26	14.80	7.44	2.116	13.24	52.41
31.	Sree-Varndhini	19.80	11.00	--	--	--	--
32.	Taiwan-Munkao-Chiangmai	22.10	6.80	--	--	--	--
33.	Mun-Don-Nakorn	21.90	6.38	--	--	--	--
34.	Kao-Chine-Patalung	24.28	8.00	--	--	--	--
Mean ($\bar{x}$)		--	--	--	--	12.66	52.42
Standard deviation		--	--	--	--	2.91	6.33

-- = Not enough sample for production.

10. The percent loss in weight from those three varieties were about the same during the drying period. The drying time for shredded sweetpotato (up to 7 cm long shreds) was about four hrs. The final moisture content was 7-8%. The chemical composition of the carbohydrate content of the three varieties was not different as shown in Table 11. The percentage of yields after drying based on whole roots was 20.7-21.52% as shown in Table 12. The sweetpotato flour used was not precooked flour and could, therefore, be used for substituting for various types of flours in processed food products.

Sweetpotato flour was further tested by using a cooker extruder. Substituting 40% sweetpotato flour for rice flour obtained an acceptable product. The process is being developed for use in commercial products.

Table 5. Starch quality of 34 sweetpotatoes varieties.

No.	Varieties	Moisture	Fiber	Ash	Protein	Amylase	Amylopectin
		(%) composition (as dry basis)					
1.	Mae-Jo	11.95	0.65	0.30	0.19	30.51	69.49
2.	Ais 057-4	5.45	0.56	0.39	0.20	27.55	72.45
3.	Heartegold	13.88	0.68	0.53	0.49	24.49	75.51
4.	Pis 091	8.04	0.72	0.45	0.18	24.21	75.79
5.	Pis 094	8.53	0.73	0.51	0.14	25.40	74.60
6.	04-Roi-Et-7	4.46	0.61	0.31	0.11	24.31	75.69
7.	Tis 8250	5.50	0.71	0.76	0.09	24.00	76.00
8.	Centenial						
9.	E-Kaa	7.16	0.68	0.50	0.10	23.68	76.32
10.	Huay-Si-Thon	5.75	0.68	0.63	0.10	27.16	72.84
11.	Negro-2	9.66	0.68	0.44	0.16	23.31	76.69
12.	010-1	9.95	0.71	0.25	0.08	25.35	74.65
13.	Norin-03	11.44	0.59	0.46	0.29	19.21	80.79
14.	Tainung-69	5.64	0.59	0.30	0.13	25.36	74.64
15.	V20-429	6.11	0.25	0.37	0.13	25.52	74.48
16.	V16-12	9.90	0.26	0.53	0.25	26.00	74.00
17.	Hao-Dang-Jai-Kao	9.46	0.24	0.33	0.19	25.57	74.43
18.	Hom-Mali	11.94	0.71	0.49	0.19	26.31	73.69
19.	Pis 57-28	10.41	0.42	0.54	0.17	23.55	76.45
20.	Negro-Ayuthaya	10.00	0.50	0.85	0.28	11.83	88.17
21.	Pakchong-Ayuthaya	9.35	0.55	0.75	0.18	23.89	76.11
22.	Philippines	11.44	--	--	--	22.74	77.26
23.	Ob-Cheuy	8.87	0.23	0.46	0.27	23.89	76.11
24.	Hao-Kao-Jai-Muang	9.11	0.92	0.64	0.34	24.32	75.68
25.	Mun-Kai-Sukothai	9.04	0.32	0.35	0.25	23.84	76.16
26.	Mun-Soy	11.57	0.21	0.18	0.37	27.21	72.79
27.	Mun-Kaset-Nakorn	7.68	0.96	0.39	0.43	27.78	72.22
28.	Po.Mo.Po.Jo.2	7.94	0.33	0.61	0.46	30.47	69.53
29.	Munkao-Sukothai	8.95	0.29	0.31	0.32	27.52	72.48
30.	Malaysia	7.44	0.49	0.37	0.01	30.47	69.53
31.	Sree-Varndhini	7.42	0.25	0.46	0.16	29.84	70.16
32.	Taiwan-Munkoa-Chiangmai	7.71	0.31	0.62	0.20	27.26	72.74
33.	Mun-Don-Nakorn	6.74	0.46	0.71	0.27	28.78	71.22
34.	Kao-Chine-Patalung	7.38	0.53	0.74	0.24	29.05	70.95
Averages		--	--	--	--	25.45	--
Standard deviation		--	--	--	--	3.46	--

A village-style texturizer was used to develop sweetpotato flour products for cottage-level processing. The formulated products and quality need more study to prolong the shelf life.

There are more sweetpotato flour products being developed for the processing industry. The utilization of sweetpotato flour products have not been available at the commercial level, especially as appropriate technology at the economical scale required by the local snack-food industry.

Table 6. Yield of fractionated product by salting out in 11% magnesium sulfate solution.

Starch (g)	pH of solution[a] 6.3	6.75	6.75 (filtered)
1	42.95b	52.85a	39.21c
2	21.10e	28.00d	20.30e
3	14.78	18.58e	15.07f

[a]Values within a column or row not having the same letter are significantly different at P = 0.01.

Table 7. Yield o' fractionated product by salting out in magnesium sulfate solution and one gram s arch.

$MgSo_4$ (%)	pH of solution[a] 6.3	6.75	6.75 (filtered)
11	42.95bcd	52.85ab	39.21cd
12	47.34abc	54.94a	37.46cd
13	47.65abc	55.3a	36.19d

[a]Values within a column or row not having the same letter are significantly different at P = 0.01.

Table 8. Yield of fractionated product by precipitation with BuOH.

	Starch content (wet basis, gram)[a]			
	12.5		15	
Concentration of HCl (N)	BuOH (ml) 7.5	15	7.5	15
0.1	12.53gh	11.37h	11.63gh	10.89h
0.05	20.81f	19.34fg	21.12f	19.23fg
0.025	30.16cde	22.76ef	31.81cd	24.45def
0.01	37.06abc	35.63bc	45.80a	42.16ab

[a]Values within a column or row not having the same letter are significantly different at P = 0.01.

Table 9. Amylose content in fractionated product by precipitation with BuOH.

	Starch content (wet basis, gram)[a]			
	12.5		15	
Concentration of HCl (N)	BuOH (ml) 7.5	15	7.5	15
0.1	41.89fg	46.79ef	37.53gh	35.43h
0.05	51.30abcde	58.98a	48.28e	50.14bcde
0.025	49.07cde	55.37abc	46.79ef	54.58abcd
0.01	47.98e	56.78ab	46.72ef	48.45de

[a]Values within a column or row not having the same letter are significantly different at P = 0.01.

Table 10. Weight, moisture content (%) and weight change (%) of three sweetpotato varieties, dried in a cabinet air dryer at 50°C.[a]

Time (hr)	Change in weight (g)	Weight change (%)	Weight loss (g)	Loss (%)
Mae-Jo variety				
0	1,000.0	0	0	0
1	679.5	67.95	320.5	32.05
2	442.7	44.27	557.3	55.73
3	330.2	33.02	669.8	66.98
4	302.0	30.20	698.0	69.80
5	300.0	30.0	700.0	70.00
E-Kaa variety				
0	1,000	0	0	0
1	794	79.40	206	20.60
2	423	42.30	577	57.70
3	294	29.40	706	70.60
4	256	25.60	744	74.40
5	248	24.80	752	75.20
Kaset variety				
0	1,000.0	0	0	0
1	762.5	76.25	237.5	23.75
2	572.5	57.25	427.5	42.75
3	392.5	39.25	607.5	60.75
4	290.0	29.00	710.0	71.00
5	285.0	28.50	715.0	71.50

[a]Figures are based on a starting weight of one kg (1,000 g).

Table 11. Chemical composition (%) of sweetpotato flour.

Varieties	Chemical composition (as dry basis)					
	Moisture	Ash	Fibre	Fat	Protein	Carbohydrate
Mae-Jo	8.37	2.30	2.25	0.52	6.48	88.45
E-Kaa	8.85	2.89	2.17	0.48	5.33	89.13
Kaset (commercial)	7.86	2.11	2.26	0.49	4.61	90.53

Conclusion

The 34 sweetpotato varieties were used for starch analysis and extraction. The high amylase variety Mae-Jo was studied for fractionation. The separation of amylase from sweetpotato starch was obtained by the forming of an amylase complex with 1-BuOH and diluting HCl with a 49.07% amylase content. The method could be further developed for producing an edible film for the food processing industry. Three varieties were studied for flour production. Up to 40% uncooked sweetpotato flour can be substituted for rice flour in snackfood processing. The experiments discussed in this paper could be developed into techniques for the food processing industry.

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Table 12. Yields of sweetpotato flour after drying (Kaset variety).

Raw sweetpotato (kg)	Skin (kg)	Flesh (kg)	Sweetpotato flour (kg)
100	22.14	77.85	21.16
100	17.96	82.04	21.52
100	20.41	81.44	20.70

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Small-scale Equipment for Processing Food Products from Cassava

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Abstract

Several types of small-scale equipment have been developed at the Visayas State College of Agriculture (ViSCA) for processing cassava into dehydrated cubes, grates, and fried strips and slices. The operating capacities were 181 kg/hr for the pedal-operated cuber-sorter; 86 for the strip cutter; 72 for the slicer; and 50 for the grater.

Key words: small-scale equipment, cuber-sorter, strip cutter, slicer, grater-pulverizer, dehydrated cubes, fried strips, fried slices, dehydrated grates.

Introduction

Cassava is an important crop in the Philippines in terms of total production and hectarage, ranking third as a food crop following rice and corn. It is mainly used for human food, and in manufacturing and animal feed (Truong et al. 1990). It is also utilized in many different traditional snack items. Processing is usually done by household processors with school children and low-income people as the main consumers.

Apparently, poor product quality and low profitability are the major barriers to increasing productivity (Alkuino and Truong 1986). To address these problems, current research on cassava processing and utilization for food includes the improvement of traditional products and processes, and development of new ones. The products developed for processing cassava as food are classified into fried chips/strips prepared from fresh roots; baked, puffed, and steamed/boiled products from cassava flour and dried grates; and dried cubes. The related research has included development of the processes as well as design and modification of needed equipment (Truong et al. 1990).

This paper presents the development of small-scale equipment used in the processing of food products from cassava, specifically those that do not pass the flour stage. It describes their operation and performance, and recommends further improvements.

The Need to Develop Equipment

The processing parameters standardized in processing the established products include among other things the size of the products.

For Dehydrated Cubes

The processing of dehydrated cubes includes the cutting of peeled cassava roots into 1/2-inch cubes, steam cooking, and dehydrating (Truong et al. 1988). The dehydrated cubes are part of a developed product prototype, the "*guinata-an* mix" for possible export to Filipinos abroad.

For Fried Strips

The processing of fried strips or "fried sticks" needs peeled cassava root to be cut into 7 cm long cylinders, then into strips 5 mm thick, blanched, soaked in 2%

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(w/v) brine, fried, soaked in 50° Brix syrup, refried, and packed in plastic bags ready for consumption (Amestoso and Truong 1990). For these processes, the perceived need is for equipment able to cut cassava uniformly into the desired sizes and to sort the cuts at a reasonable capacity. The equipment should be efficient enough to allow for possible scaling up of the process. Manual cutting and sorting needs to be eliminated because it is very laborious, time-consuming, and difficult to produce cubes and strips of uniform shape and size.

For Fried Slices

Fried cassava slices are processed by cross-sectionally slicing peeled cassava roots into 1-1.5 mm thick slices, soaking either in syrup or brine and frying (Amestoso and Truong 1990). For these very thin slices, the need is for a slicer that produces slices of uniform thickness and of a desirable shape.

For Dehydrated Grates

The processing of dehydrated cassava grates as a flour-like material is done traditionally to extend the availability of cassava for the processing of traditional food products like *puto, shakoy*, and *suman*. Being relatively stable, the product was considered as having commercial potential (Alkuino and Truong 1986). Dehydrated grates are produced by grating peeled cassava roots, extracting the juice, pulverizing the compacted pulp, and dehydrating. The essential equipment needed for village-level sized reduction operations are the grater and pulverizer.

Development of Small-scale Equipment

Equipment has been developed following the criteria of functionality, ease in fabrication, operation and maintenance, sanitation, availability of fabrication materials, and low cost.

Cuber-Sorter

Cubing of root crops was attempted by Orias (1984) using three designs: a shearing lever, a dice-puncher, and a press-cutter. The shearing lever cuts roots cross-sectionally before cutting them into squares, while the dice-puncher and press cutter have blades arranged in grids for cutting cubes from pre-cut slabs. Guarte and Truong (1986) reported another cuber using a steel shaft machine in which ten circular flanges served as slicing blades spaced at 1/2 inch intervals and flat bars serving as dicing blades arranged as spokes of a wheel rotating perpendicularly with the slicing blades. The device used pre-cut slabs as the starting material for slicing, followed by dicing. Although the device could cut the slabs during slicing, the cuts produced during dicing were not really cubical in shape but more rhomboid. The dicing blades cut the slices in their upward turn producing the less desirable shapes of the cuts. Moreover, the device needed to be operated by two persons, one rotating the crank and another feeding the slabs. To solve these problems, other designs were tried. The results are discussed below.

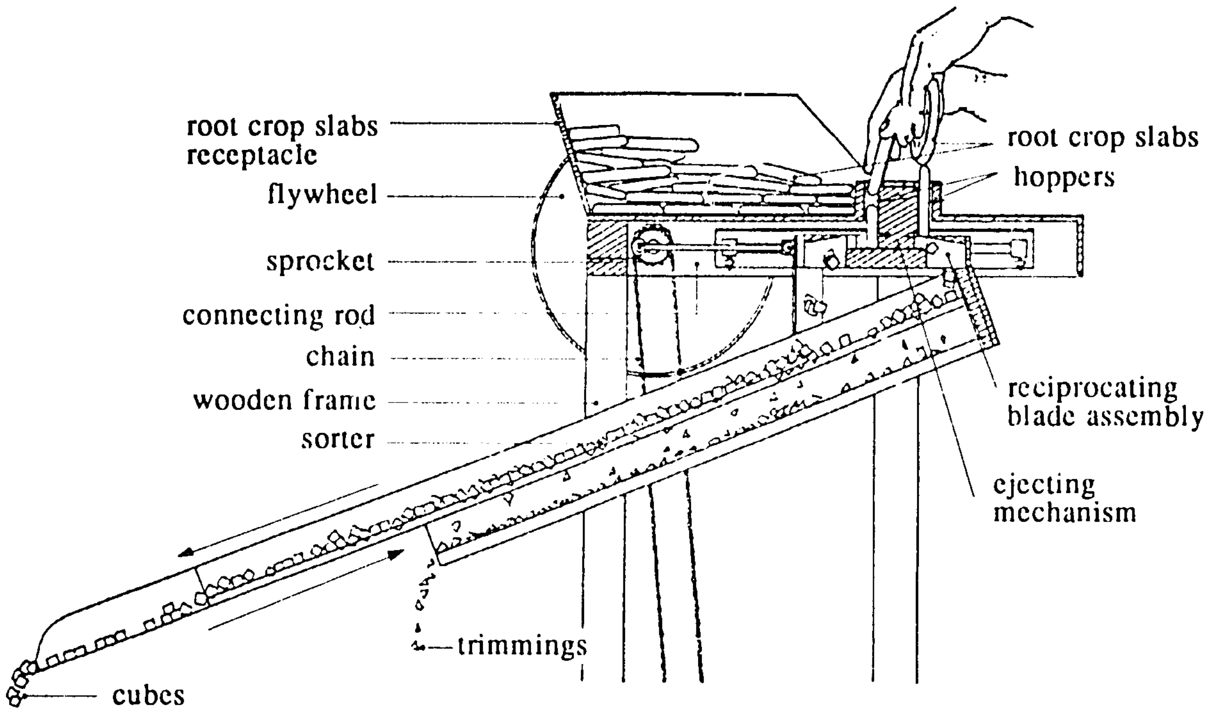
The first prototype fabricated was a pedal-operated machine which used a blade assembly made of two types of fixed blades: a single blade for cutting a strip from the slab and a row of equally-spaced multiple short blades to cut the same strip simultaneously into cubes. The blade assembly was designed to move vertically in a reciprocating pattern while cubing the horizontally-fed slabs. This design worked quite well in the initial cuttings, but problems developed in subsequent cutting operations. This was due to the cutting platform being clogged with the trimmings which blocked the movement of incoming slabs. This caused the production of cuts of less than the desired size. Moreover, this arrangement was not easy to clean and relatively dangerous due to the way the slabs were fed and due to the exposed moving blades. Also, the chute provided with screens to serve as sorter did not operate very well because it was non-moving.

Modifications were then made to improve the prototype. The same blade assembly was used in the second prototype, but it was oriented to cut horizontally while slabs were gravity fed vertically. Also, a reciprocating sorter was added. This model appears to have solved all the problems of the previous prototype. The cubes were produced in uniform shape and size, discharged easily causing no clogging, sorted faster and more effectively, and cut by a covered blade assembly ensuring safety during operation (Fig. 1).

Description of Developed Cuber-Sorter

The cuber-sorter is composed of four essential components: (1) the wooden frame, (2) blade assembly, (3) power transmission system, and (4) the vibrating sorter. It covers a floor area of 0.70 x 1.75 m and has a height of 1.27 m.

Figure 1. Cross-sectional view of the cuber-sorter in operation.



The wooden frame houses the blade assembly at the top while the vibrating sorter is located directly below the blade assembly. Power is transmitted to the blade assembly with the use of a rotating disc and a connecting rod. The disc in turn is rotated by a chain connected to pedal power. The sorter is made of 1.25 x 1.25 cm welded screen which serves as the main sorter. Below this is aluminum wire mesh serving as a collector for the trimmings.

Operation

Root crop slabs are fed into the cuber-sorter while pedal power is applied. The reciprocating blades cut the slabs into cubes and, together with a set of ejectors, discharge the cubes to the reciprocating sorter. The cuber-sorter is operated by only one person.

Performance

The average cubing output of the cuber-sorter at the normal pedalling speed of 60 rpm is 181 kg/hr which is about 55 times faster than the manual cubing capacity of 3.27 kg/hr. The recovered cubes including 75%-cubed cuts range from 65-70%.

Strip Cutter

The development of the strip cutter followed stages similar to the cuber-sorter. The earlier designed strip cutter was a vertical cutting prototype. The modified one was designed following most of the features of the improved cuber-sorter. It has basically the same components. The main difference is in the thickness and length of the cuts. This required that there be a difference in the spacing of the multiple cutting blades and the size of the hopper. The strip cutter uses 7 cm long pre-sized root pieces as starting material for cutting 5 mm thick strips. The roots are fed longitudinally parallel with the direction of cutting. At the normal pedalling speed of 60 rpm, the capacity of the strip cutter is about 86 kg/hr at about 50% recovery of intact strips.

Slicer

A number of slicers exist to produce cassava chips for flour processing. The feature common to these machines is the production of various thickness and orientation of cuts. Slicing the raw material for fried cassava chips needs to be done cross-sectionally for more uniformity of the slices in terms of shape and thickness.

Using the basic operation of the Visayas State College of Agriculture (ViSCA)-developed strip cutter, a slicer was designed. The main difference is the absence of an ejecting mechanism and the multiple cubing blades in the blade assembly. The gravity feed for roots to be sliced was adopted because only the blade assembly was changed. The capacity of the slicer at normal pedalling speed of 60 rpm is 72 kg/hr with a recovery of about 95% of the raw material.

Grater-Pulverizer

In the production of cassava grates, the basic equipment is the grater. Existing graters use metal sheets punctured all over their surfaces to serve as the cutting surface. Problems associated with this design are clogging with the cassava pulp and fibers of the spaces in between the punctures. This makes the cutting less effective during sustained operation and makes the cutting surface more difficult to clean. To solve this problem, the blade assembly and the hopper assembly were modified for the prototype (Fig. 2). The cutting surface of the grater was provided with punctures arranged in straight lines along the axis of rotation and placed one inch apart. The hopper assembly together with the clearance adjuster mechanism was made to open for easier cleaning after operation. The grater could produce grates at 50 kg/hr at normal pedalling speed of 60 rpm and 150 kg/hr using a 1/2-hp motor.

Juice is extracted from the grates using a platen-type extractor. The compacted grates are then returned to the grater for pulverizing, which readies them for sifting to separate out the fibers, and final drying. The grater functions both as a grater and pulverizer.

General Discussion

The developed equipment met most of the criteria initially set. However, further work needs to be done in improving the usefulness of the machines. This will be done in collaboration with the target clientele during pilot testing of the technology. The limitations of the usefulness of the equipment seem to be tied up with the products developed by the individual equipment. However, this need not be true for size reduction equipment such as cuber-sorters, which can be used for other commodities with little modification. As such, the equipment are themselves products of the whole process of technology development.

Conclusion

A number of the products developed to address the problems observed in the small-scale processing of food products from cassava needed specific equipment to facilitate the processing operations involved, to ensure greater quality control, and to increase cost-effectiveness of the operations. The equipment developed were the cuber-sorter, strip cutter, slicer, and grater-pulverizer. This equipment was developed based on functionality, ease in fabrication, operation and maintenance, sanitation, availability of fabrication materials, and low cost. Further work remains, however, for improving the usefulness of the equipment during pilot testing in order to come up with truly appropriate technology and an improved product.

Acknowledgment

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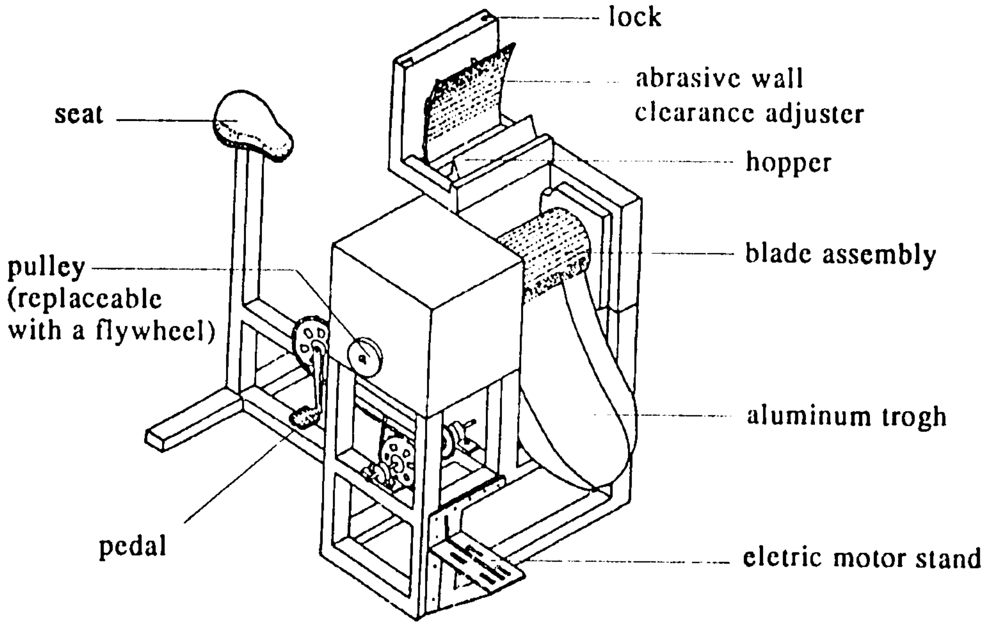
Figure 2. Pedal-operated root crop grater-pulverizer (drawing shows blade assembly open).



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Cassava Flour Processing: ViSCA's Experience

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Abstract

Cassava flour is generally made following the typical processing operations: peeling, washing, chipping, drying, grinding, and sieving.

The Philippine Root Crop Research and Training Center (PRCRTC), through its Engineering Section, has developed various small-scale equipment for root crop flour processing. To maximize the utilization of cassava flour, the Department of Agricultural Chemistry and Food Science (DAC-FS) of the Visayas State College of Agriculture (ViSCA) did research on the substitution of wheat flour with cassava flour.

The flour processing and utilization technology was disseminated to Hindang and Silago, Leyte. Evaluation results showed that the use of cassava flour as a substitute for wheat flour still needs thorough economic analysis. Whether a small-scale plant should be set up or a linkage with the existing wheat flour millers made, remains one of the important issues for research.

Key words: equipment, processing procedures, case studies.

Introduction

Tropical root crops are a staple food for 400-500 million people, particularly poor people in Asia, Africa, and Latin America. In 1985, world production of cassava was 136 million t, sweetpotato was 111, yam was 26, and taro was 5.6 (FAO 1986). In the Philippines, freshly harvested cassava roots are usually consumed directly as food. However, a large fraction is also processed into dried products such as chips, flakes, pellets, and starch. In 1989, the country exported a total of 405,980 t of cassava flour and cassava meal to other countries. This volume is 30% higher than that exported during 1988. An increase in the demand for cassava flour, due to increased consumption in baked products, has also been observed in the domestic market (Diamante 1987). Recently, the escalating price of wheat flour in the Philippines has triggered flour/starch users to utilize cassava flour instead of wheat flour (Bulayog 1990). However, the supply of raw materials for cassava flour/starch processing is quite low; hence, factories are operating at less than capacity. As a consequence, the demand for cassava flour cannot be met. With the aim of meeting this demand, the Philippine Root Crop Research and Training Center (PRCRTC), through its Engineering Section, initiated research on village-scale root crop flour processing. Much of the staff's efforts have been concentrated on the development of processing machines/equipment that can be used under rural conditions.

Process Operation

To produce cassava flour, roots are peeled, washed, chipped, dried, ground or milled, and then sieved (Fig. 1). Among the processes, peeling and drying are the most tedious and time consuming, not to mention the selection of raw material for processing.

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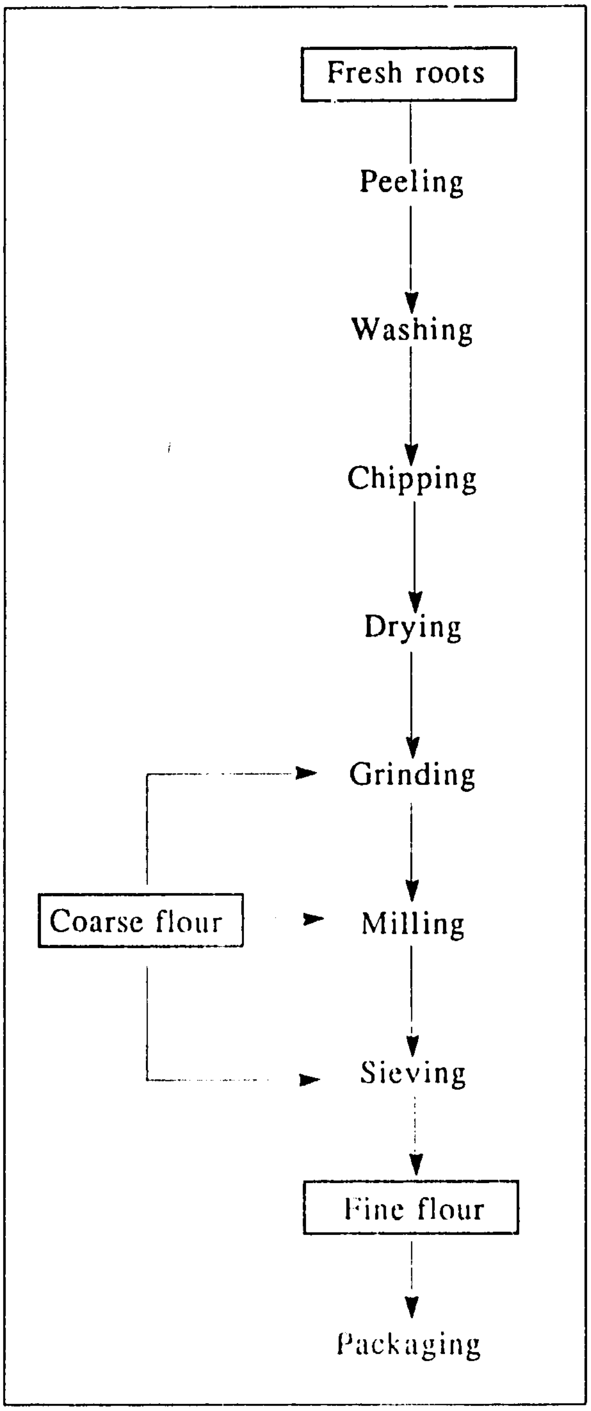
Figure 1. Diagram of cassava flour processing.



Peeling

Peeling is necessary in order to reduce the hydrocyanic acid (HCN) content of the roots. The peel (cortex) contains 60-70% of the total cyanide content of the roots, while the parenchyma tissues contain only 30-40% HCN (Iwatsuki et al. 1984). Hence, removing the peel substantially decreases the cyanide content of fresh roots.

Another consideration supporting peeling before processing is the presence of the brown peel (periderm) in the fine flour. This also results in high ash content and produces dark tints which may be perceived as dirt. Thus, not peeling the roots could lower flour quality.

To date, PRCRTC has yet to develop a peeler for cassava, although attempts were made to design one. The irregularity in the shape of the roots is the primary problem in designing such a peeler. The Center still relies on hand peeling (using a knife or a *bolo*) which constitutes about 43% of the total labor cost in flour production.

Washing

Washing after peeling is done to thoroughly clean the roots. This can be accomplished faster using the PRCRTC hand-operated root crop washer. It consists of a rotary cylinder made of slotted flat bars fixed at a certain degree of inclination for better washing. It also has a water sump that holds approximately 32 liters of water per batch at loading. Despite being manual, it has a rated capacity of 300-500 kg/hr depending upon the strength of the operator.

Chipping

Chipping is the first size reduction operation in flour processing. It is important to facilitate drying of the roots. Results of experiments at PRCRTC indicated that chip configuration can significantly affect loading density and drying time. Cylindrical chips (7 x 50 mm) can be dried in 23 hrs at a loading density of 5 kg/m^2, while flat chips (3 mm thickness) can be dried in 23 hrs at a loading density of 3 kg/m^2.

Chipping can be done faster using the PRCRTC pedal-operated chipper/grater, which is operated similar to a bicycle. Only one person is needed to operate the machine. It is economically efficient because while the feet are pedalling, the hands are used to feed the roots into the hopper. Its chipping capacity is 500 kg/hr at normal brisk speed. The chip produced is cylindrical in shape and has an average dimension of 7 x 50 mm.

Drying

The chips can be dried under the sun. They can also be dried using natural convection or forced-air dryers. In solar drying, we recommend that chips be placed in inclined trays at a loading density of 5 kg/m^2 for cylindrical chips, and 3 kg/m^2 for flat chips.

For artificial drying, PRCRTC modified the *tapahan* dryer (designed for copra) to suit the drying requirements of root crops. A 2 x 3 m dryer has a capacity of 200 kg per 7 hrs of drying time.

Tabianan et al. (1988) also developed a cabinet-type root crop chip dryer with a capacity of 100 kg/hr. The main feature of this dryer is the presence of a heat exchanger made from a used oil drum which is connected to the furnace. The heat exchanger is situated below the drying floor and has a chimney to channel the smoke away from the chips. Hence, only the heated air goes to the chips to dry them.

Another type of dryer used by ViSCA is the forced-draft dryer. It has a burner and a suction fan to force the heated air to go into the drying chamber. It has a capacity of 1,000 kg per 7 hrs drying time. The fuel consumption of the engine is 8 liters of gasoline and of the burner 25 liters of kerosene per hr. Drying temperature is regulated at 60-70°C which is suitable for drying cassava chips. This temperature range, according to Cooke (1983), removes 25-30% of the bound cyanide, while a higher temperature range (80-100°C) removes only 15-20% of the cyanide content of the chips.

Grinding

This is the second size reduction operation in flour processing. PRCRTC uses attrition grinders for this step. There are two commercially available grinders: the Almeda Cottage Industry motor-operated grinder and the modified corn grinder. The former, which is a rice grinder, has a capacity of 50-60 kg/hr, while the latter has a grinding capacity of 150-100 kg/hr of crude flour when powered by a 1.5 hp electric motor. Comparing the two grinders, the modified corn mill is more acceptable due to its availability, low cost, and higher capacity.

Sieving

To separate the fine from the coarse flour, the crude flour should be sieved. The fine flour can already be used in the preparation of various products, while the coarse flour can be remilled to recover a certain percentage of fine flour. For faster sieving, PRCRTC developed a root crop flour finisher. The main component of the machine is its silk screen (110 T) (Tan 1990). The fine flour passes through the screen and is collected in its receptacle, while the coarse flour travels to one end of the cylinder before dropping to its receptacle. It has a capacity of 20 kg fine flour per hour.

Quality and Storage of Chips and Flour

Chip quality is an important factor in flour processing. Sajise (1991) standardized the quality of cassava chips for food and feeds (Table 1). The standardized quality approximates the quality standards of different firms engaged in dried cassava chips trading in the Philippines.

Table 1. PRCRTC quality standard of dried chips for food.

Attributes	High quality	Standard quality
Moisture content (%) (Wb)	10-12	12-14
Starch content (%)	76-85	66-75
Ash content (%)	not >1.8	1.9-3.00
Crude fiber (%)	not >2.1	2.2-5.0
Presence of peels	peeled	Usually peeled
Other	Totally clean and devoid of foreign matter, without fungal contamination or insect infestation	With minimal foreign matter; minimal fungal contamination or insect infestation

In terms of storage, Data (1991) recommended that chips must be stored in polyethylene plastic bags with a thickness of .005 mm. Using this method, the chips can be stored for six months with no aflatoxin contamination detected.

For flour, the same packaging material was recommended. However, Data (1991) emphasized that the plastic bags should be properly sealed so that entry of insect pests is prevented. Both the chips and the flour can be stored at room temperature.

At the PRCRTC processing laboratory, it was found that there are a lot of insect species that attack both the chips and the flour. The most prominent among these is the *Tribolium castaneum*, or rust red flour beetle (Table 2). However, insect infestation by this pest can be easily prevented by sanitation or spraying with systemic chemicals such as Azocord.[2]

Uses of Cassava Flour

Research on the utilization of cassava flour has also been conducted at ViSCA. Results show that cassava flour can substitute for wheat flour in some food products at different levels ranging from 10-100% (Table 3). With the increasing trend of flour demand at 7-8% per year, a 10% level of substitution could generate foreign exchange savings amounting to US$ 329,000 (Roa 1991). Hence, the use of cassava flour has great potential to contribute to the Philippine economy.

Technology Transfer

After a series of evaluations, the cassava flour processing and utilization technology was confirmed to be ready for dissemination. Attempts were made by ViSCA to disseminate the technology to rural areas. Two of these areas were Hindang in Leyte and Silago in southern Leyte.

Hindang Case

The type of business set-up in this case was a sole proprietorship. This means that the owner is the manager, purchaser, and even one of the workers.

Before engaging in cassava flour processing, the processor had been producing *chicharon* using wheat flour as the main ingredient. His interest in cassava flour as a substitute for wheat flour in producing *chicharon* started after attending the PRCRTC anniversary celebration which showcased different food products from root crops. Dried cassava chips were commonly available, hence, milling and sieving were the only operations he had to set-up. He requested technical assistance from ViSCA in setting up a cassava flour mill. ViSCA granted his request. In the beginning, the business was quite profitable. The flour that was processed was used in making *chicharon*. Later, the processing capacity was expanded to supply flour to nearby bakeries. However, when the price of dried chips increased by as much as 70%, the processor was not willing to continue processing flour because the business was no longer profitable. Also, he encountered problems in marketing his flour. Some bakers complained that mixing wheat and cassava flour was more laborious and would increase the cost of producing bakery products. Thus, they stopped buying cassava flour. With all these negative factors, the flour processor discontinued the business.

Silago Case

The uses of cassava flour processing and utilization technology were introduced to an existing farmers'

Table 2. Insect pests attacking chips and flour.

Common name	Scientific name	Chip	Flour
Coffee bean weevil	*Araecerus fasciculatus*	+ +	--
Foreign grain beetle	*Ahasverus advena*	+ +	+
Rust red flour beetle	*Tribolium castaneum*	+ +	+ +
Cigarette beetle	*Lasioderma serricorm*	+	+
Flat grain beetle	*Crytolestes* sp.	+	+
Hide beetle	*Dermestes*	--	+

[2] E. A. Vasquez, personal communication.

Table 3. Food products utilizing root crop flour as substitute to wheat flour.

Name of product	Level of substitution (%)[a]	Authors
Yeast bread		
Cinnamon roll	50 C	Monserate et al. 1983
Pan de sal	20 C/SP	Palomar et al. 1981
Hot roll	20 C/SP	Palomar et al. 1981
Loaf bread	10 C/SP	Palomar et al. 1981
Quick bread		
Paborita	50 C	Palomar et al. 1981
Cheese crackers	50 C	Palomar et al. 1981
Cookies	60 SP	Monserate et al. 1984
	50 C	Palomar 1981 and Lauzon 1984
	100 Yam flour	Palomar 1987
Doughnut	50 C	Palomar 1981
Fried cheese sticks	50 C	Truong et al. 1983
Gollorias	50 C	Palomar 1981
Muffins	50 C	Monserate et al. 1985
	100 Yam flour	Palomar and Bacusmo 1988
Butter cake	100 C	Landerito and Perez 1984
	50 SP	Lauzon and Dalion 1988
Chiffon cake	100 C/SP	Lauzon and Palomar 1987
Marble cake	50 SP	Lauzon and Dalion 1989
Royal *bibingka*	50 SP	Lauzon and Dalion 1989
Other products		
Chicharon	100 C	Lauzon et al. 1985
Soy sauce	100 C/SP	Diamante and Date 1985

[a]C = cassava flour; SP = sweetpotato flour.

cooperative. Some of its members learned about the technology when they attended a training on root crop production, processing, and utilization organized by the Regional Training Center for Rural Development (RTC-RD) based at ViSCA. Cassava was common in their area, so they decided to try the technology. At first, interested cooperative members processed root crop products on a very small-scale. Later, the cooperative set up a bakery which uses a certain percentage of cassava flour for selected products. Flour processing was done by the members themselves at a centralized processing area near the bakery. To date, their bakery is still using cassava flour for selected food products.

Conclusion

Analysis of the two cases points to the fact that the potential of using cassava flour as a substitute to wheat flour still needs a thorough economic analysis. Whether a small-scale plant will be set up, or a link with existing wheat flour millers established to integrate the use of cassava flour in bakery products remains an issue for future research.

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Formulation and Evaluation of Sweetpotato and Cassava Chiffon Cake

L. S. Palomar[1]

Abstract

Cakes, cookies, and other products made from wheat flour have become a widely accepted part of the Filipino diet. As considerable wheat flour is currently imported, growing interest exists in developing substitutes or extenders for wheat flour in baked goods. This paper presents research results of experiments carried out to test the substitutability of different sweetpotato and cassava flours for wheat flour in chiffon cake. The findings indicate that this sort of substitution is indeed quite promising.

Key words: Philippines, flour, experiments, taste panels.

Introduction

Bakery products are now popular in the Philippines as snack foods and are well accepted as a part of the Filipino diet (Arroyo 1974). Wheat flour, the most important and main ingredient in bakery products, however, is imported and thus commands a high price. To partly solve this problem, a search has been made for wheat flour substitutes or extenders. Root crops have been identified to have some potential.

Early studies showed the possibility of using sweetpotato and cassava flours as partial substitutes for wheat flour, but not as the main ingredient in yeast leavened breads. It was reported that cassava and sweetpotato flour could substitute for only up to 20% in breads (Palomar et al. 1981). However, higher levels (about 50%) of substitution are possible in quick breads like muffins and cookies (Monserate 1985; Lauzon et al. 1984).

The Research Project

Therefore, a study was conducted to determine the suitability of using 100% sweetpotato flour and cassava flour in chiffon cake and other similar products. It was assumed that if sweetpotato flour and cassava flour can partly substitute for all-purpose flour in yeast and quick breads it might completely substitute for wheat cake flour in cakes like chiffon cake, considering that cake flour contains the lowest amount of protein (gluten) among the wheat flours.

Objectives of the Study

This study was conducted specifically in order to: (1) formulate chiffon cake from sweetpotato and cassava flour; (2) evaluate its sensory acceptability and consumer acceptability; (3) formulate a cake flour from sweetpotato and cassava and evaluate its suitability in the earlier formulated products; and, (4) determine its shelf life.

Procedure and Methodology

Flour Processing

Sweetpotato and cassava were processed in the laboratory by following the steps.

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Development of the Products

Chiffon cake from 100% sweetpotato flour and cassava flour was processed following standard procedures and combinations for the purpose of considering the differences observed between sweetpotato flour and wheat cake flour. When sweetpotato and cassava flours were used in the processing of these products, the amounts of flour, liquid, and baking powder were adjusted as necessary. Products were also made from wheat flour as applicable. Three to four treatments were used. They were replicated at least two times. Formulations were scaled down to about one quarter of the original formulation for ease in evaluation.

Sensory Evaluation and Consumer Acceptability Testing

Sensory evaluation was carried out to determine the acceptable treatments of chiffon cake. The different products were presented to a group of ten trained panelists from the Department of Agricultural Chemistry and Food Science (DAC-FS) to evaluate the products for color, aroma, flavor, texture, and general acceptability. The standard procedure for sensory evaluation was followed using the hedonic scale. In addition, a panel of 50 tasters were selected randomly from different areas to determine the common acceptability of the products.

Physical Property Measurement/Evaluation

The volume of chiffon cake was determined using a modified seed displacement method (Claudio et al. 1977). A big wooden box with funnel and ruler were used instead of the seed displacement machine.

Statistical Analysis

Data obtained from the different tests were analyzed using analysis of variance (ANOVA), following a randomized complete block design. Significant differences among treatment means were determined using the Duncan's Multiple Range Test (DMRT).

Results and Discussion

Standardization

Chiffon cake from sweetpotato was made by following the standard formulation. However, it was observed that the consistency (ability to flow) of the batter was thicker than the wheat flour formulation when the same amount of liquid ingredient was used. Therefore, more liquid was added to the sweetpotato formulation to have the same consistency as that of the wheat flour. Chiffon cake can be made from sweetpotato flour; however, first attempts were not acceptable especially in terms of texture. Therefore, more refinements were made to develop a better and more acceptable product.

Sensory Evaluation

Chiffon cake made from sweetpotato flour with either pineapple juice or tru-orange pop cola as the liquid was less acceptable in terms of color, aroma, flavor, and texture to panelists compared with one made from wheat flour. The ratings, however, were within the "like moderately" category in the hedonic scale. Results from this test are shown in Table 1. The low rating in this test might be due to the differences in color between wheat flour and sweetpotato flour. Foster Meggos (1989) reported that food selection or judgment of food quality is conditioned by its color. Attractive foods are sought out as pleasure-giving, and can significantly increase our desire/appetite for it.

Colored masks were used in the succeeding evaluation to eliminate the bias against sweetpotato products. The results showed no significant difference in texture

Table 1. Mean sensory scores of chiffon cake from 100% VSP-6 flour with either tru-orange or pineapple juice.[a]

	Sensory quality				
Types of liquid	Color	Aroma	Flavor	Texture	General acceptability
Control	8.25a	8.00a	7.98a	8.15a	8.18a
Tru-orange	6.78b	6.93b	7.10b	7.15b	6.94b
Pineapple juice	7.18b	6.88b	7.13b	6.85c	6.84b

[a]Means in a column followed by the same letters are not significantly different at 5% level using DMRT.

and general acceptability (Table 2). The differences in flavor and aroma can be attributed to still noticeable sweetpotato aroma in chiffon cake. When three different treatments of sweetpotato chiffon cake with different levels of baking powder were presented, the ratings (shown in Table 3) were higher. This finding suggests that sweetpotato chiffon cake is acceptable, especially when tasted without the product made from wheat flour.

Chiffon cake from VSP-6 flour was also processed with different liquid ingredients. The results show no significant differences in all sensory qualities (Table 4). This indicates that either tru-orange or water can be an acceptable liquid ingredient in making sweetpotato chiffon cake. Thus, a cheaper product could be made with water as the liquid without adversely affecting the sensory qualities.

Sweetpotato Cake Flour

Since cake flour is formulated with the addition of starch, sweetpotato flour was refined by adding corn starch at different levels. Results of sensory evaluation

Table 2. Mean sensory scores of chiffon cake with different levels of VSP-6 flour using color masks.[a]

Levels of VSP-6 flour	Sensory quality			
	Aroma	Flavor	Texture (n.s.)	General acceptability (n.s.)
Control	8.14a	8.03a	8.06	8.21
52.80 g	7.00b	7.31b	7.10	7.13
49.80 g	7.03b	7.33b	7.03	7.70

[a]Means in a column followed by the same letter are not significantly different at 5% level using DMRT.

n.s. = Not significant.

Table 3. Mean sensory scores of chiffon cake from 100% VSP-6 flour with different levels of baking powder.

Levels of baking powder	Sensory quality (n.s.)			
	Aroma	Flavor	Texture	General acceptability
2.57 g	7.55	7.73	.7.03	7.60
3.21 g	7.83	7.84	7.85	7.91
3.85 g	7.60	7.89	7.92	7.76

n.s. = Not significant.

Table 4. Mean sensory scores of chiffon cake from 100% VSP-6 flour with different liquid ingredients.

Types of liquid ingredients	Sensory quality (n.s.)				
	Color	Aroma	Flavor	Texture	General acceptability
Tru-orange	7.35	7.46	7.53	7.41	7.57
Pineapple juice	7.65	7.28	7.65	7.50	7.49
Water	7.23	7.25	7.20	7.43	7.33

n.s. = Not significant.

(Table 5) show that higher acceptability scores were obtained in terms of texture and general acceptability with the highest level of corn starch. The product had a better texture.

The possibility of using root crop starches instead of corn starch as a component of sweetpotato cake flour was also explored. No significant differences were found in the sensory qualities among treatments with different starches (Table 6). Root crop starches, especially cassava starch which can be processed locally or which is commercially available at a low price, can substitute for corn starch in the sweetpotato cake flour formulation. The higher acceptability scores obtained can be attributed to its soft and velvety texture and a very light yellow internal color of the product.

Chiffon cake from sweetpotato cake flour and plain sweetpotato flour together with the control were presented to a group of taste panelists to evaluate its sensory quality and to test whether refinement of sweetpotato cake flour improved the quality of the product. Again, colored masks were used to eliminate the bias effect of sweetpotato color during evaluation. Results showed no significant differences in all sensory qualities (Table 7). However, the sweetpotato cake flour obtained higher scores than the sweetpotato flour. This could partly prove that sweetpotato cake flour produces a better product. To partly improve the acceptability of chiffon cake made from sweetpotato cake flour, different levels of emulsifier were used (see Table 8). No significant differences were observed in flavor, texture, and general acceptability among treatments. Results showed that emulsifiers did not further improve the sensory qualities of the products. The higher acceptability of the control in terms of color and aroma can be partly due to the bias effect of the sweetpotato color and the noticeable sweetpotato aroma. Further evaluation using emulsifiers or stabilizers needs to be done.

Cassava Cake Flour

Since cassava also had the potential for chiffon cake making, cassava flour was also used in the chiffon cake formulation. Results showed that chiffon cake can be processed from 100% cassava flour from different stages at harvest (Table 9). No significant differences were

Table 5. Mean sensory scores of chiffon cake using VSP-6 flour with different levels of corn starch.[a]

	Sensory quality				
Levels of corn starch (%)	Color (n.s.)	Aroma (n.s.)	Flavor (n.s.)	Texture	General acceptability
00.0	7.13	7.23	7.30	7.28c	7.01c
12.5	7.22	7.42	7.50	7.50b	7.37b
25.0	7.35	7.57	7.37	7.54b	7.54b
50.0	7.68	7.72	7.52	7.80a	7.91a

[a]Means in a column followed by the same letter are not significantly different at 5% level using DMRT.

n.s. = Not significant.

Table 6. Mean sensory scores of chiffon cake from VSP-6 cake flour with different types of starches.

	Sensory quality (n.s.)				
Type of starch	Color	Aroma	Flavor	Texture	General acceptability
Corn	7.45	7.53	7.55	7.63	7.53
Sweetpotato	7.39	7.70	7.55	7.48	7.58
Cassava	7.53	7.68	7.65	7.63	7.70

n.s. = Not significant.

Table 7. Mean taste panel scores of chiffon cake from different types of flour.

Types of flour	Sensory quality (n.s.) Aroma	Flavor	Texture	General acceptability
Wheat cake flour (control)	7.61	7.80	7.85	7.29
VSP-6 cake flour	7.53	7.55	7.55	7.40
VSP-6 flour	6.90	7.32	7.32	7.04

n.s. = not significant.

Table 8. Mean taste panel scores of chiffon cake from wheat cake flour and VSP-6 cake flour with different levels of emulsifier.[a]

Levels of emulsifier	Sensory quality Color	Aroma	Flavor (n.s.)	Texture (n.s.)	General acceptability (n.s.)
Control	8.08a	8.00a	7.50	7.96	8.06
0.0 g	6.90b	7.39b	7.23	7.38	7.12
0.25 g/c flour	7.10b	7.20b	7.38	7.43	7.13
0.50 g/c flour	7.21b	7.48b	7.35	7.52	7.51

[a]Means in a column followed by the same letters are not significantly different at 5% level using DMRT.

n.s. = Not significant.

Table 9. Mean sensory scores on chiffon cake from cassava flour at different age levels at harvest.

Age at harvest (mos.)	Sensory quality (n.s.) Color	Aroma	Flavor	Texture	General acceptability
08	7.65	7.62	7.65	7.73	7.75
10	7.65	7.35	7.65	7.50	7.65
12	7.48	7.49	7.56	7.69	7.67

n.s. = Not significant.

observed in all sensory qualities among treatments. To further improve the acceptability of cassava chiffon cake, cassava cake flour was formulated. When different levels of cassava cake flour were used, no significant differences were observed in all sensory qualities among treatments. Results indicate that different levels of cassava cake flour can be used for chiffon cake making (Table 10).

To compare the acceptability of chiffon cake from sweetpotato and cassava, four treatments were presented. Results (Table 11) show that chiffon cake from VSP-6 cake flour and cassava flour had no significant differences in all sensory qualities. In terms of color and general acceptability, these two treatments were significantly lower than the control. However, no significant differences were observed between the three products in terms of aroma, flavor, and general acceptability. Chiffon cake from VSP-6 flour obtained significantly lower scores. This still can be attributed to the bias effect of the sweetpotato flour.

Table 10. Mean taste panel scores on chiffon cake processed from different percent levels of cassava flour (CF) and cassava starch (CS).

Levels of CF and CS	Sensory quality (n.s.)				
	Color	Aroma	Flavor	Texture	General acceptability
100% CF	7.88	7.53	7.71	7.80	7.68
90% CF + 10% CS	7.93	7.52	7.83	7.88	7.89
80% CF + 20% CS	7.88	7.75	7.85	7.90	7.95

n.s. = Not significant.

Table 11. Mean taste panel scores of chiffon cake flour different types of flour.[a]

Types of flour	Sensory quality				
	Color	Aroma	Flavor (n.s.)	Texture	General acceptability
Wheat cake flour	7.93a	7.85a	7.74	7.73a	7.99a
VSP-6 cake flour	7.51b	7.58a	7.56	7.67a	7.62b
VSP-6 flour	6.58c	6.89b	7.14	7.20b	7.06c
Cassava flour	7.46b	7.63a	7.61	7.42ab	7.49b

[a]Means in a column followed by the same letter are not significantly different at 5% level using DMRT.

n.s. = Not significant.

Volume Analysis

Varying the amount of baking powder gave no significant differences in scores for sensory qualities. Higher volume (676.67 cc) was observed in the treatment with the highest amount of baking powder than the control (621.66 cc) using the seed displacement method.

Conclusion

Bakery products in the form of cakes and cookies are an increasing popular component of the Filipino diet. Such products traditionally have required the use of imported wheat flour as an essential ingredient. This paper has reported on research results aimed at identifying the quantity, quality, and form of substitute flows made from locally-produced cassava and sweetpotato that might be used as a partial substitute for wheat flour in the preparation of chiffon cake. Based on a series of taste panel experiments, the findings indicate that considerable potential exists for this substitution in the case of both cassava and sweetpotato.

Development of Cassava Processing at the Village Level in Indonesia

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Abstract

The development of cassava flour production in Indonesia represents an alternative for diversification of cassava products. It has the potential to increase farmers' incomes, to extend marketing, to support food diversification, to minimize wheat imports, and to help develop various chemical and food industries.

Cassava flour processing involves the development of technologies and equipment for chipping, pressing, and milling, as well as techniques for peeling, washing, soaking, and drying.

The cassava flour agroindustry is designed as a group of nucleus-plasma models. The system can be grouped into three models based on the capital, capability, level of knowledge, and distribution system of raw materials. These plasma systems include Model I for the farmer level and Model II for the farmers' group level. Model III represents milling units with private companies or Village Cooperative Units (KUD) as the nucleus of the system. The milling units act as processors of intermediate products, i.e., dried chips from Model I and Model II, to be processed into cassava flour as final products.

Economic analysis showed that the three models are feasible as a system to develop an agro-industry for cassava flour production at the village level. Under a decree from the Ministry of Industry and Presidential Aid, 30 cassava flour milling units have been set up in seven provinces.

Key words: flour, wheat imports, agro-industrial models, equipment, economic analysis.

Introduction

Rapid urbanization in Indonesia has led to increased consumption of processed food and bakery products. This process has raised the demand for imported wheat due to an absence of local production. The partial substitution of local flours made from corn, rice, sorghum, cassava, and sweetpotato for imported wheat flour has been proposed to save foreign exchange.

Cassava is grown on close to 1.3 million ha of land in Indonesia. Cultivation is distributed all over the country; hence, cassava is a crop well known by farmers. An average of 15.4 million t is produced yearly. Cassava is used for food, raw material for starch extraction, and for feed (Damardjati et al. 1990). Nevertheless, the cassava market is unstable. Moreover, farmers have little incentive to produce more cassava due to the low price resulting from decreased demand, as the export quota to the European Community (EC) has already been filled (825,000 t in 1989/90). Therefore, there will be a surplus of cassava beginning in 1990 if no new market is found (CRIFC 1991). In short, increasing cassava production is not difficult. The problem of surplus production recurs every year during the peak harvest season with different severity. The few products currently available limit the quantity of cassava the market can absorb without depressing prices.

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The government has recommended that the agricultural and industrial sectors should make special efforts in the case of cassava including diversification of processed cassava products, quality improvement, and promotion of cassava products for food among different social strata of the Indonesia population. Several research institutes and private companies have developed prototype machines for cassava processing. New recipes for preparing food using cassava products are available. The use of composite cassava-wheat flour in the preparation of breads, pasta, and cookies has been promoted.

Distribution and Consumption of Wheat

In Indonesia, wheat is not produced. All the wheat needed in the country is imported as grain. Three huge wheat milling plants to produce wheat flour are located in Jakarta, Surabaya, and Ujung Pandang. Consumption of wheat in Indonesia continues to increase from 125,000 t in 1972 to 1.668 million t in 1983 (Table 1).

Table 1. Supply of cassava and wheat in Indonesia, 1972-89.

Year	Cassava (000 t)	Wheat (000 t)
1972	9,378	125
1973	10,976	663
1974	11,927	672
1975	12,243	664
1976	12,117	965
1977	12,016	692
1978	12,046	792
1979	11,779	772
1980	12,653	1,482
1981	12,265	1,417
1982	12,372	1,485
1983	11,355	1,740
1984	13,046	1,444
1985	12,496	1,329
1986	12,094	1,610
1987	14,356	1,543
1988	15,477	1,588
1989	17,091	1,668

Source: Central Bureau of Statistik 1990.

Wheat-based products are important, but do not dominate the national diet. On an average per capita consumption basis, wheat contributed only 66 calories per day (or 2.4% of the calories), and 1.6 grams per day (or 2.66% of the proteins) from total national consumption during 1988 (CBS 1989).

Since the 1960s, National Logistics Bureau (BULOG) has had a monopoly on wheat imports in grain form. Milling is carried out by three main wheat milling plants owned by private companies. Wheat flour is then distributed by BULOG within the country. It is no coincidence that control of wheat imports coincided with the initiation of P.L. 480 concessional sales to Indonesia. BULOG used this monopoly on imports and distribution both to control the level of support prices and as a principal source of revenue. Thus, imports and, in turn, domestic consumption are administratively determined by BULOG, based on their institutional objectives and constraints.

Cassava Processing and Utilization

The demand for cassava in Indonesia seems to have reached a plateau. Nevertheless, some experts anticipate an increase in the internal demand for food during the next decade. Expansion of the industrial sector will further increase the demand. However, quota restrictions by the EC will probably not be released in the near future. Consequently, prospects for increasing exports to this market are not very optimistic.

Use of cassava in the feed industry is still limited in Indonesia for two reasons. Most farmers are unaccustomed to feeding cassava to livestock. Prices are not low enough to create incentives for farmers to switch from other sources of feed such as rice bran which are abundant and cheap in rural areas.

Cassava roots in Indonesia are predominantly used in fresh form as food, in dried form (*gaplek*), and as starch. Based on the Food Balance Sheet in 1988 (CBS 1989), the use of the cassava production of 15.471 million t was 64.4% for direct food as fresh roots or *gaplek*; 9.2% for export as *gaplek*, chips, or pellets; and, 12.8% for industrial raw material. The latter comprises 6.3% as raw material for the tapioca starch industry and 6.5% as raw material for non-food industries. Most of the tapioca starch is used in the *krupuk* industry. The rest is used in other food, textile, paper, glucose, and pharmaceutical industries (Table 2).

Tapioca starch can be produced through the wet method. Fresh cassava roots are washed and the end

Table 2. Cassava products and their utilization in Indonesia, 1987.

Cassava product	Food (000 t)	Feed (000 t)	Others (000 t)	Noodles (000 t)	Baking (000 t)	*Krupuk* (000 t)
Fresh roots	842.9	--	8.9	1.0	--	0.2
Gaplek	30.0	337.7	0.05	--	--	--
Tapioca starch	3.1	--	5.0	18.0	2.9	26.6
Tapioca pearl	2.7	--	--	--	--	--
Gaplek chip	--	75.3	--	--	--	--
Gaplek flour	--	--	--	--	--	0.18
Total	878.7	413.0	13.95	19.0	2.9	26.26

Source: Central Bureau of Statistik 1989.

-- = No data available.

parts of tubers that contain lots of fiber are removed. Roots are rewashed, peeled, cut, grated, and their starch extracted; the rewashed starch is separated and dried. Drying is done at ≤ 50°C to avoid dextrinization (Barrett 1984). From 1000 kg of fresh cassava, 250 kg tapioca starch, 114 kg residue (*onggok*), and 120 kg sludge (Enie 1989) can be produced.

Other types of tapioca starch are tapioca pearls and tapioca flakes. These products are produced by boiling the tapioca pulp, partly gelatinizing the starch, and then molding into pearls or flakes. Various food products can be made from these materials. Tapioca pearls and flakes are usually for export. Pearls should have 12.5-15% moisture and flakes 15%. Both products contain 0.2-0.5% ash.

Identification of Alternative Appropriate Technologies

Traditional technology is used by farmers to convert fresh cassava into *gaplek*, either as whole cassava as well as in cut form without appropriate drying. Therefore, the drying process is slow and uneven. Fungal and insect infestation often follows. The *gaplek* deteriorates. The main weakness of *gaplek* is its low quality. Furthermore, farmers are not interested in improving the quality of their *gaplek* because they do not receive an incentive for better quality *gaplek* from buyers.

Diversification of cassava utilization and technology will strengthen the bargaining power of farmers. They will be able to choose those offering a better price for their product. Development of alternative uses for cassava should be simple, easy, and should give value added directly to the farmers.

Development of cassava flour production can be expected to expand cassava utilization in Indonesia, to increase income and value added for the farmers, to increase job opportunities, to dampen the increase of wheat flour consumption, and to encourage additional exports. In connection with this program, a feasibility study is needed for the development of a rural agro-industry for cassava flour production based at the farmer level. This may complement upstream industry to support the supply of raw material for the downstream cassava food and feed industry.

Quality Assurance of Cassava Flour

At present, assessment of cassava qualities is authorized by the Ministry of Industry for domestic consumers and the Ministry of Trade for export purposes. To support the development of cassava flour production, the Ministry of Industry has issued quality standards for cassava flour (Table 3).

R&D of Processing and Equipment

Cassava Flour Production

The Steps of Cassava Flour Processing

The process for producing cassava flour is presented in Figures 1 and 2 (Damardjati et al. 1990a). In general, the process of cassava processing can be divided into three unit operations: harvesting and handling; processing; and milling.

Harvesting and handling fresh cassava. This operation is conducted entirely at the farm level to produce

Table 3. Quality specifications for cassava starch and flour in Indonesia.[a]

Characteristics (condition)		Cassava starch Grade: I	II	III	Cassava flour
Moisture	% max (w/w)	17.5	17.5	17.5	12.0
Ash	% max (w/w)	0.6	0.6	0.6	1.5
Crude fiber	% max (w/w)	0.6	0.6	0.6	0
Whiteness	(% as $BaSO_4$=100%)	94.5	92.0	92.0	85.0
Viscosity	(o Angler)	3.0-4.0	2.5-3.0	<2.5	0
Acidity	(ml 1N NaOH/100 g)	4.0	4.0	4.0	3.0
HCN	(mg/kg)	0	0	0	40.0

Source: Ministry of Industry.

[a]At an acceptable "normal" condition.

Figure 1. Rural postharvest system for cassava flour production.

	Farmer		Processor			Milling unit	
Process	Harvesting	Fresh handling	Peeling	Chipping	Drying	Milling	Marketing
	Harvesting	Reception	Peeling	Chipping	Drying	Pre-milling	Storage
	Transporting	Sorting	Washing	Pressing	Sorting	Milling	Promotion
		Fresh storage	Soaking		Cleaning	Packaging	Selling
Product form		Fresh cassava	Peeled cassava	Wet chips	Dried chips	Cassava flour	Packed flour
Percent recovery		100 %	70-80 %		25-30 %	24-29 %	
Alternative process	A<---- (a)	---->	<----	(b)	---->	<---- (c)	---->
	B<----	(a)	----	----	---->	<---- (c)	---->
	C<---- (a)	---->	<----	----	(c)	----	---->
Price/kg		Rp 40-50	Rp 55-60		Rp 225-250		Rp 400-425

Source: Damardjati et al. 1990a.

(a) Farmer or farmer group.
(b) Collector/processor/farmer group.
(c) Milling unit.

fresh cassava for market, temporary storage, or for processing into semi-processed products.

Producing cassava chips. This operation can be conducted at the farm level either individually, in groups, or in a flour milling unit.

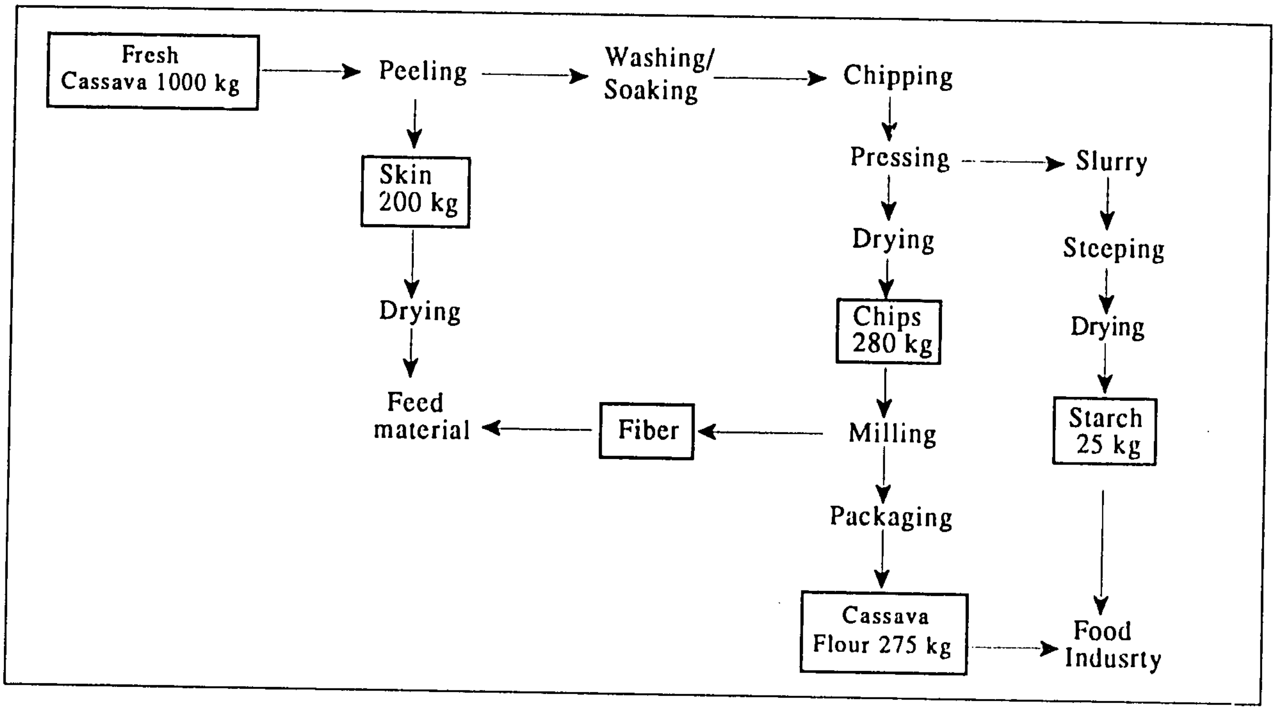
Milling cassava flour. This operation is conducted by a flour manufacturing operation which is managed by a cooperative or private company with larger capital.

The development of models emphasizes the operation of the system at the farm level. It is expected that these farm products can be absorbed by the industrial sector generating value added for farmers.

Development of Cassava Flour Processing Equipment

The equipment needed for cassava flour processing at the village level are:

Figure 2. Processing system for cassava flour production in Indonesia.



- Simple cassava peeling equipment
- Washing and soaking tank for peeled cassava
- Chipping and shredding equipment
- Chip processing equipment
- Chip drying equipment
- Milling equipment
- Packaging and storage equipment

Several research institutes and universities, as well as workshops of governmental and private companies, have developed designs and prototypes of this equipment (Damardjati et al. 1990a).

Cassava peeling equipment. Simple peeling can be done manually with a knife. The capacity of manual peeling of cassava is about 15-20 kg/hr/person, depending on skill. The cost of peeling is Rp 5-7.5/kg.

Washing equipment. Washing is also done manually and depends on water availability. Washing can be carried out by using washing tanks or flowing water. The use of deep wells requires investment in a water pump. The use of spring water requires a higher cost for labor. It is estimated that a 0.5 man/day is needed to wash 210 kg cassava.

Chipping equipment. Several designs and prototypes of cassava chipping machines have been introduced with designs by Moros Institute for Food Crops (MORIF), Sukamandi Research Institute for Food Crops (SURIF), or private companies.

Manual chipping machine (design by SURIF). This equipment is designed with exchangeable blades, depending on the purpose (slicing, shredding, chipping, or rasping). Capacity is 30 kg/hr of fresh cassava with two laborers.

Pedal chipping machine (design by SURIF). The operation of this equipment is the same as the manual chipper but its capacity is larger. It is also equipped with a feed hopper. The capacity is about 100-120 kg/hr and needs two people for its operation. By using an engine of 0.5 hp, its capacity can be increased to 200-250 kg/hr, and only one person is needed.

Power chipping machine (Design by MORIF). Models CSM-1 and CMS-2 are designed with 0.5 hp engines with a capacity of 170 kg and 370 kg chips/hr, respectively.

Large-scale chipping machine. Mariza Product Company has manufactured larger scale, cassava chipping machines to serve the demand of five national companies in five provinces. Chipping machine type M5 #16 cm has a capacity of 300-400 kg chips/hr by using an engine of 0.5 hp. By using a pedal, its capacity is 150-200 kg. Chipping machine type M5 #32 cm, with an engine of 2 hp, has a capacity of 2 t/hr.

Wet chip pressing equipment. Chip pressing equipment is not essential equipment. During the rainy season or during peak supply periods, however, it facilitates chip drying. MORIF has developed a manual chip press using a car jack. Chip pressing equipment type PREN-1 has a capacity of 75 kg chips/hr and type PREN-3 has a capacity of 140 kg chips/hr.

Sun-drying equipment. The method for chip drying depends on solar energy. The major investment for sun-drying equipment is bamboo or metal trays or other drying sheets and the availability of a drying floor.

Flour milling unit. The model and type of milling unit affects flour quality. The common rural grinding equipment or coffee grinder can be used for this purpose, but the resulting flour does not meet quality standards, especially its mesh. SURIF has developed grinding equipment using an impacting system (hammer mill). Its capacity is only 40-50 kg/hr for flour of 50-60 mesh. MORIF has developed a design for milling equipment type TEM-1 with a capacity of 20-25 kg for flour of 60-80 mesh.

Mariza Product Company has manufactured grinding equipment using an abrasion model. Its capacity is 100-150 kg/hr for flour of 80-100 mesh. The Multi-purpose Disk Mill Model 6FZ-308, made in China, shows good performance with a capacity of 300 kg/hr for flour with 90-100 mesh.

Agro-industrial Models and Their Economic Analysis

Alternative Cassava Flour Processing Models

Based on existing systems of rural trade engaged in handling agricultural produce, three types of participants are involved in the cassava agro-industry: farmers and farmer groups; chip collectors/processors; and millers, i.e., Village Cooperative Units (KUDs) or private entrepreneurs.

Based on the steps involved in cassava flour processing, from harvesting in the field to marketing of the flour, intermediate products can be grouped into fresh cassava, wet peeled cassava, dried or wet chips, and cassava flour.

Using the prevailing trading systems, alternative agro-industrial operations can be developed. For example, for the 1,000 ha cassava plantation, with a production of 15,000-20,000 t/yr, 5% of output can be expected to be available for processing into cassava flour. It requires about 1,500 to 2,000 t/yr to supply about 10 t of raw material per day in a five-month period.

Three main models of agro-industry can be proposed depending on capability, capital, and distribution of value added.

Model I: Home Agro-industry for Individual Farmers

A family of 2-3 persons can process about 200 kg of fresh cassava per day; this gives about 70 kg of dried chips. The main investment (Rp 500,000) is for buying equipment: one unit of hand chipping equipment, one unit of pressing equipment, washing tanks, and sun-drying equipment (Fig. 3). The dried chips produced can be utilized by agro-industry Model III.

About a third of the production (two t/day) can be processed by this model. Therefore, 20 farmers can be included in Model I.

Model II: Agro-industry for Farmer Groups

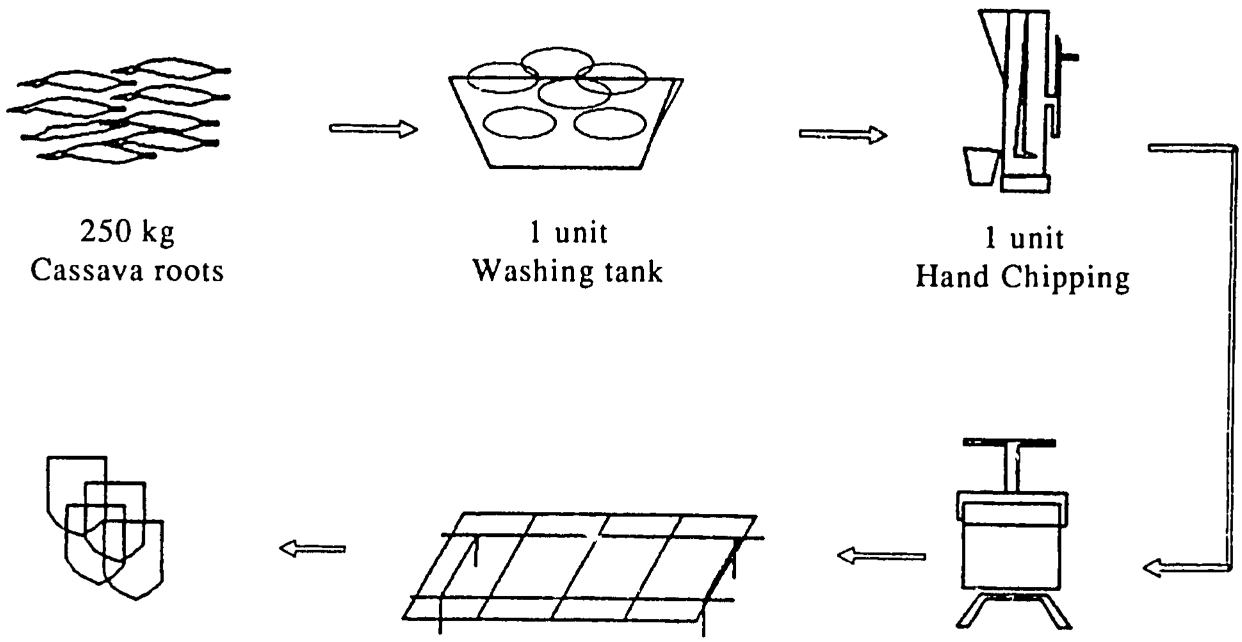
A group of 10-12 persons can process 1,000 kg of cassava per day and produce about 300 kg of dried chips. Equipment costs are Rp 2,500,000 for buying one unit of pedal shredding equipment, two units of pressing equipment, washing tanks, and sun-drying equipment (Fig. 4). The dried chips produced are expected to be utilized by Model III.

If a third of the raw material produced (5 t/day) is processed by this model, six groups of farmers can be included with a production capacity of 1.5 t of chips per day.

Model III: A Nucleus Cassava Flour Agro-industry

The unit is expected to be a governmental company/KUD with 20-25 laborers and a processing capacity of 3,000-5,000 kg of cassava flour per day. This milling unit mainly processes dried chips from the neighboring farm-

Figure 3. Model I for cassava flour production at the farm level.



ers. Model III is more directed toward cassava flour processing. It is also responsible for marketing. The investment in equipment is estimated to be Rp 90,000,000, e.g., for buying two units of power chipping machine, two units of pressing equipment, drying equipment, and two units of milling equipment (Fig. 5).

Model III is expected to absorb one to two tons of fresh cassava per day, to be processed into dried chips. About two to three tons of dried chips per day can be produced by Models I and II.

Area of Development

Cassava flour technology must be developed considering the current cassava production and marketing system. An evaluation by the Research Center for Agricultural Economics (1990) showed that production and marketing systems of commodities in Lampung and East Java are different. In Lampung, cassava is produced mainly for export, e.g., dried cassava, chips, pellets, and tapioca starch. In East Java, cassava is mainly used for local consumption.

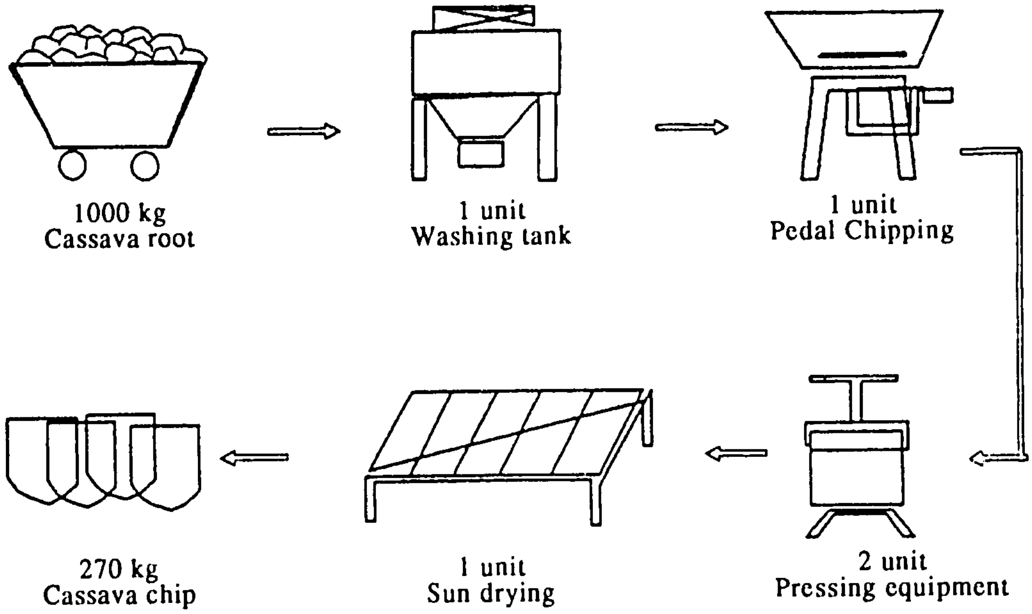
Considering these two different marketing systems for cassava, the development of the cassava flour industry could be implemented in at least three locations e.g., Lampung, Central-, and East-Java.

Economic Analysis of the Various Models

Limitations and Assumptions

Several assumptions must be made in conducting an economic analysis of the three agro-industrial models.

Figure 4. Model II for cassava flour production at the farmer group level.



Price of Raw Material

The price of fresh cassava is fixed at Rp 40/kg at the farmer level, fresh peeled cassava at Rp 50-55/kg, dried chips at Rp 240/kg, and cassava flour at Rp 400/kg.

Form of the Products Traded

In the production and distribution systems, the traded products are in the form of fresh cassava, fresh peeled cassava, dried chips, or cassava flour.

Marketing Conditions

The market is still unsaturated. Thus, the entire production can be absorbed by the market at the same price. Fresh cassava as raw material is available during at least five months per year.

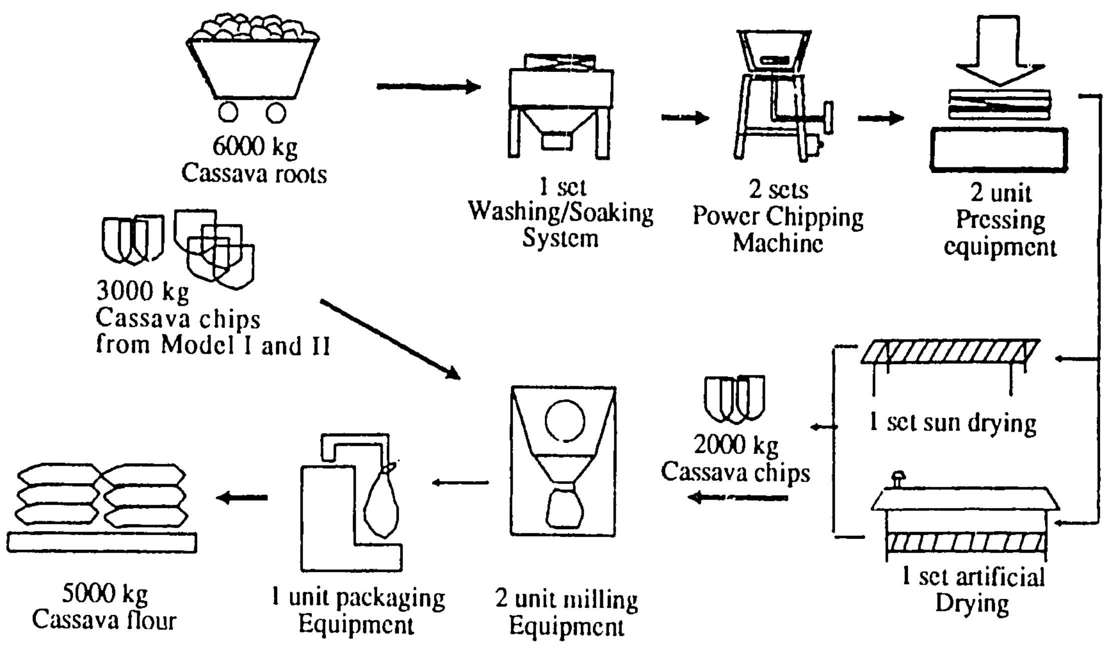
Feasibility Analysis

Based on the assumption that depreciation of production equipment is more than ten years, a feasibility analysis shows the following:

Model I—Individual Farmer Level

The price of fresh cassava can be maintained at Rp 40 kg for 210 kg fresh cassava if the farmers can produce about 70 kg of dried chips per day at a price for dried chips of Rp 240 kg. Based on a feasibility analysis with the discount factor at 10-20%, the Internal Rate of Return (IRR) ratio is 33-45% and the net Benefit/Cost (B/C) ratio is 4.4 to 5.4 (Table 4). This means that, in the first year, the profit is five times the investment for equipment and the cost of maintenance. An IRR of 33-45%/yr is much higher than the rate of interest offered by a bank (about 20%/yr). It can be concluded that Model I is highly feasible economically.

Figure 5. Model III for cassava flour production at the governmental company/KUD.



Model II—Farmer Group Level

An enterprise in Model II has a production capacity of 300 kg dried chips/d from 1,000 kg of fresh cassava. This enterprise absorbs 9-12 laborers/unit/cycle of production. A feasibility analysis with the discount factors at 10-20% showed that the net B/C ratios at 2.5-3.1 and an IRR of 29-39% (Table 4). Hence, profits are two times the investment in equipment and the cost of maintenance. The IRR of 39% is nearly two times the rate of bank interest at 20%/yr.

Model III—Cassava Flour Producer Level

The activities of this model are: producing cassava flour from fresh cassava, and producing cassava flour from dried chips bought from Model I and Model II enterprises. Therefore, Model III is a nucleus system of agro-industry.

Based on a production capacity of 3,000-5,000 kg cassava flour per day, the company is able to process 2,000-3,000 kg of fresh cassava per day and to absorb about 2,000-3,000 kg/day dried chips from enterprises in Models I and II. Furthermore, the milling unit of Model III can act as the market for the chip products from Models I and II.

The feasibility analysis showed that the net B/C ratio is 8.1-9.9 and the IRR 35-48% (Table 4). Based on these feasibility indicators, it appears that the Model III enterprise is highly feasible.

Marketing Margins and Value Added

A case study in Lampung Province showed that at peak harvest time, the marketing margin for cassava roots was Rp 15 and for *gaplek* Rp 20, whereas the estimated margin for chips was Rp 10 and for cassava flour Rp 25 (Table 5). From July to September, the price of fresh cassava was drastically reduced to Rp 20 or 30/kg. The farmers usually dry the cassava following simple methods to produce *gaplek*, which often has low quality. Introduction of cassava flour processing through producing chips will enhance the value added of cassava.

Table 4. Economic analysis of different models for cassava flour production.

Capacity end product	Model I (70 kg/day chip)	Model II (330 kg/day chip)	Model III (5,000 kg/day flour)
Discount Factor (DF) 10 %			
NPV (Rp 000)	879	3,264	515,753
IRR (%)	33	29	35
Net B/C	5.4	3.1	9.9
Discount Factor (DF) 15%			
NPV (Rp 000)	687	2,416	412,703
IRR (%)	39	34	42
Net B/C	4.8	2.8	8.9
Discount Factor (DF) 20%			
NPV (Rp 000)	543	1,785	334,847
IRR (%)	45	39	48
Net B/C	4.4	2.5	8.1

Source: Central Research Institute for Food Crops 1991.

NPV = Net Present Value.
IRR = Internal Rate of Return.
Net B/C = Net Benefit/Cost.

Table 5. Marketing margins for cassava fresh roots, gaplek, chips, and flour (Lampung), 1990.

Jenis Biaya root	Fresh root (Rp/kg)	*Gaplek* (Rp/kg)	Chip (Rp/kg)	Flour (Rp/kg)
Price paid to the farmer	40	155	240	400
Price paid to the middleman	55	175	250	425
Margin	15	20	10	25
Distribution of margin:				
Cost for harvesting and loading to truck	5	0	0	0
Cost of tranport	7	15	5	20
Trader net income	3	5	5	5

Source: Central Research Institute for Food Crops 1991.

Value added to fresh cassava is Rp 12/kg for cassava chips and Rp 15/kg for flour processing. Much higher than for *gaplek* processing at Rp 4/kg (Table 6).

Cassava processing at the farmer level, such as in Models I and II which produced dried chips, will offer additional income of Rp 2,133 and Rp 2,667/day/worker (Table 7).

Supporting Activities

Governmental policies are urgently needed to support attempts to develop technology. The objectives of the policies should be to create a production environment and quality improvements that are advantageous to the industrial trading environment, as well as to distributors and farmers, and to change the consumer's attitude towards cassava.

Price and Distribution Policies

Price and distribution policies for cassava products (cassava flour and chips) of a particular quality can provide incentives for production and for improvement of product quality. The assurance of the supply of cassava as a raw material requires a well-organized system. The continuous distribution of cassava flour throughout the year could stabilize cassava production. BULOG and KUD are expected to play an important role in this system.

Support for Industries and Export Diversification

Development of cassava flour processing is the major element involved in developing the cassava industry in general. To meet the consistent demand for raw material for processing into cassava flour, it is important to ensure production increases at the farmer level. Development of this industry needs capital from investors.

Traditional export of dried cassava chips and pellets is difficult to expand due to quota limitations. Non-traditional commodities, such as fructose candies, sorbitol, and modified starch, however, are not covered by quota regulations and there may be potential to increase their export volumes. Also, various food products with cassava flour as the raw material have been formulated. These have good prospects for export.

Extension

Extension systems are aimed at the various levels of the community: farmers, farmers' families, processor groups, and other social groups. The extension materials selected depend on the level of the respective community.

Campaigns and Promotion

Governmental attempts to change the appreciation of cassava by the community must be made through promotion, extension, expositions, cooking festivals, etc.

Table 6. Value added in different processed products made from cassava (Lampung), 1990.

		Cassava processed product[a]		
Factor	Fresh root	Dried cassava	Chips	Cassava flour
Yield recovery (%)	100	35	30	25
Price of product	40	155	240	400
Value of product per kg fresh roots	40	54	72	100
Production cost	0	10	20	45
Real value per kg fresh roots	40	44	52	55
Value added	0	4	12	15

Source: Central Research Institute for Food Crops 1991.

[a]All figures are Rp/kg, except yield recovery.

Table 7. Estimated income for different systems of cassava chip production.

Factor (unit)	Model I Farmer family	Model II Farmer group
Production capacity (kg)	200	1,000
Added value of chips (Rp/kg)	12	12
Added value per day (Rp)	2,400	12,000
Processing cost (Rp/kg)	20	20
Labor cost per day (Rp)	4,000	20,000
Total of income (Rp)	6,400	32,000
Worker/unit (person/day)	3	12
Income per worker (Rp)	2,133	2,667

Source: Central Research Institute for Food Crops 1991.

Community Participation

The catering and bakery industries play an important role in absorption of cassava flour, especially as a substitute for wheat flour in their products. The other participants that can facilitate campaign activities are Governmental and semi-governmental organizations, such as KORPRI, Dharma Wanita, Persit, social institutions, professional organizations, and the mass media.

Conclusion

- The development of an agro-industry for cassava flour production in Indonesia provides opportunities for diversification of cassava products. It has the potential to increase the farmers' incomes, improve marketing, support food diversification, minimize wheat imports, and promote the development of various food industries.
- Cassava flour processing involves the development of technologies and equipment for chipping, pressing, and milling, as well as techniques for peeling, washing, soaking, and drying.
- The cassava flour agro-industry is designed as nucleus-plasma models. The system can be grouped into three models based on capital, capability, level of knowledge, and distribution systems of the raw material. The systems include Model I at the farmer level, Model II for farmers' groups, and Model III represents a milling unit owned by private companies or KUD. The milling unit uses intermediate products, e.g., dried chips from Models I and II to be processed into cassava flour as the final product.
- Economic feasibility analysis showed that the three models are feasible.

Follow-up Policy

Government efforts to help develop the cassava flour industry have been initiated. The Minister of Industry assigned five governmental companies under his Ministry to develop and act as foster-parents of cassava flour production plants in five selected provinces (decrees number 331 and 332/MMP-X/1989). In 1990, under Presidential aid to KUD, 25 cassava flour production units were distributed to KUD in seven provinces.

The development of cassava flour production systems is expected to support the effort of technology transfer from researcher to a commercial scale at the farm level.

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Development of Milksap-free Cassava Half-product in Vietnam

Quach Nghiem[1]

Abstract

After harvesting, fresh cassava spoils rapidly, limiting its utilization and consumption. Therefore, major part of the fresh cassava harvested in Vietnam must be converted into preservable dried cassava or starch. Processing cassava slices is difficult because of the hot, humid, tropical climate. Cassava slices have high humidity, mold easily, and contain toxins; this results in low market value. In order to overcome these problems, the National Institute of Agricultural Sciences (INSA) has developed a new half-product of cassava based on a milksap-removing technology. This technology allows cassava processing to be carried out in any weather, without prior drying, and the costs of processing and preservation are lower. In dried form, the milksap-free cassava is easy to preserve, free from hydrocyanic acid (HCN), non-toxic, and does not taste like cassava. This processing method is expected to contribute to reducing the product price and expanding cassava consumption.

Key words: new products, research, farmers, technical procedures.

Introduction

Under Vietnam's hot, humid, tropical climatic conditions, fresh cassava roots spoil quickly because of infection by microorganisms within 4-6 days after being harvested. In order to preserve and consume cassava, it is processed into dried slices. The success of this method depends on the weather. Losses during processing and storage are very high (30%). This has discouraged farmers from cultivating and processing cassava (Table 1). Due to poor infrastructure, the establishment of village-based processing is an important strategy to help convert a large amount of fresh cassava, approximately 2.6-2.8 million t/yr, into a valuable half-product.

Recently, the National Institute of Agricultural Sciences (INSA) has achieved success in the development of a cassava milksap-removing technology. This technology permits the farmer to process a large amount of fresh roots under any climatic conditions without the necessity of drying the roots. Milksap-free cassava can be preserved under anaerobic conditions for several months. The storage of dried milksap-free cassava is easy due to minimal spoilage caused by microorganisms. This new half-product which has no hydrocyanic acid (HCN)-content or cassava taste can increase cassava utilization in animal feeding and in the confectionery and fermentation industries.

Furthermore, milksap isolation technology and milksap-free fresh cassava storage allows a reduction in losses during storage and processing and eliminates the need to build special storage units. Application of this technology opens up opportunities in rural areas with potential for creating more employment possibilities and increasing farmers' incomes.

Processing and Utilization of Dried Chips

Dried cassava chip processing does not bring high profits for the most part. Processing, therefore, has been

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Table 1. A comparison of local processing of cassava into dry chips, wet starch, and maltose.

Processing factors	Cassava product: Dry chip	Wet starch	Maltose
Processing capacity kg product/day-labor	10-20	55-100	60-100
Total processed product/year	300-700	18,500	21,900
Income/labor day in Vietnamese dong[a]	200-1,000	4,000-10,000	7,000-15,000
Marketing ability	fair	good	good

[a]Vietnamese dong 6,000 = US$ 1.

mainly implemented by cassava farmers who do not have access to large-scale, cassava processing plants.

Fresh cassava roots contain about 60% water. The conventional method of drying chipped cassava roots by using charcoal is too expensive because dried cassava chips can fetch only a limited price on the market. The use of solar energy for drying cassava chips is often difficult because of high air humidity and the short duration of sunshine during the harvest time in winter (Table 2). This results in more than 30% of the product being of low quality.

Furthermore, the high relative humidity also results in reabsorption of water by dry cassava chips causing mold formation and rotting. At present, about 45-62% of the total cassava production is processed into cassava chips. Because of the short duration of sunshine, cassava roots must be sliced thinly after which they take about 2-3 days to dry. Large losses occur during the long drying time.

Frequent changes in the weather (rain or a sudden increase in temperature) result in substandard quality and large losses due to rotting. Various kinds of chipping machines have been introduced, but the average cultivated area of cassava per household is very small so Vietnamese farmers prefer to use a simple chipping knife. Cassava chip processing plants have been uneconomical and the production of cassava chips shows the lowest profit when compared to other processing activities (Table 1).

In recent years, the price of cassava chips has fallen due to the improving rice supply in the country and it has been difficult to sell cassava. Until now, most dried cassava has been used for livestock feed and alcohol fermentation at both the rural and industrial levels. The confectionary and textile industries also need more cassava chips.

HCN-toxicity and the typical cassava taste are the main factors limiting the use of cassava in animal feed, the confectionary industry, and alcohol production at the

Table 2. Relative humidity and sunshine hours during the cassava harvest in Vietnam.

Location	Relative humidity (%) Oct	Nov	Dec	Jan	Feb	Sunshine (hr/day) Oct	Nov	Dec	Jan	Feb
Hanoi	81	79	80	81	84	5.7	5.0	4.4	2.6	1.8
Hue	86	87	89	88	89	4.4	3.6	3.3	3.6	3.8
Soc Trang (Mekong Delta)	88	87	83	80	77	5.3	6.4	6.5	8.0	9.3

rural household level. In terms of alcohol production, cassava alcohol is considered to be of lower quality than rice alcohol. Hence, farmers prefer to ferment up to 20% of their rice production to make alcohol for household consumption. The introduction of more low-priced cassava raw material into these production sectors will help to improve the food supply in the country and increase farmers' incomes.

The Milksap Removing Process

This technology was developed by the Department of Biochemistry and Food Technology of INSA in 1989 with the objective of developing an alternative for substituting the method of processing cassava chips.

Some Chemical Characters of Milksap

Cassava roots contain milksap which is a source of nutrition for the plant. Our research has found that this milksap has a negative effect on cassava storability. During observations of starch settling during the manual starch purification process, we have always recognized a black fraction on the surface of the starch fraction. This black fraction is a mixture of lower density starch and milksap. In early 1980, starch processors detected this milksap-starch and used it for pig feed. The pigs that were fed this milksap fraction grew fast and there have been no reported cases of intoxication. After drying, this black fraction was brought to our laboratory for analysis. Results of this analysis have shown that this milksap-starch fraction has a composition of 9% protein and 3.2% lipid, which is higher than that found in cassava chips and cassava starch (Table 3). This clearly indicated that some important nutrients, such as protein and lipid, are not equivalently distributed in cassava roots but are mainly concentrated in cassava milksap vessels.

Phenomena of Rotten Fresh Cassava (musty-milksap loss)

In spoiled fresh cassava roots, we can see mold bacteria invading through the milk vessels into the whole root. From results of our observations, we have come to the conclusion that milksap is an optimum medium for growing microorganisms. Thus, milksap isolation might improve cassava preservation.

The Technical Procedure

The technical procedure of processing and preserving fresh cassava by removing the milksap is as follows.

- Peeling and washing fresh cassava root (by hand or machine).
- Grinding cassava into very fine particles (grinding machine operated by a motor or by hand).
- Isolating the milksap using a chemical mixture (milksap contains proteins, lipids, tannins, polyphenole, etc., which are soluble in water) for one hour.
- Dewatering using pressure-equipment.
- Preserving wet cassava without the milksap under anaerobic conditions for 1-6 months.
- Filtering starch through cloth for formation of cassava pellets or cassava flour.
- Solar drying of cassava starch or solar drying of HCN-free cassava pellets or flour.
- Packaging.

This technology permits the producer to process cassava under all weather conditions and to reduce waste. Milksap-free cassava is easy to preserve with only minimal microbial infection; it is also free of HCN, does not have the typical taste of cassava, and can be easily used for different purposes (Table 4). Milksap-

Table 3. Chemical composition of three cassava half-products.

	Dry chip	Milksap-starch fraction	Starch
Moisture	15.0	18.0	14.0
Carbohydrate	74.4	68.0-70.1	84.0
Protein	3.9	6.8-9.0	0.1
Lipid	1.2	3.2	--
Cellulose	1.2	0.7	0.4
Ash	3.9	0.4	0.45

Table 4. Comparison of cassava processing technologies.

Processing factor	Traditional cassava chips	Milksap-free cassava pellets
Processing capacity per laborer	100 kg	250-300 kg
Rate of loss in processing	6-14%	5%
Proportion of first class product	40%	90%
Quality		
color	White-yellow	White
taste	Cassava taste	No cassava taste
HCN-content	60 mg/kg	Trace
Proportion of spoiled cassava after two-months of preservation	18%	3%
Relative production costs	100%	115%
Percentage that can be used for animal feeding	25%	50%
Conversion rate per 10 kg fresh roots	2.8-3.4 kg	2.8-3.4 kg

free cassava is a valuable material for producing cassava pellets or flour.

The composition of milksap-free cassava is as follows:

Component	Percentage
Moisture	15.0
Starch content	78.8
Protein	0.2
Lipid	--
Cellulose	3.8-4.5
Ash	1.0
HCN	Trace

Both starch particles and cellulose fibers are the two main components of milksap-free cassava that are insoluble in water. This quality allows us to store it underground anaerobically. The experimental anaerobic preservation of milksap-free wet cassava during 1989-1990 shows a possible preservation time of six months. Underground preservation does not need a storage building. It can reduce processing costs and losses enormously. The cost of storage is about 3-5% of the value of the stored material and losses are estimated at <3%.

Conclusion

We are now transferring this new technology to farmers and marketing this half-product. The economic data relating to this technology will now be collected.

Village-level processing plays a key role in the marketing, and utilization of cassava in Vietnam's urban and rural areas. This new half-product will help to reduce the product price and to expand cassava consumption in the country.

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V. Setting Up Pilot Plants

The pilot plant phase is a critical step in the product development process. At this stage, all the separate components involved in product, equipment, process, and market research must be integrated, then optimized to constitute a functional, economically viable enterprise. This section reviews the various activities undertaken in the pilot plant phase and presents criteria to consider in their successful integration. It also includes a retrospective analysis of the pilot plant experience with potatoes in Peru and cassava in the Philippines.

Christopher Wheatley provides a set of guidelines for successful **Pilot-scale Operations.** These refer to plant construction, experimental and semi-commercial operation, test marketing, and feasibility studies. He notes that specific issues such as organizational structure of the pilot plant operation, raw material supply, product quality, and promotion must be addressed as well. The guidelines include criteria for helping implement each of these activities. Wheatley stresses the need for continuous monitoring of product production and marketing such that in 12 months a commercially viable enterprise can be established.

The International Potato Center's (CIP) has used its pilot plant in Peru for several purposes. In **Low-cost Potato Processing: CIP's Experience with Pilot Plants in Peru**, Siert G. Wiersema notes that these facilities first served to improve small-scale processing equipment. Subsequently, several methods for processing food mixes were developed and consumer tests carried out. The plant then became a training and experimentation center for interested local entrepreneurs and rural development groups. Based on this experience, suggestions for setting up pilot plants are enumerated including location in an area of abundant raw material supply, flexible design, evaluation of economic returns, and financing of new processing units.

Cassava-based Feed in the Philippines: The ViSCA Experience by G. R. Gerona presents an overview of the utilization of cassava by the livestock industry in the Philippines with emphasis on the experiences in the piloting of a feed mill with cassava-based formulations. Gerona indicates that the pilot feed mill project demonstrated the technical and commercial viability of cassava-based diets for pigs but only to a limited extent in the case of poultry. He also documents the impact the feed mill had on establishment of backyard pig and poultry enterprises as well as improving the price of cassava chips. In conclusion, Gerona notes the debilitating effect of cumbersome government regulations on pilot plant operations.

Pilot-scale Operations

Christopher Wheatley[1]

Abstract

A critical step in the product development process takes place at the pilot plant phase. This paper reviews the activities undertaken here including: plant construction, experimental and semi-commercial operation, test marketing, and a feasibility study. It addresses specific issues such as organizational structure of the pilot operation, raw material supply, product quality, shelf-life and packaging, preliminary marketing studies, and product promotion. Continuous evaluation of plant (process and equipment) and product (marketing) performance is stressed throughout. The experience acquired is seen as contributing to the establishment of a technically and financially viable enterprise in the course of about 12 months. Examples are cited based on work with specific root and tuber products.

Key words: processing, roots and tubers, markets, experiments, applied research.

Introduction

Overall Objective

This paper looks at the development of a new or improved prototype of a root/tuber-based product into a commercially successful product; the benefits of which will accrue to small farmers in a given region.

Specific Objectives

Four key factors must be evaluated to develop and operate a pilot plant. They include:

- determine the technical and financial feasibility of the new process being used by a farmers' coop or small-scale industry;
- assess the quality and availability of raw material (fresh roots/tubers);
- assess the quality and acceptability of the final product; and,
- determine the demand for the product.

Strategies

Holistic Focus

The key strategy within the context of an **integrated** project for product development is the simultaneous consideration of three components: production, processing, and marketing (Fig. 1). It is not possible, for example, to discuss marketing in insolation from processing because the activities undertaken in these areas are interdependent. The actual sequence of activity implementation is shown in Figure 1.

Human Resource Development

Farmer groups need to learn much more than the technical aspects of processing the raw material. They must acquire skills in operating the plant, monitoring operations and costs, negotiating, controlling quality, analyzing markets, etc.

Monitoring and Evaluation

Data gathered throughout the initial experimental operation and the semi-commercial phase make it possible to determine the feasibility of operating on a commer-

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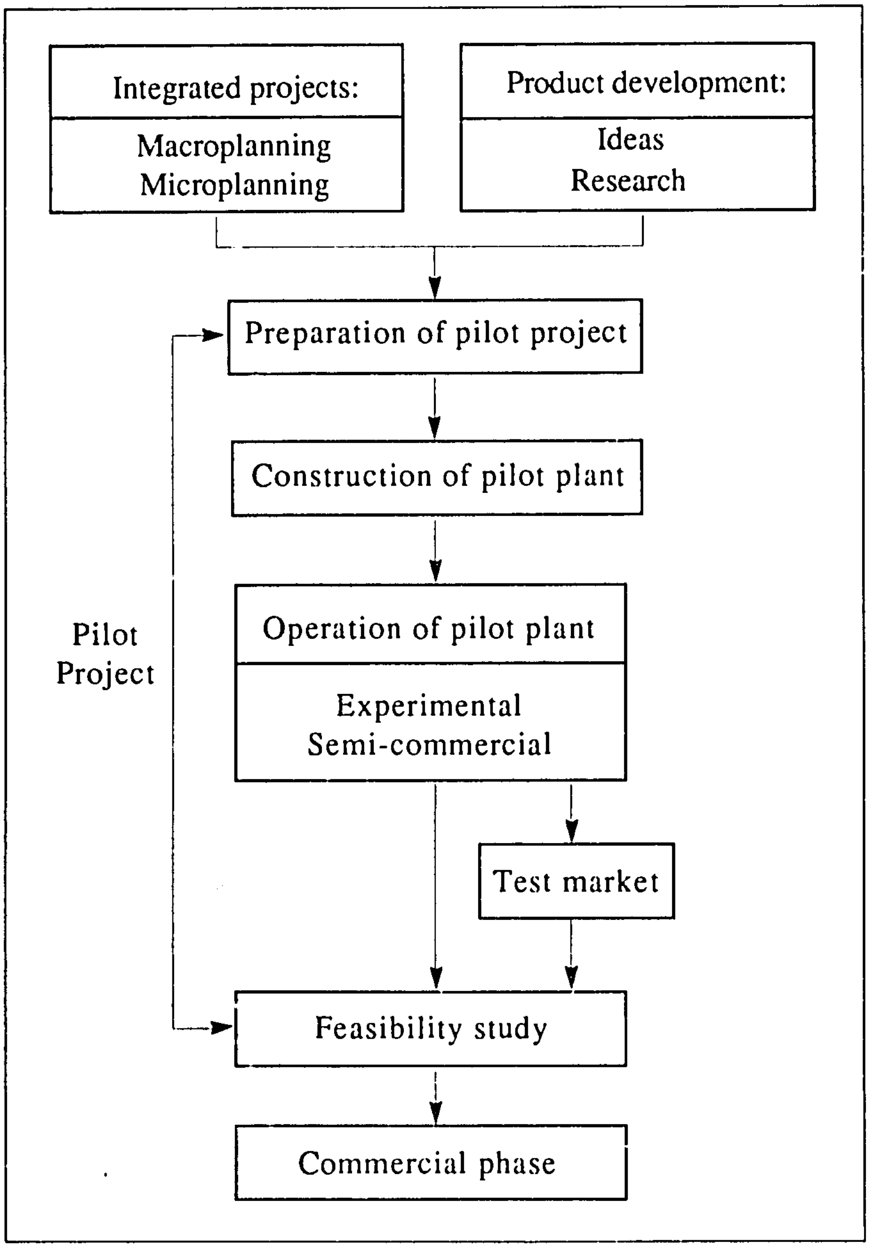
Figure 1. Position and subdivision of the pilot project in the context of an integrated cassava project and product development.



cial scale and whether the plant should be expanded or others built.

Site Selection

Prior to starting the pilot project, it is necessary to identify the site for locating the plant. Selection criteria are shown in Table 1. The objective of reviewing these criteria is to select the best option for locating the pilot plant; in other words, where there is a sufficient supply of quality raw materials not too distant from the plant (transportation of bulky fresh roots is costly). There should be good roads for transporting the raw material and for shipping the final product to its principal market (which ideally should not be too far away). If the plant operates only seasonally, i.e., during the dry season, then the condition of the roads during the rainy season is not important.

If at all feasible, the pilot plant should be located where there is a group of farmers who have had some

Table 1. Site selection criteria.

Raw material
- Availability (harvest mo/yr)
- Current and future surpluses
- Existence of competitive markets (e.g., fresh cassava)
- Quality factors (e.g., dry matter content, hydrocyanic acid levels)
- Concentration and distance from plant (affects transportation costs)

Processing
- Infrastructure (e.g., water, electricity, access roads)
- Local capacity for building the plant
- Local capacity for building and maintaining equipment

Farmer organization
- Type of association (e.g., cooperative)
- Members' level of education
- Extent of interest in project
- Availability of support (e.g., labor, land)
- Organizational capacity (e.g., leadership, level and quality of participation in decision-making, management of conflict)

Institutional support
- Institutional presence and relative strength of each
- Interest in project
- Delineation of responsibilities
- Assignation of funds for fulfilling responsibilities
- Technicians and field staff with adequate technical knowledge
- Availability of adequate and opportune credit

Market
- Ease of access from the plant
- Ease of commercial contact
- Stability (constant vs. seasonal)
- Size and future growth potential

experience in working together on a cooperative basis. The purpose is to test the new technology and if there are organizational problems, it will not be possible to make a valid test of its feasibility. At the same time, there must be strong institutional support for both technical and organizational aspects in order to ensure that the group functions well. Obviously, it will not be possible to find all these favorable conditions at one site. The criteria may not have equal weight or importance; for example, the provision of electricity at the site may be essential, but that of a paved road less so. The weights assigned to each criterion will depend upon the product and process employed.

Design of Integrated Project

The next step is to combine the prototype process and product to be introduced with the region and site selected into an integrated project. This is basically a plan for adapting the plant design and other elements to the site where the plant is going to be built. The elements to be considered are shown in Table 2.

Construction of Pilot Plant

In addition to steps inherent in any type of construction, which goes from the preliminary land preparation to general cleaning following construction, it is necessary to consider other requirements such as installing water and electricity, building access roads, and manufacturing and installing equipment.

Once all the equipment has been installed, it is necessary to make trial runs in order to optimize their functionality, efficiency, etc. In order to optimize equipment functioning, some adjustments also need to be made because there are always minor details that need to be ironed out.

At the same time, personnel who are going to work in the pilot plant should be carefully selected. If the plant is going to be run as a cooperative or association, then it will be necessary for the members to reach an agreement as to who the operators will be in accordance with the complexity of the process (the minimum feasible number so as not to inflate operating costs). Above all, it is important not to include expenses for an administrative head or secretary at the beginning when the volume of production does not justify it. Once the personnel have been selected, a training plan should be drawn up (Table 2).

Experimental and Semi-commercial Operation of Plant

The most important activity of a pilot project is the experimental and semi-commercial operation of the plant. The former consists of testing the equipment, raw

Table 2. Elements to be considered in a pilot project.

- Establishment of plant capacity in accordance with the market and production of roots/tubers in the plant's zone of influence and the funds available.
- Preparation of the site for building, including study of topography and soils; need for levelling land; permits for installing electricity and/or water.
- Design of the pilot plant, infrastructure, and equipment in accordance with the capacity and characteristics of the lot selected. Where the construction requires technical assistance from professionals such as architects or interventors, a bidding process should be implemented.
- Development of a training plan for plant operators, including important concepts of quality control, hygiene (especially for foodstuffs), and bookkeeping.
- Design of a marketing plan that takes into account the most attractive markets.

material, and operators to the point where the process is efficient and the final product is of an acceptable quality. This means that trial runs must be conducted, for example, to identify optimum variables for the process and determine acceptable characteristics of the raw material. Once the plant's operating parameters have been established and it is possible to produce consistent quality, then it is feasible to proceed with operations on a semi-commercial scale. The product can be sold regularly in order to obtain information regarding its acceptability. The most important aspects of these two processes are discussed for both stages.

Organizational Aspects

There are two critical organizational factors that can affect the success of the pilot plant effort:

- existence of a strong farmer organization; and,
- appropriate support for that organization in the form of technical and organizational backstopping, as well as financial support.

If these two elements are not present throughout this critical phase of the project, everything can fail even if the technology is viable and profitable. Thus, it is preferable not to implement pilot projects with recently formed groups because the introduction of a new technology and the need to work together as a team is risky in a group that has not yet been consolidated. It takes an experienced group who know how to work together to carry out the complex series of activities inherent in processing and commercialization. If this is present, then failure for reasons other than processing, product, or market is much less probable.

Raw Material

Supply. Supply of raw material should be organized so that the roots/tubers are not in the plant for longer than is absolutely necessary before they are processed (e.g., for one or two days in the case of cassava). Rapid perishability of fresh cassava has a strong impact on final product quality. If the plant requires a daily supply of fresh roots, it should coordinate daily deliveries. This complicates the supply side of the operations, especially if the volumes of raw material are not great during the initial phase of plant operation, which could result in dead freight. Other root crops are less problematic in this respect. Nevertheless, root storage times prior to processing should always be minimized in order to speed capital flows.

The cost of transporting fresh roots is always high because they are 65% or more water (although this is eliminated later in most processes). For that reason it is important to construct the plant in a zone where there is sufficient raw material within a short radius of the plant. In the event there is little current production (i.e., the plant was built on the basis of future production potential), then the cost of transporting raw material over greater distances will have to be financed during initial operations.

Harvesting periods. Studies need to be made to determine local harvesting times, which can vary greatly from one micro-region to another, depending upon the months with adequate rainfall for planting and the initial development of the plant. Some areas have two harvesting times a year; and, others with regular rainfall makes it possible to harvest and plant throughout the year. The same applies to irrigation districts where roots/tubers are planted. Plant operating time of course will depend on harvesting periods and can be reduced even more if other conditions exist (for example, little rainfall making it possible to dry products naturally using the sun).

Price. Root and tuber crops have several actual and potential markets. The new product from the pilot plant will complement existing markets. In most of the Latin American countries, the largest market is for fresh human consumption; in Brazil, it is for *farinha*, a roasted flour. Prices offered for fresh roots vary a great deal during a normal year, being lowest during the most important harvesting season. Preliminary studies can estimate a tentative price that the plant can pay for its raw material. Procuring raw material for operating the plant will depend on whether this price is competitive with prices on the fresh market. This could limit the supply of raw material to the peak harvesting period; or, in the case of plants located in a subsistence agriculture zone, there will be no competitive market and the supply will continue with the harvests. In general, a processing plant that depends on the supply of low-cost raw material will have more success when it is located away from massive consumption centers where the fresh market serves as a magnet for available food stuffs.

Quality. Another factor related to the supply of raw material is product quality. In general, there are fewer critical quality factors for a processing plant than for the fresh market where preferences of intermediaries and consumers can be quite demanding. While it is frequently proposed to supply a pilot plant with roots/tubers that are unacceptable for the fresh market, processes and products that require a high dry matter or starch content do not permit the indiscriminate use of non-commercial or poor quality raw material.

Initial functioning of the pilot plant will determine whether prevailing factors such as quality, price, transportation distance, harvesting periods favor a continuous and opportune supply of raw material.

Processing

Experimental operation. During this phase the necessary adjustments are made in the equipment so that the plant operates at maximum efficiency according to design. In some cases, this is a matter of days; in others, defects in construction (most often in a prototype machine, which is the first of its kind) may require more time and money to modify. Several options for a process may also need to be tested to determine which is the most efficient and easy to manage; for example, artificial drying, with or without a tempering period.

Among the most important factors determining profitability in many processes is the conversion factor (quantity of raw material required to produce a given amount of final product). A good, i.e., a low, conversion factor depends upon the quality of the raw material, dry matter content (high), and the efficiency of the process.

The experimental stage ends when the process is functioning well and the operators are skilled in its management.

Semi-commercial operation

When the supply of raw material permits a continuous operation without further modifications and/or adjustments in the process, semi-commercial operation begins. During this phase, the following aspects are evaluated:

- operators' ease in managing the process;
- efficiency of labor;
- effectiveness of operators' training;
- performance of the equipment under continuous use including energy consumption, efficiency and performance;
- need for further research related to equipment or its handling;
- possible bottlenecks in the process; and,
- actual operating costs.

By the end of this phase, all necessary adjustments to the process, management, and labor use will have been completed. Often plant workers themselves find practical solutions to problems and can contribute valuable comments and ideas with respect to other aspects of pilot plant operation. Mechanisms should be sought for incorporating their contributions into the evaluation process.

The Product

During the experimental phase of plant operation, it is not enough to optimize the process by taking into account the efficiency of the machinery. The quality and quantity of the final product are also important.

Product quality results from the interaction of raw material and the process. In the case of cassava the most important parameters are dry matter and/or starch content, hydrocyanic acid (HCN), the presence of aflatoxins, and/or pathogenic microbes; and, in the case of products for direct human consumption, product taste, texture, and appearance. For other root and tuber crops, relevant anti-nutritional factors, e.g., alkaloids, trypsin inhibitors, or nutrients such as protein and vitamins must be included. In the case of products where norms have been established by law or national quality standards exist, analysis or quantitative determination of those norms need to be part with these evaluations. (For example, if the HCN content is below 50 ppm or the microbial count for fecal bacteria is 0.) Should the product not consistently meet quality standards in the experimental phase or under lab conditions in the preliminary stages, the reasons for irregular performance should be sought—whether they lie in the raw material being utilized or in different conditions of the process. With respect to the level of microbial contamination, the environmental conditions of a pilot plant located in a root crop production zone are going to be very different from those in a lab. It is especially important to insist on rigorous control of personal hygiene and of equipment to maintain the cleanliness required for many products of human consumption. Nevertheless, many traditional products made from root crops have high levels of contamination and completely lack any sanitary controls. It may also be necessary to obtain a sanitary license when the product is for human consumption.

In the case of products destined for human consumption, organoleptic characteristics are important. Organoleptic and acceptance tests should be conducted in order to confirm whether the new product is acceptable to both buyers and consumers. There are two ways of conducting this type of test: under controlled conditions, or normal use. The advantage of the former, conducted in the lab with some sensorial analysis, is that the results are clear, and reliable data can be obtained with respect to the taste or acceptability as compared to another product (the traditional one or the competitor). On the other hand, giving samples to homemakers for tasting under normal meal conditions gives a better idea of its acceptability. However, recipes and preparation can easily vary; hence, the ease of making comparisons between products is lost. As an intermediate option, a consumer panel can be formed to evaluate one or more samples so as to compare results. Panels of this type can be costly to set up. The same type of tests (i.e., lab, at home, or panels) are also pertinent for studying other product characteristics such as shelf life or forms of use. It is important that the new product:

- be acceptable to the consumer;
- be acceptable *vis-à-vis* competitive products; and,
- fulfill the desired characteristics (e.g., nutritional, organoleptic).

Shelf Life and Packaging

The commercialization chain—short as it may be—always requires some sort of product durability, to which must be added the storage time until the final user consumes/uses it. It is important that the product characteristics do not undergo any significant change during this period of time. Factors that can affect the product's useful life are as follows:

- product moisture content;
- relative humidity during storage;
- level of contamination by fungi, bacteria, and insects during processing;
- type of packaging used; and,
- size of packaging (product weight/unit).

Packaging is a barrier between the product and its environment. As it may be porous, it can permit the interchange of gases (CO_2, O_2, H_2O) and can be penetrated by insects and rodents, which in turn facilitate contamination by microorganisms. Hence, it is important that the packaging not only be of a reasonable price and easy to obtain, but also serve to protect the product sufficiently for the desired storage time under the environmental conditions found at the storage sites.

In the case of a root crop processing plant, it is not enough to conserve the product until its sale. Training may be required to consider product quality beyond the moment of purchase so that intermediaries and the final users encounter no problems. Consequently, packaging that is not the least expensive, but rather one that permits the greatest storage time, may be necessary.

In the case of products that are transformed by drying to moisture levels under 14%, there are no storage problems because of fungal growth, particularly of aflatoxins. In the case of the feed rations market, commercial firms mill the chips immediately after purchase so packaging is not critical. Where purchases are made by state enterprises in order to regulate prices and markets, storage time can be long so that the packaging used becomes important. It may be best to use new packaging in this case.

Processed products for human consumption such as flours, noodles, and cookies require packaging that resists insect (weevil) attack, above all if product turnaround time is slow. Conserved fresh cassava, for example, requires a polyethylene bag as an integral part of the conservation technology.

Marketing

Two markets exist for pilot plant products: industry and individual consumers. Their characteristics are fundamentally different. Moreover, the marketing process is distinct for each.

The industrial market consists of selling the product to enterprises for a second transformation or incorporation into another product. The consumer market consists of selling the product with no further changes through a wholesale distribution channel. The industrial market is the simplest since there are generally few enterprises and it is possible to have direct contact with the purchasing heads of each one. Moreover, their purchasing decisions are based on logic, price comparisons, availability, and performance of all the suppliers. In addition, the monthly unit of purchase can be very large, equal to, or greater than the plant's production capacity.

The consumer market, on the other hand, is quite complex because it is necessary to sell the product to thousands, possibly millions, of consumers who are daily being bombarded with publicity about competing products. Consumers may make their purchasing decisions on the basis of illogical factors such as product image and status. In order to reach the consumer on a large scale, an efficient distribution system is necessary at terminal markets, as well as the resources and capacity for carrying out mass product promotion. These two activities are not commonly understood by groups of small farmers; thus, other organizations have to be created for product distribution and promotion.

To date, the only improved fresh cassava product developed for the consumer market in Colombia has been that of conserved fresh cassava. It may also be possible to commercialize cassava flour and starch in this market.

Marketing studies. After selecting a site for the pilot plant, it is necessary to carry out a marketing study focusing on markets nearest the plant. The scope of the study depends on the product. In the case of fresh cassava on the Atlantic Coast of Colombia, the urban market of Barranquilla was studied; for cassava flour, national, regional (Atlantic Coast), and local markets were analyzed (Janssen 1986). For a consumer market, the study should include intermediaries, final outlets, and consumers; for the industrial market, only potential clients.

Cassava flour provides an interesting example because it is a potential substitute for a very well-known raw material—wheat flour. Potential clients are manufacturers of foods such as crackers and cookies, pasta, processed meats, and breads. These manufacturers are not familiar with the characteristics of cassava flour because they are somewhat different from those of wheat. The study was therefore designed in two stages. First, a preliminary survey was made on the use of flours in general; and, second, samples were distributed. These samples were recommended for carrying out partial substitution trials in various products, followed by a survey on the trial results, and a review of the amount of interest generated in purchasing the new product. Thus, very concrete information on the potential use of cassava flour in a wide gamut of products was obtained without having to conduct laboratory trials.

Product marketing. The marketing study is the basis for a plan for selling the product produced by the pilot plant. During the initial takeoff and experimental operation of the plant, product quality is not uniform. Optimizing the process leads to an improvement in quality and operational efficiency. It is important that the first samples purchased by the initial clients be of optimal quality. Production that does not meet quality requirements should not be sold to this market. Thus, dried cassava was sold to the animal feed market until it was of a quality acceptable for the cassava flour plants. A project should not expect on experimental plant to be profitable. There should be sufficient funds to cover occasional losses.

These first sales to an industrial market require a detailed follow-up. It is important to know, for example, the client's:

- level of satisfaction with the product;
- use of the product;
- evaluation of its quality;
- comparison with other raw materials;
- opinion of its price;
- estimate of demand and potential for increased purchases;
- view of the consumer's reaction to the final product; and,
- desired unit of purchase and frequency of delivery.

In the case of a consumer market, it is preferable to begin with a limited geographic area, distributing to several shops nearby or to a chain of supermarkets. This facilitates gathering some information without having to use many resources.

During semi-commercial operation, product quality will have become stable and operation costs more controlled. At this point, the market can be developed in accordance with the results obtained in the demand study.

Several options for presenting the product need to be explored:

- size/weight per purchase unit;
- type of packaging;
- design of packaging (logo, brand name, etc.); and,
- price per unit.

The reaction of the market to these alternatives can be very useful in defining some of the alternatives. Once the brand name has been chosen, it is important to register it legally. (It is also important to check whether it has already been registered by another firm before going to the expense of getting the dies made.) With the investment in promotion, the brand name increases in value; and it is important that the owners of the plant (e.g., cooperative members) benefit from that investment.

Termination of the Semi-commercial Phase

When there is sufficient information available for conducting a feasibility study with respect to mounting a full-scale rural industry based on the pilot experience, then the semi-commercial phase ends. The plant generally has to function for an entire year during all the months foreseen as feasible for processing. In the event that the year is abnormal (little production or high prices and low supply of raw material for the plant), it may be necessary to extend operating time to another harvesting season. This requires financial information on production costs, prices, and volumes of sale. It is also necessary to include financial costs in the study even if they are not required for the pilot plant stage.

When the semi-commercial operation ends, it is expected that:

- the supply of raw materials is constant;
- the process is functioning efficiently;
- the operators are trained and working efficiently;
- product quality is good and uniform; and,
- the market is in accordance with the forecasts and in the process of expanding.

Test Marketing

A product that is destined for the consumer market requires activities which organize its distribution and promotion above and beyond what is required for a product to be utilized in industry. These activities are quite complicated and costly; therefore, before launching a full-scale commercial project, it is advisable to begin with a test market. This consists of manufacturing a product for distribution and promotion on a limited scale, albeit in a location typical of the total potential market. The distribution system and the commercial-scale promotional activity therefore can be tested at moderate cost, but within a reduced radius of action; so as to determine the feasibility of launching production on a larger scale. Table 3 shows the requirements for a test market.

Possible options for product distribution within an urban market include: shops, institutions (schools, army stations, etc.), supermarkets, shopkeepers, coops, restaurants, and stalls in wholesale or retail markets.

It is easier to deal with a market that is made up of only a few high-volume clients, than with one consisting of numerous clients, each purchasing only a small amount. Nevertheless, the largest market may be a multitude of low-volume buyers. Options for distributing the product in this case are as follows:

- set up an enterprise specialized in distributing products in urban centers;
- contract a private distributorship on a non-exclusive basis;
- distribute the product to a central warehouse operated by a shopkeepers' association (they may have to be organized around that concept); and,
- obtain warehouse space at a wholesale market where shopkeepers go to purchase other food.

Each of these distribution systems has its advantages and disadvantages. It is important to identify the one that keeps distribution costs at a minimum so that the price of the product is low enough to compete with other products on the market.

When promoting the product, it may be necessary to advertise. The design and execution of a publicity campaign—even with simple, low-cost media—requires experience to make the most efficient investment of money.

Table 3. Requirements for a test market.

- A continuous supply of the product or sufficient inventory to meet the the expected market demand
- A product of the quality specified
- An attractive promotional price
- Promotional materials ready for distribution and airing, together with an advertising campaign based on them
- A distribution system in place for the product, not only for the initial volume, but also for its expansion within a short time period
- A distribution system capable of feeding back the information required by the project to judge its success or not, including weekly data on volumes delivered and sold by shop. This information should be complemented with data on purchases by a sample of consumers, which would provide the rate of repeated purchases compared with initial purchases.

The most important elements for promoting a product on the consumer market are:

- an attractive, duly registered brand name that reflects the product's advantages;
- a logo; and,
- a slogan.

Advertising media include:

- the package (with the logo, slogan, and recipes, instructions for use, packing or expiration dates, name, and sanitary license);
- material for the point of sale: promotional materials such as shelf talkers at the supermarket, posters for shops, leaflets, etc.;
- supermarket promotors/sales representatives;
- newspaper advertisements;
- advertising billboards;
- radio commercials; and,
- TV commercials.

Although an advertising campaign that uses all the foregoing media is very costly and unfeasible for most integrated projects, costs can be reduced and an important impact made if the following are done:

- clear identification of the initial target market (for example, low-income housewives from the poorest residential districts), so that only those media that reach them (e.g., a radio commercial on the station that most of them listen to) are used, thereby not having to spread limited resources too thinly;
- promotion of the product on the news and other programs of public interest to consumers; and,
- special campaigns for shopkeepers (leaflets explaining the benefits of the product, not only for the consumers but also for them) so that they themselves promote the product directly with their clients.

According to Kotler (Fig. 2), if initial purchases are good and a large percentage of the buyers repeat purchases, the product is a success. If initial purchases are high but only a few are made a second time, then the concept of the product is good, but it does not meet its promises—in other words, the consumer is disillusioned. In the case of initially low purchases but most of the consumers buy it again, then the product is good but there are problems in distributing or promoting it. In the last case where both initial sales and repeat purchases are low, the product should be abandoned.

Conducting a test market trial is difficult, but it is equivalent to a commercial-scale launching without having to risk much investment. For that reason, it should be carried out as part of pilot project when the final products are ready for the consumer market.

Feasibility Study

At the end of the pilot-level experience, an assessment is made the results to date, including a financial analysis based on the assumption that the financing of tne project would involve interest payments equal to those that would have to be paid in the commercial phase of the

Figure 2. Illustration of Kotler's hypotheses regarding product success.

Initial purchases \ Repeat purchases	High	Low
High	Product success	Good product concept but poor product quality
Low	Distribution or promotion problem	Product failure

Source: Kotler 1986.

project. Table 4 shows the elements that should be included in the feasibility study.

On the basis of the information gathered on the raw material, processing, and on the end product and its commercialization, it is possible to construct a model to determine the plant's profitability.

This model includes financial costs even though they are not incurred during the pilot stage. Calculations are based on the same interest rate as the one that would be charged for the later expansion phase of the project, as well as the same loan conditions including the initial grace period. The return on the capital invested should

Table 4. Elements for the feasibility study.

The process itself.

- Analysis of ways to reduce costs, adjusting the scale of the infrastructure or equipment on the basis of their utilization and function during the pilot plant phase.
- Redesign of the plant with commercial-scale capacity and calculation of budgetary requirements based on the pilot plant experience.

Raw material specifications for defining parameters of acceptable quality.

Specifications for operating the equipment.

Specifications for the final product based on those for the raw material, the process, and in accordance with market requirements detected in the semi-commercial phase.

Quantification of the markets based on the pilot process, taking into account the following:

- Price behaviors of the product and its competitors.
- Transportation and warehouse costs.
- Experiences, both positive and negative, of the businesses or distributors who buy the product in order to define parameters such as levels of substitution in industrial markets.
- Months of production during the year.
- Conversion factor for fresh to processed product.
- Price for raw material and availability during the year.

be greater than that obtained if the funds were invested on the financial market (financial rate of return).

This model also makes it possible to conduct a sensitivity analysis by varying the prices of the raw material, operating costs, the conversion factor, etc., in order to determine how the financial rate of return would respond to these changes. It is also important that the project be in a position to absorb a rise in the cost of the raw material and still make a profit. If the feasibility study is positive, then the decision is made to proceed to the commercial phase, which is dealt with in a subsequent section of this workshop.

Conclusion

Pilot-scale operations constitute a critical step in product development. They serve as a testing ground for products, procedures, and personnel prior to initiating commercial processing. This paper has reviewed the various dimensions involved in operating a pilot plant from design of the overall project to construction of the facilities, to experimental operation, to semi-commercial plant activities. Particular attention is paid to the experimental operation of the plant. Issues here include: organizational structure (i.e., farmers' organizations), the supply of raw material, processing and promotion, and sale of the test product. Successful completion of the pilot-scale phase culminates with research for expanding pilot scale operations to full commercial level in which the knowledge and experience acquired in the pilot phase are utilized to evaluate the commercial potential for specific products and processes.

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Low-cost Potato Processing: CIP's Experience with Pilot Plants in Peru

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Abstract

The International Potato Center's (CIP) experience with potato processing plants in Peru has gone through various learning stages. In the first stage, suitable small-scale processing equipment was developed for processing starch and dehydrated potato. Due to low profit margins, few rural entrepreneurs adopted the equipment.

In the second stage, a market survey was carried out to identify the needs of low-income consumers. Results of that study found that a potato-based food mix had commercial potential. Several food mixes were consumer tested and processing methods were developed. A pilot plant was set up to test processing procedures and determine costs and returns. In the next stage, CIP's pilot plant became a center for training and experimentation for food scientists, development assistance organizations, and rural entrepreneurs. Processing methods and products were further modified in close cooperation with these groups. As a result of the interaction between research staff and users of the pilot plant, several processing units were implemented, each adapted to specific local conditions. Based on these experiences, suggestions for setting up pilot plants are given.

Key words: postharvest technology, mixes.

Introduction

The International Potato Center (CIP) has concentrated its processing research in Peru on upgrading traditional methods and on development of technologies for use at the village level by rural entrepreneurs.

Traditionally, farmers in the Andean region process part of the potato harvest into dehydrated potatoes which are used in various local dishes. Initially, CIP developed a simple pilot processing plant for converting potatoes into starch and dehydrated products. Small-scale equipment was designed that could be easily built by local manufacturers. The pilot plant was located at one of CIP's experimental stations (Huancayo) in a major potato production area in the central highlands. Several entrepreneurs showed interest in the plant and its equipment. However, limited market demand and relatively high prices of raw material meant profit margins from potato processing were low. Consequently, most rural entrepreneurs were hesitant to invest in processing equipment for transforming potatoes into starch and dehydrated products.

As a result, it was felt that a broad-based and flexible processing capability would need to be developed that could respond to market needs and produce a range of different products in order to make simple potato processing more attractive to rural entrepreneurs.

Low-cost Potato-based Food Products

After the experience with dehydrated potatoes and starch, a new processing project was started. This project would

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explore ways of utilizing potato in processed products according to the needs of low-income consumers. It was envisaged that the activities in Peru would serve as a testing site and that specific products would be developed for the Peruvian market. The project was to emphasize a commercially-oriented approach to product development. Experiences from the project in Peru would then be replicated in other countries.

A market survey was carried out in various urban areas with emphasis on identifying the needs of low-income consumers. The survey found that seasonal price fluctuations of fresh potatoes make the crop too expensive for many consumers during certain months of the year. The survey also identified the need for easy-to-prepare breakfast foods, because in many households both parents have a job that takes them out of the house. Results of the survey indicated that a potato-based food mix would have a high probability of acceptance in the market provided that the mix would be extended with low-cost cereals and legumes to make it affordable by low-income consumers. Subsequently, different combinations of potatoes, cereals, and legumes were processed into nutritious food mixes. These mixes were extensively tested through communal kitchens located in low-income urban areas. Based on consumer reaction, the mixes were further modified to arrive at a limited number of acceptable formulations.

Subsequently, the development of processing procedures for the selected mixes was carried out in CIP's experimental processing plant. Details of processing procedures and consumer tests can be found in Keane et al. (1986).

Pilot Plant Experiences

After developing the processing procedures, a section of the experimental plant was used to assemble a complete processing line for producing potato-based food mixes. Considerable quantities of this product were produced by the research group to gain experience with the technology, to evaluate shelf life of the product, and to supply various communal food centers to continue consumer testing of the product. Processing equipment as well as processing were modified several times. Eventually, the process was well under control, and cost and returns could be determined. At this stage, food scientists, development assistance organizations, rural entrepreneurs, and other interested groups were invited to participate in the further development of this technology. Within the experimental plant, a pilot processing line was set up to serve as a prototype.

Once the technology was introduced to the various groups, it became clear that one important role of CIP's experimental/pilot plant would be to enable individuals and groups to experiment with the technology. Several people indicated the need to modify the processing methods to fit their specific situations. However, they lacked the research facilities to do this work. As a result, during several years CIP's pilot plant became a center for training and experimentation for numerous persons interested in potato processing. Furthermore, the interaction between CIP's research staff, visitors, and users of the pilot plant resulted in the development of additional products. Also, CIP's staff at the pilot plant were invited to help implement small rural processing plants in various Andean communities. As a result, several small processing units were implemented and adapted to specific local conditions.

Replication of Pilot Plant Experiences

It is important to note that the pilot model for producing potato-based food mixes was never replicated in its entirety. In all cases, certain experiences with the technology as well as certain, specific components of the processing line, such as equipment and the use of chemicals, were utilized. In one case, a nationally recognized local center for technical and social development (*Centro de Ideas*) used the CIP pilot plant to work out and design their own rural processing facility. Initially, *Centro de Ideas* planned to replicate CIP's prototype. However, after approximately two years of experimentation with CIP's equipment and processing procedures in the experimental plant, the processing facility *Centro de Ideas* proposed showed little resemblance to the original CIP prototype. For example, due to economic considerations, *Centro de Ideas* decided to increase plant capacity and to make it a multi-purpose processing facility where a range of products from different crops could be made. In other words, CIP's original approach of setting up a broad-based and flexible processing capability was taken one step further to include all major Andean crops as raw material for processing. This enabled the plant to be in continuous operation throughout the year. Potatoes would be included in the process only when available at sufficiently low prices. Details of the experience at *Centro de Ideas*, including a commercial appraisal, can be found in ATI (1986) and Scott et al. 1991.

After completing its own processing facility, *Centro de Ideas* continued to modify its processing procedures as well as equipment. Since the facility was built near

CIP's pilot plant, a productive interaction between both processing facilities was maintained. Visitors and rural entrepreneurs from other parts of the country would often visit both plants on the same trip.

Most of the modifications implemented by *Centro de Ideas* resulted from economic considerations and practical experience in CIP's pilot plant. For instance, in CIP's original processing procedures for potato-based mixes, a dry flour of legumes and cereals was mixed with a wet mass of boiled, mashed potatoes. The reason for this procedure was to reduce the overall moisture content of the unfinished food mix to facilitate solar drying. A decrease in drying time of the mix was important to reduce risks of spoilage and increase the overall quality of the food mix. Since solar-drying appeared not to be practical when large quantities have to be dried, *Centro de Ideas* introduced a combination of solar and fuel-based drying. Although this considerably reduced drying efficiency, it eliminated the need for pre-drying the food mix through mixing cereal and legume flour with mashed potatoes. Instead, *Centro de Ideas*, as well as several other processing units, produced dry, pure potato flour as well as dry flour of several other crops. Specific food mixes were then made by mixing these flours in specific proportions.

Centro de Ideas placed considerable emphasis on the marketing of their products and choice of packaging labels. The commercial aspects of processing as experienced by *Centro de Ideas* complemented the technical experience at CIP's pilot plant and must be seen as an invaluable component of CIP's experience with potato processing in Peru.

The processing facility of *Centro de Ideas* continues to function today and the experience acquired serves as an important reference point for rural entrepreneurs interested in processing Andean crops.

Conclusion

Based on CIP's experience, the following suggestions for setting up pilot plants have been identified.

- A pilot plant for processing should be located in an area where the raw material is widely available and where some interest in processing already exists.
- The design of the pilot plant should be sufficiently flexible to allow experimentation with alternative processing systems and to permit regular modification of processing techniques and equipment.
- The organization of pilot plant activities should not only facilitate training but should also provide the opportunity for experimentation by interested rural entrepreneurs that have no processing facilities of their own.
- The initial level of investment in processing facilities should be in accordance with the overall pilot plant objectives. This applies to construction material for the building as well as to the type of processing equipment.
- Economic returns of processing should be evaluated in close cooperation with rural entrepreneurs.
- Specific attention needs to be paid to securing financing for new processing units to be set up. The organization responsible for the pilot plant can sometimes assist in securing loans for rural entrepreneurs by guaranteeing technical backstopping for proposed, new processing plants.

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Cassava-based Feed in the Philippines: the ViSCA Experience

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Abstract

This paper presents an overview of the utilization of cassava by the livestock industry in the Philippines with emphasis on the experience in the piloting of a feed mill with cassava-based formulations. Despite the industry's high dependence on imported yellow corn as an energy source, interest in the pilot project came about in late 1983 when the scarcity of foreign exchange, brought about by the devaluation of the peso, made importation of yellow corn more difficult and expensive.

The pilot feed mill project demonstrated, technically and commercially, the use of cassava to completely replace corn in the various diets of hogs but only to a limited level in the diets of poultry. With cassava chips priced at 60-80% of the price of corn, the cassava-based feed was cheaper than the corn-based formulation despite the increase in the use of protein-rich ingredients to overcome the inherently low protein content in cassava. The experience also manifested the important role of a small, village-level feed mills in encouraging the establishment of backyard pig and poultry projects and in improving the farmgate price of cassava chips. It also demonstrated the constraints encountered when operating a commercial or business-like project following restrictive government auditing rules in the procurement of supplies.

Key words: action-research, cassava-based, corn-based, feed mill, mixed feed, substitution.

Introduction

The poultry and pig industries in the Philippines have been heavily dependent on imported corn and other major ingredients not readily available. The keen but passing interest here in the use of root crops to substitute for corn in the diets of non-ruminant livestock was triggered by the problem of foreign exchange brought about by devaluation of the peso in late 1983. This condition made importation of feed stuffs difficult and expensive.

Hence, Pilot Feed Mill, an action-research project was strategically situated at the Visayas State College of Agriculture (ViSCA), where the Philippine Root Crop Research and Training Center (PRCRTC) is located. The feed mill was operated as a pilot project from February 1984 to June 1987, after which it became part of the income-generating program of the college, while continuously serving as a facility for instruction, research, and extension. The project's objectives were: (1) to spearhead the generation and development of root crop-based feed technology; (2) to demonstrate the feasibility of commercially formulated root crop-based animal feeds; (3) to provide a supply of low-cost quality feeds to local raisers and to encourage local animal production; (4) to provide a market to sustain the production of root crops; and, (5) to package and disseminate the technology generated and developed.

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An Overview of the Feed Industry

Location and Capacity of Feed Mills

One hundred twenty-three feed mills with a total rated capacity of 1.52 million t annually were registered with the Animal Feed Control Division of the Department of Agriculture in 1985 (Map 1). It can be seen that the location of most feed mills is concentrated in two strategic areas: Metro Manila and its adjoining regions to the north with 81 units (66%) and Metro Cebu and Central Visayas with 12 units (10%) to serve the demands for mixed feeds in the central part of southern Philippines. These feed mills have an aggregate capacity equivalent to 74% and 19%, respectively, of total rated annual capacity.

Cabanilla (1988) indicated two main reasons for this phenomenon. First, the livestock industries are concentrated in the Metro areas, Manila and Cebu, where the demand for feeds is higher. And, second, imported ingredients enter the country through Manila ports as well as Cebu ports. As a consequence, the lack of regulations and the inefficiency of domestic transportation makes it more costly to ship ingredients, particularly corn, from Mindanao, where it is produced, than from foreign ports such as Bangkok. He further reported that 51% of the total rated capacity or 68% of the actual production is controlled by the 11 large feed millers who are all members of the Philippine Association of Feed Millers Incorporated (PAFMI). The biggest five of the 11 feed millers are integrators. In addition to feed manufacturing and marketing, they are also engaged in producing, processing, and marketing livestock products.

Feed Production

From 1977-85, the Philippines produced an annual total average of 961,385 t of commercial feeds (Table 1). The trend of production was increasing from 1977 to 1983 which may be indicative of the growth of the poultry and pig industries. However, the output of mixed feeds declined from 1984 to 1985 which likewise reflected the decline in animal inventory and, consequently, in the demand for feeds as the country experienced an economic crunch brought about by a currency devaluation. This, in turn, led to skyrocketing prices for imported ingredients.

Importation of Feeds

The growth of the livestock industry, particularly poultry and hogs, has been dependent on imported ingredients. The two leading imports in terms of volume and value have been yellow corn and soybean meal, followed by meat meal and fish meal. Figure 1 shows the geometric increase in the quantity of imported yellow corn and soybean meal from 1965 to 1984. The annual average volume from 1980-84 of imported yellow corn was 310,933 t valued at US$ 51.3 million and soybean meal was 287,793 at US$ 75.3 million.

Utilization of Cassava as Feed

The continuous high importation of corn, the traditional source of energy in the diet of non-ruminant livestock, as presented in Figure 1, implies the failure of the country to produce enough to meet the burgeoning demand. On the other hand, cassava, as reflected in Table 2, has been used by the feed mill industry to replace corn probably when available or at times when inventories of corn were low. Although it is difficult to determine the extent to which cassava had been used for animal feeds, nevertheless, Cabanilla (1988) has made an estimate based on the assumptions indicated in the footnotes of Table 2. His calculation showed an increasing use of cassava for feeds from 11.6 percent in 1961 to 33.1 percent in 1983. However, data from 1983 to date are not available since corn has become limited due to the problem of foreign exchange. Incidentally at this time, concern about utilizing root crops as an alternative to corn increased as indicated earlier. Although some feed millers, through personal contact, have admitted an increase in their usage of cassava imported from Thailand, they attributed the highly irregular supply—not to mention the problem of quality of locally-produced-chips—as the main constraint in the increased and continuous use of cassava.

The ViSCA Experience

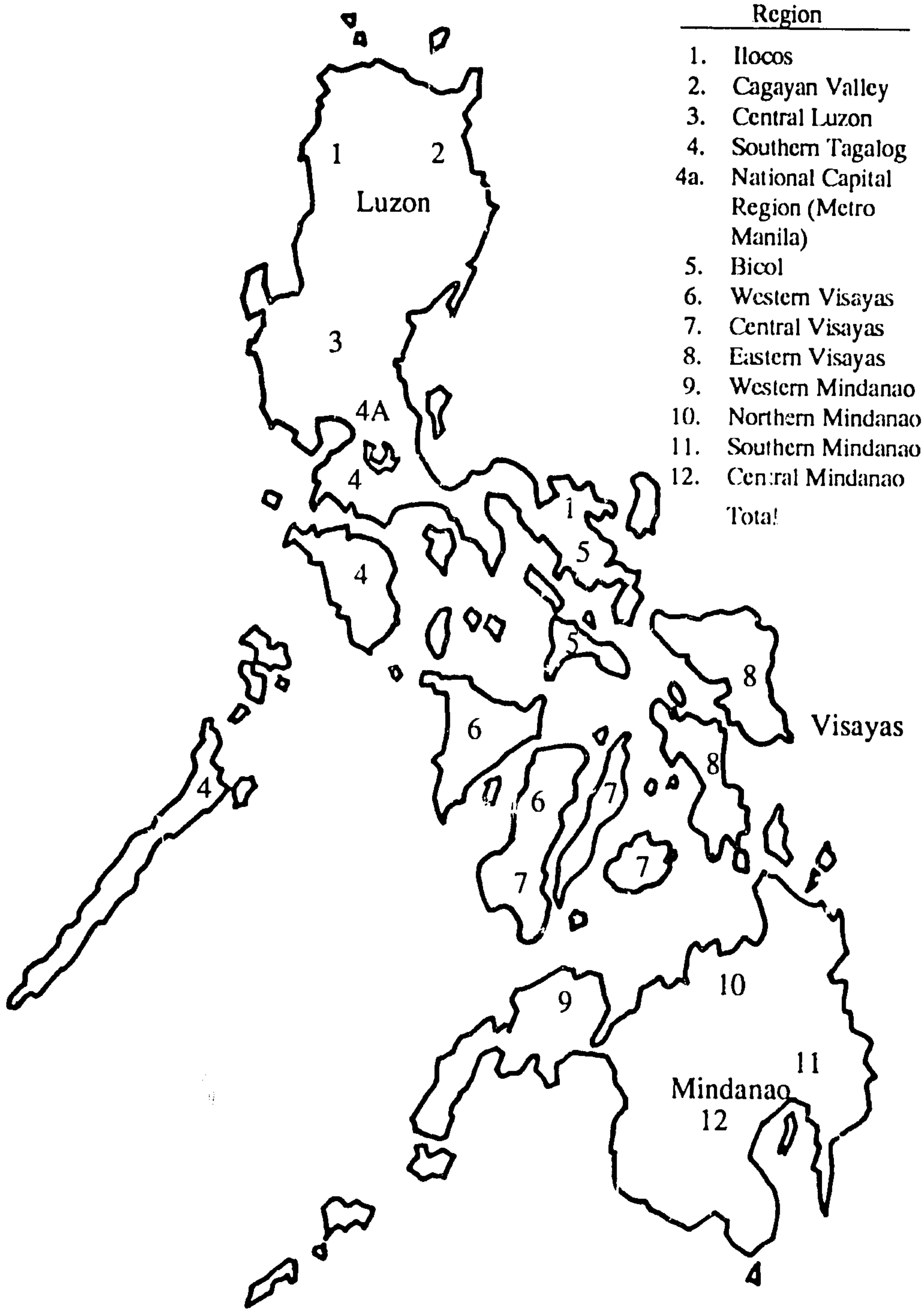
The Structure of the Pilot Feed Mill

As an action-research and a commercial pilot project, the following features of the ViSCA pilot feed mill were considered.

Production and Marketing

The goal was to produce and sell a proven root crop-based formulation. The activities of this section included the procurement of supplies following government procurement procedures and establishing linkages with suppliers and users.

Map 1. Location and capacity of registered feed mills in 1985.



Region	Number Registered Feedmills	Production Capacity (000 t)
1. Ilocos	3	6.5
2. Cagayan Valley	2	16.5
3. Central Luzon	22	343.8
4. Southern Tagalog	17	255.5
4a. National Capital Region (Metro Manila)	42	525.4
5. Bicol	5	9.2
6. Western Visayas	2	6.2
7. Central Visayas	12	293.9
8. Eastern Visayas	2	3.1
9. Western Mindanao	5	5.6
10. Northern Mindanao	4	54.6
11. Southern Mindanao	5	12.5
12. Central Mindanao	2	3.1
Total	123	1,525.9

Source: Cabanilla 1988.

Table 1. Volume (t) of mixed feed production by type, 1977-86.

Year	Poultry	Swine	Cattle	Horse	Others[a]	Total
1977	536,769	211,884	4,623	3,594	7	756,877
1978	603,155	262,483	4,655	3,708	4,249	878,250
1979	608,533	264,147	7,953	3,324	5,526	889,483
1980	648,450	253,226	19,142	3,466	22,692	946,976
1981	695,504	321,083	6,026	3,386	7,103	1,033,102
1982	785,546	364,421	9,030	3,261	10,656	1,172,914
1983	767,572	363,621	4,441	2,871	6,105	1,144,710
1984	639,338	346,428	2,474	3,686	11,638	1,004,564
1985	484,357	319,449	2,747	3,653	15,385	825,591
Average	641,025	300,749	6,899	3,450	9,262	--

Source: Philippines, Bureau of Animal Industry.

[a]This includes feed for pigeons, crustaceans, fish, rabbits, ducks, and goats.

Research and Development

Its activity was supportive to production and marketing. Experimentation was required before the commercial production of certain formulations. When possible, tests were to be verified at the farm level to enhance confidence in results (Appendix Tables 1, 2, and 3).

Extension

The goal was to organize training on production and processing of roots into chips as well as providing technical assistance to other feed millers and livestock raisers to promote adoption of the root crop-based feed technology.

Strategies of Implementation

The strategies employed for the operation were more tuned towards achieving the commercialization of the project.

Establishment of Linkages and Credit Lines

Shortly before the operation began, all possible suppliers and private and government agencies that could be of assistance to the project were identified and contacted either by a visit or letter to establish linkages (Fig. 2). The possible outlets and users were also identified and likewise contacted as part of market development.

Credit lines were extended by almost all of the major suppliers at varying amounts and terms once the integrity of the feed mill operation was proven. One supplier, for example, extended a credit line of as much as ₱ 100,000 (US$ 4,348) for 15-20 days. This arrangement or privilege was very useful to the operation considering its meager initial capital.

Direct Purchase of Chips from Farmers

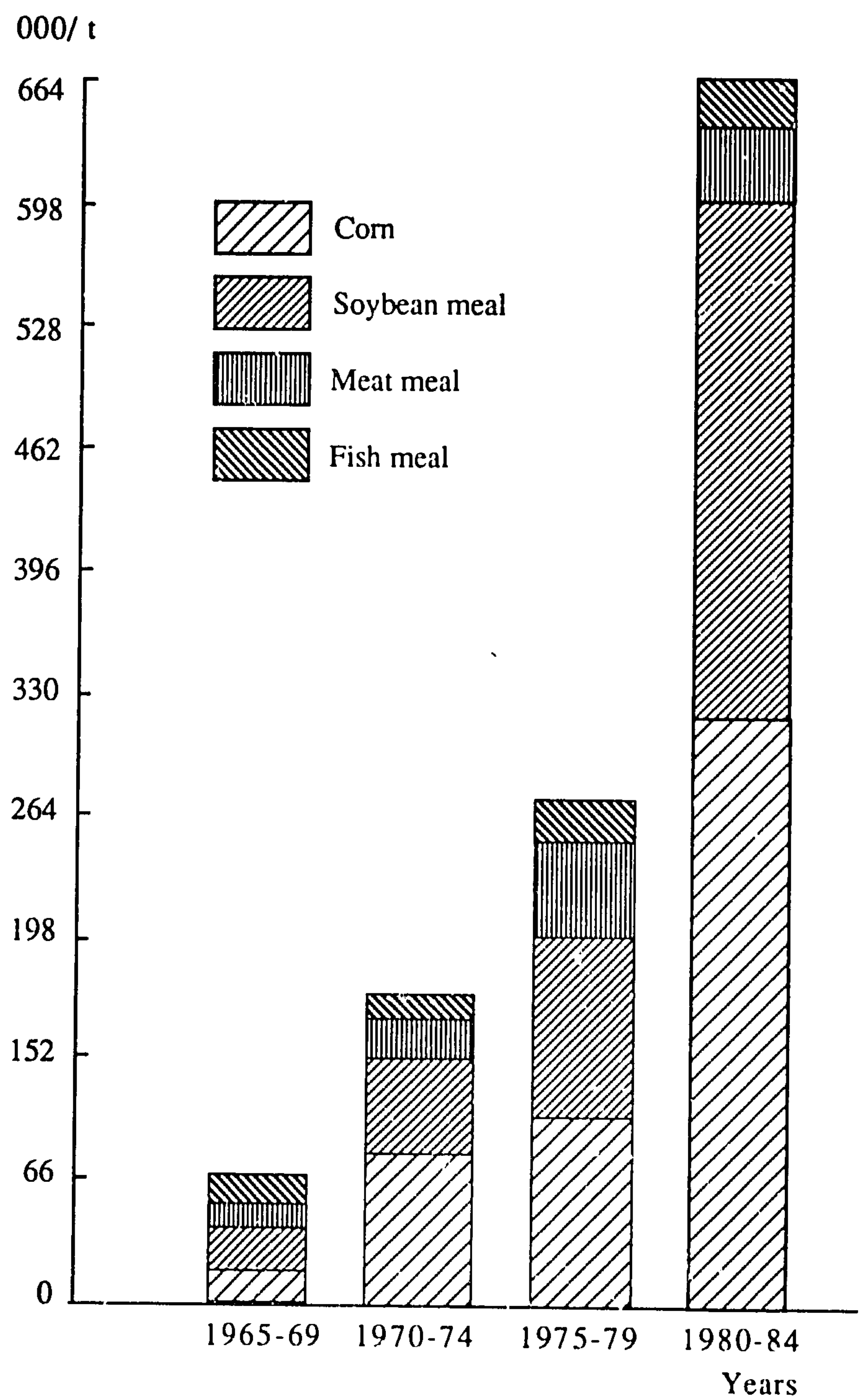
The basic idea was to let farmers get the most return from their produce by shortening market channels. However, during the implementation, this strategy failed because farmers were producing only small quantities of chips and they encountered difficulties in transportation and communication with the pilot feed mill. The problem caused by the urgent and immediate need for cash by farmers once the chips are marketable also contributed to the failure of the direct purchase strategy. The pioneering experience of the pilot feed mill demonstrated the important and practical role played by local assemblers, although the farmers receive lower prices for their goods from these traders.

The arrangement to schedule purchasing and hauling of chips at selected locations along the route also turned out to be expensive due to irregularity of the volume that could be made available during the scheduled trip. Under the prevailing conditions in the rural Philippines, what proved to be a more practical arrangement was for the village merchants to deliver the chips to the pilot feed mill.

Pricing Scheme

For chips. To encourage production of root chips, a price incentive was offered. This price, however, took

Figure 1. Average quantity of imports of major feed ingredients.



Source: Cabanilla 1988.

Table 2. Utilization of cassava supply and use, 1961-83[a].

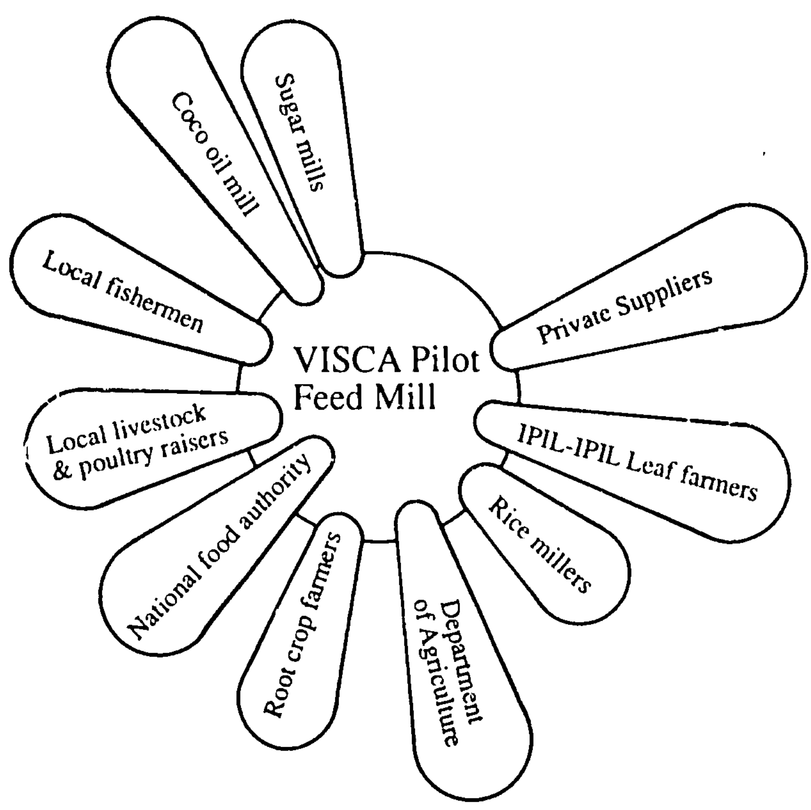
Year	Total production	Food	Manufacturing	Feed	Total use	Balance
1961-70	529,575	361,215 (68.2)	109,886 (20.7)	61,279 (11.6)	532,380	-2,805
1971-80	841,476	364,607 (43.3)	316,666 (37.6)	169,278 (20.1)	850,551	-9,075
1981	1,589,565	417,285 (26.2)	837,848 (52.7)	336,641 (21.2)	1,591,774	-2,209
1982	1,581,120	416,362 (26.3)	778,493 (49.2)	387,056 (24.5)	1,581,991	-791
1983	1,182,676	413,153 (34.9)	369,231 (31.2)	391,030 (33.1)	1,173,414	9,262

Source: Cabanilla 1988.

[a]All figures are in fresh root equivalents (t). The figures for feed use were calculated using a number of substitution ratios of cassava to corn in feed requirements of swine and poultry. The ratio for 1961-74 was 2%; 1975, 4%; 1976, 5%; 1977, 7%; 1978, 8%; 1979; 9%; and 1980 to date 10%.

( ) = Percentages.

Figure 2. Established linkages.



into consideration the inherent low protein content of root chips as a corn replacement which needed a higher protein supplement in order to meet the nutritional requirements of a given class of animals. Considering further the interaction between the price of corn and soybean, it was found that the price of chips, particularly cassava, should be from 60-80% of the price for corn. The lower limit of 60% was more advantageous to the livestock grower. On the other hand, the upper limit of 80% would encourage root crop production. Being a developmental project aimed at encouraging and sustaining root crop production, the pilot feed mill pegged the price of dried root chips at 80% of the price of corn FOB mill site.

Grading of chips. During the early stage of the operation no grading of deliveries of cassava chips was made except for dryness. This was mainly estimated by either breaking the chips by hand or by biting, similar to the traditional way farmers determine the dryness of corn and *palay*. As a result, cassava chips delivered were of highly variable quality with respect to color and the presence of foreign material. Later, a grading classification was instituted to encourage production of quality chips. The better the quality, the higher the price, as shown in Table 3. After the institution of the simple quality grading system, the quality of chips delivered improved considerably.

For formulated feeds. The principle of competitive pricing was the marketing strategy used in order to sell the newly formulated feeds. The guidelines were: (1) the price must take into account the ex-plant prices of feeds of leading brands produced on a nearby island (Cebu), one of the major feed manufacturing centers in the country; (2) prices must be lower than the local prices of leading brands; and, (3) in no case shall the price of feeds be less than the cost.

Table 4 shows the comparative prices of feeds produced by the pilot feed mill versus those of a leading brand in the local market. The price differences, particularly at the local market, indicate the competitive edge of the root crop-based formulations.

Table 5 indicates the profit margins of feeds produced and sold by the pilot feed mill. The profitability of cassava-based feed was found higher (where corn is completely replaced) than corn-based. A comparison on the cost effect of substituting corn with cassava is presented in Table 6 which showed lower costs of cassava-based formulations. It may be further pointed out that the ViSCA cassava-based formulation is much cheaper than the official recommendation (Philippine Council for Agriculture and Resources Research and Development 1987).

Quality Control

Prime consideration was given to quality control in the commercial production of feeds, although this was occasionally hampered due to inadequate laboratory facilities. Samples for analysis were sent periodically to other laboratories to determine the quality, particularly of locally-sourced fish meals, a highly variable product which is a critical ingredient in feed formulation.

Feedback from users of the root crop-based formulations was monitored as part of the quality control scheme for the product.

Product Identification and Labeling

The finished products were neatly packaged in properly labeled 50-kg bags. The trademark "ViSCA FEEDS" was printed to facilitate marketing because the name and integrity of the College as an academic and research institution are known all over the country.

Table 3. Quality pricing of cassava chips at the pilot feed mill (July 1985).

Grade	Price/kg	Bases for grading
First class	US$ 0.11 (₱ 2.50)	Moisture content, color, fungus, and foreign matter
Second class	US$ 0.098 (₱ 2.25)	
Third class	US$ 0.087 (₱ 0.00)	

Source: Project records.

Note: The price of corn in July 1985 was at ₱ 3.10/kg (US$ 1.00 = ₱ 23.00).

Table 4. Comparative selling price (US$): ViSCA Feeds vs. leading commercial brand at the local market.

	1984		1985		1986		1987	
	ViSCA	Commercial	ViSCA	Commercial	ViSCA	Commercial	ViSCA	Commercial
Cassava-based:								
Hog starter[a]	10.72	12.42	11.25	13.99	11.52	13.26	9.78	10.86
Hog grower[b]	9.78	11.41	10.28	12.39	11.26	12.39	9.35	10.22
Hog finisher[b]	8.93	10.60	9.37	11.52	11.08	12.04	8.69	9.56
Corn-based:								
Broiler starter[c]	12.61	15.51	13.24	1.19	15.26	14.60	11.95	14.35
Chick grower[c]	10.87	13.26	11.41	14.26	12.17	12.39	11.08	11.95
Layer mash	11.55	13.89	12.13	15.49	12.39	13.26	11.30	12.39

Source: Project records.

[a]50/50 cassava and corn for energy source.

[b]Cassava-based.

[c]Corn-based.

Exchange rate = US$ 1.00 to ₱ 23.031.

Table 5. Profit margin per 50 kg/bag for ViSCA feeds, 1987.

Kind	Selling Price[a]		Cost of Production		Margin (%)
	(US$)	(₱)	(US$)	(₱)	
Cassava-based:					
Hog starter	9.78	(225.00)	8.41	(193.44)	16.32
Hog grower	9.35	(215.00)	8.34	(191.73)	12.14
Hog finisher	8.69	(200.00)	7.60	(174.87)	14.34
Corn-based:					
Broiler starter	11.96	(275.00)	11.22	(258.20)	6.51
Layer mash	11.30	(260.00)	10.30	(237.00)	9.70
Chick grower	11.09	(255.00)	9.89	(227.54)	12.60

Source: Project records.

[a]Bases for mark-up price: cost of production and ex-plant price of leading brand (Cebu).

Exchange rate (US$ 1.00 to ₱ 23.00).

Contract Growing Scheme

The pilot feed mill as a developmental project later included a contract growing scheme for hog fattening which was patterned after the broiler growing contract which is carried out by the five major feed mill integrators in the country. The fattening scheme had the following objectives. First, to try to accelerate the development of the backyard hog raising industry in this part (Leyte) of the country; and second, to create markets for its own manufactured cassava-based feeds.

After the initial success of the fattening scheme and three consecutive production cycles, the sow-piglet contract growing scheme was added to help assure the village of a source of weanlings for fatteners. This had become a problem after the second cycle. In the two schemes, the project provided weanlings and/or sow, feeds, medicines, and technical assistance. The cooperators provided housing made of local materials, and the care, feeding, and cleaning necessary to assure the well being of the animals. The costs and returns as presented in Tables 7 and 8 are encouraging from the

Table 6. Cost effect of substituting cassava for corn in hog rations.

		Formulation					
		Corn-based[b]		Cassava-based		ViSCA cassava-based	
Ingredient	Price[a]	(%)	₱	(%)	₱	(%)	₱
Corn	5.00	59.74	298.70	--	--	--	--
Cassava meal	3.00[c]	--	--	43.62	130.86	50.00	150.00
Soy bean meal	8.40	23.34	196.10	30.74	258.22	16.50	138.60
Copra meal	2.50	7.63	19.80	12.10	30.25	14.00	35.00
Molasses	2.60	6.00	15.60	6.00	15.60	2.00	5.20
Hycaphos	3.00	2.59	7.77	2.15	6.45	--	--
Salt	2.60	0.50	1.30	0.50	1.30	0.25	0.65
Vit Premix	72.00	0.20	14.40	0.20	14.40	0.25	18.00
Coconut oil	6.00	--	--	4.62	27.72	--	--
Melliorine	80.00	--	--	0.07	5.60	--	--
Fish meal	11.80	--	--	--	--	6.00	70.80
Rice bram	4.00	--	--	--	--	10.00	40.00
Meat & bone meal	10.50	--	--	--	--	1.00	10.50
Total		100.00	552.95 (US$ 19.75)[d]	100.00	490.40 (US$ 17.51)	100.00	468.75 (US$ 16.74)

Source: Project record.

[a]Prices of ingredients as of August 1990 FOB Metro Cebu except for copra meal, cassava meal, molasses, and rice bran which are locally available.
[b]From PCARRD 1987.
[c]Sixty % of the price of corn.
[d]Exchange rate US$ 1.00 to ₱ 28.00.

standpoint of development, for the cooperators as well as for the project.

Technical Assistance

Although the technology for root crop-based feed formulations was available to everyone, the project incorporated into its activity technical assistance to hog raisers and feed mill operators to facilitate adoption. Personal contact at farms and sites was made and an invitation given to visit the pilot feed mill to reinforce the initial contact visit.

In addition to the contact visit, a regional verification feeding trial was conducted on layers and hogs fatteners in southern Luzon (Luzon is the biggest island) with the financial support of the Farming System Research Development Project of the Department of Agriculture. Results in both trials confirmed the earlier findings of the pilot feed mill that cassava can replace corn in the diets of layers and hogs fatteners. However, the replicability or establishment of an outreach program in the Bicol region was hamstrung by the lack of funds.

Production Figures

Root Crop Chips

Comparing cassava and sweetpotato, cassava is more readily available for feed utilization inasmuch as sweetpotato is considered more as a staple crop after rice and corn by the Filipinos. This may explain why the price of sweetpotato at the wet market is two or more times higher than cassava. On the other hand, cassava, the sweet variety, will likely be used as food only during emergencies such as prolonged drought and a poor rice and corn harvest or typhoons. There is also more area planted to cassava (219,090 ha) than sweetpotato (184,332 ha).

Figure 3 shows the great increase in volume of cassava procured for feeds in 1986 and 1987. This could be attributed to the higher prices offered by the pilot feed

Table 7. Cost and return (₱) analysis in hog fattening contract growing.

Cooperator	No. of head	Gross income	Expenses: Stock	Expenses: Feed	Expenses: Medicine	Net income (cooperator share)	Project income
1	3	4,806.00	1,890	2,238.00	14.60	663.40	267.00
2	1	1,900.00	525	1,026.00	--	348.40	100.00
3	3	5,605.00	2,085	2,671.00	--	849.00	295.00
4	2	3,353.50	990	1,811.60	--	551.90	176.50
5	3	5,510.00	1,950	2,671.00	--	889.00	290.00
6	3	8,295.00	1,600	4,340.00	24.00	2,331.00	395.00
7	2	3,872.00	800	1,750.00	25.80	1,296.20	176.00
8	3	5,817.00	1,350	3,190.00	58.50	1,203.50	277.00
9	2	3,674.00	800	1,315.00	--	1,507.00	167.00
10	3	4,854.00	1,200	3,110.00	32.60	450.60	234.00
11	3	6,050.00	1,200	2,515.00	18.00	2,317.00	275.00
Total		53,733.50	14,390	26,637.60	173.50	12,406.10	2,652.50
Average/head		1,919.05	513.93	951.34	6.18	443.08	94.73
US$		(68.54)	(18.35)	(33.98)	(0.22)	(15.82)	(3.38)

Source: Project records.

Sharing: All net income goes to cooperators as their share; the projects income is from marketing of fattened hogs because it buys the hogs at ₱ 1.00 lower per kilo liveweight than the prevailing local price. The additional income of the project comes from the profit of the feeds used.

Summary of total Net Income of the project per head of fattener:

a) from marketing = ₱ 94.73
b) from feeds = 113.86
₱ 208.59 (US$ 7.45)

Ratio of cost and return of the project: ₱ 208.59 1,481.45 = 14%. Feed consumption rate per head/cycle = 189 kg.

Table 8. Cost and return analysis in sow-piglet contract growing (₱).

Cooperator	No. weaned	Gross sales	Expenses: Feed	Expenses: Medicine	Net income	Coops shares	Project share
1	7	2,800	1519.50	38.80	1241.70	620.81	620.85
2	6	2,400	1348.00	48.95	1003.05	501.00	521.00
3	7	2,800	1484.00	26.80	1289.20	644.60	644.60
4	10	4,000	1522.00	32.35	2445.15	1222.55	1222.55
5	5	2,000	1320.00	23.10	656.60	328.20	328.20
6	6	2,400	1359.00	24.00	1016.00	508.00	528.00
Total		13,880	8553.00	194.00	7651.70	2725.20	2725.20
Average		2313.33	2313.33	32.33	1275.28	454.20	454.20
US$		(82.62)	(50.91)	(1.15)	(45.54)	(16.22)	(16.22)

Source: Project records.

Sharing: Net income divided by two.

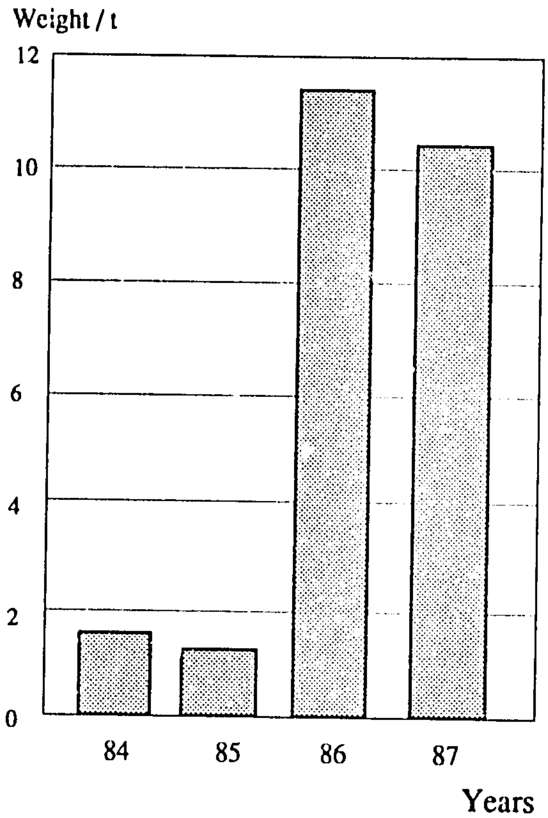
Summary of total income of the project per sow:

a) from share of piglet sold = ₱ 454.20
b) from feed = 171.06
₱ 625.26 (US$ 22.33)

Feed consumption/head/cycle = 333 kg.

Exchange rate US$ 1 = ₱ 28.

Figure 3. Yearly procurement of cassava chips, 1984-87.



mill which were about four times more than the usual farmgate price, along with the campaign to increase the area planted to the crop. In some instances, the farMgate price of cassava chips increased from about US$ 0.017 (₱ 0.40) to US$ 0.069 (₱ 1.60) per kg and the feed mill offered up to US$ 0.11 (₱ 2.50) per kg (FOB site) depending on the quality.

The 115 t of cassava chips procured in 1986 benefited about 123 farmers who found a market for their produce in addition to the increase in the farmgate price.

Formulated Feeds

Although the minimum capacity of the feed mill is about four t (80 bags) daily, it could only be operated from 10-13% of its capacity as shown in Table 9. The low production of feeds could be attributed to low capital, red tape, and cumbersome government auditing rules which caused delays in the procurement of materials by 2-3 weeks. Its meager initial capital of only US$ 4565.00 (₱ 105,000) was borrowed by the project from the revolving fund of the college which compelled the management to turn down large orders from feed dealers from nearby cities and municipalities. Had there been no constraints of that type, the feed mill could have operated to almost full capacity. The lack of cassava supply, particularly during the earlier part of 1986, also forced the operation to reduce production, although corn was used initially and when cassava supplies were low. However, large quantities of cassava chips were procured only in the later part of 1986 (Fig. 3).

The number of buyers progressively increased during the four years of operation (Table 9). This may imply that many small raisers ventured into animal production, more particularly into hogs and poultry. The con-

Table 9. Production of feeds, 1984-87.

Particulars	Year 1984	1985	1986	1987
Metric t	117.70	114.60	89.11	154
50 kg bag	2,354	2,292	1,782	3,080
No. of buyers	63	105	162	188

Source: Project records.

tract-growing scheme under the umbrella of the pilot feed mill—initiated with fatteners and later with sow-piglets—helped popularize the root crop-based formulations in nearby villages.

Comparative Feeding Values of Root Crop-based Feeds vs Commercially Formulated Diets

Formulated root crop-based feeds are nutritionally comparable with the leading brand of commercial feeds available in the localities adjoining the site (Table 10).

Impact of the Pilot Project

The project had several significant results; these are summarized below:

- technically and commercially demonstrated the utilization of cassava to completely replace corn in the diets of animals, particularly hogs of all classes;
- demonstrated the need to establish small feed mills (municipal-level capacity) to enhance the development of the livestock industry in the countryside;
- enhanced the establishment of small (backyard) poultry and hog operations for which the supply of low cost quality feeds were provided;
- provided a market to sustain the production of cassava as evidenced by the increase of volume procured from 16 t in 1984 to 115 t in 1986 (the 3rd year operation of the project), and 105 t in 1987;
- increased the farmgate prices of cassava chips from US$ 0.017 to US$ 0.07 (₱ 0.40 to ₱ 1.60) per kg. The project offered a price of US$ 0.087 to US$ 0.11 (₱1.00 to ₱ 2.50) per kg FOB mill site; and,

Table 10. Comparative feeding values of root crop-based and commercial feeds.

Nutrient content	Feeding standards values	Root crop-based feed	Commercial
Hog starter			
Protein content (CP/DP)	18	18	18
Energy value (kcal/kg)	2900-3160	2940	--
Calcium (1%)	0.65	0.65	--
Phosphorous (% available)	0.55	0.49	--
Carotene (mg/kg)	7.0	n.d.	--
Vitamin A (1,000 IU/kg)	1750 IU	1750 IU/kg	--
Vitamin D (IU/kg)	200 IU	100 IU/kg	--
Hog grower			
Protein content (CP/DP)	16	16	16
Energy value (kcal/kg)	2800-3160	2959	--
Calcium (1%)	0.60	0.50	--
Phosphorous (% available)	0.50	0.43	--
Carotene (mg/kg)	5.20	n.d.	--
Vitamin A (1,000 IU/kg)	1300 IU	2750 IU/kg	--
Vitamin D (IU/kg)	200 IU	1100 IU/kg	--
Hog finisher			
Protein content (CP/DP)	13	13	13
Energy value (kcal/kg)	2850-3160	3010	--
Calcium (1%)	0.50	0.50	--
Carotene (mg/kg)	5.20	n.d.	--
Vitamin A (1,000 IU/kg)	1300 IU	2750 IU/kg	--
Vitamin D (IU/kg)	125 IU	1100 IU/kg	--

Source: Project records.

n.d. = Not determined.

- showed that contract growing of fatteners and sow-piglets can be employed to enhance hog production in the rural areas as well as creating a local market for feeds.

Income Statement

In spite of stringent auditing which seriously hampered operations, the feed mill was able to realize a net income of US$ 10,715.32 (₱ 246,455.56) for the period covering February 16, 1984, to April 30, 1987 (3.16 years), as shown in Table 11. Interest income of US$ 485.41 (₱ 11,164.56) was earned from the sales deposited in the bank when the financial management of the operation was under the Depository Unit, but this income was withdrawn and transferred to the Trust Fund upon the order of the government auditor in 1986. Thereafter, sales no longer earned interest income.

Projected Demand of Cassava as Feed

Considering the potential of cassava, an increase in yield (with fertilization) and the concomitant decline in the cost of production and the inability of the country to produce corn, it is imperative for the livestock industry to use more and more cassava, particularly if the import policy for soybean meal becomes favorable. Based on the experience of ViSCA and the projected feed requirement (estimated by Cabanilla 1988) by the year 2000, Table 12 shows that the quantity of cassava chips and the corresponding hectarage required to meet the demand of the animal industry at various levels of substitution.

Issues to be Addressed

The pilot feed mill has technically and commercially demonstrated the utilization of root crops, particularly cassava to completely replace corn in the diets of animals, especially hogs. However, the adoption of the technology has been slow As reported, some major feed manufacturers have started using cassava when the supply of corn is low. They always cite the problem of the cassava chip supply, and their need for a greater quantity and better quality if they are to shift and continuously use cassava in their formulations. The same issue has been raised by animal raisers mixing their own feeds. Therefore, to promote and sustain the utilization

Table 11. Income statement of the pilot feed mill, 1984-87.

INCOME STATEMENT
(For the period Feb. 16, 1984 to April 30, 1987)

Sales			
Feeds:			US$ 86,062.56 (₱ 1,979,438.84)
Less:	Cost of goods sold	US$ 69,428.39 (₱ 1,596,853.09)	
	Wages	3,551.79 (81,691.15)	
	Travel and Transportation	647.37 (14,889.59)	
	Depreciation and other services	2,553.13 (58,722.01)	
	Miscellaneous	59.97 (1,379.35)	
			76,240.65 (1,753,535.19)
Net Profit			9,821.91 (225,904.65)
Add:	Other Income:		
	Platrate vehicle charging	408.10 (9,386.35)	
	Interest	488.47 (11,164.56)	
Net Income		US$ 10,715.32	(₱ 246,455.56)

Source: Project records.

Table 12. Projected demand for cassava as feed and area required, 2000.

Livestock year	Required mixed feed[a]	Corn required (metric t)[b]	Levels cassava (chips) substitution[c]		
			High	Medium	Low
Swine	5,324,011	2,662,006	2,662,006	1,331,003	665,502
Broilers	2,704,749	1,352,375	338,094	202,856	135,238
Layers	1,024,540	537,270	134,318	80,591	53,727
Total	9,103,300	4,551,651	3,134,418	1,614,450	854,457
Area required (ha)[d]					
W/out fertilizer	--	--	1,316,982	678,340	359,645
W/fertilizer	--	--	464,358	239,178	126,588

Source: Project records.

[a]Cabanilla 1988.

[b]Proportions of corn to feed mixture is 50%.

[c]Level of corn-cassava substitution based from the ViSCA experience.
High: 100% for swine and 25% for broilers and layers.
Medium: 50% for swine and 15% for broilers and layers.
Low: 25% for swine and 10% for broilers and layers.

[d]Area required based from PRCRTC unpublished data, 1985-86 which is 5.67 t fresh/ha without fertilizer and 16.08 t/ha with fertilizer.

Note: Chip (with 14% mixture) recover 42%.

of root crops as feeds, a national policy is needed which the concerned agencies have failed to initiate.

Further demonstration is needed by expanding the pilot feed mill project in livestock-growing provinces and centers, particularly where the weather is drier during the harvest of root crops to facilitate processing and drying of chips. The establishment of outreach pilot plants in other areas which simulated the ViSCA experience has been hamstrung by the lack of funds.

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Appendix Table 1. Summary of results of feeding studies (100% cassava replacement for corn) in swine at ViSCA, 1984-88.

Class	Corn-based	Cassava-based	Sweetpotato-based
Fatteners			
At ViSCA station			
Average daily gain, kg	0.55ns	0.61ns	0.59ns
Feed conversion efficiency	3.58a	3.15b	3.20ab
At farmer's level			
Average daily gain, kg	0.42b	0.58a	0.56a
Feed conversion efficiency	3.93a	2.60b	2.55b
Contract growing			
Average daily gain, kg	--	0.64	--
Feed conversion efficiency	--	2.90	--
Starters			
Average daily gain, kg	0.38ns	0.35ns	--
Feed conversion efficiency	2.72ns	2.87ns	--
Breeding sows (long-term)			
All reproductive traits	ns	ns	--

Source: Project records

Note: Figures with the same letter are not significantly different at the 0.05% level, DMRT.
Hog grower and hog finisher ratios contain by weight 50 parts of corn and 60 parts of cassava or sweetpotato.

Appendix Table 2. Summary of performance of broiler feed with varying of root crops, 1985-87.

Parameter	Corn-based (n=75)	Cassava replacement for corn (%) 25	50	75	100
Ave. final wt (kg)	1.38a	1.25ab	1.22ab	1.06b	1.05b
Ave. daily gain wt (gm)	28.23a	25.41ab	24.82ab	21.56b	21.53b
Feed conversion efficiency ns	2.23	2.36	2.46	2.65	2.66
	(n=75)	Sweetpotato replacement for corn (%)			
Ave. final wt (kg)	1.30a	1.23ab	1.12ab	1.06b	0.90b
Ave. daily gain wt (cm)	26.43a	25.17ab	22.86ab	21.50b	18.37b
Feed conversion efficiency	2.41b	2.37b	2.53b	2.73ab	3.11a

Source: Project records.

Note: Figures with the same letter are not significantly different at the 0.05% level, DMRT.

Appendix Table 3. Summary of performance of layer feed with varying levels of root crops, 1985-87.

Parameter	Corn-based (n=10)	Cassava replacement for corn (%)			
		25	50	75	100
Egg production (%) (hen-day)	70.96a	66.90b	65.73b	64.34b	60.38c
Egg weight (gm) ns	60.80	60.53	60.33	60.03	59.47
	(n=8)	Sweetpotato replacement for corn (%)			
Egg production (%) (hen-day)	52.2a	52.5a	52.7a	51.4a	45.8b
Egg weight (gm) ns	62.5	64.1	60.3	64.7	64.7

Source: Project records.

Note: 1. Figures having the same letters are not significantly different at the 0.05% level, DMRT.
2. The cassava and sweetpotato studies were conducted during different years.

VI. Expansion into Commercial Production

When a pilot plant becomes technically and economically viable, decisions must be made whether and how to expand to full commercial operation. These require consideration of a variety of factors including the social objectives of the enterprise, raw material supply, market requirements, economic analyses, and credit. This section begins by reviewing these and other elements to be taken into account when contemplating expansion into commercial production. A series of questions or issues to be resolved are outlined for each with the aim to provide flexible, but systematic guidelines for the principal points to be addressed at this stage of new product and process development. The section also provides an illustrative example from the Philippines of the type of basic economic analysis needed to assess the commercial viability of small-scale processing operations. Finally, as expansion into commercial production completes the product development process, the section includes two case studies—one from India and one from Peru—that incorporate all the various aspects and offer a synthesis of the lessons learned in each instance.

As Christopher Wheatley points out in his review of the **Commercial Expansion Phase**, a number of aspects need to be considered carefully as the basis for deciding whether and how to expand operations of a pilot plant to that of regular business enterprise. Wheatley enumerates these factors, then sets out specific issues to be resolved in relation to each. For example, in the case of raw material supply, he notes that it is necessary to identify actual and potential production regions, contact farmers' groups to ensure an adequate supply, and study competing markets to determine whether the price to be paid for raw material is sufficient to interest growers. Wheatley also notes the need for monitoring and evaluation of the commercial operation. The set of ideas presented are intended as a useful aid for successful processing of roots and tubers at the commercial level.

Economic monitoring of rural processing enterprises is the subject of J. M. Alkuino, Jr.'s paper on **Costs and Returns to Small Scale Processing of Cassava and Sweetpotatoes in the Philippines**. The report describes an alternative to the usual sample survey for generating data on costs and returns to small-scale processing. Use of the method is illustrated with examples based on the production of different types of processed products made for human consumption using indigenous technology. Among the principal findings, Alkuino reports the use of inappropriate equipment (i.e., too labor intensive) and unnecessary quantities of particular ingredients (e.g., sugar).

In **Village-level Potato Processing in Developing Countries: A Case Study of the SOTEC Project in India,** Robert W. Nave and Gregory J. Scott review the experience of a non-governmental organization (NGO) in trying to develop village-level potato processing for low income households. Results to date highlight the technical complexity of this type of processing. Nave and Scott also stress the need for a multi-disciplinary approach to assess the economic viability of technical processing options and alternative postproduction techniques. The authors conclude their study with a list of lessons learned. These cover such topics as the basic prerequisites of village-level potato processing; the need for time to develop—as opposed to transfer—village-level processing technology; and the observation that management and institutional arrangements are equally, if not more, important than certain technical bottlenecks.

In **Potatoes, Mixes and Soups: A Case Study of Potato Processing in Peru,** Gregory J. Scott, David Wong, María Alvarez, and Alberto Túpac Yupanqui analyze attempts of several institutions to improve simple potato processing over the last 15 years. Traditional potato products and processing techniques are briefly described. Efforts to improve the techniques are evaluated. The development of new products is also examined. The lessons learned from this experience cover three broad areas: technology, marketing, and finance. According to Scott et al., the most important of these, perhaps, is the need to clearly identify at the outset the relevant product characteristics and the target market segment.

Commercial Expansion Phase

Christopher Wheatley[1]

Abstract

Commercial expansion of pilot processing facilities requires attention to various considerations including: social objectives, the nature of the market for the processed product, site selection, raw material supply, product promotion and distribution, and credit, as well as monitoring and evaluation. This paper examines these and other factors involved in developing commercially viable processing enterprises intended to be operated by small farmer associations, or small rural or urban entrepreneurs. Specific issues related to each factor are also treated in some detail with examples cited based on the author's professional experience. The integration of technical, economic, and organizational components is stressed throughout the review of this process.

Key words: processing, roots and tubers, developing countries, small farmer associations, markets.

Introduction

When the operation of a pilot plant reaches the point at which it has become economically and technically feasible, a decision must be made whether or not to expand to a fully commercial scale. A number of aspects need to be considered carefully as a basis for making this decision including: social objectives, the nature of the market including demand estimates, product packaging and promotion, raw material supply, distribution channels, administrative capability, economic and financial analyses, and financing the expanded capacity.

Social Objectives

When designing the commercial expansion phase, the social objectives of the project and any inherent constraints that can affect these should be borne in mind. Primary processing of root and tuber crops needs to be done at the rural level, either as cooperatives, associations, or small business ventures. This means that expanding from a pilot to a commercial scale will involve the formation of several plants rather than one or two large ones.

The actual distribution of the products, or any secondary processing that may be required, could be done by a special enterprise located near large urban markets or could be done by a second-order organization.

The formation and consolidation of these rural enterprises is a relatively slow process, which is complicated by the fact that the legal registration of these groups entails bureaucratic processes that can take considerable time and effort to complete. Moreover, the administrators, who generally have limited formal education, may have difficulties in completing these steps on their own. Without legal status, it is practically impossible to receive credit, which can act as a significant deterrent to rapid expansion of demand for the product unless measures are implemented to facilitate this process well in advance.

It is usually difficult if not impossible for small farmer groups to obtain credit, not only because of their legal status but also because of their lack of (or poor) credit history. In many countries, a coop or association cannot be incorporated as a legal entity unless all members have a title to their land. Where tenure rights have never been legally regulated, as is typically the case with small root and tuber farmers, this is a major limitation.

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This situation becomes even more critical if landless members are included because they have no land and are therefore considered too risky to fund. Throughout the Third World, a need exists for an institution specializing in granting credit to these groups or one that can provide surety or guarantees to the regular credit agencies. This issue must be addressed in the project if it is to reach a commercial expansion phase and if benefits are to reach the target groups—the small farmers and landless laborers.

Nature of the Market

Roots and tubers have a wide variety of end uses including human consumption, animal feed, and industrial uses. The type of market affects the quality of raw materials required, marketing strategy, and financing requirements.

Industrial Markets

The number of potential industrial clients in a country is generally relatively small; thus it is feasible to establish personal contact with most of them. Typically, decisions to purchase a new product are made by company purchasing agents who take into consideration price, quality, continuity of supply, and competing products. Since demand is relatively easy to estimate, market testing is not usually required, and large-scale product promotion is not needed. In some cases industrialists may not be aware of the advantages of using root and tuber products and it may be necessary to provide samples so that they can test them first.

Once the demand has been established, projections have to be made as to:

- the association's or coop's capacity to meet that demand;
- the industry's quality and packaging requirements, if any;
- the possibilities of establishing contracts or pricing agreements; and,
- the terms of payment (this is critical for determining cash flow requirements).

The root and tuber processors can normally handle marketing and distribution aspects themselves. Care needs to be taken to program product supply realistically in order to avoid entering into agreements that cannot be met. Product supply can be gradually increased to meet unfulfilled demand and to take on new clients.

Consumer Markets

This type of market is much more complex and requires significant testing of consumer demand before a realistic marketing strategy can be developed. Consumers' decisions to purchase are not always taken on a logical basis. Rather, factors such as product image and sensory stimuli can have more impact than nutritional value on the final decision to buy. Advertising plays an important role in promoting that image.

Product distribution is also much more complicated because purchasing habits differ significantly among social strata and also depend on location of the residence relative to access to the retail outlet.

The foregoing is made much more complex when one considers the numbers involved and the problems inherent in trying to characterize the "typical" urban (or rural) consumer or retail outlet. Surveys must be conducted, organoleptic tests run, and a market plan devised if it has been shown that:

- the product meets an identified need of consumers;
- packaging (size and appearance) is acceptable;
- there appears to be good intent to purchase at a given price; and,
- distributors and retailers find the product and profit margins acceptable.

Consumer awareness of a new product does not just happen. In order to make consumers aware that a product exists, let alone inform them of its advantages as compared to those of the competition, requires substantial product promotion. A campaign to promote consumer products emphasizes price, convenience, quality, uses (e.g., recipes), nutritional value, and where it can be purchased. When the decision is made to implement such a campaign, the association or coop must be sure that it is capable of fulfilling that demand. Creation of unfulfilled demand for a consumer market is a costly error, besides being frustrating for a consumer who cannot find an advertised product. This situation can be avoided by:

- ensuring an adequate raw material supply;
- maintaining sufficient product inventory to meet expected demand;
- expanding promotional activities in accordance with plant capacity to meet the additional demand; and,
- monitoring distribution channels.

If the product is to reach a significant number of consumers, it must be made available through a corresponding number of retail shops or markets. This implies the organization of an efficient distribution network that covers the target markets adequately. Given that farmer associations or coops are located in rural areas and that product distribution will most likely focus on urban markets, the logical option is to create a separate service operation. The skills required to run a distribution business are quite different from those needed to process roots and tubers.

The Market Plan

Prior to initiating commercial-scale activities, a market plan should be prepared taking into account the factors indicated at the beginning of this paper. This plan should integrate the following aspects: raw material supply, processing operations, packaging and other operations, product distribution, and promotion. The result is a series of planned activities aimed at reaching specific markets or profit targets based on estimates of percent market share, geographic distribution, and rates of return.

Site Selection

The pilot plant typically is located at the best possible site in order to maximize its potential for success. In order to expand the number of plants, these may have to be located at sites that are not so favorable. At the same time, the experience acquired in constructing and operating the pilot plant may have modified some of the variables for selecting the plant site. At this point, it should be possible to identify the more important points and those that are not so critical in order to establish the minimum rather than the optimum conditions for locating a plant. For example, the availability of electricity and water may be necessary, but the existence of organized and well-consolidated farmer groups may not be since this can be dealt with during the construction of the plant. In some cases, it may not be necessary to have large quantities of roots and tubers available for processing if the plant is able to offer an attractive price for fresh roots and tubers, which would be sufficient to motivate farmers to plant more roots and tubers for sale than for on-farm consumption.

Raw Material Supply

In order to make an accurate estimate of the availability of raw materials within a reasonable distance from the processing plant, it is necessary to:

- identify actual and potential production regions;
- identify farmer groups in each region which are interested in ensuring an adequate supply (quantity and quality) of raw materials and who may be interested in participating as primary processors; and,
- study competing markets to ensure that the price that can be paid for the raw material is sufficient to motivate farmers to sell to the plant.

Where there is a competing fresh market for roots and tubers, an effort should be made to obtain data on historical prices to identify seasonal patterns. The creation of a new market for a root or tuber crop should act to stabilize prices.

Given that roots and tubers are highly perishable, it is critical to take seasonal factors into account. Is it economically feasible to store fresh product for later processing? Or, will the plant have to operate only during harvest periods? Moreover, if the process involves sun drying of the raw material, climatic variables also need to be studied to ensure that the dry season coincides with harvest time. Experience in Latin America suggests that planting and harvest times, as well as dry season months, can be highly variable, even within one region of a country. It is not safe to assume, therefore, that the conditions at the site of the pilot plant can be extrapolated to the whole region. An important step in this direction is the effort being made by the International Agricultural Research Centers (IARCs) to map root and tuber production areas by agro-climatic zone. The more detailed the information, the more accurate will be the identification and prioritization of the main target production areas.

Processing Operations

The associations and coops involved in primary processing in rural areas usually require substantial technical assistance in processing operations. The members or plant operatives often have relatively little formal education and limited experience with machinery operation and maintenance. Although the processing operations and equipment tested in the pilot plant are appropriate for small-scale, urban operations, operatives will still require substantial training.

Few changes in the actual process itself should be required when moving from the pilot to the fully commercial scale, especially if the scale of plant operations are maintained; i.e., in the case where commercialization is based on replicating the pilot plant in other locations rather than expanding the initial pilot plant itself. Some increase in scale may be required, however, and it is important to identify the stages of the process that could present bottlenecks as the plant increases in capacity. In any case, capacity should not increase beyond the managerial capabilities of the small coop or association.

Timing of new plant construction is crucial, especially where processing seasons are well-defined. The date for plant completion should allow for a period of start up and training prior to the main harvest season. Construction activities almost always suffer some delays (e.g., shortage of labor at peak harvest times of other crops, shortage of building materials, untimely arrival of credit). Thus, some flexibility should be built into the timetable of activities.

If a coop is formed to operate a new plant, members should participate in the construction activities to as great an extent as possible (under the supervision of an experienced journeyman or master workman). This not only helps reduce costs but also serves to consolidate the group as they collaborate on joint activities.

Maintaining good product quality is an important consideration when expanding the number of plants. The existence of many small processing operations makes quality control complicated. In order to obtain a product of consistent quality, it is important to standardize as many components as possible across the different coops. Reception of raw materials, selection, and storage time to processing can have important effects on product quality. Both managers and operatives of these small plants need to understand the vital nature of establishing and maintaining rigid standards of quality control. If there is a second-level organization that is responsible for commercializing the product, this process can be facilitated by their active involvement. In the case of products destined for human consumption or, to a lesser extent, for animal feed, sanitary and hygiene regulations become critical. Some of these may be difficult to implement for technical reasons, i.e., inadequate water quality, or lack of knowledge, e.g., no hygiene education. These factors need to be taken into account before plant operation starts, both from the standpoint of technical adjustments and processes, and training requirements. Local, regional, and national health regulations and licensing requirements also need to be checked before the plant has been built.

In order to ensure that the plants are operated efficiently and economically, substantial training and backstopping is required in the areas of administration and accounting. It is in the interests of the agency responsible for providing credit that funds are well used; thus training in these areas should be considered an integral part of credit activities.

A training plan needs to be drawn up in order to ensure that there are sufficient plants operating to meet the expected demand for products. State entities and non-government organizations (NGOs) have a crucial role to play in technical assistance and training, but much of the practical training can be horizontal. This process can be facilitated by creating a second-order organization of coops, which can assume some of the training functions themselves. The pilot plant can fulfill a useful training and demonstration role at this stage. Operatives of new enterprises can spend time working in the pilot plant to gain hands-on experience in processing operations, etc. In addition, people who have acquired experience in operating the pilot plant can spend time assisting those who are starting new plants; however, this has to be organized carefully in order to not make too heavy demands on their time.

Packaging and Other Operations

When the processing group is ready to enter into commercial-scale operation, it is time to establish a trademark or a brand name. The advantages of this include:

- the product is readily distinguished by both retailers and consumers;
- the product and name become associated with certain quality characteristics which should be maintained;
- promotional material can be developed around the product name; and,
- competitors will not benefit from generic advertising.

The brand name should be selected carefully in order to ensure that it reflects the advantages of the product as perceived by the consumer. Technical factors of the raw material or process—irrelevant to consumer acceptance—should not be included. Several names should be tested in several potential markets in order to select the one that is most widely acceptable.

Product Distribution

As pointed out earlier, a product targeted at the industrial market can be distributed by the processing groups themselves; whereas those destined for the consumer market will need a specialized network. Should the product be an improvement of a traditional product, the existing distribution network may be considered as an option. Nevertheless, this will usually involve several levels of intermediaries, each one requiring a marketing margin sufficient to cover expenses and provide an income. At the same time, with the evolution of the processing enterprises, they will almost certainly want to participate in the marketing chain to a greater extent than before, taking over some of the intermediaries' functions and margins.

A decision must be made on how far to take the distribution of the product: whether to rely on independent wholesalers or a second-order enterprise to take charge of wholesale activities, or to include retail-level sales within the scope of distribution. This decision has to be made on the basis of product characteristics, market characteristics, and consumer purchasing habits.

It is absolutely essential that this enterprise be operated on a purely commercial basis. Should it be under the umbrella of a second-level coop, for example, it should be administratively and financially separate. Only in this way can the enterprise be truly competitive and maximize profits for its members.

The distribution enterprise should manage the following aspects.

- Product supply from the different production enterprises; i.e., coordination of supply with market demand.
- Quality control of the finished product; and, if required, selection into different quality products.
- Management of warehousing, stocks, and inventories.
- Sale and distribution of the product to wholesalers and retailers.
- Coordination of promotion campaign activities to complement those of distribution.
- Monitoring and evaluation of sales volumes, including those of the competitors, as well as profit margins of wholesalers and retailers.
- Feedback to both the processing groups and product development research organizations.

The actual location of the central offices and warehouse is very important. If the product is to be sold in small shops, then the warehouse should be located near the central wholesale market where small shopkeepers purchase most of their goods.

It can be seen from the foregoing that the skills required to manage such an operation are quite different from those of the processing enterprise. Marketing and business skills are essential, as well as technical skills in the area of product storage and warehousing. These skills are not to be found in government agencies as they themselves do not function along commercial lines. Rather, it is necessary to seek input from organizations that support small businesses and who will be in a position to cover these aspects in training and technical assistance.

Product Promotion

In order to meet the objectives outlined in the market plan, promotion of the product is needed to make consumers aware of it, its advantages, and where it can be purchased. A number of texts have been written on planning and executing a promotional campaign; but there are several basic factors that need to be considered when deciding what media to use. Characteristics of the target consumers must be taken into consideration, e.g., newspaper advertisements will not reach the barely literate, low-income strata. When developing materials, the use of regional terms, dialect, and the like should be avoided so that they can be used for as wide a geographic scope as possible. The brand name, logo, and slogan should figure prominently in all materials developed.

A small coop cannot afford a wide-scale launching of a new product traditionally associated with large food companies who bombard the consumer with a fanfare of publicity. A safer alternative is to increase promotional activities gradually as the distribution network expands and product supply increases. A sudden increase in demand would be most difficult to fulfill and could cause problems.

Creating a market is expensive even though it should pay for itself in the long run. Financing of these activities, which require considerable investment, is discussed in the introductory paper of this volume.

Funding

Pilot-scale activities are normally funded through special projects in view of the fact that no business or cooperative enterprise could be expected to finance something that has not proven to be technically and economically feasible. Once the plant reaches the point of expanding to a commercial level, however, provision of credit for replicating and/or expanding the manufacturing capability and providing sufficient working capital to cover initial expenses should, theoretically, be feasible. Nevertheless, there is still an element of risk in that these projects are based on integrating small farmers into cooperative ventures.

When the product is destined for consumers, promotional activities are essential for breaking into the market. Small producers/processors rarely have capital of their own to engage in a commercial-scale enterprise. Unless there is a second-order organization, it will be impossible for the plants to cover the costs of these promotional activities.

Given the foregoing, credit will generally have to be provided at reasonable rates and terms by an organization in the public sector, accompanied by well-designed training and technical and administrative backstopping, either by the public or private sector. Funds for institutional support can be generally found in the budgets of the state organizations involved, if their development priorities are in accord with those of the project. In many countries, however, root and tuber crops are not of high priority. Therefore, funds may have to be sought from appropriate NGOs active in rural development or working with small farmer groups. The most difficult area to support is product promotion, which is not considered an element of a rural development project. One avenue to explore is with organizations interested in improving availability of staple foods in urban areas.

To reduce producers/processors' dependence on external credit, they should be encouraged to build up their capital. This means that the coops must reach a balance between profit distribution (pressures are great for this among the poorer groups) and reinvestment. Some groups have a policy of paying high prices for the raw material in order to encourage non-members to sell to the coops rather than to a competitive market, e.g., fresh consumption. In the long run, however, the coop may suffer from this policy, which does not permit them to strengthen their organization.

Technical Assistance

To the extent that the industry grows and the number of plants and coops increases, the need for technical assistance also increases. In the short term, it is possible to expand the technical teams of the entities responsible for processing, production, commercialization, organization, etc.; but this is very costly over time and the coops will never stop depending on them. Another alternative consists of creating a team of persons trained for this purpose within the coops themselves. This model (farmer-to-farmer or promoters) is much less costly and more responsive, but it requires a significant training effort. The experience with projects in Colombia highlights the importance of technical assistance—especially for accounting and maintaining equipment—even for those drying plants that had been operating for several years (Bode 1991).

Monitoring and Evaluation

Once the decision has been made to implement the commercial process, it is necessary to monitor the progress of the product's introduction and market penetration in order to ensure that objectives are being met in accordance with the market plan. The success of this operation depends upon the quality of the market plan, which must be detailed and yet flexible.

Information input is essential to ensure that changes are made in accordance with developments in the areas of production, processing, and commercialization. If, for example, there has been a poor growing season and the supply of roots or tubers has fallen, processing activities will then have to be reduced or other supply sources will have to be sought. If the organization has to depend on funds from the public sector, it is important to monitor changes in government. Activities related to the formation and consolidation of coops, provision of credit, and plant construction all tend to suffer delays, which if not taken into account, could lead to other project activities getting out of phase. It is also important to document experiences learned at the onset of the commercialization phase because this information will invariably serve to improve planning for breaking into other markets.

A monitoring system should cover three important areas.

- volumes as well as volumes by market outlet and a breakdown of the socio-economic status of the consumers.
- Consumer behavior with respect to first and repeat sales data.
- Consumer satisfaction with product quality, usefulness, price.

The monitoring system has to be in place when the project begins and is an ongoing activity to be carried out by the organizations themselves.

Evaluation of the commercial process should be done not only in terms of the financial viability of the system but also the distribution of benefits. Benefits can accrue to farmer-producers, landless laborers, rural transporters, urban distributors, retail shopkeepers, and consumers. At the same time, it is important to determine whether there are any adverse effects from the enterprise. This evaluation should be done by the organization(s) that provided some sort of support to the process and who wish to learn whether the investment has been sound.

Data generated by the monitoring and evaluation of the project can also serve to generate ideas for new markets or new products. This information should feed back to the technical research components of the project for further evaluation.

Conclusion

The decision to expand pilot plant activities to commercial operation has important implications for the product and process as well as the farmers and consumers potentially involved. In this paper, the various considerations to be evaluated in making this decision have been briefly discussed and their respective components analyzed. Concisely stated they include: social objectives, market and technical requirements, promotional and logistical factors as well as funding and technical assistance. Should commercial processing begin, then monitoring and evaluation of these operations become imperative so as to ensure not only effective implementation of the original plans but also that the guidelines set forward are adhered to (or adjusted) in light of emerging developments. While the issues mentioned here and their treatment may not be all inclusive, they hopefully should serve as a useful aid for launching successful processing of roots and tubers at the commercial level.

References

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Costs and Returns to Small Scale Processing of Cassava and Sweetpotatoes in the Philippines

J. M. Alkuino, Jr.[1]

Abstract

This report describes an alternative method for generating costs and returns to small-scale processing of cassava and sweetpotatoes at the village level in the Philippines where the usual sample survey methods are sometimes inappropriate. The sample data used in this report were taken from the author's studies of root crop processing especially of indigenous technologies and their improved versions.

Key words: economics, costs and returns, cassava, sweetpotatoes, processing, root crops.

Introduction

Farm business analysis has long been used as a farm management tool by agricultural economists. One aspect of farm business analysis that has been widely used for decision making is costs and returns analysis of farm or farm-related enterprises. This procedure, sometimes referred to as "profit and loss" or "statement of results of operating the business during a given year," provides a picture of activities during a given period. An analysis of costs and returns may be prepared for a farm as a unit or for farm-related enterprises, such as root crop processing. The procedures are basically the same, although statements of costs and returns may differ considerably between the two, depending on the objectives of the analysis and the planning period.

Planning period refers to the time-frame upon which the decision maker wishes to base his decisions. It could be a short- or a long-run time-frame. In making a costs and returns analysis, the time periods must be defined because it can make a difference in not only the treatment of the cost and return variables, but also in the final result.

An analytical dilemma in cost and return studies exists. Whether such studies are part of their extension or research projects, researchers always find dealing with studies related to small farmers, household processors, or any village-level enterprise a problem when primary data are required and when no such data are readily available. Most small farmers and processors seldom keep records and accounts (Alkuino et al. 1990). Moreover, gathering information through a survey and relying solely on the data and information collected may result in various types of non-sampling errors. Oftentimes, there is a need to check survey data by monitoring the operations of selected cooperators. Such monitoring techniques have been widely used in most of the author's studies of small, village-level processing of root crops. This has done away with survey data a the main basis of analysis.

The Method

An example of the monitoring method used in this paper is described in the author's study on rural processing of sweetpotato and cassava (Alkuino 1986a and 1986b) and utilization of root crops and the Integrated Root Crops Program (Alkuino 1990 and Alkuino, forthcoming). These studies required the active participation of agricultural engineers and a food technologist who formed a team to work with agricultural economists. The method includes the following phases:

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1. Definition of indigenous technologies:

   a. the product and its process, and

   b. the equipment used.

2. Identification of municipalities in the study area:

   a. listing of all municipalities, and

   b. sample selection.

3. Identification of technologies/cooperators:

   a. preliminary survey of markets for existence of indigenous technologies;

   b. back tracing of area origins through interviews of key informants;

   c. final listing of possible indigenous technologies as defined in Phase 1 for monitoring; and,

   d. identification of cooperators.

4. Monitoring of the processing activity:

   a. arrangement for monitoring date;

   b. actual monitoring of processing equipment performance:

      - equipment performance;

      - process/process flow;

      - organoleptic test of product; and,

      - costs and returns.

5. Analysis of data and information:

   a. laboratory tests of product quality;

   b. costs and returns analysis; and,

   c. designing improved equipment.

6. Improvement of indigenous technologies:

   a. process;

   b. equipment;

   c. product quality; and,

   d. profitability.

The phases outlined above were applied in the study of the indigenous technologies. The costs and returns analysis was used as a diagnostic instrument to determine the economics of root crop processing in comparison with the use of local practices and equipment, and to determine the phases in local processing for possible modification to improve quality and profitability. The monitoring technique was modified in subsequent studies to fit study objectives. (For instance, in the study on "Root Crop Utilization," monitoring was employed over a longer period starting with Phase 4 because a more in-depth analysis was desired. The objective was to determine the incremental benefits derived from processing using different stages of improved technologies that had been introduced.)

In addition to the above objective, the monitoring format of the costs and returns analysis was made simple for two reasons. First, it meant farmer cooperators could easily understand what items to include in their records. Second, it was hoped that at the end of the project the cooperators would be able to prepare their own simple farm business analysis.

Research Findings

These results consist of two types. The first type presents results from the study in which costs and returns were monitored and the incremental money benefits compared between stages of technology adoption. The technology being referred to, however, involved equipment only because they had been observed to have a significant effect on costs and returns, thus affecting the net returns. Other variables affecting quality were held constant in the analysis. The products involved were cassava chips used for feed formulation and the cassava chippys used as *munchies* or finger food.

The second type of study showed the costs and returns analysis as a diagnostic instrument for determining returns to processing of root crops using indigenous technologies among small-scale rural processors.

Processing of Cassava Chips and Chippys

Cassava Chips

The monitoring process of costs and returns in processing cassava chips and chippys by two farmers' associations (one each in the villages of Bubon and Amparo) was made over a one-year period. The farmers' association in Bubon produced cassava chippy and the one in Amparo produced cassava chips for feeds. The summary of costs and returns for chips is presented in Table 1. Figure 1 is a flow chart showing the processing steps.

Cassava Chippys

The farmers' association of Bubon produced cassava chippys for food. The summary of costs and returns is presented in Table 2. Figure 2 is a flow chart showing the processing steps.

Processing Using Indigenous Technologies

The costs and returns analyses were used as a diagnostic instrument in the study of the indigenous technologies in household processing of food products to determine the returns using these indigenous processing practices. Some of the native food products studied include:

Cassava crackers	- Carmen, Bohol
Molido	- Legaspi City, Albay
Camote candy	- Guimaras, Iloilo

The Cassava Cracker Process

Generally, the processing steps in making this product included: peeling, washing, cooking, slicing into chips, sun drying, frying, applying syrup, mixing, and packing. All steps from peeling to packing were done manually. The indigenous processing devices used were: knife, chopping board, cooking pot (*carajay*), and open fire stove. Out of the 2 kg of cassava tubers usually processed, the processor was able to produce 55 packs of cassava crackers priced at 25 centavos per pack. The packaging material commonly used by the processors was ice wrapper. Processing had no definite schedule, but was usually done 2-3 times per month, depending on time availability. The finished products were usually sold by family members in schools during school days.

Table 1. Incremental costs and returns in processing chips per 100 kg of fresh cassava roots.

Item	Quantity	T_0[a]	Quantity	T_1[b]	Quantity	T_2[c]
Costs						
Fresh cassava[d]		₱ 57.00		₱ 57.00		₱ 57.00
Labor[e]						
washing[f]	3 m-hr	11.25	1 m-hr	3.75	1 m-hr	3.75
chipping[g]	6 m-hr	22.50	6 m-hr	22.50	1 m-hr	3.75
drying	3 m-hr	11.25	3 m-hr	11.25	3 m-hr	11.25
Depreciation						
bolos		0.63		0.63		--
washer		--		3.59		3.59
chipper		--		--		4.02
containers		0.40		0.40		0.40
Total		103.03		99.12		88.76
Returns						
Dried chips produced	48 kg	156.00	48 kg	156.00	47 kg	152.75
Net return		₱ 52.97		₱ 56.88		₱ 68.99

[a]Traditional method using bolo.
[b]Using Visayas State College of Agriculture (ViSCA) root crop washer
[c]Using ViSCA root crop washer + pedal-operated chipper.
[d]Fresh cassava tubers at ₱ 0.57/kg.
[e]Man-hr at ₱ 3.75.
[f]ViSCA root crop washer's cost, ₱ 2,993.80; life span = 8 years.
[g]Pedal-operated chipper's cost, ₱ 4,177.60; life span = 10 years.

Figure 1. Process flow of dried cassava chips production.

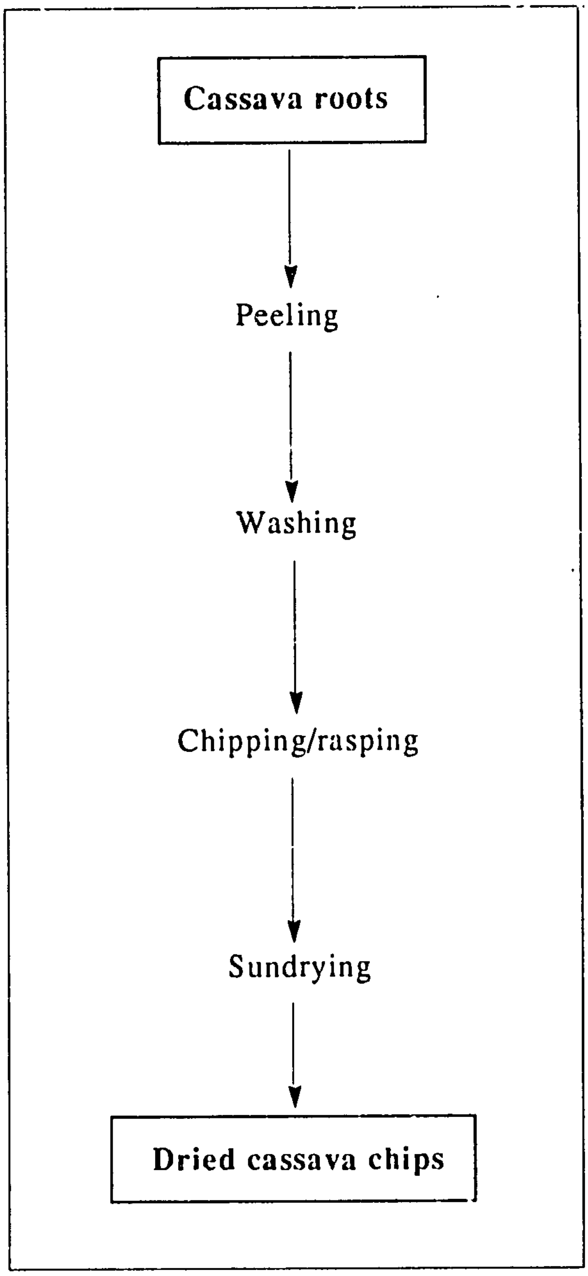

Figure 2. Process flow of cassava chippys production.

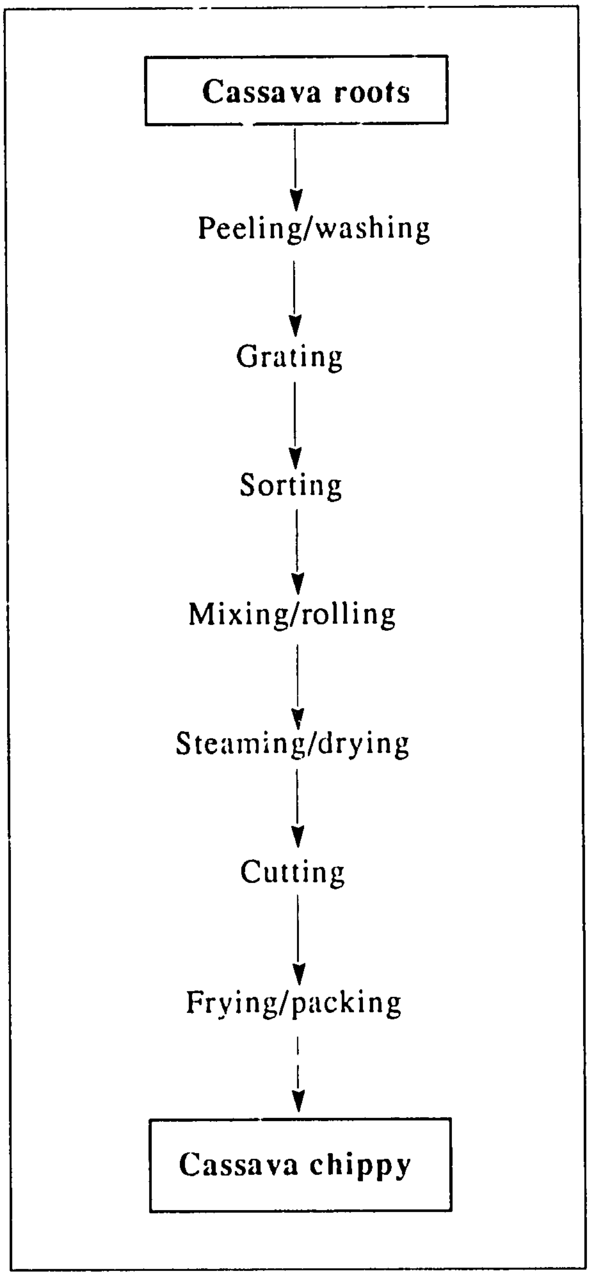

Table 2. Incremental costs and returns in processing chippy per 100 kg of fresh cassava roots.

Item	Quantity (kg)	T_1[a] (₱)	Quantity (kg)	T_2[b] (₱)
Cash receipts				
Chippy[c]	27.00	1,620.00	28.50	1,710.00
Trimmings[d]	1.75	70.00	2.15	86.00
Total		1,690.00		1,796.00
Non-cash receipts				
Fresh cassava rejects[e]		6.00		6.00
Ungrated particles (waste)[f]	2.00	14.00	1.00	7.00
Cash expenses				
Raw materials[g]		260.85		260.85
Labor[h]		792.45		792.45
Packaging		6.00		6.00
Total		1,059.30		961.30
Non-cash expenses				
Depreciation cost[i]				
Motorized grater		--		5.22
Sealed-oven drier		8.48		8.48
Mesh trays		2.54		2.54
Lorena stove		3.83		3.83
Other equipments used		10.26		10.26
Building		9.23		9.23
Gathering of water		5.00		5.00
Fresh cassava rejects		6.00		6.00
Total		45.34		50.56
Net cash income (1-3)		630.70		834.70
Net non-cash income (2-4)		(25.34)		(37.56)
Net earnings (5-6)		605.36		797.14

[a]With sealed-oven drier.
[b]With motorized grater + sealed-oven drier.
[c]Chippy at ₱ 60.00/kg.
[d]Trimmings at ₱ 40.00/kg.
[e]Used as snacks for the processors.
[f]Milled into flour and sold at ₱ 7.00/kg.
[g]Include fresh cassava, barbecue spice, black pepper, spices, firewood, and sugar.
[h]At ₱ 4.00/hr for processing and ₱ 3.00/hr for cutting.
[i]Computed using straight line method with 104 days use per year.

Table 3 gives a summary of costs and returns in the cassava cracker business.

The Molido Process

This product was processed by first boiling the sweetpotato, then peeling, slicing, pounding, and mixing it with brown sugar. A few drops of vanilla and finely grated coconut were added to enhance the flavor of the mixture. The mixture was further cooked in a *carajay* and stirred constantly until the mixture became dry. The dried mixture was spread on a table, flattened, cut into slices, and sun dried for a few min. The slices were wrapped individually with plastic. The product has an estimated shelf life of six weeks. All activities were done manually. Processing had no definite schedule and depended on orders for special occasions or *fiestas*.

For the 2 kg sample of sweetpotato tubers processed for monitoring purposes, the processor was able to produce 39 pieces, priced at ₱ 1.00 each, 25 pieces at 50 centavos each, and 50 pieces at 25 centavos each. Total receipts obtained were about 65 pesos and the total cost incurred was ₱ 39.10 resulting in net earnings of ₱ 25.89. Table 4 gives a summary of costs and returns.

The Camote Candy Making Process

Sweetpotato candy was locally called "*camote* pieces." In the production of this product, sweetpotato tubers were first thoroughly washed using a brush. They then

Table 3. Costs and returns for marketing cassava cracker in Carmen, Bohol.

Items	Quantity	Pesos (₱)
Cash receipts		
Cassava crackers[a]	50 packs	12.50
Non-cash receipts		
Consumed at home[b]	5 packs	1.25
Cash expenses		
Raw materials[c]		6.55
Packaging materials		1.82
Total		8.37
Non-cash expense		
Depreciation cost		
Tools and utensils[d]		0.11
Family labor[e]		7.21
Total		7.32
Net cash income (1-3)		4.13
Net-non cash income (2-4)		(6.07)
Net earnings (5+6)		(1.94)

[a]Sold at 25 centavos each.
[b]Priced at 25 centavos each.
[c]Include fresh cassava, ingredients, firewood.
[d]Computed using straight line method of 36 days use per year.
[e]Rate at ₱ 2.80/hour.

Table 4. Costs and returns for making sweetpotato into *molido* in Legaspi, Albay.

Items	Quantity	Pesos (₱)
Cash receipts		
Molido[a]	39-54-20 pcs	62.50
Non-cash receipts		
Consumed at home[b]	10 pcs	2.50
Cash expenses		
Raw materials[c]		28.85
Packaging		3.50
Total		32.35
Non-cash expenses		
Depreciation cost[d]		
Tools and utensils		0.44
Family labor[e]		6.32
Total		6.76
Net cash income (1-3)		30.15
Net-non cash income (2-4)		(4.26)
Net earnings (5+6)		25.89

[a]Sold at ₱ 1.00, ₱ 0.50, and ₱ 0.25 each.
[b]Priced at ₱ 0.25 each.
[c]Include sweetpotato tubers, ingredients.
[d]Computed using straight line method of 12 days use per year.
[e]Rate at ₱ 1.90 per man/hour.

were boiled, pounded using a rolling pin and mixed with sugar. The mixture was cooked until balls were formed or until dry. While cooking, vanilla and food coloring were added. After cooking, the mixture was spread on the slicing board and flattened uniformly with the rolling pin. The flattened mixture was then air dried for hardening, sliced to uniform sizes using an ordinary kitchen knife, and packed in a plastic wrapper with ten pieces of "*camote* candy" per pack.

The average volume of sweetpotato tubers processed was about 30 kg per processing, usually twice a week. This was done during the harvest season from September to February. Out of the 30 kg of raw tubers, the processors were able to produce 450 packs of sweetpotato candies priced at ₱ 1.80/pack. The total receipts obtained were ₱ 810.00 with a total cost of ₱ 482.81; net returns amounted to ₱ 327.19 (Table 5).

Table 5. Costs and returns in processing sweetpotato into *camote* candy, Buenavista, Guimaras, Iloilo.

Items	Quantity	Pesos (₱)
Cash receipts		
Camote candies[a]	450 packs	810.00
Non-cash receipt		
Consumed at home	1 pack	1.80
Cash expenses		
Raw materials/ingredients[b]		403.50
Packaging material	40 pcs.	57.10
Firewood	4 bdl.	20.00
Labor[c]		50.36
Total		530.96
Non-cash expenses		
Depreciation cost		
Tools/utensils[d]		0.28
Net-cash income (1-3)		283.04
Net-non cash income (2-4)		1.52
Net earnings (5+6)		284.56

[a]Priced at ₱ 1.80/pack.
[b]Include sweetpotato tubers and sugar.
[c]Rate at ₱ 7.50 man/hour.
[d]Computed using straight line method of 48 use per year.

Analysis and Recommendation

The results presented above have shown some basic commonalties which are of interest to the agricultural economist.

- The equipment used in processing was largely inefficient and laborious. It can be seen from the costs and returns tables that labor was a critical item which significantly affected returns. This concern was, therefore, passed on to the engineering group for their possible improvements of the indigenous technologies or for their designing of devices which would improve low-cost technologies and be acceptable to small household processors.
- The extensive use of unnecessary ingredients, such as sugar, significantly increased the cost of processing food products. Processors argued that consumers, especially school children, prefer food products with a lot of sugar. Whether this is a healthy practice or not, remains to be answered by the processing group, but from a business perspective costs could be greatly reduced in proportion to the reduction of sugar used.
- On the basis of the results of the food products analyzed, no general conclusion can be generated as to the practices of the rural households. Some food products seem profitable and some incur losses. The only general observation that can be made is that returns to small-scale household processors still can be greatly improved if the right equipment is used and the quantity of some unnecessary ingredients is controlled or adjusted.

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Village-level Potato Processing in Developing Countries: A Case Study of the SOTEC Project in India

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Abstract

Seasonal production and price patterns for potatoes in developing countries have generated considerable interest in alternative market outlets for the crop. In India, there is particular interest in low-cost alternatives to refrigerated cold storage. This paper reviews the experience of an non-governmental organization (NGO) in trying to develop village-level potato processing for low-income households. Results to date highlight the technical complexity of rustic processing. They also point to the need for a multi-disciplinary approach to assess the economic viability of technical processing options, alternative postproduction techniques (e.g., storage), and the importance of particular cost components.

Key words: rural poor, postharvest techniques, equipment, costs and returns.

Introduction

Prospects for potato processing have attracted growing attention in a number of developing countries over the last two decades (Keane et al. 1986; Horton 1987). The reason for this can be briefly enumerated. Although total production has increased remarkably—particularly in South Asia in the last 20 years, output patterns remain highly seasonal. Improvements in the marketing system for fresh potatoes have enabled a much larger volume to be either sold at harvest or placed in storage. However, available supplies still exceed the capacity of existing infrastructure. Potatoes are bulky and perishable. Processing reduces the costs associated with transporting a product that in its fresh form is 80% water. It also allows the release of potato products into the market in a more systematic fashion. In addition to these considerations, farm households are frequently interested in generating off-season employment for family members as well as adopting procedures whereby they can increase the value added associated with the sale of their agricultural production.

This case study reviews the experience of one rural development project in trying to establish village-level potato processing as an alternative market outlet for low-income potato farmers in rural India. It explains the principles and procedures associated with this type of processing as well as the institutional and socio-economic factors that have influenced its evolution over the last 7-8 years. The conclusions emphasize the need for technology development that adapts general principles to local circumstances, as well as realizing the importance of economic considerations in determining the outlook for such ventures in the future.

Origins of the SOTEC Project

Bareilly is situated in Western Uttar Pradesh which is the largest potato growing state in India (Srivastava 1980). Annual potato production is over 6 million t. Nearly all of these potatoes are harvested between mid-February and mid-March.

The largest potato growing region is on the plains with production concentrated in the districts of Farrukhabad, Budaun, Shahjahanpur, Moradabad, Etah, and Hapur. While the Bareilly District does not grow as

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many potatoes as these other districts, it is bordered on three sides by them. Farms are small and incomes are low.

About every other year there is a glut of potatoes. Some fields are not even harvested because of low prices and lack of cold storage space. Even in normal years, only about 70% of the available potatoes can actually be placed in cold storage. Consequently, prices crash at harvest time only to rebound sharply 2-3 months later. Small farmers traditionally have been unable to take advantage of these delayed price increases.

The idea of processing potatoes at the village level developed in the late 1970s when Robert Nave, a founding member of the U.S.-based, Non-governmental Organization (NGO), Compatible Technology Inc. (CTI), observed the immense quantity of potatoes that were harvested in a very short time period.[2] He noted that under these circumstances farmers were forced to sell their potatoes at very low prices because they needed cash (hence, could not afford to put them in cold storage); or, they simply left many fields unharvested. A few months later potatoes would be sold at a very high price. By the early 1980s, Nave began evaluating processes that could be used by poor farmers to convert their potatoes into dried chips and julienne strips. He envisioned that the value added from processing their potatoes could bring much needed income to peasant households and provide up to four months of employment to the village community, especially women. Consequently, village-level potato drying could also improve the broader rural economy.

As Nave's experience with potato processing became more extended, he noted that in Northern India potatoes can normally be sun-dried from mid-February until mid-June. Prices are lowest immediately after the peak of the main harvest and this is the time when potatoes should be purchased for processing, if the farmer does not have a sufficient supply of his own. He also found that the potatoes must be kept in a rustic store, i.e., a non-refrigerated but well-ventilated structure so that their quality does not deteriorate. Furthermore, storing potatoes at the processing site ensures a ready supply. Initial trials using rustic stores showed that potatoes kept for 10-12 weeks made good dried products. The ability to store potatoes for this length of time was one of the major factors that prompted further work on drying processes, because it was estimated that processing could be economically viable if conducted for at least 60 days.

During 1984, all the experimental work was done using the methods and equipment normally used for cooking in the home kitchen. In trying to increase productivity per worker to ensure economic viability, it soon became apparent that more rugged, specialized equipment would have to be developed. Fortunately, two groups of experienced blacksmiths, carpenters and other workmen were available locally to work on these problems. They were asked to come up with their own solutions as well as to produce some prototype pieces of equipment that met the following standards. Such equipment must be low-cost; fabricated locally; operated by hand or electric motor; and utilize procedures easily understood by rural people. Meanwhile, CTI staff in the USA were also working on a cycle-powered slicer. They sent some machine parts to India with drawings of a prototype.

By 1985, Nave's efforts led to the establishment of the Society for Development of Appropriate Technology (SOTEC) at Bareilly. SOTEC has a board of about 20 members that meets annually and an Executive Committee of seven persons—five elected members, the Project Director, and the Secretary—that meets quarterly. SOTEC is legally registered as a charitable organization.[3]

Since its inception, SOTEC has used part of a private house that has provided living accommodation for the Project Manager, one room for an office and other facilities for working space.[4] For example, a pilot processing unit was set up immediately in front of the house; the drying was done on the roof; and the dried chips and strips were stored and ground in out buildings.

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[2] Compatible Technology, Inc. (CTI) was founded in Minneapolis, USA, in 1981 by a group of people interested in supporting the development of simple technology to process agricultural produce in rural areas. CTI is a voluntary organization dedicated to establishing projects that provide on-going earning opportunities for the poor so as to enable them to manage businesses of their own, share profits of a viable business in an equitable manner, and grow personally through the education and experience of being part of an income-earning enterprise.

[3] SOTEC is also registered with the Commissioner of Income Tax, Lucknow, under section 80 G of the Income Tax Act 1961, thereby being exempt from paying income tax, and with the Ministry of Home Affairs under the Foreign Contribution Regulations Act, vide No. 136300014 of April 24, 1987. This latter registration permits SOTEC to receive foreign currency to finance its operations.

[4] By 1988 the project had developed to the point where physical facilities had to be expanded. In November of that year, SOTEC purchased a 2.5 acre parcel of land about 12 kms from Bareilly.

A rustic store with a capacity of 10 t was built in the garden.

The machinery was developed by the design engineer at his own house. While far from ideal, this arrangement allowed SOTEC personnel to develop processing technology in an environment not vastly dissimilar to those of poor farmers. Consequently, the streamlining of techniques for peeling, cutting, blanching, and drying potatoes was done under conditions comparable to those of the potential users. This strategy has also kept research and development (R&D) costs to a minimum.

By the end of 1985, all the basic items of equipment were conceived or fabricated. However, it soon become apparent that many refinements and alterations had to be made to bring this equipment up to the necessary standard. A three-year grant from the International Potato Center (CIP), through its Regional Office in New Delhi, made it possible to employ two experienced technicians to work on these problems full time and to have funds for materials and trials. Typical of the problems faced was that of applying abrasive grit to the surface of the potato peeler. No one was willing to give SOTEC the technology. It took two years to find the sources for all the materials necessary and to develop a technique for applying the abrasive.

Product Uses

Product uses was another area that required experimentation and development. Dried potato chips are frequently fried before serving in India. SOTEC staff thought that the market for dried chips could be expanded if they could be popularized as a rehydrated vegetable as well. However, people traditionally use chunks of potatoes in their curries and vegetables. They do not like to use potatoes in the form of flat slices for this purpose. Moreover, it is difficult to dry chunks or strips of more than about 7 mm thickness. These are often unsatisfactory, especially in terms of rehydration and texture.

In an effort to overcome this problem, a cooking contest was set up in which dried potato slices were used in various ways such as main dishes, desserts, etc. Unfortunately, in all but one of the resulting 50 dishes, the slices were rehydrated, cooked, and mashed. This preparation made their use as time consuming as starting with fresh potatoes.

The dried slices were then ground into a coarse powder and a number of the better recipes tried with it. The powder proved very easy to use and improved the recipes. It was then decided to develop and popularize the uses of powder. About 50 recipes suitable for home and restaurant use were developed and several products with commercial prospects were tried out with support from the CIP grant.

Meanwhile, the introduction of extrusion cooking for making snacks created an interest in potato-based snacks made from dried potato. Various companies conducted trials with both potato powder (finer than 60 mesh) and granules (about 40 mesh) made at SOTEC's pilot facilities. These products proved satisfactory and were less expensive than potato powder produced in factories.

Establishing Village-level Processing Plants

By late 1985, SOTEC was in a position to assist with the setting up of village-level processing plants by providing equipment and loans for operational costs (such as the purchase of potatoes). Although a pilot plant operated from March to June 1985, everything was largely theoretical. The steps required to implement the project involved determining optimum plant size; preparing an operating manual; selecting and training prospective users of the technology; helping construct the necessary infrastructure; procuring requisite equipment; reviewing operating procedures; meeting legal requirements; and setting up a three-tier system for managing production and distribution of the processed products.

Determining Optimum Plant Size

SOTEC set operational goals for the village plants very early in the project. The person responsible for setting these targets had many years of experience working with projects and local labor in both an educational institute (including a farm) and an agro-based industry.

A goal was set in which a plant operated by ten workers could, in 60 working days, process 60 t of fresh potatoes. While this goal remains unchanged, it has not been achieved except for very limited periods when all conditions were exceptionally favorable. It thus became apparent that it was more useful to determine the minimum production under adverse conditions which would still result in a viable operating unit. This assumes that purchasing of fresh potatoes has been properly done, a reasonable market price is available, the plant has 15 employees, and it processes 40 t in 60-70 working days.

Some of the factors and constraints which were considered in determining optimum unit size are as follows:

- Working backward from the expected retail sale price, the price at which a plant could sell chips and strips at a reasonable profit was determined.
- Labor productivity was estimated by processing several hundred kg per day for about ten days. At the same time, the amount of chemicals and fuel needed were determined.
- Based on the above, it was determined that 50 kg or more of fresh potatoes should be processed each day for each person employed, and that 10-15 employees formed an efficient work team.
- The drying season is 100-115 days long. Holidays, bad weather, the wheat harvest, etc., will make it improbable to carry the processing period beyond 80-90 days.
- Although viability was reached when about 40 t of potatoes were processed in a season, it did not allow for many unexpected price or weather adversities. Higher production, higher productivity, and more days of processing, increased profitability very much and gave a margin to absorb any setbacks.
- It appears that 60 t of fresh potatoes can be processed by an efficient plant in 60-75 working days and by a somewhat inefficient unit in 90 working days. This also provides a very attractive return.
- A loan of Rs 150,000 (US$ 8,000-9,000) for setting up a plant and operating it during the first year seemed as much as could be obtained from local lending institutions. This is about sufficient for a 60 t/season. Providing additional space and facilities beyond this volume per season would be too expensive.

Operating Manual and Training

An operating manual was written explaining the philosophy of SOTEC, the objectives of the project, the process, proposed organization, and estimated profitability. This manual has been updated three times and a fourth revision is underway.

Since SOTEC had limited contacts with farmers, a series of one-day training workshops were organized. These events aimed at introducing the basic procedures involved in village-level processing to farm households as well as encouraging those interested in starting up a unit. In addition, private voluntary organizations and government personnel involved with rural projects, as well as individuals known to SOTEC staff who might be interested in the project were also invited. The workshops were conducted several times each year and continue to be conducted as the need arises.

Increasingly, these workshops are attended by farmers of the SOTEC target group. This trend seems partly the result of the establishment and operation of the type of units for which the project is intended. Initially units were established by companies and organizations. However, by 1989, the village plants were all run by people from the SOTEC target group. These plants are displaying a degree of interest, efficiency, and stability not shown by the earlier units. This seems a logical development because the project was designed to be appropriate for low-income, peasant households and not more affluent, urban entrepreneurs.

Selecting Units

In addition to the publicity growing out of the workshops, SOTEC personnel have visited a number of villages to locate and meet farmers who might be interested in setting up a plant. Those still interested after attending the one-day workshop are visited again by a SOTEC staff member who surveys the site and makes a written report. Once the individual and site are approved, the arrangement for financing has to be made. Grants to SOTEC have helped finance seven of the ten units currently operating. Selecting successful units also requires creating a business tradition among low-income rural people with very little education, and those who have been led to believe they are only capable of menial labor.

The second type of workshop provides on-site worker training. A SOTEC staff member conducts this training while actually starting up the operation of the unit. This may take from one to several days depending on a variety of factors. After this training, follow-up visits are required to assure that plants are run properly.

Plant and Equipment

Infrastructure Requirements

Space and installations required for a village-level processing plant encompass the following:

- Storage for fresh potatoes and other supplies;
- Rustic storage for keeping potatoes that will not be used immediately;

- Work area for processing;
- Drying area; and,
- Storage area for dried product.

Fresh potato storage. Potatoes which are to be processed after harvesting, i.e., March and April in northern India, may be stored in any cool, shady, dark place without any special attention. However, potatoes meant for processing during the rest of the season, until about mid-June in northern India, should be stored in a specially constructed room or building called a "rustic store".

The rustic store. The profitability of the village units is greatly reduced or eliminated unless potatoes for processing are purchased at the peak of the harvest and stored during the drying season. Practical experience showed that potatoes could be stored in any reasonable cool and ventilated room or shed for processing during the first 20-30 days. A rustic store is required for more longer term storage Therefore, it was necessary to design an inexpensive, practical way to store potatoes to be processed over 90-120 days.

A passive evaporative storage building, or a rustic store, is based on a design developed by CIP for bulk storage of up to 20 t of potatoes piled 1 m high on a slatted floor. The walls are of mud and roof of thatch. To cut down on solar radiation, such a structure can be built in the shade of trees and the outside walls—including the door—white-washed. These are typical village construction materials and techniques for this region. The base of the building is a flat, cement plastered, brick platform, with a 4" high rim around the outside edge so that it will hold water. Bricks are placed on this platform in a way that allows air to flow in all directions and will also support a split bamboo floor. A fine chicken wire mesh is stretched over the bricks but under the bamboo floor. Another piece of this mesh is placed from wall to wall at ceiling level to keep rodents out. The cost of constructing a 20 t rustic storage is about 1.5 times the cost of storing 20 t of potatoes in a commercial storage for one season. Maintenance and operating costs are about 20% of the cost of storing in a cold store. Potatoes from the rustic store process better that those from the cold store. During the off season, the rustic store can be used for other crops, equipment or as living quarters.

Supply storage and office space. If the unit is set up near the manager's home, supplies such as chemicals, bags for packaging, etc., can be kept wherever there is some space such as veranda or corner of a room. It is desirable to have a table or desk to keep records and accounts. Otherwise a room about 10 m^2 is sufficient.

Wet processing area. This is where the potatoes are peeled, sliced, and blanched. It must have a brick or plastered platform with sufficient slope to provide good drainage and easy cleaning. Ideal size is about 5 x 7 m, though a smaller area (e.g., 3 x 7 m) can suffice. The wet processing area must be shaded. A thatched roof (or *chappar*) is adequate. The thatched roof should extend over the edges of the platform far enough to give shade during both morning and evening.

Drying area. This should be located as near to the wet processing area as possible and completely exposed to the sun. There should be a small shaded area where workers can spread slices on the racks before moving them into the sun. To put out 70 racks and work around them easily, this area should be about 300 m^2, or roughly 4.5 m^2 floor space for each drying rack, including walking space.

Storage for dried product. Dried slices take up almost as much space as the fresh potatoes from which they were made. If one plans to store any quantity of slices, they should calculate 0.17 m^3 space for each 20 kg of slices. Thus, 1,000 kg requires 8.5 m^3 of space (3 m long x 1.8 m wide x 1.6 m high). Potato powder is more compact and requires less storage space, so slices meant for conversion into powder should be ground to save space. Julienne strips take one-third the space of chips.

Once a substantial portion of the rustic storage has been emptied, it may be used to store slices. In this case, slices should be packed in closed plastic-film liners inside a woven outer bag to keep them from absorbing moisture. The product must be protected from moisture and rodents while it is stored. Sufficient storage space is essential because the chips/strips are bulky, and the processed product which is produced for three months (March through May) will be sold for 12 months.

Estimated construction costs for the working area, drying area, and rustic store are Rs 30,950 or about US$ 1,800 (Table 1). The extent to which some or most of the facilities area already available (e.g., a room could be converted into storage space), these costs will be reduced accordingly.

Equipment Needs

Essential equipment for village-level processing includes a blancher, slicer, drying racks, and tubs. The size and number of each of these pieces will depend on the

Table 1. Infrastructure costs for village-level processing plant.[a]

	Costs (Rs)
Rustic store for potatoes (40 t capacity)	22,000
Construction of processing area:	
cement, floor, pillars, and thatched roof	4,200
Water tank and other site requirements	4,000
Transportation and contingencies	750
Total	30,950[b]

Source: SOTEC.

[a]Daily capacity of 1,000 kg of fresh potatoes.

[b]Or, US$ 1,820 at an exchange rate of Rs 17 = US$ 1.00.

volume of potatoes the village unit plans to process per season.

Washer-cum-peeler. This is a 200-liter drum lined with silicon carbide grit, mounted on a hollow axle. The drum and axle are mounted on an angle iron frame. The drum is rotated by a handle fitted at one end. Water is fed into the drum from the other end of the axle through a 1/2" plastic hose pipe. If running water is not available, water may be siphoned from a tub or bucket set slightly higher than the peeler. This washer-cum-peeler has a capacity for 30-60 kg of potatoes at a time. Removal of peelings (about 70%) requires 2-10 min of rotation depending on the thickness of the skin.

Slicer. Two types are functional depending on the volumes to be processed. A hand-cranked slicer is suitable for slicing up to 200 kg of fresh potatoes per day. It consists of a rotating drum with several blades. Potatoes are fed into a tube and pressed down against the drum. A cycle-cum-motor slicer must be used for higher production programs. It can slice from 200-400 kg/hour. It can be run either by a person pedaling a cycle or by a 1/2 hp electric motor. To maintain the same capacity when cutting julienne strips a 3/4 to 1.0 hp motor will be required.

Blancher. The blancher is a stainless steel tub with a galvanized sheet metal top, fitted into a masonry structure in which water is heated to boiling point. A variety of fuels may be used to heat the blancher.

Drying Racks. The drying racks are frames of about 1 x 3 m metal conduit pipe. They have 15 cm long legs which are arranged so that the racks can be stacked on each other. Chicken wire is stretched between the frames.

Tubs. Several small and large tubs are required to handle the potatoes during processing. These are made of black sheet metal and coated with paint.

The estimated costs of equipment required for a village-level potato processing plant are Rs 34,292 (Table 2), or about US$ 2,000. The washer/peeler, blanching tub, slicer, holder and blades for butting chip and julienne strips, and knit nylon bags can be ordered through SOTEC. The machinery is made locally under SOTEC's supervision and final adjustments are made by their staff. In northern India, the nylon net can be purchased from the market. All other items can be made locally following plans obtainable from SOTEC.

SOTEC is at the point where it is confident of the quality and utility of the equipment it has designed and which can be produced in local workshops. However, this experience has fostered several new ideas for equipment which may be as efficient and may cost less. With inflation and the government policy to put increasing tax burdens on metals, and on engineering and industrial materials, the financing of fabricating equipment has become an increasingly critical problem.

Processing Procedures

After several years of experimentation, SOTEC eventually settled on the following operations for village-level potato processing:

Table 2. Equipment costs for village-level potato processing plant.[a]

Equipment (number)	Cost (Rs)
Washer/peeler	3,080
Slicer, cycle-operated	6,135
Stainless steel tub for blancher	1,300
Masonry work, chimeny, etc., for blancher	1,000
Large tubs (3)	900
Small tubs (8)	1,632
Knitted nylon bags (25)	450
Drying racks (70)	14,700
Nylon nets (140)	2,800
Holder & blades for slicer	1,795
Buckets, baskets, wooden spoon, spanner, etc.	500
Total	34,292[b]

Source: SOTEC.

[a]Daily capacity of 1,000 kg of fresh potatoes.

[b]Or, US$ 2,017 at an exchange rate of Rs 17.00 = US$ 1.00.

- Selecting and storing fresh potatoes;
- Washing and peeling the potatoes;
- Rectifying the peeled tubers;
- Slicing the peeled tubers;
- Rinsing the slices;
- Blanching the slices;
- Chemically bathing the slices;
- Spreading the slices to dry in the sun;
- Grinding the dried slices;
- Grading for particle size;
- Making and packaging potato powder;
- Bagging for sale or storage;
- Bagging for bulk sale or storage; and,
- Packing for retail sales.

Based on SOTEC's experience, each of these operations has its own recommendations. The flow chart in Figure 1 shows all the processing steps.

Selecting potatoes. Some varieties do not dry well using village-level processing techniques. Varieties which have good results are Kufri Chandramukhi (A 2708), Kufri Bahar (E 3797), and Kufri Jyoti. Generally white skinned potatoes dry well and red skinned potatoes do not. To test the drying quality of a potato variety, process 5 kg of that variety for two or three days using the process described. Potatoes selected (or purchased) at the peak of the harvest season are the least expensive and store best. For best results select potatoes which:

- have been properly cured. To cure potatoes, remove the aerial part of the plant and leave the tubers in the ground for one to two weeks before digging. As soon as potatoes are dug, they should be kept in the shade;
- are free of all damaged, diseased and discolored parts. Slightly damaged potatoes should be processed right away. Store only good potatoes;
- are of uniform shape and have shallow eyes; and,
- are 4.5 cm or more in the narrowest dimension and weigh about 120 g (about 8-10 potatoes to a kg).

It should also be noted that potatoes of any size can be sliced but it is usually not economical to process smaller ones.

Storing fresh potatoes. About two-thirds of the anticipated quantity of potatoes to be processed during the season should be stored in a rustic store as described earlier. Only good quality potatoes should be stored. Water should be filled under the floor every few days. This is especially important if the potatoes are stored for over a month. When potatoes are being used from a store, it should be opened only once each day, preferably early in the morning.

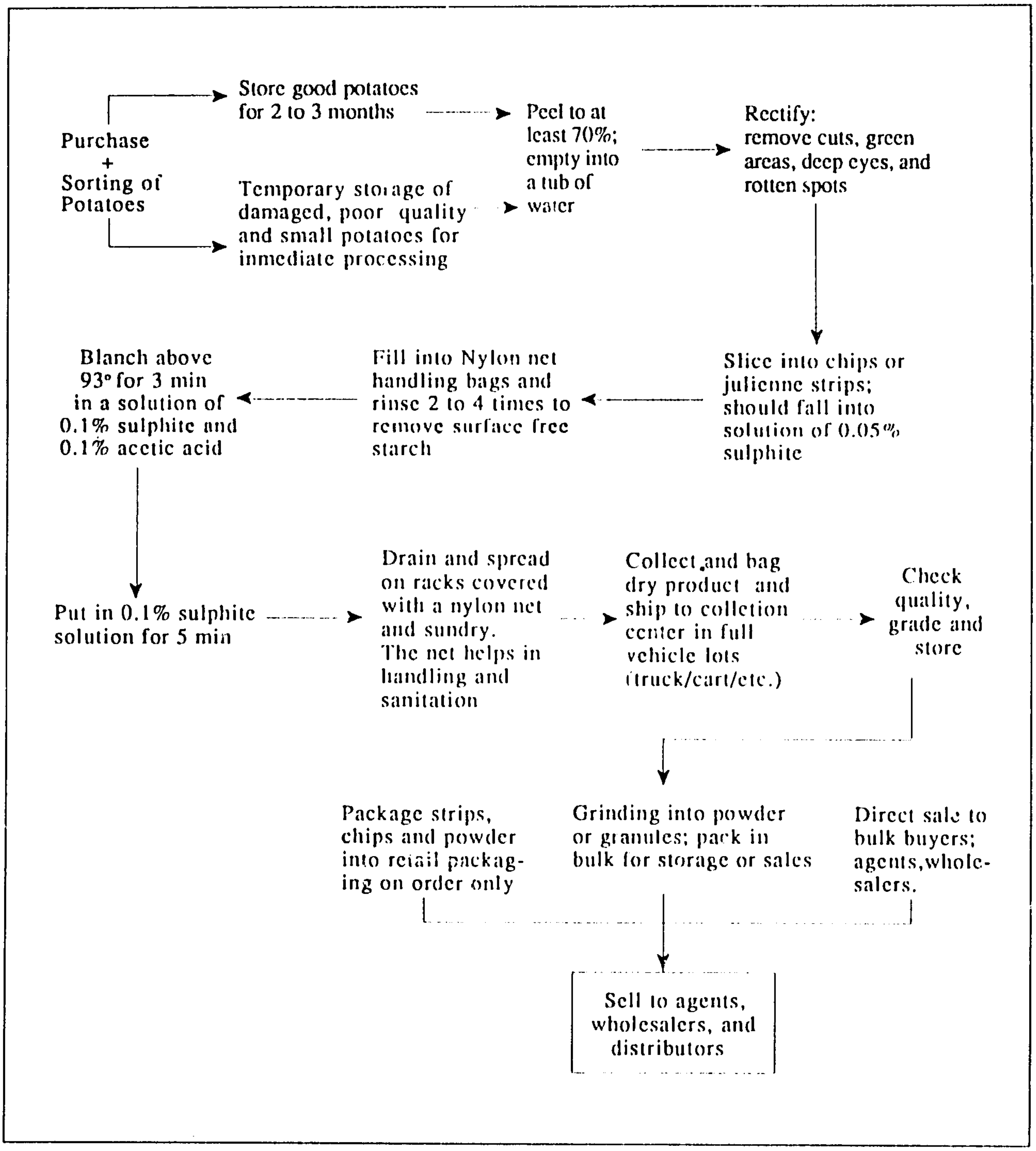
Washing and peeling. Place 25 to 50 kg unwashed potatoes in the washer-cum-peeler, start water flowing into the drum and revolve the drum until water becomes nearly clear and about 70% of the peel has been removed. This may take between 1-2 min for new potatoes and about 5-15 min for old potatoes which have become spongy. Peeled potatoes should be kept immersed in cool water at all times to prevent darkening.

Rectifying. Cuts, green areas, rotten spots, deep black eyes and other discolorations are removed with a knife before chipping. SOTEC has experimented with several designs of knives and find some shapes and lengths result in much quicker work. Because these are very small units rectifying is done by women squatting around tubs of potatoes. The most efficient arrangement is one woman at each tub. Four or more women around one tub reduces the output by almost 50%. Rectifying is the most expensive step of the process when making julienne strips. There is a tendency to rectify too much or too little. Village women in this area are not used to using paring knives and have to be taught.

Slicing. Slice potatoes directly into water containing 0.05% solution of sodium meta bisulphite to keep slices from darkening. The thickness of the slice may vary from 1.5 to 4.0 mm. (Thin slices require more time and labor to process but are whiter and dry faster). The ideal thickness is 3.0 mm. A nylon mesh bag placed in the tub makes it easier to remove the slices. Collect the starch from slicing water.

Rinsing. After slicing, the chips are filled into nylon mesh bags for easy handling. They are then rinsed in tubs of plain water 2-4 times to remove surface starch which has been freed by the slicing. Starch in the slicing and rinsing tubs is accumulated, rinsed and put out to dry at the end of each day. A hook is placed above each tub where chips should be drained before being taken to the next step. Another hook is also placed through the drawstring of the bag to speed hanging and handling. Tubs can be of any convenient size and shape. We use two sizes. They each have a height of 11.5 in. One has a 60-liter capacity and the other has a 160-liter capacity. Stainless steel tubs would be ideal but are much too expensive. We now use black-sheet metal tubs and paint

Figure 1. Flow chart of village-level potato processing.



Source: Chowfin and Nave 1991.

these with the most durable finish we can find. They generally have to be repainted each year. Galvanized iron sheet tubs do not hold up either, unless they are painted. We are now exploring the possibility of heavy duty plastic tubs. The commonly available plastic tub and bucket found in the market last only a few weeks.

Blanching. Prepare water for blanching by adding 0.1% sodium meta bisulphite and 0.1% glacial acetic acid (0.1% is the same as 1 g per liter of water). In a blanching tub containing 150 liters of water, add 150-170 g of each of the two chemicals in order to process about 300 kg of potatoes. You can then add 110 g of each chemical to process 250 kg more. With another 110 g of each chemical you can blanch 250 kg more of potatoes. Finally, with another 110 g of each chemical, you can process another 200 kg. Thus, 1,000 kg of potatoes can be processed with about 500 g of each chemical.

Put the bags or slices into the blanching water and agitate 2-3 min during blanching. The water should be boiling (or very near boiling). Slices 3.0 mm thick should be blanched in about 3 min. Thicker slices need to be blanched for more min. Slices should be about "half-cooked" during blanching. If they are cooked too much, they become soft and tend to break during spreading. To test the degree of blanching, insert a thermometer into the blanched potatoes immediately upon removing from the blancher. If the temperature is 89°C, or slightly more, the potatoes are sufficiently blanched.

Post-blanching chemical bathing. Prepare a solution of 0.1% sodium meta bisulphite in two or more small tubs holding about 35 liters of water. After draining bags of blanched potatoes about 1 min, place in the chemical bath for 5 min (experiment with this timing as you may get equally good results with a shorter time). Drain bags well and immediately spread potatoes for drying.

Spreading and drying. Immediately empty bags on drying racks. Spread with a wooden spoon or rake to assure speedy cooling and drying. The potatoes are spread on nylon mosquito netting placed over the racks to keep the chips from touching the wire mesh and to make handling easier. Only one person is required to spread julienne strips. They are spread and later turned over three or four times during the day simply by running one's fingers through the layers of potatoes. Wafer type chips take at least five times as much labor as each chip has to be separated on the netting. Wafers also take up about five times as much rack space.

Drying is done in open sunlight. It takes from a minimum of 6 hrs to a maximum of three days. When drying takes more than one day or the weather threatens, the racks of chips are stacked in a well ventilated shelter. As soon as chips are cool, separate them into a single layer.

Packing the dried product. Slices or strips may be sold directly in bulk or in 100 to 500 g plastic bags. This requires purchasing adequate standard size bags, weighing, filling, and heat-sealing the bags. A small slip of paper may be required to meet labeling requirements; it should include information such as net weight, month of packaging.

Making and packaging potato powder. To make powder, one grinding unit can serve 8-12 drying units and should be located as close to the drying units as practical. The steps involved in making potato powder and readying it for sale are as follows:

- *Inspecting dried slices.* Dried slices should come from the drying units in woven polyethylene or Hessian bags. (If chips are to be stored during the rainy season, they must be packed in a 200-gauge plastic liner inside the woven bag). These bags must be clean and completely free of insect eggs. Before grinding or storing, the chips must be inspected, and discolored chips, foreign matter, etc., removed. For this process, there should be two inspection tables onto which the bags are emptied. These tables should feed directly into the grinding mill. Discard the whole bag of chips if it is infested with insects or shows visible signs of fungus growth. These chips may be used as animal feed.

- *Grinding.* This may be done in a 40 cm to 60 cm horizontal stone mill or a screen mill which can be run with a 5-10 hp motor. To reduce the danger of insect infestation—which is always present in cereal grains—use the mill for dried potato only.

- *Sieving.* The powder will have to be sieved if ground in a stone mill. This may be done manually or by a sieving machine. A sieving machine will reduce dust losses and improve cleanliness. Regrind oversize or large pieces. The powder should have a granule size similar to *suji* (semolina). With hand-sieving, grinding losses will be about 1.0%. This is made up mostly of moisture lost to the heat of grinding, and dust. Most of the dust losses take place during hand-sieving.

- *Packaging.* The basic packaging requirement for both dried chips and powder is that they be protected from moisture, rodents, insect infestation, and dust. For easy handling, powder should be packed in quantities of from 25 kg to 40 kg. However, bulk users may specify the weight they prefer. Furthermore, bulk packaged powder requires an inner plastic liner of about 200-gauge low density or high density polyethylene or polypropylene and an outer bag of jute or woven plastic. Pack all powder in the standard bulk packing and later fill into retail packages if required. For retail packaging use a pre-printed opaque plastic bag of about 200-gauge and heat seal after filling. A convenient weight for all retail packing is 200 g. Be sure the bag has the information required by law printed on it (maximum price, net weight, and month of packing). After sealing, check that there are no leaks in the seal.

Shelf life. Powder or chips fully protected from moisture and infestation remain good for at least two years. Dried chips do not attract infestation as much as powder does.

Licenses and Legal Requirements

The village-level processing plants have had to comply with food and storage licensing requirements in India, as well as sales tax and packaging laws. Furthermore, certain labor laws related to minimum wages, permanency of employment, and number of employees, had to be dealt with. However, due to remoteness and the small size of the enterprises involved, these regulations are not very strictly enforced.

SOTEC has assisted plants located in or near urban areas to obtain food and storage licences. Generally, compliance with these operating procedures has not been difficult. The main purpose of the food licence is to assure sanitation and eliminate adulteration. Because of the nature of the products, laboratory tests have shown very low bacterial counts. The cost of the food licence is quite low. A food inspector is supposed to visit the site before a licence is issued but often does not.

Specific regulations govern the labeling of packages for retail sale. Besides the name of the product and ingredients, labels must include weight, date of packaging (or manufacturing) and, when appropriate, an expiration date.

Manufacturers and marketing companies become subject to sales tax in India when sales reach a certain level. So far the producing units are exempt, though the main marketing unit for SOTEC is not (see Three-Tier System below). Due to the nature of its business, it applied for—and was granted—a higher sales tax exemption.

Although every effort has been made to comply with minimum wage requirements, the plants find they have to conform to the going wage rate in the area as well as the season in which they operate. For instance, wages are much higher during the wheat harvest. Consequently, the plants have to either pay higher wages or close down during that period. Until now, the average wage paid by the plants approaches and occasionally exceeds the official minimum wage for rural agricultural workers. So as to facilitate marketing of the dried chips and other processed products, SOTEC has established an elaborate production and distribution system.

Three-tier Production-distribution System

Several distinct activities are necessary to make village-level potato processing successful. These include: (1) processing and drying; (2) storing and grinding; (3) packaging, storage, and dispatch; and (4) sales and marketing. An individual processing plant might do any one or more of these activities. However, SOTEC has established the following three-tiered structure to provide quality control and technical support in processing as well as to capture certain economies of scale in marketing.

Tier I. This is the village plant or unit which processes and dries chips. It is small, based in a village, operates with unskilled labor, is locally owned, and is seasonal. It may also include other activities such as *papar* making from starch.

Ideally, a number of these units should be located close together and feed their production into a Tier II unit.

Tier II. The activities of this unit are to sort the chips it receives from 8-12 nearby drying units (quality control), grind them into powder, package the powder and/or chips in bulk or retail packages for sale, store these products, and dispatch orders.

Tier III. This unit handles sales and marketing. Several Tier II units channel their products for sale through a single Tier III unit which is responsible for advertising, packaging, designing, getting products into retail stores either directly or through distributors, locating bulk industrial users, handling billings and collections, and giving Tiers I and II production targets. Tier III may also become the principal financing unit by getting bank loans for product purchases so that Tiers I and II receive payments promptly.

Initially SOTEC operated at all three levels. In 1988 about 95% of the sales activities were turned over to three independent sales companies. In 1990 SOTEC discontinued operation of its own pilot facility production, so that all the production is now done by village units. Some of the activities of Tier II units were turned over to the Tier III marketing people on a trial basis. This did not work well.

SOTEC is currently arranging the establishment of a federation (similar to a coop) in conjunction with a program of the Khadi and Village Industries Board (KVIB), an autonomous government organization. The membership will be made up of all production units, marketing units, SOTEC, and other parties willing to join the federation. The federation will assume all the Tier II and some of the Tier III responsibilities and also the supply of equipment; and it will help with the procurement of raw materials and financing. The federation should also be helpful in fixing product prices and margins, and in quality control. Its effectiveness will be evaluated after its first year of operation.

History of the Units Established

Twenty-one plants have been established since the inception of the project. Ten plants are presently in operation (Table 3).

In 1985, the Project Director ran a prototype at Nave Institute, Shahjahanpur, from March to May. In October, a series of training programs were started in Bareilly as the project and all its activities were shifted out of Shahjahanpur. The first unit for U.P. Hortico—a parastatal food processing company, was established at Hapur, Ghaziabad District, and staff were trained during November. However, the unit did not really operate until February of the following year.

In 1986, two units were started for U.P. Hortico at Hapur and Kaimganj, District Farrukhabad. Another plant was set up in Farrukhabad city sponsored by the KVIB. Three other facilities were established in Nivari, District Tikamgarh (M.P.), by Anandit Agro Enterprises, a local NGO. SOTEC's unit continued to operate at the office site.

The Farrukhabad unit never operated properly. The U.P. Hortico and Anandit units marketed their products through their own outlets.

In 1987, the SOTEC facility was turned over to a small entrepreneur to be run on a commercial basis and to test its financial efficiency. This experience provided

Table 3. Village-level potato processing plants organized by SOTEC, 1985-90.

Year	Plants Established	Plants In operation
1985	1	1
1986	7	6
1987	4	7
1988	2	8
1989	6	10
1990	2	10

Source: SOTEC.

a great deal of information about worker productivity, recovery rates, and production problems. The three Anadit units continued to operate during 1987 but the Hortico units were discontinued due to a lack of interest by the new general manager.

The new plants included a women's unit at the office site which worked parallel to the original SOTEC plant; and one unit at the Good Shepherd Agricultural Mission (GSAM), Tanakpur, District Nainital. Two other plants were set up by private entrepreneurs; one in Bareilly and another at Chandausi, District Chandausi.

The Bansal unit produced about 1.7 t of chips which were sold independently after having SOTEC mill them into powder. The GSAM sold about 170 kg of their product and used the rest for their staff and orphanage. The Chandausi unit was started by a large farmer who planned to sell directly to a private snack factory in Lucknow. He produced 5-6 t of product. However, when the snack factory failed, the potato drying unit was shut down.

In 1988, the SOTEC unit was taken over by a new operator since the previous manager wanted to set up his own unit in a village. However, he was not successful in finding a site. The Anandit, Chandausi, and GSAM units discontinued operations. New units were established at Bantra, District Shahjahanpur at a women's training program, and at Poliganj, a village in District Nainital. The Bantra project is very small and markets its own products.

All the units which operated in 1988 continued operations in 1989. New units started were: (1) a SOTEC unit at its new Rural Development Center near Bareilly, and (2) one each at Mahhola and Bisalpur in District Pilibhit; at Bijamaw and Harharpur in District Bareilly;

at Isanagar in District Rampur, and at Bhambi in District Shahjahanpur. All these units are run by small farmers located in villages off the main roads and are typical of the SOTEC target group.

Abnormal weather conditions during the first half of 1990, characterized by frequent heavy rain and high humidity, caused severe late blight damage to potato plants in the field and substantial losses for growers. This resulted in potato prices increasing by 215% in three weeks. Drying was also difficult. In spite of this, six of the seven village units operating in 1989 continued to do so in 1990. The seventh one did not operate because the potato crop scheduled for processing was ruined by the rain.

The women's unit and the commercial unit at the SOTEC office site were converted into a demonstration unit of the new Research, Training, and Village Development Center (RTVD), 12 km from the office. The plant at Bantra in Shahjahanpur District continued to operate. One new unit was started at a village in District Kanpur and at Sirsaganj in District Mainpuri.

Production

Accurate production figures are difficult to come by. Some products were sold directly by units and no information is available. SOTEC marketed over 6 t of dried chips and strips in 1988, and about 40 t in 1989 (Table 4). Unfortunately, production was much lower during 1990. However, demand was so great that about 90% of output was sold as soon as it was ready.

Table 4. Sales (t) of processed potato products by village plants, 1987-89.[a]

	Year		
Product	1987	1988	1989[b]
Chips	0.2	2.0	3.5
Strips	0.15	1.5	3.0
Powder	2.0	6.0	6.0
Starch	--	0.4	1.2
Total	2.35	9.9	13.7

Source: SOTEC.

[a]Figures do not include sales by plants that do their marketing directly.

[b]March-August only.

Future Expansion

In 1988, SOTEC signed a three-year agreement (1988-90) with Appropriate Technology International (ATI) for Rs 1.5 million-quoted in the project document as US$ 115,000, but valued at US$ 87,000 at the then current exchange rate[5]. Due to a delay in receiving these funds, this project did not actually start until late 1988. Therefore, it has only been operational during one processing season. The objective is to develop, field test, and establish the commercial operations of sorting, processing and drying, and grinding potatoes. The first two years are designated as a demonstration project during which several potato stores are to be built, three processing units established, and a milling unit set up. During this time, the project is expected to employ 39 persons (in the units and stores) and to process 405 t of potatoes each year.

If the demonstration project proves successful, an expansion phase will follow during which time a loan application will be made to a commercial bank for financing capital costs. Working capital will be covered by a loan from an ATI-financed revolving fund managed by SOTEC. Six more processing units with supporting facilities are to be established during this phase. The project will be run by a project manager and a field worker. It also includes product appraisal and market development, as well as support to local entrepreneurs.

Costs and Returns to Village Processing

In tandem with the R&D work on the technical aspects of village-level potato processing, the SOTEC project has also gone through a series of adjustments in the estimated operating costs and returns to such activities. The economic viability of village-level processing—and the best ways to achieve it—remain topics of ongoing discussion within SOTEC as well as between project staff and the team of advisors from CIP.

In the initial years of the project, SOTEC personnel envisioned village processing plants operating at widely different output levels per day and per season. For

[5] Appropriate Technology International (ATI) is a US-based, NGO that supports projects to diffuse improved technology to low-income groups in developing countries.

example, in one of the earliest versions of the operating manual for such plants, estimated costs are for units that process from 200-1,000 kg of fresh potatoes per day (CIP n.d.). Furthermore, the booklet based its calculations on a drying operating season of 60 days for all units, but noted that "in some locations 90-150 days of drying are quite possible." However, it did indicate that the rate of return was 20% for the smallest plants, 200 kg/day, versus 115% for the largest facility (1,000/kg). Yet, both facilities used essentially the same technology.

In an effort to explain this apparent paradox, a much more detailed set of estimated operating costs were developed by CIP social scientists (Scott 1988). These calculations were more systematic. Hence, they included some costs that had been overlooked. They also were more realistic. They used a conversion rate from fresh potato to dried chip of 16% rather than the 20% assumed earlier. As these figures demonstrated, the smallest village-level plants, i.e., 12 t per season, simply do not process enough potatoes over even five processing seasons to pay for fixed costs in the form of infrastructure and equipment as well as the costs of day-to-day operations, e.g., labor and potatoes (see Appendix Tables 1, 2, 3). In the slightly larger units, 400 kg/day, profitability is extremely vulnerable to disruptions in the form of bad weather or mechanical breakdowns that reduce the volume of fresh potatoes they can process in a season. In other words, village-level (small-scale) processing still has to be big enough to be economically viable. SOTEC now considers 60 t over about 75 days to be a realistic, minimum level of operation from an economic point of view.

A second economic issue to emerge had to do with the accuracy of the estimates of operating costs. The initial calculations were based on trial runs that took place from January to April 1985. This seemed realistic enough. However, the reported figures were based more on spontaneous recall (for the inputs utilized, prices paid) than a systematic recording of actual costs incurred, because SOTEC staff were extremely busy trying to address a myriad of problems. The figures presented were intended as approximations or guidelines for making investment decisions, not actual operating costs. As records from the respective processing seasons began to accumulate, it was possible to review these estimates in light of actual performance. A careful inventory of these costs showed that a number of items were more expensive than originally estimated, e.g., drying racks, and that technical conversion factors were less efficient than believed. In particular, conversion rates from fresh potatoes to dried product ranged from 14% to 20%, and not the 20% originally estimated. SOTEC has subsequently adjusted their guidelines for village processing plants to include more realistic cost estimates in the operational goals for prospective units.

A third area of economic discussion concerned the role of storage in village-level potato processing. SOTEC personnel always considered storage to be a necessary component of village-level potato processing operations. They argued that to achieve the volumes of processed product per season necessary to assure profitability, the plants would have to operate over about 75 days. It would be impossible to process the same quantity of fresh potatoes in half the time because the plants were not equipped to handle this type of volume. Consequently, to ensure a steady supply of potatoes to the processing facilities, each of the plants was to include a rustic store. Some fresh potatoes would be harvested (or purchased) at peak harvest time and processed immediately. At the same time, i.e., when potato prices were especially low and the condition of the mature tubers ideal for placing into storage, some potatoes would be collected and put into the rustic store. As the supply of fresh potatoes ran out and the price of potatoes in the marketplace went up, the village processing plant could begin to use the potatoes kept in storage. This procedure would not only allow the plant to use cheaper potatoes, but also would avoid disruptions in daily operations due to difficulties in procuring raw material as the harvesting season came to an end.

Although storage was always considered integral to village-level potato processing operations for the above mentioned reasons, the actual costs of constructing the rustic store to keep the potatoes were not included in the original estimates of operating costs and returns of the plants. Instead, the estimated cost of renting such a facility was listed among operating expenses. Once these construction costs were estimated, it was possible to simulate the returns to: (1) processing without storage; (2) storage without processing; and (3) processing and storage.

The results were surprising to SOTEC staff in that they showed storage alone was not only more profitable than the other options in absolute amount, but also offered a much more attractive rate of return on total annual costs (Appendix Table 4). CIP technical advisors suggested that these figures indicated at a minimum that rustic storage could be utilized as a way to generate capital for peasant entrepreneurs interested in establishing a complete storage and processing operation, but who lacked the financial resources to adopt the entire postharvest package at once. Alternatively, these data suggested that some small farmers might only store potatoes as a way of overcoming the seasonal fluctuation in potato prices. In other words, product development may well involve a variety of strategies to benefit different types of farmers. SOTEC staff remain skeptical about these results, but feel the storage option should be examined more closely.

SOTEC's latest estimates of the costs for infrastructure to process potatoes include storage costs (Table 1) and are for a facility equipped to handle between 800-1,000 kg of fresh potatoes per day (Table 2). Daily operating costs are calculated to be about Rs 1,400 for 1,000 kg of fresh potatoes (Table 5). If it is assumed that the plant operates over 90 days and processes potatoes on 60 days during that period, then the total cost per kg of dried chips will be Rs 10.24 (Table 6). This assumes as well that the facility will average 1,000 kg/day and a conversion rate of fresh potatoes to dried product of 18%. Conversely, if the productivity of the plant is lower and the conversion rate less favorable, the costs per kg will be higher.

Fixed costs make up less than 25% of total costs (Table 6). Hence, these costs represent more of a barrier to entry to village processing for households with little or no capital than items that greatly influence profitability. Consequently, efforts by SOTEC staff to try and lower the costs of the drying racks, for example, overlooked the fact that these costs simply do not influence total costs per kg to any appreciable extent.

Table 5. Daily operating costs for processing dried chips.[a]

Input	Costs (Rs)
Labor	230
Potatoes (Rs 1.00/kg)	1,000
Chemicals	20
Fuel	110
Maintenance	20
Supplies	10
Contingencies	10
Total	1,400[b]

Source: SOTEC.

[a]Daily capacity of 1,000 kg of fresh potatoes.

[b]Or, about US$82.35 at an exchange rate of Rs 17.00 = US$ 1.

Alternatively, the cost of raw material accounts for slightly over 50% of production costs and, therefore, has a much stronger effect on economic viability. As costs of processing roots and tubers may not always be what they seem, it is probably best to have a clear picture of their relative importance before investing scarce human resources to try and lower one rather than the other.

According to SOTEC, the bottom line on these calculations is that for a 20% profit margin, the price per kg of dried chips paid to the village plants has to be

Table 6. Total operating costs per season for processing dried chips.[a]

Type	Cost (Rs)
Fixed[b]	
Infrastructure (.25 of 30,950)	7,738
Equipment (.25 of 34,292)	8,573
Interest charges	7,829
Variable[c]	
Inputs not including potatoes, e.g., labor	24,000
Potatoes	60,000
Interest charges	2,520
Total	110,660
Cost per kg of dried chips[d]	10.24

Source: Table 1, 2, 3, and SOTEC.

[a]Costs are for processing 1,000 kg per day for 60 days during a period of 90 days.

[b]Principal and interest (12%/yr) are paid during 4 years.

[c]Interest charges are for Rs 24,000 at 12%/yr for 90 days.

[d]60,000 kg with a conversion rate of 18%.

about Rs 12.29/kg, or about ten times the price of fresh potatoes during the peak harvesting period. If the plant processes fewer potatoes, e.g., 800 kg/day, then the price has to be higher still. SOTEC estimates this to be about Rs 14.5/kg all other things being equal. With these prices, the owners of the village plant will pay for all infrastructure and equipment as well as completely cancel outstanding loans to cover these costs in four years. Thus, it appears that a longer payback period or lower interest rates will not have a great deal of effect on the year-to-year profitability of the processing plants. Put somewhat differently, although credit is necessary to establish village-level processing plants, daily operating costs are what account for profitability.

Difficulties Faced

The SOTEC project has faced operational difficulties of both a technical and financial nature. They also relate to compliance with the project's stated objectives. The most important of these are summarized below.

Collection and Storage

Collection of dried chips and storage of the finished product have presented a series of logistical and financial problems. The village plants are too small to do their own marketing in part because they require income during the production period. They also do not have storage space for large quantities of finished product. Shipments from units, therefore, tend to be less than truckload lots. This, combined with low product density, results in high transportation costs. During 1989, all product was brought to SOTEC headquarters for sorting and storage, and then re-shipped to the market as required. It is much less expensive to ship directly from the village to the market but this leads to problems of quality control. When unsatisfactory product is returned from the market, it adds to costs. In an effort to minimize these problems, SOTEC tries to collect product from two or more nearby units and bring the combined lot to headquarters for inspection, repacking, storage, and dispatch.

The storage problem involves both the space required and the type of building needed. Since production occurs during 3-4 months and sales over 12 months, about three-quarters of the processed product must be stored. Much of this is bulky because it is in the form of chips and strips. If storage space has to be rented, it adds to costs and increases the possibility of insect infestation. At present, SOTEC (or the villagers) has to store the product in a thatched-roofed, mud building. While this stores the product well, it is not possible to get either insurance or bank loans on the product thus stored. Therefore, buildings of masonry, or other fireproof and storm resistant materials, are required for product storage.

Quality Control

Two main points at which quality control is essential are during grinding and sieving of the dried chips and at storage. The latter includes proper inspection on reception of the product as well as storage in a manner which assures retention of quality during the storage period.

When the dried chips or strips come from village units to the SOTEC headquarters, each bag is emptied onto a screen table allowing any small foreign particles to fall through. Any larger foreign matter is manually removed. The moisture is checked by putting a sample in a sealed plastic bag and placing it in the sun to see if moisture collects on the plastic surface. Product, which is too damp, is redried and then packed in bags of a standard weight.

During the dry season, processed chips can be kept in woven bags. This reduces costs and allows drying to continue. After grinding or before the monsoons start, all product is sealed in 200-gauge polyethylene bags inside a woven bag. Without this liner, the dried chips and powder can become discolored and may even spoil during the rainy season.

Only ground processed potatoes can be adulterated. This usually occurs during (or after) grinding and sieving. For this reason, these operations are done at a central location where quality control can be maintained and insect contamination prevented. Therefore grinding should not be done in mills where various grains such as wheat and maize are milled. A major cost associated with the production of potato powder has been the loss of dust which flies into the air during grinding and sieving. Grinding is done on a horizontal stone mill and sieving in large sieves placed over tubes and agitated by hand. Some sort of enclosed, motorized sieving machine is required to reduce labor costs and dust losses.

Different customers for bulk product have different specifications for particle size and the range of particle size allowable. Maintaining these specifications requires extra labor, increases costs, and results in fine powder for which a market must be found. SOTEC feels that if a proper screen mill is used for grinding, granule sizes will tend to be more uniform, thereby reducing the production of unwanted particle sizes.

Because of the emphasis on sales to commercial users, the marketing units are shipping powder in 35-50 kg woven bags. When required, a plastic film liner is also placed in the bag. Chips and strips are supplied in woven bags weighing 10-20 kg each. During humid weather a plastic liner is also used.

Assuring Supplies, Equipment, and Services

Supplies of raw materials, equipment, and spare parts are often very difficult for small enterprises to obtain—both in terms of costs and quality. Proper arrangements must be made for small enterprises to obtain these materials.

SOTEC does not have the resources to produce equipment to keep in stock, therefore, fabrication of equipment is started after it has been financed either by the applicant or through a grant directly to SOTEC. SOTEC will sell equipment to units for which SOTEC has no subsequent responsibility beyond initial training. In such cases, the units must understand that they are fully responsible for their own marketing before SOTEC will supply the equipment.

At present the only source of equipment is SOTEC. However, SOTEC is not a manufacturer and arranges for the equipment to be fabricated for each unit on its behalf. SOTEC provides the design, contacts the artisans, helps with the purchase of parts and materials, and supervises the work. Anything not properly done is rectified by SOTEC staff who also check the proper assembly and final testing of the equipment. The costs of equipment repair are charged to the unit.

Also, small rural industries of this type cannot afford to get technical, business, or legal consultancy from commercial consultants. In SOTEC's experience, few, if any, commercial consultants understand the needs or concepts sufficiently to provide useful advice for this level of operation. As a result, SOTEC provides technical, managerial, and marketing advice free of charge as required by the units.

Marketing and Sales

For the benefits of village processing to reach a rural, farm-based community, most of the produce must be exported to population centers. Yet, the plants which can be run by the target group typically are too small to undertake marketing beyond their localities. Without proper distribution procedures, these plants simply will fail.

During the first several years, marketing was a real problem. Chips and strips sold in the market were of very poor quality and less expensive than the good quality product made by SOTEC. Powder was unknown and a market had to be developed. In recent years, consumer demand for quality dried chips has increased and they now sell better than the poor quality ones.

A market survey carried out in Delhi during April-May, 1989, by the Agro-economic Research Center of Himachal Pradesh University, Shimla, showed that considerable quantities of dried chips are now being retailed in Delhi (Sikka 1990). Ninety-two retailers were interviewed in six markets in six different zones of Delhi to gain primary information on the marketing of all types of dried potato products. One important finding was that these retailers alone had average monthly sales of over 222,000 packets of dried potato products. Dried chips comprised 50% of the packets sold; potato powder accounted for only 1%.

Secondary data on the supply of processed potato products to Delhi market was not available. Wholesalers and retailers could not provide this information either. In the absence of such statistics, total sales of sampled retailers was assessed and the average monthly sales of sampled retailers estimated (Table 7). Sales were highest for dried chips (50%). Potato chips were also preferred to potato papar and other processed products.

The introduction of potato powder for household use has not been successful so far. When demonstrations were conducted for groups, sales were good. Where SOTEC had personal contacts, resales continued. However, retailers have told SOTEC personnel that increased sales of the powder require attractive, good quality packaging. So far neither SOTEC nor the marketing groups have had sufficient funds to have a well designed, high quality package made. Still, some retail sale of powder continues. Almost all granules and powder are sold for reprocessing into extruded snacks.

The 1989 production of 40 t had all been sold by April 1990. Losses of 600-700 kg of powder were due to moisture damage. Since the beginning of the 1990 season, the new product has been sold as quickly as it has been produced. Market size is not a constraint though demand will possibly be greater than supply for the period from July 1990 to January 1991.

Table 7. Monthly retail sales of processed potato products in Delhi.[a]

Product/Unit of sale	Number of packets	(%) of total	Monthly range
Potato crisps			
100 g	20,000	9.0	15,000-45,000
40 g	10,000	4.5	5,000-18,000
25 g	4,800	2.2	2,000-7,000
Dried chips			
1,000 g	4,000	1.8	2,500-6,500
250 g	15,000	6.7	9,000-24,000
100 g	60,000	27.0	40,000-110,000
80 g	25,000	11.2	12,000-41,000
25 g	6,200	2.8	4,000-10,000
Potato powder			
100 g	800	0.4	200-1,400
200 g	2,500	1.1	1,200-4,000
Potato *papar*			
200 g	23,700	10.6	15,000-35,000
Other			
1,000 g	23,000	9.2	14,000-30,000
250 g	30,000	13.5	18,000-45,000
Total	222,350	100.0	180,000-230,000

Source: *Sikka 1990.*
[a]April-May 1989.

The marketing units have been operating through SOTEC facilities because the product was received, stored, and milled at SOTEC headquarters. At times, the marketing people have supervised the grinding and sieving operation at headquarters to ensure compliance with required product specifications. As an experiment, from March to June, 1990, one of the marketing units was permitted to take deliveries of product directly from the village production units. Grinding quality is essential for the processing industry because certain granule sizes are required for different extrusion processes. In late 1990, one company gave an order for 9 t of granules per month. This was two and a half times as much as the previous year's total production. This order therefore placed a strain on the production units because other customers also had to be supplied. Even supplying 3 t per month is problematic because of the difficult harvest and drying season during 1991.

Loan Repayments by Units

SOTEC has, through grants for this purpose, financed the establishment of seven processing plants. This financing has been in the form of loans as often as possible. Equipment loans are for three to five years. Operating loans have to be paid back in full each year. SOTEC has not charged interest on these loans so far but plans to do so as the project plants become better established.

Recovery of loans is done at the time the product is delivered to headquarters. The estimated average production for units is calculated for the season. The cost of machinery was divided by four. One fourth of the equipment loan is divided by the estimated number of kilograms of product expected for that season. For instance if one-fourth of the cost of equipment was Rs 8,000 and the unit was expected to produce 7,000 kg of product, Rs 1.14 kg was deducted when the producers were paid for the delivered product. In the same way, the loan for potato purchases, bags, and chemicals, which had to be supplied through SOTEC, and the unit's share of transportation costs were prorated against production and deducted when they delivered their products.

Because the project is so new and so complex, SOTEC is still feeling its way. SOTEC feels it is necessary to assure that units which are being properly operated end the season with some profit including some cash in hand. When calculating the repayment schedule, the total financial picture of the unit is considered before the amount to be deducted is finalized for the season. Therefore, during 1990, the equipment repayment requirements were partially or completely put off for one year because of low production and high prices due to unseasonal rains.

Lack of Financial Sources or Reserves

Small farmers and small entrepreneurs usually do not have the financial reserves to survive without "immediate" payment for goods and services provided. Therefore, the way in which payments are made or credit provided can be critical to their economic viability. Appropriate sources of financing must be found.

Furthermore, to assure a sufficient quantity of product is available to generate an attractive market, funds have to be available early enough to enable the units to be set up and sufficient potatoes to be bought and stored. About 6-8 months lead time is needed to construct equipment and conduct training, and 6 weeks to purchase potatoes.

Project Management

Too much of the project's management has centered around one person. Job responsibilities have not been adequately defined. Management needs strengthening to allow SOTEC to grow as it should. In particular, project accounting would benefit from being contracted out to a local firm with computing capability. At present, the project's director and secretary have to spend too much time on budgeting, accounting, and reporting on accounts.

Conclusion

Village-level potato processing has potential in developing countries for a number of reasons. It raises the value added of low-priced farm produce. It utilizes an inexpensive, environmentally friendly energy source—the sun. Village-level processing is very labor-intensive. As a result, it provides employment for unskilled, underemployed rural workers at a time of the year when job opportunities are scarce. Processing and storage activities also offer an opportunity for peasant farm households to own their own business, thereby generating an alternative source of income. Village-level processing produces a tasty, versatile product at a lower than factory cost. The techniques involved in village-level potato processing can be adopted for other products, e.g., sweetpotatoes. The processes themselves and the operating procedures are easy to learn and therefore lend themselves to rapid replication. After more than five years of experience, SOTEC staff feel confident that the process and equipment are sufficiently developed to ensure profitable operation when used according to instructions. In addition, several important lessons have been learned for other individuals or institutions interested in village-level potato processing.

Lessons Learned

1. Village-level potato processing has certain basic prerequisites including: (1) a suitable drying season; (2) sufficient potatoes available at a reasonable price and time; (3) capacity to store potatoes for 2-3 months to ensure a cheap, ready supply of raw material; (4) equipment easy to operate and relatively inexpensive; (5) adequate financial support to cover losses during the development period; (6) credit to finance the costs of setting up village plants and to cover annual operating costs and on terms peasant households can meet, i.e., alternatives to real estate as collateral for loans, as well as available at the proper time and in the amounts needed; and, (7) a potential market.

2. Development—as opposed to transfer—of village-level technology takes time. Although the basic principles of potato processing are already known, the adoption of this knowledge to location-specific circumstances involves several years of applied research, experimentation, and trial and error. To see this process through requires dedicated personnel willing to remain with a project for 5-8 years.

3. Management and institutional arrangements are equally, if not more, important than purely technical bottlenecks. The latter may be solved through temporary outside support, whereas the former requires on-the-job training and coordination with

public and private organization over an extended period of time.

4. Village-level potato processing is much smaller and less technically sophisticated than factory-sized operations. An analogous comparison could be made between rustic potato storage versus storage in large, refrigerated facilities. The latter is common in northern India. The advantages of a small-scale processing unit in competing with larger operations are:

- it minimizes overheads by keeping machinery simple and reducing management costs, the units remain small enough to be handled by the villagers themselves;
- it uses family members or relatives as a significant part of the labor force thus making the income from wages as important to the plants as income from pure profits. Furthermore, family-run plants do not come under some labor and tax laws thus reducing costs;
- it markets dried chips through a coop-type association of the units so that product supplies are assured to customers from the association and only a few persons are employed for the whole year. People who want to set up large plants feel they need a year-round operation and use mechanical dryers. These result in high overheads, expensive raw materials, and processing problems which all add to high costs and limited flexibility. SOTEC plants have been able to sell product at 25-30% less than some automatic vegetable drying plants which have been established in India; and,
- it keeps the units flexible so they can extend or reduce the length of their drying season or even close down for one season with minimal losses.

5. Economic considerations—the bottom line—require continuous refinement. Each of the initial, rough, and ready estimates must be compared with actual operating costs to ensure that guidelines for future facilities are realistic. These calculations can also serve to focus improvements in economic performance in areas where the major costs are incurred (e.g. on price of raw material rather than the cost of drying racks) and to identify the scale of operation in terms of the minimum quantity of potatoes that must be processed per season to ensure profitability. Finally, economic considerations may suggest alternatives to the original project design that can facilitate diffusion of the entire package as well as adoption of particular components, e.g., storage, for those prospective users who may prefer to do so.

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Appendix Table 1. Fixed costs (Rs) of processing potatoes.

	Amount of fresh potatoes to be processed/day											
	200 kg			400 kg			600 kg			1,000 kg		
	quantity	Cost per unit	total	quantity	Cost per unit	total	quantity	Cost per unit	total	quantity	Cost per unit	total
Equipment												
1. Washer-cum-peeler	1	1,800	1,800	1	1,800	1,800	2	1,800	3,600	2	1,800	3,600
2. Tubs	6		810	7	945		12	1,620		16	2,160	
Tubs peeling	1	135	135	1	135	135	2	135	270	3	135	405
Tubs slicing	2	135	270	3	135	405	4	135	540	6	135	810
Tubs rinsing	1	135	135	1	135	135	2	135	270	2	135	270
For post blanch rinse	1	135	135	1	135	135	2	135	270	2	135	270
Chemical bath	1	135	135	1	135	135	2	135	270	3	135	405
3. Hand slicers	2	40	80	4	40	160	0	40	0	0	40	0
4. Mechanical slicers	0	0	0	0	0	0	1	1,800	1,800	1	1,800	1,800
5. Mash bags	4	22	88	5	22	110	6	22	132	8	22	176
6. Draining stands	1	50	50	1	50	50	2	50	100	2	50	100
7. Blancher with cover including masonry work	1	1,000	1,000	1	1,000	1,000	1	1,000	1,000	1	1,000	1,000
8. Drying racks with nylon nets	12	145	1,740	24	145	3,480	36	145	5,220	60	145	8,700
Total cost of equipment			5,568			7,545			13,472			17,536
Structure												
1. Scale for potatoes	0	0	0	0	0	0	0	0	0	0	0	0
2. Scale for chemicals	0	0	0	0	0	0	0	0	0	0	0	0
3. Shed for shade & night store	1	1,600	1,600	1	3,200	3,200	1	4,800	4,800	1	8,000	8,000
4. Cement & brick work	1	300	300	1	600	600	1	900	900	1	1,500	1,500
5. Shade for Spreaders	0	0	0	1	0	0	1	0	0	1	0	0
6. Drum & stand	1	150	150	1	175	175	1	200	200	1	250	250
7. Masonry tank on ground	1	250	250	1	312	312	1	375	375	1	500	500
Total cost of structure			2,300			4,287			6,275			10,250
Storage for fresh potatoes	1	500	500	1	800	800	1	1,100	1,100	1	1,800	1,800
Total fixed cost												
Equipment and structure	:		7,868			11,832			19,747			27,786
Equipment, structure, and storage	:		8,368			12,632			20,847			29,586

Source: Scott 1988.

Appendix Table 2. Variable costs (Rs) of processing potatoes for 3 month's work (90 working days).

Assumptions:

-Labor for processing: 1 supervisor (Rs 15/day) and 3, 5, 6, and 8 workers (Rs 9.5/worker/day) to 200, 400, 600, and 1,000 kg of fresh potato processed, respectively.
-Package: Ratio chips/fresh potato = 0.16 and 1 package = 0.25 g. Then for 200, 400, 600, and 1,000 kg correspond 128, 256, 384, and 640 package, respectively.
-Each 2 days, 210 packages are packed.

	Amount of fresh potatoes to be processed/day							
	200 kg		400 kg		600 kg		1000 kg	
Labor								
Processing	Rs 43.5/day x 90 days	3,915.00	Rs 62.5x90	5,625.00	Rs 72.0x90	6,480.00	Rs 91.0x90	8,190.00
Packing	Rs 9.5/day x 45 days	427.50	Rs 9.5x45x2	855.00	Rs 9.5x45x3	1,282.50	Rs 9.5x45x5	2,137.50
Package								
Plastic bag & label	Rs 0.27 x 128 pack/day x 90 days	3,110.40	Rs 0.27x256x90	6,220.80	Rs 0.27x384x90	9,331.20	Rs 0.27x640x90	15,552.00
Outer packing	Rs 0.04 x 128 pack x 90 days	460.80	Rs 0.04x256x90	921.60	Rs 0.04x384x90	1,382.40	Rs 0.04x640x90	2,304.00
Chemicals	Rs 6.0/day x 90 days	540.00	Rs 12x90	1,080.00	Rs 19x90	1,710.00	Rs 30x90	2,700.00
Coal	Rs 12.0/day x 90 days	1,080.00	Rs 17x90	1,530.00	Rs 23x90	2,070.00	Rs 32x90	2,880.00
Marketing & transportation	Rs 0.345 x 128 pack x 90 days	3,974.40	Rs 0.325x256x90	7,488.00	Rs 0.305x384x90	10,540.80	Rs 0.295x640x90	16,992.00
Others costs (miscelaneous)								
Maintenance	Rs 15.0/day x 90 days	1,350.00	Rs 25x90	2,250.00	Rs 34x90	3,060.00	Rs 43x90	3,870.00
Supplies	Rs 5.0/day x 90 days	450.00	Rs 7x90	630.00	Rs 10x90	900.00	Rs 15x90	1350.00
Rental	Rs 10.0/day x 90 days	900.00	Rs 15x90	1350.00	Rs 20x90	1800.00	Rs 40x90	3600.00
Contingency	Rs 2.0/day x 90 days	180.00	Rs 4x90	360.00	Rs 6x90	540.00	Rs 9x90	810.00
Total variable costs		16388.10		28310.40		39096.90		60385.50
Number of packages		11520		23040		34560		57600
Total variable cost/package		1.42		1.23		1.13		1.05

Source: Scott 1988.

Appendix Table 3. Economic feasablity of producing dried potato chips in packets (90 work days, 5-year credit).

Assumptions:
-Fresh potato price: Rs 60/100 kg.
-Selling price of potato chips: Rs 2.5/package of 250 g.

	Amount of fresh potatoes to be processed/day							
	200 kg 5-year credit		400 kg 5-year credit		600 kg 5-year credit		1,000 kg 5-year credit	
	1 st Year	5 th Year	1 st Year	5 th Year	1 st Year	5 th Year	1 st Year	5 th Year
Annual costs								
Fixed cost loan repayment	1,573.60	1,573.60	2,366.50	2,366.50	3,949.40	3,949.40	5,557.20	5,557.20
-Equipment	1,113.60	1,113.60	1,509.00	1,509.00	2,694.40	2,694.40	3,507.20	3,507.20
-Structure	460.00	460.00	857.50	857.50	1,255.00	1,255.00	2,050.00	2,050.00
Variable costs	27,188.10	27,188.10	49,910.40	49,910.40	71,496.90	71,496.90	114,385.50	114,385.50
-Potatoes	10,800.00	10,800.00	21,600.00	21,600.00	32,400.00	32,400.00	54,000.00	54,000.00
-Other variable costs	16,388.10	16,388.10	28,310.40	28,310.40	39,096.90	39,096.90	60,385.50	60,385.50
Interest costs	1,035.58	248.78	1,583.23	399.98	2,624.63	649.93	3,733.67	955.07
-Fixed cost 12.5%/year	983.50	196.70	1,479.06	295.81	2,468.38	493.68	3,473.25	694.65
-Operating capital	52.08	52.08	104.17	104.17	156.25	156.25	260.42	260.42
Total (1.1 + 1.2 + 1.3)	29,797.28	29,010.48	53,860.13	52,676.88	78,070.93	76,096.23	123,676.37	120,897.77
Total annual cost/package	2.59	2.52	2.34	2.29	2.26	2.20	2.15	2.10
Annual revenues	28,800.00	28,800.00	57,600.00	57,600.00	86,400.00	86,400.00	144,000.00	144,000.00
(# of Packages produced)	11520.00	11520.00	23040.00	23040.00	34560.00	34560.00	57600.00	57600.00
Annual net revenues (II-I)	-997.28	-210.48	3739.87	4923.12	8329.07	10303.77	20323.63	23102.23
Net revenues/package	-0.09	-0.02	0.16	0.21	0.24	0.30	0.35	0.40

Source: Scott 1988.

Appendix Table 4. Economic feasibility of different postharvest operations.

	Potato storage[a]		Dried, sliced potaoes[b]		Dried, sliced potatoes with storage[c]	
	66,000 kg/yr	110,000 kg/yr	600 kg/day	1,000 kg/day	600 kg/day	1,000 kg/day
Annual costs						
Fixed cost loan repayment[d]	220	360	3,949	5,557	4,169	5,917
Variable cost[e]						
- Potato	39,600	66,000	44,400	74,000	39,600	66,000
- Labor	1,045	1,045	9,488	12,623	9,488	12,623
- Others			38,298	61,182	38,298	61,182
Interest cost[f]						
- Fixed cost at 12.5%/year	138	225	2,468	3,473	2,606	3,698
- Variable cost	1,531	2,526	3,473	5,568	3,292	5,267
Total annual cost	42,534	70,156	102,076	162,403	97,452	154,687
Revenues						
- Potato	74,250[g]	123,750[g]	--	--	--	--
- Dried chips	--	--	118,349[h]	197,248[h]	118,349[h]	197,248[h]
Net revenues						
- Potato	31,716	53,594	--	--	--	--
- Dried chips	--	--	16,273	34,845	20,897	42,561

Source: *Scott 1988.*

[a]Assumptions: Only storage potato. First of five years, 110 working days. Purchase price of fresh potato: Rs 60/100 kg. Sale price of potato: Rs 125/100 kg. Annual increase for potato cost and selling price is 10%. Annual increase for other variable costs: 7.5%. Annual interest rate: 12.5%.

[b]Assumptions: Only producing dried, sliced potato. First of five years, 110 working days. Purchase price of fresh potato: Rs 60/100 kg for 70 out of 110 days, the remaining time increased at Rs 80/100 kg. Sale price of package of dried slices: Rs 2.5 for 70 out of 110 days, Rs 3.33 for the remaining 40 out of 110 days.

[c]Assumptions: Including storage fresh potato. First of five years, 110 working days. Purchase price of fresh potato: Rs 60/100 kg. Sale price of package of dried slices: Rs 2.5 for 70 out of 110 days, Rs 3.33 for the remaining 40 out of 110 days.

[d]Principal only.

[e]See Appendix Table 2.

[f]Interest formula: Fixed cost: Total fixed cost x interest rate.
Variable cost: Total variable cost x interest rate x 110 working days/365 days.

[g]Revenue calculated as follows: 66,000 kg of potatoes stored less 6,600 i.e. 10% lost to shrinkage; or, 110,000 kg of potatoes stored less 11,000 lost to shrinkage.

[h]Revenue calculated as follows:

	600 kg/day	1,000 kg/day
Chips (packages of 250 g)	42,240	70,400

Potatoes, Mixes and Soups: A Case Study of Potato Processing in Peru

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Abstract

Simple potato processing is an age-old Peruvian tradition. Present day techniques bear great resemblance to those utilized many hundreds of years ago. Recent interest in improving potato processing was spurred by production and marketing developments, particularly those concerning product development for mass consumption in urban markets. Efforts to improve traditional processing covered both products and processes. Initial work on potato drying processes gave way to experiences using potato products in mixes with other Andean products, building of a pilot plant and the introduction of appropriate, simple machines. Transfer of the technology through a rural development project resulted in a series of modifications intended to develop adequate processed products, alter plant size and design, and improve final product processing. Although the project was not replicated in its entirety for financial, technical and organizational reasons, new ideas and useful knowledge were disseminated.

Key words: postharvest technology; equipment; pilot plant; marketing; rural development organization; Peru.

Introduction

Potatoes have been processed in Peru and Bolivia for hundreds of years. This activity permits potato consumption long after harvest and facilitates their transport and exchange for other products. During the last two decades, interest in improving traditional processing techniques has grown, particularly in years of abundant supply. While potato remains a traditional part of the rural diet in many Andean countries, the vast majority of consumers have moved to the cities. Consequently, supplying urban areas with food has become an increasingly important concern; and, efforts to reduce transportation costs, as a component of marketing costs, a major priority. Furthermore, food consumption habits have changed, with processed products taking on added importance because their preparation requires less time and energy, their shelf life is longer because they are less perishable, and their utilization promoted through mass media advertising. Such activity is also seen as a way to give rural families an additional source of employment and income by expanding the market for increased potato production.

This paper analyzes attempts of several institutions at improving simple potato processing over the last 15 years in Peru. First, traditional potato products and processing techniques are briefly described. Second, efforts to improve these techniques are evaluated. The third section deals with the development of new products through mixing of potatoes with other staples. The closing section summarizes the lessons learned for those interested in developing similar projects in the future.

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The Potato in Peru

Production

Potatoes cover 10% of the total cultivated area in Peru. Only corn covers a larger area (15%). During the 1970s, average annual cultivated area was approximately 268,000 ha. In the 1980s, harvested area fell to an average 196,000 ha per year. Average annual production was 1,735,000 t in the 1970s. It fell to 1,619,000 t in the 1980s. Average yields per hectare rose from 6.5 t to 8.3 t over the same period. Despite this increase, yields remain well below the technically feasible 30 t/ha.

Potatoes are grown in all Peruvian regions. However, 95% of the potatoes are grown in the highlands (sierra). Only 4.5% are grown on the coast, and 0.5% in the Amazon jungle region (Scott 1986). In the highlands, potatoes are grown on 20% of the total planted area, compared to 17% for corn. In the central highlands, in particular in the Department of Junin, east of Lima, the capital city (Map 1) potatoes cover 48% of the total harvested area.

Potatoes are grown by small, medium, and large farmers depending on (1) area planted; (2) type of production; and (3) utilization patterns. Small farmers plant less than one ha of potatoes, in combination with other crops and mainly for home consumption. Medium-size farmers plant up to 3 ha of potatoes, generally in combination with other produce but are market-oriented. Large growers are profit-oriented and specialized in seed and ware potato production. They plant up to 100 ha. Approximately 90% of all potato growers in Peru are small farmers, 9% are medium-size farmers, and only 1% are large growers according to available estimates (Ibid.).

Due to the agroecological diversity of the country, potatoes are grown in Peru all year round. Hence, they are harvested in at least one producing area at any one time during the year. However, due to varying soil and climatic conditions of the producing areas, only potatoes from a particular area will reach Lima markets at any given time of year (Gomez and Wong 1989). For example, during the first half of the year potatoes are harvested in Junin, in the central highlands, while the harvest in Moquegua, in the south, takes place in the last quarter. This ensures a constant supply of fresh potatoes to the Lima market.

Marketing

Commercial potato production has grown in relative importance in Peru with the decline of subsistence-oriented potato cultivation as in the southern Peruvian highlands. Improvement and expansion of roads have fostered the development of regional and interregional commerce. This led in turn to an increased interest in new potato uses, products, and markets.

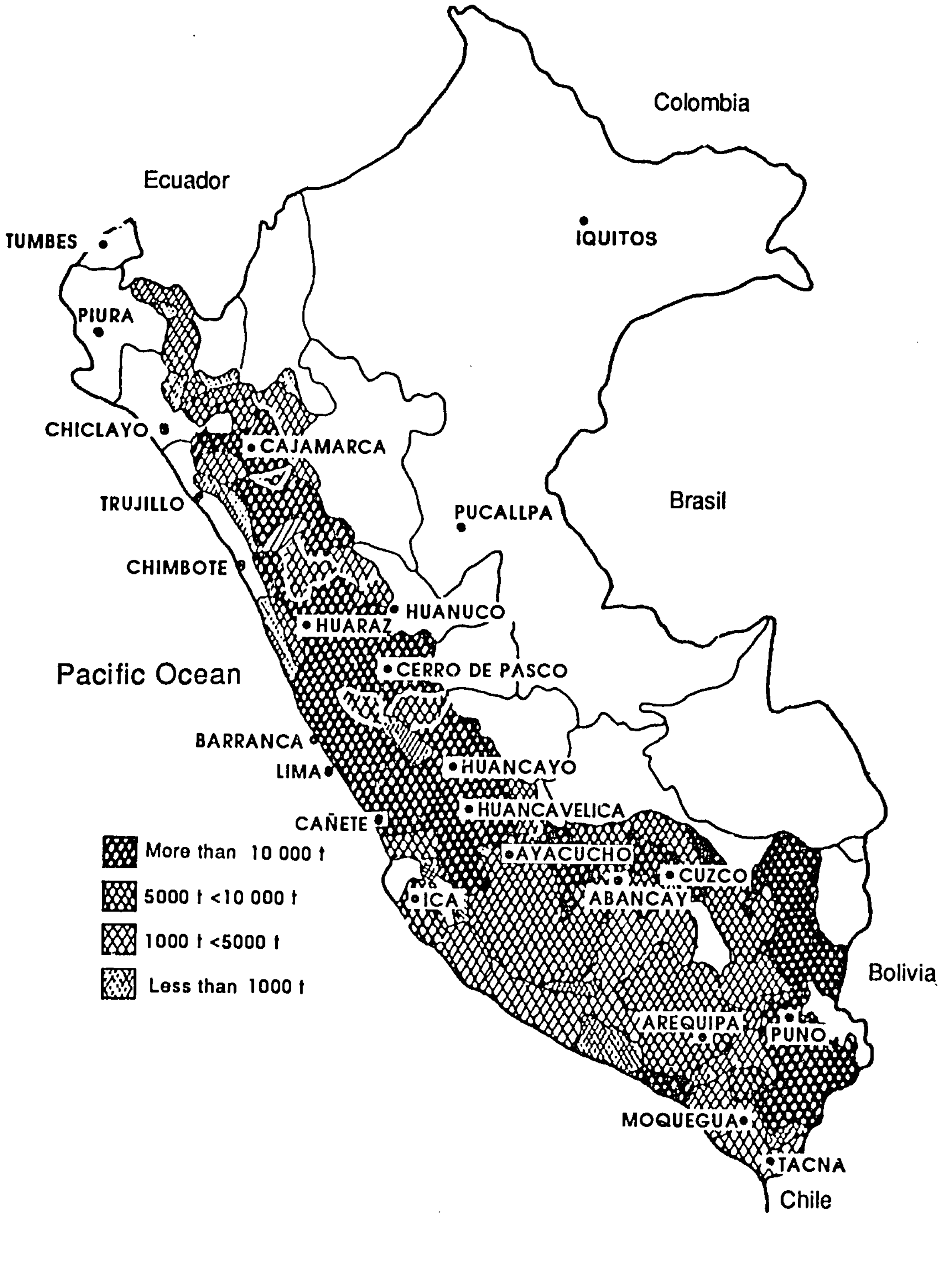
The search for new markets is also due to the peculiarities of potato marketing in Peru itself. Given the long distances from producing areas in the highlands to consumption centers on the coast, transportation costs long have been an important component of marketing margins. The relative importance of these costs has mushroomed in recent years with the sharp rise in fuel prices. Thus, processing that could shrink the large (80%) water content of the potato would reduce the depressing effect of transportation costs on farm-gate prices. Processing technologies could also help farmers manage the release of surpluses onto the market in response to favorable price movements. By using technologies to preserve potatoes when prices are low, farmers could sell potato products at a later time when prices are high.

Demographic and income changes have also spurred interest in processed potato products. Traditionally processed potatoes are an important component of the family diet in the highlands. However, these products typically are consumed on the coast only on special occasions (Werge 1979). Therefore, though there are no detailed statistics in this respect, regional variation in consumption patterns reflect the fact that traditional potato products vary greatly in quality and presentation (color, appearance, and purity) as well as price. The absence of suitable technologies to reduce water content has generally meant higher consumer prices for processed potato products in urban markets on the coast. Consequently, a potential market for inexpensive, good quality, potato products was identified contingent upon the improvement of processing technologies to produce a better and cheaper product.

Traditional Processing

Although potatoes have been processed in Peru for several hundred years, little has been written about the products and processes involved. Yamamoto (1988) argues that many contemporary scientists see these products as part of a traditional activity with little relevance to modern life.

Map 1. Peru: Location of potato production.



Source: Scott 1985.

Nevertheless, Werge (1979) identified two main reasons for the continued prevalence of traditional potato processing. One is to obtain a product from potatoes that cannot be consumed fresh. For example, bitter potatoes used to make *chuño* must be processed due to their high content of glycoalkaloids; damaged and rotten potatoes which cannot be consumed directly, must also be processed. Secondly, storage is a vital concern in areas where the potato is an important component of the diet, but where seasonality prevents uninterrupted consumption of fresh tubers. Under such circumstances, part of the potato harvest has to be processed to ensure a constant supply of food.

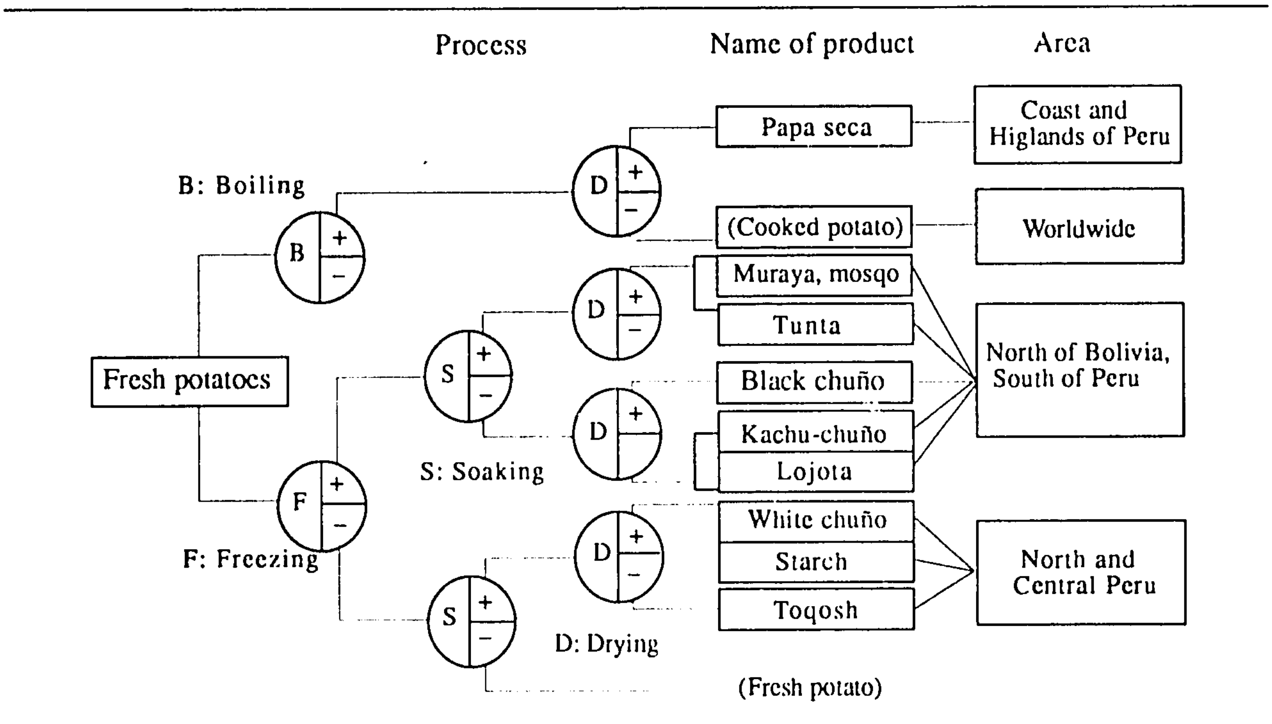
Traditional potato processing also has several important advantages over other techniques. First, these processes do not require the use of inputs other than solar energy, water, and labor (usually family labor). This fact is particularly relevant in environments like the upper Peruvian highlands (*puna*), where natural (i.e., firewood) or generated (i.e., electricity) sources of energy are scarce. Additionally, these processing techniques provide employment for family labor immediately after the harvest season when local job opportunities are scarce.

The extent of use of such technologies was revealed by a survey among a sample of 1,200 farmers in the Mantaro valley, an important potato producing area in the central highlands (Franco et al. 1979). Results of that survey showed that 33% of those interviewed were *chuño* producers, 11% produced dried potatoes and 2% produced starch.

The potato products obtained with traditional technologies listed by Yamamoto (loc. cit.) include: *lojota, kachu-chuño, tunta, moraya, mosqo-chuño, toqosh, chuño*, dried potatoes (*papa seca*), and potato starch (*almidón de papa*). However, the first six products are merely different forms of *papa seca*. Thus, only three major types of traditional processed products are made from potatoes: *chuño, papa seca*, and starch (Fig. 1).

A comparison based on the accounts found in 16th and 17th century chronicles and observations of present-day processing techniques reveals few, if any, changes. Processing of potatoes in the Peruvian highlands takes place in June and July during the night-frost season. *Lojota* and *kachu-chuño* are obtained by selection of bitter potatoes which are then frozen in the open air, thawed, ground, and cooked (Table 1). However, larger tubers must be used to obtain *chuño*. The potatoes also must be sun-dried, making the processing generally longer. *Chuño* is used in soups and porridges (*mazamorra*), and annual per capita consumption is estimated at 5-6 kg. Consumption is greatest in the rural south of

Figure 1. Potato processing in the highlands of Peru and Bolivia.



Source: Yamamoto 1988.

Table 1. Processed potato products in Peru and Bolivia.

Product	Type of potato	Time needed for processing	Storage
Lojota	Mainly bitter	1-2 days	No
Kachu-chuño	Small	1-2 days	No
Chuño	Small and medium	2 weeks	Yes
Tunta	Mainly bitter	1 month	Yes
Muraya	Damaged potatoes	1 month	Yes
Mosqo-chuño	All	3 months	Yes
Toqosh	Mainly bitter	2 weeks-1 year	Yes/No
Chuño	Not bitter	1 month	Yes
Dried potato	Not bitter	2-3 days	Yes
Starch	Not bitter	1-3 days	Yes

Source: Yamamoto 1988.

Peru (Scott 1986). *Tunta, moraya*, and *mosqo-chuño* are obtained by immersion of tubers in running water. The processing of *toqosh* does not require drying.

The processing of *papa seca* requires boiling of the chosen tubers, peeling and slicing, sun-drying and grinding into small pieces (Werge 1979). According to Benavides and Horton (1979), statistics for the 1970s reveal that production of *papa seca* was mainly in the departments of La Libertad (59%), Junin (21%), Lima (11%), and Ica (3%). Also, *papa seca* typically is used only for the preparation of a dish served on special occasions (e.g., *carapulcra*). Thus, increased consumption of *papa seca* results from simple population growth rather than higher per capita consumption.

Potato starch is obtained by mashing potatoes that are then soaked in water for several days. The water is changed regularly, and the starch precipitates. After straining with a fine mesh cloth, the starch is sun-dried. Potato starch is used as a thickener, and to make desserts and cakes.

Development of Improved Technology

First Attempts

Given the growing interest in the commercial potential of traditional potato products, and the variable time required to make them, scientists at the International Potato Center (CIP) became interested in finding faster drying methods for *papa seca*. These improvements were intended to allow producers to increase and accelerate production, diminish production costs per kg, and ensure a larger commercial supply for the one traditional processed potato product thought to have an untapped market potential. This concern led to the development of the black box technology.

The Black Box

This technology consists of a simple, black wooden box with a removable plastic lid that can be used as an improved solar drier. It was envisioned that the black box would reduce dehydration time while preserving the nutritional and culinary properties of the potato. A number of experiments were carried out in Concepcion (3,200 m) in the Mantaro valley in June and July, 1977 to compare black box performance *vis à vis* traditional drying methods. Participant farmers supplied the tubers.

The black box was tested against drying methods such as drying on jute cloth, other thin fabrics, and layers of straw. One-kilo lots of potatoes were placed in the black box and on the other drying surfaces. The samples were weighed daily to assess loss of water content until total dryness was achieved. Farmers helped to determine any noticeable differences between results obtained with the black box versus other drying methods.

Initial water loss was significant with all techniques used. However, no method showed clear superiority in drying speed. Furthermore, farmers did not perceive differences in quality amongst techniques. One negative aspect of the black box was the lack of adequate ventilation. Humidity was trapped by the plastic lid. Removal of the cover did not result in substantial improvements as compared to the other methods. Additional findings showed that tuber size was of foremost importance for all techniques employed.

More importantly, although manufacturing of *chuño* and *papa seca* was seen as highly labor-intensive, the degree of difficulty varied at different stages of the process. For example, in the case of *papa seca*, the peeling of potatoes after cooking was seen as the most labor-intensive stage of processing. The participant farmers did not consider the labor required for sun-drying of the potatoes as a constraint. Nor did they think that sun-drying was too time-consuming, or that faster drying techniques would be an important innovation.

The Muquiyauyo Experience

In a related experience, the rural community of Muquiyauyo in the Mantaro valley showed interest in reaching an agreement with the National University of Agriculture to develop large-scale production of *papa seca*. This lead to the purchase of heavy equipment and the building of appropriate infrastructure. However, these facilities were never utilized as planned due to the high market price of potatoes and the small consumer market. At the same time, factory management and coordination of technical assistance required too much dedication on the part of participant farmers. As a consequence, the plant was abandoned for all practical purposes. Scientists learned two main lessons from this experience.

First, new potato products had to be developed that would be less vulnerable to seasonal potato supply and price fluctuations. This innovation would allow the plant to operate with a continuous supply of low-cost raw material. It would also ensure a sustainable flow of finished product for interested buyers. Second, consumers should be able to use these products in more than just one way of food preparation. This marketing strategy was intended to increase utilization, per capita consumption, and the demand for processed potatoes.

The M6 Mix

Work started on the development of highly-nutritious, low-cost processed potato products using combinations or mixes of local crops as an outgrowth of the above-mentioned experience. Low income consumers were chosen as the target beneficiaries of these efforts for two reasons. CIP's mandate as a non-profit international organization calls for the center to assist less well off groups. Furthermore, these consumers are the largest segment of the local market. Gaining access to this market segment, it was reasoned, would allow larger-scale operation and, thereby, reduce unit production costs.

Plans were made to: (1) experiment with several crop mixes; (2) build a pilot plant; (3) test consumer preferences; (4) conduct marketing studies; and, (5) carry out a brief study of the economic feasibility of this type of processing.

Experimenting with Different Crops

Small farmers and potential rural processors in the highlands of Peru grow a variety of crops including *quinua*, lupine, broad beans, oats, and barley, among others. These crops were evaluated for their compatibility with potatoes, and the resulting mixes were tested for their organoleptic acceptability by consumers. The highest ranking prototypes were then evaluated for their nutritional characteristics.

The M6 mix was rated as the most acceptable. It consists of 30% fresh potato combined with rice, oats, barley, and corn flours. It can be reconstituted by adding approximately one liter of water for every 80 g of dry mix. The product then has to be boiled for 25 min until thickening to be used as a breakfast cereal, with other savoury foods, or as a dessert.

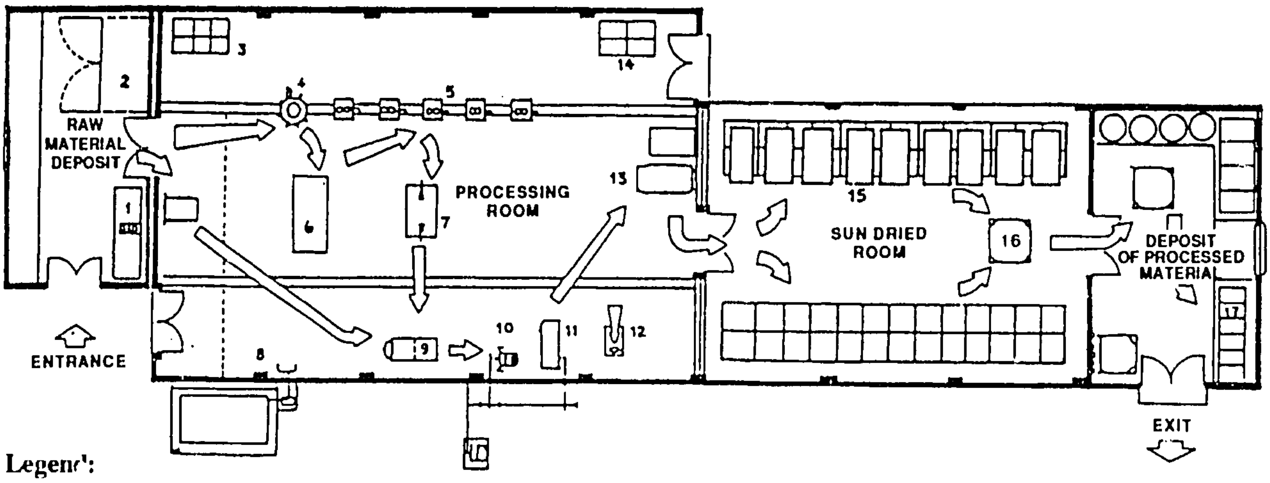
The approximate nutritional value of the mix is measured by its 10.6% protein and 333 kcal caloric content per 100 g of mix. The probable protein efficiency measure using the Food and Agricultural Organization of the United Nations (FAO)/World Health Organization (WHO) method is 86%, compared to 82%, 70% and 41% for potato, rice, and broad beans, respectively.

The Pilot Plant

A pilot processing plant was built at the CIP's high altitude experiment station outside the city of Huancayo. Construction work concluded in July 1984. The facilities include a drying area with a capacity to process 1 t of M6 per week. The processing plant itself includes four main components: (1) a reception and storage area for potatoes and other supplies; (2) a processing unit; (3) a drying chamber; and, (4) a finished product store (Fig. 2).

Processing unit. The processing unit is 14.35 m long and 9.78 m wide. The walls are made with local materials, i. e., eucalyptus boards and trunks. Two drainage ditches on the cement floor allow easy cleaning of the facilities. The aluminium sheet metal roof has a few fiberglass-covered openings for lighting above the work areas.

Figure 2. Processing plant and work flow chart.



Legend:

1. Platform scale
2. Closet
3. Closet for pots and plastic ware
4. Potato peeler
5. Kerosene stove
6. Inspection table
7. Press
8. Water source
9. Mixer
10. Masher
11. Strainer
12. Hammer mill
13. Cart conveyor
14. Dry box closet
15. Drying shelves
16. Fiberglass deposit
17. Sacks with finished product

Source: Booth et al. 1986.

Drying chamber. The solar energy collector in the drying chamber is made of eucalyptus boards and mud bricks (adobe). The ceiling and the north wall are covered with no. 14 plastic (PVC) conduit pipe. The floor is polished cement, and the walls and floor are painted black for greater solar heat absorption. The remaining walls have six windows 0.5 m above the floor for improved ventilation and an air extractor helps remove saturated air. In the drying chamber, two metal racks at each end of the drier are used to place trays with the homogenized, humid mix ready for drying.

Equipment

The location of the processing equipment in the plant is depicted in Figure 2. The equipment includes the following.

Peeler. The mechanical peeler is a galvanized metal drum with a rotating bottom. The abrasive surfaces inside the drum help remove the peel. The peeler's approximate capacity is 300 kg of peeled potatoes per hour and it is powered by a 1.8 hp, 220 volt electric motor with a 1.32 kw/hour energy consumption.

Inspection table. Inspection and rectification of peeled potatoes is carried out on this 2 x 1 m table. Two workers on each side of the table perform potato inspection while 0.10 m sidewalls prevent potatoes from falling off the table. A formica sheet tabletop allows easy cleaning.

Cooking pots. Cooking is made in 40-liter aluminium drums with two side-handles for easy manipulation.

Stove. The steel angle bar stove is 0.5 x 0.5 m^2 and 0.6 m high, and is provided with two kerosene burners, a kerosene tank, and a pump. Fuel consumption is 800 cm^3 per hour.

Potato grinder. The grinder is a drum with a helix axle, a rotating knife, and a perforated disc. An external hand crank allows to operate the grinder manually. The disc has 3 mm holes. Output is about 75 kg of potatoes per hour.

Mixer. The stainless steel mixer has a double mixing helix along the rectangular body. At the bottom a dispenser allows to empty the container. The mixer rests on four steel legs and is driven by a 2.4 hp, 220 volt electric motor. Capacity is 50-100 kg at a time, and ideal mixing time is half a min.

Masher. The work surface of the potato masher is made of a circular cutting dish to which the product is sent through a funnel. The material is mashed by the rotation of the dish and sent to the bottom. Capacity is 200 kg/hour and the machine is driven by a 11 hp oil engine. Oil consumption is 900 cc per hour.

Processing

The production of mixes involves a simple process (Fig. 3). The potatoes are boiled and mashed. Cereal and legume flours are then added to the humid potato mash.

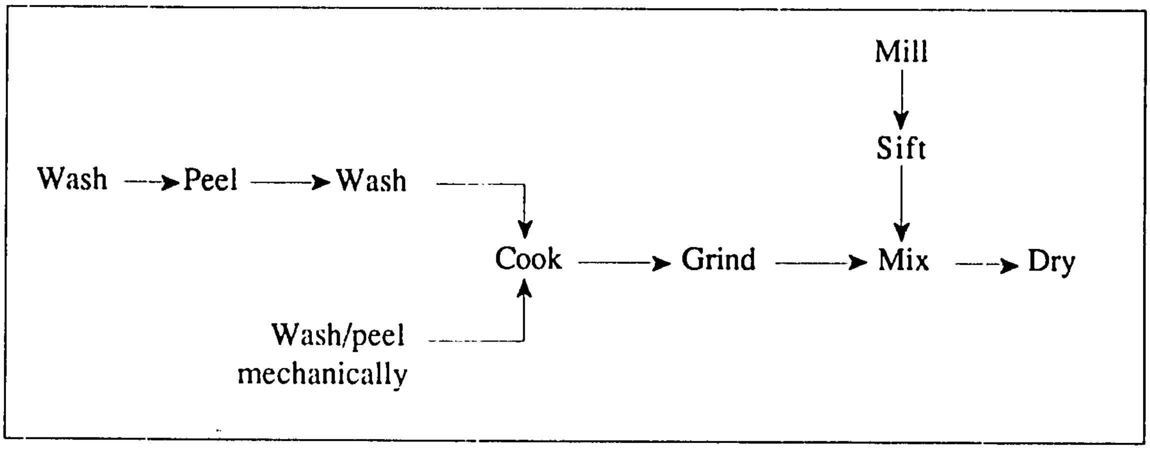
The humidity of the potato mash is transferred to the mix thus making drying easier. Drying can be by solar radiation or artificial means though at a higher cost. The approximate quantities o. raw material and processed raw material appear in Table 2.

The processing plant designed for this project had a 1 to 2.5 t operating capacity. One ton of the processed product yields 50,000, 20 g or 250 ml rations of rehydrated mix which can feed 396 six-member families three times a day for a week.

After harvest, the potatoes are stored at approximately 12°C. Processing takes place once tubers have been selected and bad tubers discarded.

Washing and peeling. Dirt and other foreign matter must be washed away from tubers. Peeling is made with a peeling machine with a 0.5 m^3/hr water jet. The undulating bottom turns and pushes the potatoes against the abrasive walls, and makes the potatoes rub against each other. The resulting softening of the skin makes the dirt and the skin fall off the tubers to the bottom where they are then removed by the water jet. Tubers not properly peeled are rectified by hand. Maximum peeling capacity of the machine is 300 kg/hr and energy consumption is 1.324 kw/hr. Chemical peeling with sodium hydroxide (caustic soda) may also be used.

Figure 3. Flow diagram for production of M6, 1-2.5 t per week.



Source: Booth et al. 1986.

Table 2. Input requirements (kg) per 100 kg of M6.

Raw material	Potato	Rice	Broad beans	Oats	Barley	Corn	Salt
Requirements	170	17	21	21	23	12.5	4

Processed Raw material	Potato mash	Flours					
		Rice	Broad beans	Oats	Barley	Corn	Salt
Requirements	120	16	16	16	16	12	4

Source: CIP.

Cooking. Washed and peeled tubers are placed in 40 kg-capacity pots. It is advisable to place the potatoes in 15 liters of boiling water at the most. Total cooking time depends on the variety of potatoes though usually a mix of varieties will require, on average, 2 hrs for a maximum 40 kg-capacity pot.

Grinding. This is performed manually using two meat grinders.

Mixing. Cereal and legume flours are mixed with the potato mash as follows: (1) 60% humid potato mash; (2) 8% broad bean flour; (3) 8% rice flour; (4) 8% oat flour; (5) 6% corn flour; (6) 8% barley flour; and, (7) 2% salt. The ingredients are homogenized in the mixer.

Shredding. After mixing the product is shredded into 1-2 mm granules for easy drying.

Drying. The fine mix is placed on wooden trays at a rate of 5 kg/m^2 for 52% average humidity of the mix. The trays are placed on metal shelves in the drying chamber. Temperature in the chamber is 40°C, average ambient humidity is 30% and wind speed is 0.4 m/sec. The plant has a 500 kg drying capacity and an output of 250 kg of M6 mix every 48 hrs.

Consumer Acceptability Tests

As part of the evaluation of the potential product, 1,000 consumers were asked to taste the mix. After a demonstration, they received a half kilo of the mix. The mix also was consumed for a whole year at a community restaurant (*comedor popular*) in a low-income neighborhood in Huancayo. Results of both tests showed good consumer acceptability (Booth et al. 1986).

Other consumer acceptability tests were carried out at 12, low-income municipalities (*pueblos jóvenes*) in Lima; for two years at the low-income restaurant "*Señor de los Milagros*" also in the capital, and with 2,000 school children in the central highlands for two months. These consumers reported that the product's taste and texture were highly acceptable (Table 3). Acceptance among sample homemakers was increased by the product's high nutritional content.

Table 3. M6 consumer acceptability tests.

Location	Use of M6	Result
Universidad Nacional de Ingeniería -Lima restaurant (1,800 people)	beef stew (thickener)	good
	carapulcra (side dish)	good
	fish stew (thickener)	bad
Low-income restaurant Ate Vitarte (900 people)	chicken stew (thickener)	good
	carapulcra (side dish)	good
	noodle soup (thickener)	good
	vegetable soup (substitute)	good
	cream soup (substitute)	good
	milk drink (substitute)	good
	beef stew (thickener)	good
	beef soup (substitute)	bad
Low-income restaurant Lurigancho (350 people)	chicken stew	good
	cream soup	good
	drink	
Low-income restaurant 130 people	cream soup (substitute)	good
	porridge (substitute)	good
University of Cajamarca (800 people)	drink (complement)	good
	fritters (complement)	good
	porridge (substitute)	good

Source: Centro de IDEAS.

Socioeconomic Feasibility

Analysis of the economic feasibility of the mix assumed an investment of US$ 15,000 to be financed by a loan at an annual interest rate of 12.5%. This investment excluded the cost of the land. The proposed selling price for the M6 was set at US$ 1.00. Approximate production costs were estimated at US$ 0.60, depending on production levels. However, calculations done for the feasibility study were intuitive.

An anthropological study of food consumption habits in shanty towns around Lima aimed at assessing the possibility of including M6 in the daily diet of low income consumers (Benavides and Rhoades 1987). Results of that study showed that processed products are relatively expensive, and underscored the skepticism prevalent among some CIP scientists as to the real potential of M6 for this group of consumers. Others argued these findings were too pessimistic. Meanwhile, the process was refined and arrangements made for commercial testing by transfer of the technology to a local, non-governmental organization, the *Centro de Investigación, Documentación, Educación, Asesoramiento y Servicios* (*IDEAS*).

Transfer of Technology

Centro de IDEAS is a private research and development organization devoted to the improvement of living standards among low income urban dwellers, and the development of agricultural and handicraft production. These efforts take into consideration the conservation of natural resources, national food security, and the use of integrated development policies.

Since its inception, *Centro de IDEAS* has placed great emphasis on rural development by making alternative policy proposals to increase productivity and production, develop alternative agricultural technologies, foster the efficient utilization of natural resources, and support grassroots organizations. In its search for new challenges, *Centro de IDEAS* chose to promote the development of agroindustry. This led to a growing interest in processing to increase agricultural value-added and open new markets. The Agroindustry Program therefore was created in 1985 to develop solutions to rural problems.

The Centro de IDEAS Project

By 1985, the Agroindustry Program at *Centro de IDEAS* proposed a project to build four small plants for processing potatoes and Andean cereals. The project's goal was to test the technical and economic feasibility of rural agroindustry. The project was funded by a U.S.-based, non-governmental organization, Appropriate Technology International (ATI). CIP scientists helped *Centro de IDEAS* staff prepare project documentation and establish links with ATI.

The proposed project had four objectives:

- Introduce small-scale technology suitable to rural areas that would be profitable and could be replicated elsewhere;
- Process highly nutritious and cheap potato products for low-income consumers;
- Increase small farmer income by creating a new market for excess potato supplies; and,
- Establish a rural simple processing training center for low income people.

This experience went through five stages: assimilation; development; investment; implementation; and, replication and impact.

Assimilation of CIP Technology

The above-mentioned Industria de Derivados Alimenticios del Agro (IDEAGRO) project was implemented in the framework of *Centro de IDEAS* principles, i.e, an orientation toward low-income people and possibility of replication by other enterprises. The project included an engineering study based on CIP's design, a basic financial analysis, and a market study.

CIP's initial process and equipment design was accepted, although it did not include technical specifications for the processing of cereal and legume flours. A second drying chamber was added, and plant capacity was expanded to 9.6 t from the original 4 t.

IDEAGRO proposed a simple organization in which *Centro de IDEAS* would be the owner and set the general policies, while IDEAGRO would be the project operator with a capacity to make autonomous decisions on sales, supplies, production, and other matters. Project staff included an industrial engineer or a food technician, an administrator, a plant manager, a secretary-sales assistant, and eight factory workers. Sales personnel were not included. The project did not take into consideration accounting and managerial aspects of the operation. It overlooked legal requirements as well (e.g., building and municipal authorizations, sanitary and quality control regulations, and registration of trademarks).

One pilot plant was to be built in Huancayo and three others in Puno, Cajamarca and Piura. Investment for the first plant was estimated at US$ 33,833. This included US$ 8,750 for equipment, US$ 7,000 for land, and US$ 18,083 for construction. Working capital was estimated at US$ 10,000. The investment was higher than originally planned by CIP because it included the cost of land, buildings, a hammer mill and a large-capacity potato press.

The most optimistic cost and return estimates assumed growing sales, constant positive margins of around US$ 0.22 (at a product price of US$ 0.86 and variable costs of US$ 0.64), and no price distortions. More realistic estimates showed negative net income. *Centro de IDEAS* considered that given the experimental and training nature of the project, optimism should prevail.

The marketing study complemented work already done by social scientists at CIP, though with slightly different results. Consumer acceptability tests were carried out at student cafeterias at the Universidad Nacional de Ingeniería in Lima (UNI-Lima) and the University of Cajamarca, as well as at low-income restaurants in the Lima districts of Ate, Vitarte, and Lurigancho. Although responses were generally favorable, negative comments pointed to a smell of oil, or a disagreeable smell in the food; rancid or bitter taste; and poor yield and bad thickening qualities of the product. IDEAGRO issued recommendations to improve the product in all three respects.

The marketing strategy proposed by *Centro de IDEAS* emphasized sales in Huancayo, in the Mantaro valley, and to state institutions such as schools and restaurants for low-income consumers through public sector contracts. The reasons for this strategy were two-fold. These sectors constitute the largest share of a potential consumer market. This segment of population was in most urgent need of food assistance.

Development of New Products

Project strategy changed radically after six months. Some underlying assumptions associated with M6 product came under criticism. Initially, the product did not suit consumer tastes. Introducing the product to the market would imply heavy promotional expenses. Finally, the product could not compete in price with other processed products (i.e., those made with imported wheat). For these reasons, among others, new time-saving, quality products were to be developed. Marketing efforts shifted from the countryside to big cities. Production at the plant was to be increased from 9.6 to 16 t.

The decision to increase production was based mainly on financial considerations. The price of M6 could not be significantly increased as it was directed to low-income consumers. However, escalating costs reduced project profitability (net profit/sales) from 28.2% to 2.81%. Higher prices could be charged for the new products since they were aimed at higher-income consumers thereby allowing profits to rise to previous levels (23.5%). Maintaining the initial strategy would have led to a default on loans.

The M6 mix became M5. This product is made of potato, rice, peas, barley, and corn. The marketing strategy required that all ingredients be precooked. Oats were not used due to supply difficulties, and peas replaced broad beans to eliminate the slightly bitter after taste. Cooking time for the new mix was reduced from 25 to 15 min.

Versatility was still considered one of the product's main features. However, what was initially perceived as an advantage, gradually became a problem because potential consumers did not clearly identify the product with any specific use. This, in turn, created marketing difficulties as the product did not fit easily into existing food consumption patterns. Changes introduced in the mix did not contribute to overcome this difficulty. However, other product characteristics, such as ease of preparation and high protein content, were regarded as highly desirable.

Market surveys indicated that consumers objected to the size of the granules and the undefined taste of the mix. Thus, rice flour was removed to eliminate roughness. A new mix M4 (*Ricarina*) resulted from new product testing made possible by the use of CIP's plant. M4 was made with precooked potato, corn, barley, and pea flours. Another product (*Chicolac*) was developed. It consists of potatoes, corn, milk, sugar, and chocolate (Table 4). New products (split, precooked peas and broad beans; pea and broad bean powdered soups; peeled barley and wheat; quality *papa seca*; potato powdered soup and potato semolina) were also developed and introduced in well-known regional markets (Huancayo).

The process of experimentation and new product development was accompanied by an evolution in project goals. Gradually, the improvement of living standards among the poor, peasant productivity levels, and rural food security received lower priority. Instead, the project increasingly focused on profitability and the need for self-financing to sustain operation.

Table 4. Transformations of the M6 mix.

Stage	Name of Product	Ingredients
First	M6	potato (30%) barley (14%) corn (14%) rice (14%) broad beans (14%) oats (14%)
Second	M4 (*Ricarina*)	potato barley corn peas
Third	*Chicolac*	potato (4%) corn (70%) milk (18) sugar (4%) chocolate powder (4%)

Source: Centro de IDEAS.

IDEAGRO eventually implemented three product lines: potatoes, cereals and legumes, and complementary production lines. Potato processing technologies included peeling, cutting, cooking, drying, grinding, and straining. Techniques for cereals included cleaning and selection, roasting, peeling, ventilation, grinding, and screening. Complementary production techniques included mixing, dosage, sealing, and packaging.

Potato processing required the use of peelers, [illegible]m cookers, solar drying chambers, fuel drying cha[illegible]ers, and mills. Cereal processing required stone removers, roasters, wheat peelers, fans, stone mills, hammer mills, and screens for straining. Complementary processing used mixers, dosers, and seal packers.

The new products and processes required a 540 m^2 area for facilities. Additional potato processing equipment consisted of a brick and cement solar drier to replace the rustic CIP design; a fuel drier; steam cookers to replace the kerosene stoves; and, a stainless steel cutter. Additional equipment for the processing of other grains were a sorting machine with interchangeable screens, a roaster, and a hammer mill.

Investments

Plant modifications to accommodate the expanded line the products meant the required investments almost doubled from US$ 43,833 to US$ 97,115. Higher costs accounted for 57% of the additional investment; only 43% was due to larger plant size and new processes. Higher costs resulted from exchange rate control measures, an undervalued currency, and hyperinflation. As a consequence of these budgetary changes, working capital fell as a percentage of the total investment. This became a progressively mor[illegible] severe problem.

Direct investments in the IDEAGRO project were estimated at US$ 162,451 of which US$ 97,116 were supplied by ATI and the rest by a loan from the *Banco Industrial del Perú* (Peruvian Industrial Bank). This amount did not include personal services, such as those provided free of charge by CIP scientists and *Centro de IDEAS* staff members.

ATI funds for *Centro de IDEAS* were loaned to IDEAGRO. Repayment of the loan would go towards a revolving fund to finance other enterprises wishing to replicate the experience. In fact, IDEAGRO would pay a negative interest rate and thus make a financial profit. However, by June 1989, the revolving fund amounted to only US$ 7,609 out of total funds of US$ 97,116 provided by ATI. This partly reflected the economic crisis the country as a whole was experiencing.

IDEAGRO was started at a critical time. From 1986 to 1989, Peru's Gross Domestic Product (GDP) fell at a 9% annual rate. A 26% negative growth rate was registered in 1988 alone. The September 1988 economic crisis and government's adjustment measures coincided with the begin[illegible]ng of IDEAGRO's financial difficulties. Although the agricultural sector grew at a 12% annual rate during those same four years, this was achieved through an artificial increase of purchasing power financed by the depletion of the country's foreign currency reserves.

Price distortions due to inflation generated variations in product terms of trade, particularly after 1988 when annual inflation skyrocketed to over 1,700%. Prices for tubers, other vegetables, legumes and wheat—all inputs or substitutes for IDEAGRO's products—were considerably affected. For example, the price index for the first nine months of 1988 rose faster for wheat than for potatoes (118% to 100%). During 1989, the price index for potatoes shot up while wheat showed little change (135% for potatoes and 101% for wheat).

The real monthly interest rate charged [illegible] banks was approximately 2% as a result of rapidly acc[illegible]arating inflation. This led to a decrease of the real worth of credit funds during those years. The agricultural sector was also subjected to massive imports of staples (wheat and rice), subsidized fertilizer prices, a severe drought at the end of 1989, and agricultural support prices. Ironically, these support prices did not benefit IDEAGRO; rather, they contributed to unstable input prices.

Marketing

IDEAGRO's marketing strategy must be analyzed bearing in mind the meager information available on prices, consumer tastes and preferences, marketing channels, advertising, and sales for the above-mentioned products.

Prices. Data are available only for *papa seca*. Prices vary depending on the segment of the market where the product is sold. The better quality—including more attractive packaging, of IDEAGRO's *papa seca* resulted in higher prices, when compared to prices at Lima's municipal markets and small retail stores. In supermarkets, IDEAGRO's *papa seca* competed directly with expensive "Sureña" and slightly cheaper "Dieprosa" *papa seca*.

Consumer tastes and preference. Gomez and Wong (1987) examined tastes and preferences for *chuño, papa seca*, a potato powder to make a creamy soups and semolina. Their study asked 199 high-, middle-, and low-income Lima consumers their opinion about *papa seca, chuño*, and imported potato flakes. Questions included product awareness, quantities purchased, frequency of and reasons for buying, preferences, and potential substitutes. All three types of consumers are aware of *papa seca*. Those products are consumed by 70% of the high-income consumers and 90% of the middle- and low-income consumers. However, high-income consumers buy dried potatoes occasionally (once a month or less); middle-income consumers buy them every 15 days, while low-income consumers may buy potatoes weekly.

Stated reasons for buying *papa seca* products are their filling flavor, nutritious value, good taste, and habit. Negative considerations include dirt and foreign matter found in the contents, bitterness and granule size (too large or too small). Potential substitutes for *papa seca* are beans, lentils, and split peas. IDEAGRO's products had not yet been introduced at the time of the survey, but they are free of these negative characteristics.

Survey data for imported potatoes flakes can shed some light on consumer opinions about potato powder to make creamy soups. Potato flakes were known to 100%, 80%, and 70% of the high-, middle-, and low-income consumers, respectively. However, only 80%, 50% and 30% of the corresponding consumer groups bought the product. Frequency of purchase ranged from occasionally for the low-income buyers, to weekly for middle-income consumers, to at least once a month for high-income households. Ease of preparation, good taste, nutritional value and high yield were among the reasons mentioned for buying imported potato flakes. While IDEAGRO's potato powder seems to have too strong a taste for Lima consumers, the imported product was considered too acidic. Home-made mashed potatoes, rice, and mashed sweetpotatoes were mentioned as substitutes for potato flakes.

Marketing channels. With the shift in market orientation towards high-income consumers, IDEAGRO's marketing channels became narrower. Initially each segment of the market was to be reached through a specific marketing channel. The municipal milk distribution program in Huancayo was to serve as an outlet for low-income consumers. Small retail stores in Huancayo were to sell these products to middle-income groups. Supermarket chains were the marketing outlet chosen for high income, Lima consumers. By the end of 1989, IDEAGRO's marketing efforts concentrated just on Lima's high-income consumers. In this regard, one supermarket sales manager stated that IDEAGRO's products ranked better in terms of product quality, packaging, presentation, and price than those of their competitors. However, he thought that these products were for low-income householders and consumers from the highlands, i.e., the types of buyers who were not among the supermarket's target public.

Advertising. *Papa seca, chuño*, potato powder to make soups, and other products (roasted split peas and broad beans, pea and broad bean cream soup, and peeled barley and wheat) are marketed by IDEAGRO under the "*Abril*" brand name. Significant impact and consumer acceptance were achieved for the *Abril* brand through sales promotions in supermarkets. *Chicolac* demonstrations were made for officials in charge of the Huancayo milk program. At the Huancayo agricultural fair, IDEAGRO's products won first prize in the agroindustrial category.

Poor sales were considered to be the result of insufficient knowledge among homemakers of the ways to use *Abril* products. This in turn led to the preparation of recipe leaflets for distribution in shops.

Sales. Gomez and Wong (1987) estimated the potential size of the Lima market at 113 t of *papa seca* and 7 t of potato flakes per month. IDEAGRO's average monthly sales from January 1988 to June 1989 were 8.17 t (Table 5).

Table 5. IDEAGRO production and sales, 1988-89.

Year	Month	Production (t/mo)	Sales
1988	Jan	1.50	1.51
	Feb	4.50	4.51
	Mar	5.70	5.77
	April	4.30	2.06
	May	12.40	5.59
	June	18.70	15.18
	July	15.00	12.63
	Aug	21.20	22.86
	Sept	13.90	10.97
	Oct	5.70	8.47
	Nov	18.70	11.17
	Dec	18.30	1.20
1989	Jan	13.86	
	Feb	2.43	
	Mar	6.68	
	April	8.58	
	May	7.45	
	June	6.19	
Average		11.66	8.17

Source: Seminario 1989.

Data supplied by a high income, supermarket chain on sales and shopping frequency for *papa seca*, potato powder and semolina in August 1990 may be used to estimate total sales. This supermarket chain buys 600 to 800 half-kilo bags of *papa seca* per week, i.e., approximately 1.6 t/mo, showing an increase from the average monthly buying volume of 0.5 t in 1987. However, IDEAGRO supplied only 80 to 100 bags, or 12% of these purchases. Due to political difficulties in the central highlands in 1989, IDEAGRO adopted a lower profile which contributed to a decline in sales and a loss of market share. Weekly potato powder and semolina purchases by the supermarket consequently fell to 50 half-kilo bags for each product, i.e., 0.1 t/mo per product.

Average monthly production was approximately 12 t. This figure rises to 15 t per month if the first four months of 1988 are excluded (Table 5), thus revealing that plant capacity was underutilized by about 50%.

Management

IDEAGRO also suffered from management problems. When decisions were required at critical times, *Centro de IDEAS* staff procrastinated. This was partly a function of how each viewed the project. While *Centro de IDEAS* personnel assumed an educational posture, IDEAGRO's management was profit-oriented. One IDEAGRO management member felt that the main problem was the simultaneous holding of top-level positions by some staffers at both institutions. This amplified the differences in goals and strategies in the two organizations.

From May to December 1988, the plant employed 30 workers mostly under Government-sponsored, emergency employment work contracts (*Programa de Empleo de Emergencia*). Two other workers were in charge of marketing and distribution. By the second quarter of 1990, only six workers were left.

According to one of the members of the board of directors and the manager of the company, the project never reached profitability. However, only financial aspects of the project can be analyzed. The lack of reliable data is due partly to inflation-induced price distortions and the absence of adequate reporting during the time of operation. IDEAGRO's profits were made possible only thanks to the ATI loan in local currency. The interest rate for this loan eventually fell below the inflation rate, thus allowing the operation to show a financial profit on paper.

Three factors prevented profitability in an operational sense. First, money was lost by giving credit to customers, i.e., delays in canceling accounts payable meant IDEAGRO had to assume the loss associated with rampant inflation. Next, salaries were paid even when the plant was not in operation. Finally, prices for IDEAGRO's products were not increased at the same rate as other prices.

The company was unable to honor its short-term debt for several reasons. First, investments in fixed assets absorbed most (75%) of the company's total assets. In similar businesses in Peru, this percentage rarely exceeds 25% thereby leaving considerable working capital. Some capital was also used to supply credit to customers. However, as payments by customers took up to two months, these company funds were unavailable to run (or expand) the operation.

Replication and Impact

The processing facilities have not been replicated to date. Farmers, in particular, showed little interest in plant replication. According to IDEAGRO staff, this was foreseeable from the outset since the project was originally conceived as a pilot program, leaving ample room for experimentation with different processes, products, and markets. However, replication was neither directed nor institutionally oriented. It was rather the result of a "trickle-down effect."

The experience was successful in the dissemination and partial replication of equipment, processes, products and marketing strategies by processors, equipment manufacturers, and retailers. The scale of operations at the *Centro de IDEAS* facility made it an interesting alternative for small entrepreneurs with the resources and managerial skills to start a business and adopt innovations. Thus, at least five companies copied IDEAGRO's product presentation and marketing strategies. Three of these companies now supply the same supermarkets where IDEAGRO first sold its processed products.

As an outgrowth of the project, wholesalers were forced to improve their quality control procedures and adopt sales strategies depending on prospects in different segments of the market. Potential plant, process, and product replication by farmers was made easier in that new products were already being marketed. Equipment manufacturers who built machines for IDEAGRO benefited from the experience acquired through manufacturing improved hammer mills. This type of impact stopped when the technology development process was interrupted. However, in early 1992 IDEAGRO's plant was again operating. This time with purchasing orders from the local affiliate of an international relief organization to produce more processed product than current capacity permits. Requests for information about village-level processing also have sprung up again.

Lessons Learned

The experience with potato processing in Peru generated lessons in three broad areas: (1) technology; (2) marketing; and, (3) finance and management.

Technology

1. Actual improvements of existing technologies require time not only for the transfer of the presumed improvements but also to develop new processes and products that will respond to changing market conditions. Some scientists assumed that the development of the M6 mix and the construction of the plant would mean the technology was ready to use (Seminario 1989). IDEAGRO's experience shows that a long road lay ahead.

2. More technical work was required because the receivers of the technology did not possess industrial production experience, nor did the transferring agents have much experience in this domain.

3. The original design was for a small-scale plant. However, such scale of operations proved unprofitable. Consequently, utmost care must be put in the consideration of both economic and technical requirements for appropiate plant-size (Alvarez 1990).

4. Although technological aspects are important in this kind of project, they must not become an absolute priority and impede consideration of other factors.

Marketing

5. Initially the project included only potato products, e.g., *papa seca, chuño*. Later mixes (e.g., M6) were developed in which the potato was the most important ingredient. In the last stage of the project, potatoes were only a minor ingredient in the processed products (*Chicolac*) being produced and marketed. These modifications became necessary as changes in the price and availability of potatoes meant that potato mixes and potato powder for soups could not compete with other low-price, processed products. However, a huge market exists for some processed potato products as evidenced the growing demand in Peru for french fries and chips. The black box, M6, and IDEAGRO all started with production of the product followed by efforts to sell it. All three experiences point to the strategic importance of thinking about the marketing aspect first. Product characteristics and the target market segment as well as sources of inputs and marketing channels of processed products must be clearly identified at the outset.

6. Market segmentation poses an additional challenge. In the case of IDEAGRO, three products aimed at three different groups of consumers were introduced, though emphasis was placed on the lower end of the income scale. This proved too ambitious. Projects probably need to concentrate at least initially on one product for one segment of the market.

Priority needs to be given to the product capable of generating enough profits to get the business going.

7. IDEAGRO also attempted to influence the supply-side of the process. Procurement of raw material was done directly from producers, not from established wholesalers. Experience later showed that this meant higher costs and unstable supplies (Alvarez 1990). The plant was built in a farming area to be closer to producers. IDEAGRO staff later found that easy access to markets, marketing facilities (e.g., the Huancayo wholesale market), and channels were much more effective for procuring supplies.

8. A marketing program needs to include not only buying and selling activities but also advertising, package design, and quality control.

9. The IDEAGRO experience also shows that consumers' perceived needs play an important role in product development. For example, the M6 mix had versatility as one of its main attributes. However, this led to confusion among consumers who could not assign it any specific, clearly defined use.

Finance and Management

10. Credit was not a problem for IDEAGRO, but heavy investments in plant and equipment generated cash flow difficulties. More realistic cost and cash flow estimates would have helped anticipate, and thereby overcome, this problem.

11. The cost of customer credit was high. More importantly, it was not taken into consideration when capital requirements for operating the plant were estimated.

12. It was not easy for a non-profit organization to compete with other well-established businesses. Although IDEAGRO eventually adapted to market competition, the project would have benefited from a priori consideration of this fact by the clear separation of responsibilities and staff between IDEAGRO and *Centro de IDEAS*.

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Appendices

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A Note on Writing Research Reports

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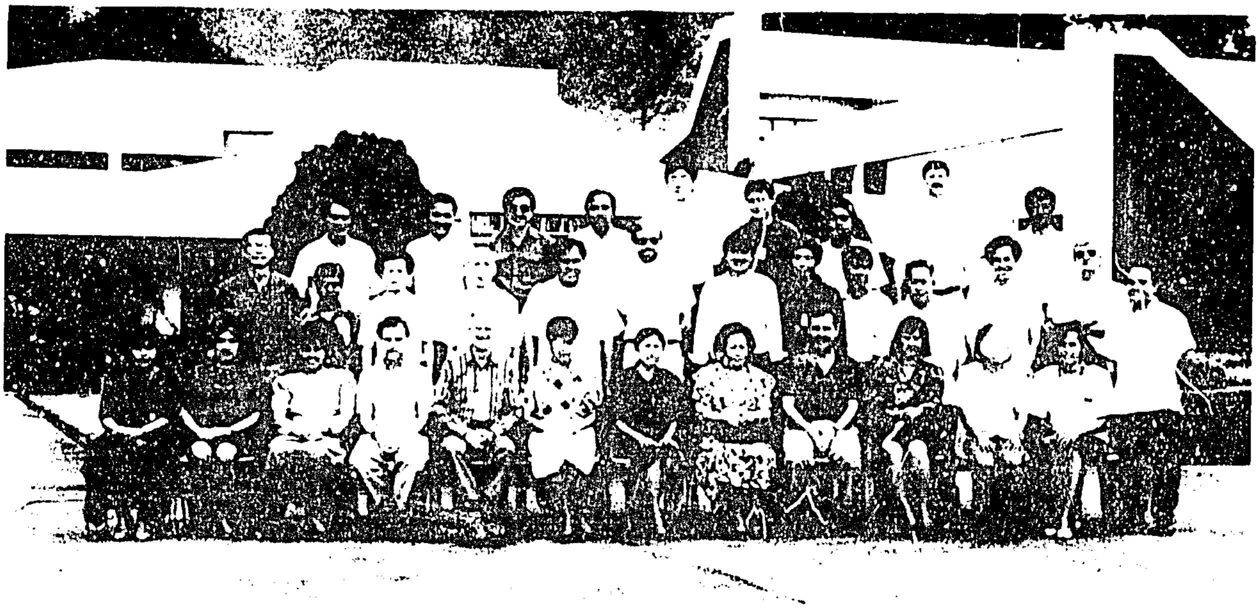

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The Three "R's" of Writing a Research Report: Getting It Written, Getting It Right, Getting It Read

Gregory J. Scott[1]

Abstract

Many researchers often find it easier to collect and analyze data than to synthesize their findings in a research report. This paper provides some practical suggestions on how to make the report writing exercise less tedious and the final product more effective. Examples are frequently cited based on the author's own experience or procedures of others as gleaned from the literature. Key elements emphasized in the paper are planning, and breaking larger tasks into more doable endeavors. A checklist of questions for effective report writing is included in a supplement.

Key words: writing, research report, planning, procedures.

Introduction

Most agricultural research projects are judged on the basis of methods, findings, and recommendations presented in a written report. Few people have time to go to the field to review procedures, to re-analyze data collected or to talk to researchers about results. Despite the importance of preparing a well-written report for the success of applied agricultural research, the literature has emphasized instead the theoretical or conceptual underpinnings of such work or ways to improve (e.g., speed-up) data collection and analysis. Relatively little has been said about how to go about writing the research report itself.[2] The purpose of this paper is to provide some practical suggestions on how to do this more efficiently and more effectively. The first part presents tips for preparing a first draft of a research report. The next part proposes guidelines on polishing that first draft into a truly readable final version. The final part offers some advice on how to broaden the diffusion of the report's central findings. Though the term report is used throughout, it applies to all forms of reporting research results including articles, papers, and studies. Supplement 1 consists of a checklist that summarizes many of the points raised in the paper.

Getting It Written: Putting Together a First Draft

Psychologists tell us that it is often easier to tackle a complex job by breaking it down into separate pieces of work which can be finished more easily. In the case of agricultural research, one commonly thinks of three phases: (1) research design; (2) data collection and analysis; and, (3) writing the final report. The first two phases are the most interesting. Writing the final report frequently proves much more tedious. One way to try and make this job less onerous is to break down the preparation of a final report into smaller bits of work. The most obvious distinction here is between preparing a draft and completing a final version. This part of the paper suggests ways to make a writing of a first draft less demanding; the following part offers similar ideas for finishing a final version.

Beginning at the End: Think of the Report First

Research reports are typically prepared at the end of a research project. Holtzman (1986) suggests another ap-

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[2] This problem is touched on albeit briefly, in Casley and Lury (1981:166-167, 174-182); Holtzman (1986:63-65); and, for policy memos, Monke and Pearson (1989:242-252).

proach. He proposes thinking very carefully at the beginning about a tentative table of contents (see below) that includes a list of topics to be covered in the final report. More specific ideas then can be jotted down under the section headings for easy reference. This serves as a sort of checklist or guide—in addition to the original research proposal—as to what sort of data are essential versus information that need not be collected. It also makes it easier to separate sections (e.g., literature review and analysis of secondary data) that can be written as the study progresses rather than wait till the end to write up everything. The basic point is that a first draft of a research report is easier to prepare if one doesn't wait to begin doing so until the end, when the researcher is mentally tired, frequently short of time, and under pressure to complete the job.

Budgeting the Time and Resources

Successful agricultural research requires many things, but perhaps none more important than the planning needed to complete a final report. Writing a good report is not easy, but writing such a report in one-tenth or one-twentieth of the time necessary is impossible. How much time is necessary? A rough estimate is nearly the amount of time needed to collect the data. Remember: writing not only takes time but also mental and financial resources. If you exhaust yourself in the data collection, you simply won't have the powers of concentration needed to complete a report. Furthermore, preparing and publishing a report costs money. Many researchers are unable to complete their reports because they failed to consider at the outset the resources necessary to do so.

Taking too much time to write a report can also be a problem. Some researchers want to prepare the definitive statement on the topic i.e., definitive in detail, in length, in coverage. In so doing, they themselves create an insurmountable obstacle to completion of their report simply because there is never enough time for a perfect report. Remember an imperfect report can be made better with revisions, editing; hence, a report always has to be finished first, then improved on.

Getting Started: State a Question, then Answer it

Some people have difficulty preparing a draft report because they have so much material, so many ideas that they don't know where to begin. One way to overcome this difficulty is to specify the key research question (or hypothesis) the report is intended to address. If that question can be clearly identified at the beginning of the report and the reason(s) why it is important, then what follows becomes simply an attempt to answer the question (or to address the issue).

In formulating the key question for the research report, utmost care should be taken to ensure that it focuses on the original objectives of the research project. Some reports pose, then answer extremely interesting questions; but fail to consider the project's objectives in so doing. Clearly, a research report needs to do both.

Different researchers use different techniques for writing the opening paragraphs of a report. Three of the most common include a statement of: (1) a key question to be addressed; (2) the purpose or objective of the study; or (3) the principal theme or subject matter to be discussed. These techniques are not mutually exclusive. For example, the author may state a question, "Under such circumstances, the following key question frequently arises: if growers produce more potatoes, where will they be marketed?" He then may follow this with a statement of purpose such as, "the purpose of this study is (1) to provide an answer to this question, in the particular case of Thailand, and (2) to present an example for similar studies in other Southeast Asian countries." Additional examples may be found in the **Preface** or **Introduction** of most research reports. Other studies therefore may provide some useful ideas on how to begin your own report.

Building Blocks for a Research Report

Once the topic has been defined and its importance indicated, the report should contain treatments of a series of related subjects. These include: (1) the methodology used; (2) the results and what they mean; (3) the conclusion, followed by a discussion of the implications for policy and for future research; and, (4) and a list of references. Although these are essential components of almost any research report, how they are structured can vary according to each author's own judgement. Ideas on how to organize a report can be found by looking through the table of contents of different reports. The important point here is that any report should include these essential components.

Once these building blocks are in place, the first draft is well on its way to completion. Nevertheless, it's easy to become overwhelmed by the prospect of writing a report, especially if you envision the task as something to be completed in one tremendous burst of energy. A more practical approach is to build on the ideas (possibly paragraphs) noted down in the course of the data collection and analysis as alluded to earlier. If the writing does not flow freely—or to make it easier, it may be useful to prepare a fairly detailed outline with chapter and sub-sections. Topics to be discussed under each sub-section can then be briefly written under each heading in a few words or a phrase or two. Utilizing this outline, one can then spend time each day writing one or two subsections of a chapter. Getting a little done over several days gradually builds self-confidence and a sense of momentum. As the sub-sections and then chapters are written up, the report itself becomes easier to work on because one can see the final product materializing.

Balance and Focus

In drafting paragraphs or chapters for a final report, one might well ask: how much space should I devote to discussing a particular section? A helpful guideline is to remember that the bulk of the study should be devoted to the presentation and discussion of the research findings. As such it should represent well over 50% of the body of the report. Another 10-15% should go to the **Introduction** and **Conclusions**; the remainder should cover the methodology used, the review of the literature, etc.

Report writing (and reading) can get bogged down if a disproportionate share of space is devoted to defining the topic or explaining the methodology. If there is more to say about methods for example, the most important points can perhaps be summarized in the main body of the report and the rest presented in an appendix. Put somewhat differently, a first draft should get quickly through the preliminary sections or chapters to emphasize the discussion of results. Furthermore, many reports present page after page of data but then only the briefest **Conclusions** (if any at all). Or many an author, apparently in a rush to finish the report, will overlook the recommendations or simply list them without any explanation. The contents of this section of the report may seem redundant or obvious to the author-researcher, but they clearly need extra attention if they are to be easily understood by others. Other studies can provide additional ideas on the proper proportions to give a report.

Focusing on only relevant research results can also help speed-up the report writing process. Many people confuse writing up their research results with writing down every research result. Remember: keep the report focused on the question to be answered; if need be, some—even a lot—of the data collected may have to be left out. By focusing on the pertinent material, the preparation of a first draft can be made that much easier.

Working Around Writer's Block

Some researchers can prepare a detailed outline, start out writing a draft report, but then find that their mind goes blank. They complain that they can't seem to write anything on the next topic. They try doing something else for a few days, but often this results in their falling completely out of the writing frame of mind. An alternative approach is to go beyond the topic that one has nothing to say on for the moment to one somewhere else in the table of contents that one can more easily write about. Once one or two sub-sections are finished, one can more easily go back to the more demanding parts and write those up.

The combination of these suggestions should help you plan the time required to write the first draft, organize and develop the basic topics to be covered in such a document, and complete the initial version of your final report by not overextending the coverage and working around momentary lapses in concentration. The next part suggests ways to transform the rough draft into a polished final report.

Getting it Right: Preparing the Final Version

Once the draft of a research report has been completed, the author shifts his attention to sharpening the analysis and improving the style. The following ideas are intended as suggestions to help facilitate this process.

Seeking and Using Comments

Some researchers assume that they are solely responsible for the contents of their reports, only to be completely dismayed when key readers cannot follow certain passages in the text or when an important policy maker points out that a critical issue has been overlooked. Even the most renowned scientists solicit comments. The point is to not take such criticisms personally (sometimes a lot easier said than done) and to look for the useful comments and react to those, ignoring the rest. One test of validity is to discuss comments with a colleague who understands your work. There is often more objectivity from a friendly, not objective other.

A prospective policy maker is more likely to respond positively to a report's recommendations if he is given the opportunity to provide some input into the conclusions and policy proposals. Nobody likes to be presented with a *fait accompli*. On the contrary, many policy makers and administrators may be flattered that someone actually asks them for their opinion. Moreover, if you ask someone for comments and they fail to respond, then they can't complain about the contents of the final report.

Researchers can also make the opposite mistake by circulating a draft that contains so many errors and omissions that, in effect, they expect the commentators to help them write the report. One consequence of passing around a poor quality draft is that the serious reader can readily correct so many basic mistakes in spelling, syntax and data presentation that he or she never has to grapple with substantive issues. If one hopes to receive quality comments from reviewers, then provide them with as good a draft as possible.

Stating the Obvious First

When one writes a research report, one tends to emphasize less what is certain and more what remains to be studied. Remember: a research report is for people who know less about the topic than the author. One therefore may need to explain certain basic facts that may seem obvious to the researcher, but that are much less evident to the reader. For example, if the report discusses farm production problems, then a brief discussion of the various types of crops grown, their relative importance in terms of total production would help orient the reader. Alternatively, if it analyzes consumption patterns for a given commodity, some information on the composition of the overall diet would also be helpful.

Some studies dedicate considerable space to explaining and qualifying specific information about particular producers, consumers, or traders without mentioning any of their common traits or predicaments. For example, it may be interesting that different types of producers paid different prices for labor, fertilizer, and pesticides; but, this fact should not obscure general results like the number of producers interviewed, or, that no producers used mechanical equipment in their crop production. Therefore, after completing the presentation of this type of data, re-read the results and ask yourself: have I included the most obvious relevant information?

Presenting Both Sides of the Issue

A research report is always much more convincing if it acknowledges different points of view, explains their respective strengths and weaknesses, and offers evidence to support one position rather than another. Most serious readers tend to be sceptical. If you expect to convince them, you have to indicate that you are aware of other points of view, that you understand them and can account for them in your interpretation of the evidence. In contrast, reports that only present the author's point of view can be dismissed by policy makers as "narrow" or refuted by critics whose own arguments (quite possibly erroneus) sound more persuasive because they mention both sides of the issue.

Being Accurate and Consistent

There is always a temptation in applied research to overstate the case. The interpretation of the evidence tends to go beyond what the facts themselves would allow. Although this may only be true for a tiny portion of the report, it tends to discredit the entire study. If the results offer indications that something is true without confirming it beyond a doubt, it is best to say instead, "it appears that..." or "the weight of the evidence suggests."

The careful reader will also detect inconsistencies in a report. For example, if you are going to say something about food consumption when discussing food production, then subsequent statements about production when analyzing consumption had better be consistent. In individual chapters, the inconsistencies may not be apparent. Therefore, during the revision of the rough draft, this is something to watch out for in particular.

Spelling, Syntax, and Grammar

Any draft report may contain spelling errors or errors of syntax.[3] Nevertheless, a final report that is riddled with these mistakes may disconcert the reader as readily as one with obvious errors of fact. Careful re-reading can eliminate them. Even the most experienced researcher recognizes the need for this type of text editing.

[3] Standard guides to professional writing include: *The Chicago Manual of Style*, 1982 (13th edition,) University of Chicago Press; *Words into Type*, 1974 (3rd edition), Pretince-Hall, Inc.; *CBE Style Manual*, 1983 (5th edition), Council of Biological Editors, Inc. See a major library near you for additional materials of this type. Note as well that some research institutes have specific guidelines for the diffusion of research results. For example, in Peru, the Ministry of Agriculture has published a manual on how to go about this, *Manual Normativo para l Difusión de los Resultados de la Investigación Agropecuaria*, 1977, Ministerio de Agricultura, Peru.

The same attention is required in the presentation of data. Any time sources and citations are not present in a research report, the credibility of the document comes into question (even if the data presented and references made could be completely verified). It suggests that the author is careless and therefore implies that his policy recommendations may be similarly flawed. If the report includes data in the text or tables, include a source for these figures. If they are data from a project survey, simply put "Source: Survey for this study." Similarly, all tables should be constructed alike: numbers, title, sub-headings, sources, and notes (I also like to put sources on all figures and maps). If the presentation varies markedly from table to table, it makes it more likely that there will be errors or omissions that are overlooked in revisions. Check the presentation in similar studies to get an idea of the different acceptable formats and to appreciate how professional writers adhere to them throughout their publications.[4]

Breaking Up the Text

The longer the report, the more complicated the argument, the greater the need to try and set up certain "signposts" to guide the reader and some "rest stops" for him to collect his thoughts before moving on. Most reports are easier to follow if they include a brief (1-2 paragraphs) introduction at the beginning of each chapter in which the topics to be taken up in that chapter are identified. Such chapters can also conclude with a brief summary and a phrase or two which provides a transition to the next chapter.

Within segments of the report (be they chapters or sections), it is also a good idea to put subject headings every time the focus of the text shifts from one major topic to another. In so doing, the heading alerts the reader to changes in subject matter. It also allows for easier, later reference to the discussion of particular topics.

Rewriting: Less is More; Too Little Not Enough

In addition to the other improvements mentioned above, rewriting should aim to minimize repetition, to shorten phrases or paragraphs that are simply too wordy and to eliminate irrelevant sections or data. The basic objective of report writing is, after all, to **inform** the reader, not to bore him.

One of the most effective ways to shorten a report without necessarily eliminating relevant information is to put all but the essential tables in an appendix. If the main body of the report contains more data than analysis, the critical reader suspects that the researcher may not have known precisely what it was he was looking for, nor what to make of the data collected. When the text refers to data in the appendix, the reader is less likely to get bogged down reviewing number after number while remaining appreciative that the figures are readily accessible if they need to be consulted.

There is, however, a danger in being so concise that the text becomes cryptic. Effective rewriting requires both eliminating the unnecessary and clarifying the essential. Policy recommendations deserve special attention so that decision makers (who want to take the researcher's advice) know precisely what it is that is being proposed.

These practical suggestions should help in the preparation of a well written, final research report. But that's only part of the job. If the research is to have an impact at the local, regional or national level, the next task is getting the findings read.

Getting It Read: Circulating Your Own Research

Agricultural scientists sometimes take the attitude that once they've finished the report and provided written recommendations it is up to a benevolent (or omniscient?) policy maker to recognize the brilliance in the findings and policy implications. Things rarely work that way. Alternatively, these researchers may assume that most of their potential readers could care less so why bother trying to reach a broader audience? The fact is that scientists have to edit their results differently for policy makers and fellow researchers. Here are some practical suggestions on how to go about this.

The Abstract

The purpose of the **Abstract** is to provide the reader with an encapsulated version of the entire report: the problem to be analyzed, the most salient research find-

[4] See the publications listed under Footnote 3 for more detailed advice on this issue.

ings, and the implications for policy and future research. Ideally, this brief paragraph focuses on only the key components of the entire study. Some authors prefer an **Executive Summary** (see below) instead. However, the **Abstract** can be an effective way of getting the message to interested readers who simply do not have time to read more. If done well, it can even prompt those who may have never bothered to read the report to actually do so.

Style and content are also (if not more) important in an **Abstract**. A crisply written **Abstract** crammed with results and policy recommendations can stimulate interest; a flat bit of prose bores readers. Likewise an **Abstract** need not answer all questions posed in the report, but it certainly should address one or two. Readers need something substantive if they are to consider reading the main repon let alone grasp the essential findings.

The Executive Summary

A second way to provide busy readers with the report's basic message is an **Executive Summary**. Many people might want to examine the entire study, but simply do not have time, e.g., they may need to make a decision now. If the report provides a 1-3 page summary at the beginning, this can stimulate someone to at least familiarize himself with the essential findings. People who read the **Executive Summary** might even be motivated to look at the complete report. It should be emphasized that the **Executive Summary** must provide a complete and accurate synthesis of the findings and recommendations so that those who only read this abbreviated version get the same information (just without the detail) as those who read the full length report. Particular attention must be given to include a succinct, but complete review of the policy recommendations. A quick look at copies of other studies that include such summaries can provide some specific examples of how to go about this.

A Concise Version of the Report

A separate, short report in which you include only the most essential data and a bibliography (which cites the main report) is another option. It may not be possible to duplicate numerous copies of the complete final report—including the **Abstract** and **Executive Summary**—given its length and the resources required for such a job. A thinner version can be circulated to a much larger number of people. Those that are interested can consult the complete version for more detail or to examine the data.

Finally, many reports are not widely read because they simply are not available, e.g., the author has one copy and his immediate boss (long ago transferred to another position) another. In many research institutes, the researcher is required to furnish one or two copies of his research report for the institution's main library. This procedure is to be recommended as a general practice.

Published Summaries and Popular Articles

In many research organizations, it may not be feasible to distribute sufficient copies of your final report to ensure proper diffusion of the findings. Nevertheless, such institutions frequently have research bulletins or magazines in which an abbreviated version of the report might well be printed. For example, the National Agricultural Research Institute in Peru (INIAA), publishes the *Revista del INIAA*; in the Philippines, the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) prints the *PCARRD Monitor*.

Developing countries typically have various publications in which articles will appear on agriculture and rural development. In Peru, for example, popularized articles often appear in such magazines as *Agro-Noticias* while short research pieces appear in *Actualidad Económica del Perú*. Results of a recently completed, original piece of applied research is just what readers of these publications find of interest. A small summary for publication in this type of press enables the results to reach an audience that the researcher perhaps does not normally come in contact with.

Conference and Seminar Papers

Meetings of professional associations, conferences, and seminars organized on particular topics are another avenue for presenting the results of your research. While such meetings typically have particular requirements in terms of topics to emphasize and the acceptable length and style of paper, they do offer the opportunity to reach an audience that one may not have come in contact with and therefore it is worth the extra effort. If the report itself has been written up, it usually does not require that much additional work to prepare another paper.

The advantages of this type of vehicle for publishing a segment of the report's findings are twofold. First, it gives one the chance, perhaps, to put a different slant on the ideas presented in the report in addition to presenting the basic findings in a new forum. Second, some ideas that may not have been as clear or as well developed as one might have wished in the original paper can now be clarified or elaborated on.

Refereed Journals at Home and Abroad

In nearly all developing countries, professional journals are published by local universities, development institutes or professional associations, e.g., *The Philippine Agriculturalist, Bulletin Agricole du Rwanda*, or *India Journal of Agricultural Economics*. Although publishing in such specialized journals frequently will require rewriting the final report to conform to the publication requirements of the journal in question, this bit of additional work is modest in comparison with the time and effort that went into preparing the original study.[5] And, publishing in a specialized journal brings the results to the attention of the professional research community—a group often more diverse than simply those who do research in Ministries or National Agricultural Research Institutes.

Some researchers assume that the only appropriate professional journals to publish in are those abroad. However, those journals published in the country where the research is carried out are likely to be much more interested in the results because their readers may be planning to do research on a similar topic. Such publications are also more likely to come to the attention of policy makers in the countries in question.

Professional journals in foreign countries are another possibility. Each journal has its own particular readership, requirements in terms of style, as well as topics about which they are most likely to publish articles. Such information can be gathered by visiting a major library and perusing back issues.[6]

Conclusion

This paper has presented a set of practical suggestions for preparing a first draft, polishing a final version, and diffusing the results of a research report. The information contained in the accompanying Notes, References, and Supplements offer additional suggestions. After reviewing these materials, readers may want to consult a major library for additional ideas on one or more of the points mentioned.

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[5] A useful publication in this field is Robert Day. 1983 (2nd edition). How to Write and Publish a Scientific Paper. Professional Writing SCR. Institute for Scientific Information. Philadelphia, PA, USA.

[6] A complete guide to refereed journals can be found in Ulrich's International Periodicals Directory (1986-1987). 1986 (25th edition). Vols. I and II. R. R. Bowker. New York, NY, USA.

Supplement 1

A Checklist for Effective Report Writing

1. Have you developed a tentative table of contents for the final report at the beginning of your research project?

2. Have you set aside enough time to write, revise, and print your research report? Have you included report writing and printing costs in the research budget?

3. Have you prepared a detailed outline for the final draft? Does it include sections on methodology, results, conclusions, and recommendations with specific topics to be discussed under each? How does it compare with the table of contents in similar studies?

4. Does the Introduction of your report identify a key research question(s) to be answered? And indicate its importance?

5. In your report, do you explain the methodology you used? Are detailed methodological facts placed in an Appendix?

6. Does your report include Conclusions? Are there recommendations to policy makers? Have you identified topics for future research?

7. Does the report include a list of references?

8. Do tables, figures, etc., all follow the same format? Do they include necessary information such as source, units of measure, economic values, etc.? Have you checked other publications to see how the format you use compares?

9. Have you eliminated all basic mistakes such as spelling errors, typos, inclusion of sources from your draft before you circulate it for comments? Have you corrected errors in syntax and grammar?

10. Have you checked for inconsistences in the data presented in different sections of the study?

11. Does the report devote most of the text to research results and discussion?

12. Have you sought out comments on a first draft from key decision makers?

13. Does the report present both sides of key issues?

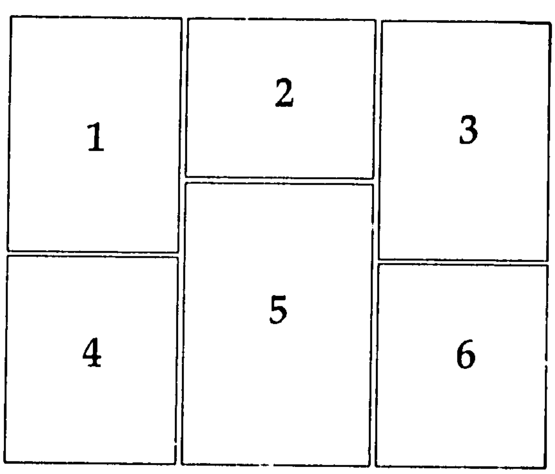
14. Have irrelevant data and repetition been eliminated in the rewriting of the first draft? Can large sets of numbers be placed in an Appendix?

15. Are the policy recommendations fully developed and easy to understand?

16. Does the report include an Abstract? an Executive Summary?

17. Have you considered preparing brief summaries for publication in the Institute's own research bulletin or in popular magazines?

18. Have you checked at a research library for local refereed journals that might publish an article based on your report?



1. Making sweetpotato bread in Peru (CIP).
2. Traditional cassava processing in Africa (IITA).
3. Cassava chipping in Latin America (CIAT).
4. Improved cassava processing in Nigeria (IITA).
5. Village-level production of sweetpotato noodles in China (CIP).
6. A drum-peeler for village-level potato processing in India (CIP).