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Adding Value to Root and Tuber Crops

A Manual on Product Development

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Preface

Root and tuber crops, also referred to simply as "root crops," contribute importantly to income and food security in developing countries. These commodities are grown mainly by small-scale farmers, and most yield more (in terms of calories per hectare per day) than other crops.

There are many opportunities to improve traditional uses of root crops and introduce them into a wide range of new food and feed markets, particularly in the rapidly urbanizing societies of the developing world. A concerted effort to realize the promise of these crops could give them a more central role in development.

The key to fulfilling the potential of root crops is to establish strong links between small-scale producers and new markets. Numerous barriers now separate them. Root crops are perishable and bulky; capital resources are scarce in rural areas; and organizing market channels is complex. To overcome these obstacles requires appropriate strategies and technology for postharvest processing and utilization.

Over the past decade, several national agricultural research and development systems and three international agricultural research centers—CIAT, CIP, and the International Institute of Tropical Agriculture (IITA)—have dedicated appreciable resources to lessening the difficulty of root crop development. This manual draws lessons from their experience in improving root crop utilization and marketing. Based on those lessons, we present guidelines for the development of self-supporting agroindustries.

The manual should be useful to anyone interested in developing root crops to generate income and increase supplies of human and animal food. That includes researchers, extension officers, rural entrepreneurs, policy makers, planners, and other staff of government and nongovernment organizations.

The manual is divided into two parts. Part I, consisting of seven units, presents an approach to product development and explains how to apply it. In Unit 1 we describe the characteristics of root crops, analyze trends in their production and utilization, and discuss their potential for contributing to the socioeconomic advancement of developing countries. Unit 2 gives an overview of the method put forward in this manual, discussing key principles of project design and outlining the various stages in developing rural agroindustries: from the generation of product ideas, to experimentation and testing of products and processes on a pilot scale, to production at the commercial level.

In subsequent units we explain each stage in further detail. Unit 3 tells how to identify and screen product ideas. Unit 4 deals with issues in research on products and processes, which provides information needed for prefeasibility studies. Unit 5 explains how to test proposed processing technology on a pilot scale. This task includes market testing of the products and full assessment of their commercial feasibility. Unit 6 considers key factors determining whether products and processes tested at the pilot level can succeed commercially. Units 3-6 contain a series of checklists designed to help you gather key information relevant to particular tasks and decisions.

In Unit 7 we highlight important issues that cut across all the stages described in Part I. The success of any effort to develop root crop products, processes, and markets will depend to a large degree on how well it addresses those issues.

Part II presents summaries of 10 case studies (selected from a total of 16) on product development projects in various countries. In addition, we draw on the experience of these projects throughout the book (mostly in a series of boxes) to illustrate particular points about the development of root crop products and processes. We are grateful to Trudy Brekelbaum for preparing first drafts of the case study summaries and for editing an early draft of the entire manual.

Many colleagues in national research systems and in regional and international

organizations have contributed to this publication by preparing case studies, consulting with us, and reviewing the first draft at regional workshops held in Latin America, Asia, and Africa (the proceedings of those meetings are valuable companions to the manual). In the Appendix we list everyone who helped prepare the manual through their participation in the regional workshops and other events. We are greatly indebted to them for sharing so generously their knowledge and experience.

Much additional information is available in the literature on product development. We've tried to include all the major references in bibliographies at the end of particular units.

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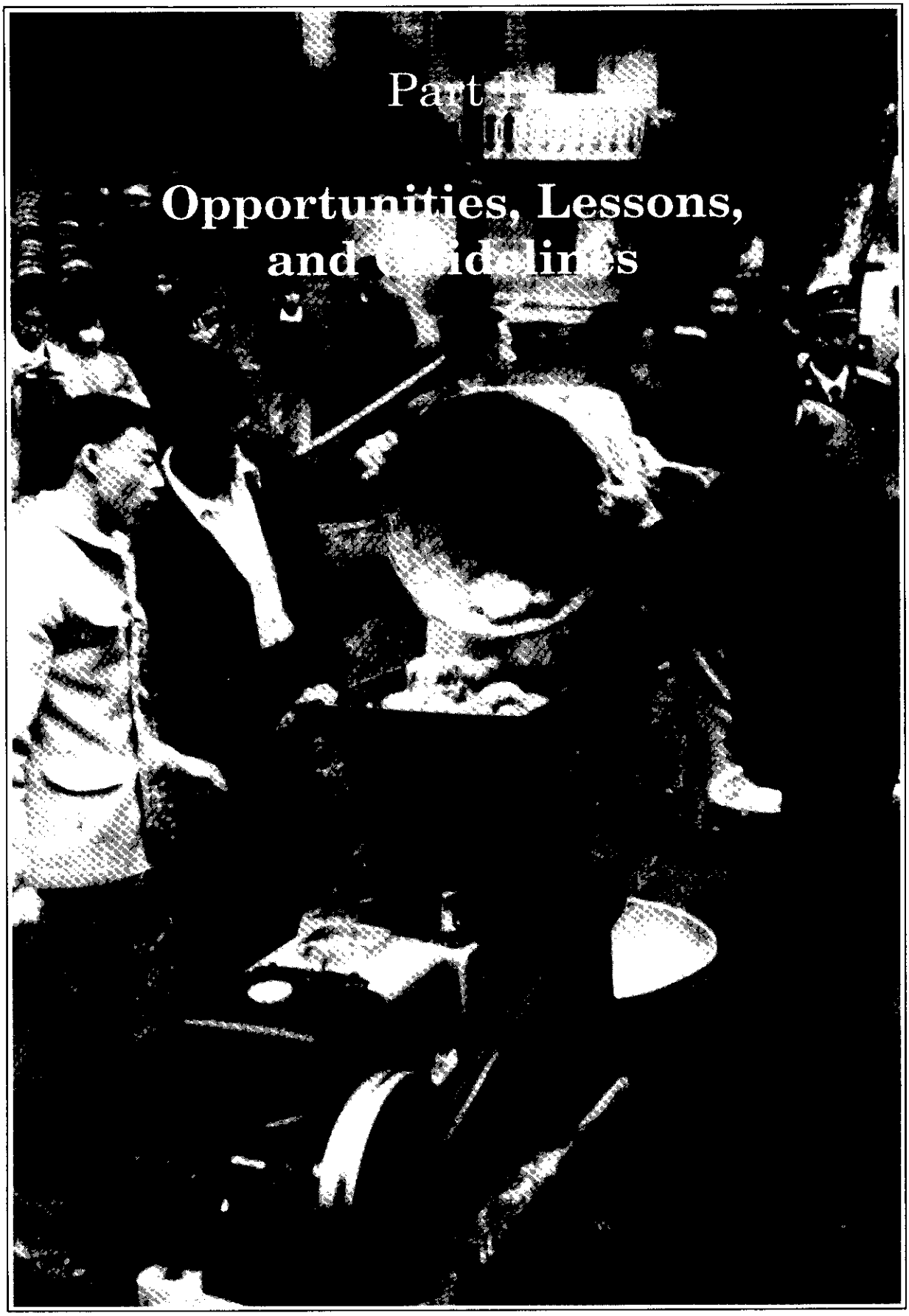

Part I

Opportunities, Lessons, and Guidelines

Unit 1

Needs and Opportunities in Product Development

Over the last three decades, many developing countries have achieved remarkable increases in food production. But decision makers and scientists believe the possibilities for further improvement in productivity, income, and consumption are far from exhausted. Specialists in various disciplines are convinced that to reach this goal will require major efforts to expand utilization of agricultural commodities through a process we refer to here as *product development.*

Though by no means novel, this concept has aroused new interest in developing country agriculture on the eve of the 21st century. Product development is frequently associated with manufactured goods, with the use of high technology, and with developed country economies (Kotler, 1986). As used here, though, the term applies to food crops—produced with labor- or capital-intensive techniques—and to markets in developing countries (Austin, 1992). Moreover, this manual focuses specifically on cassava, potato, and sweet potato—crops frequently characterized as "traditional" or "subsistence" and not commonly transformed for sale in a modern, commercial context.

There is little doubt that one *can* develop new products for root and tubers. But do the results justify the investment? In this unit we address that question by describing various circumstances that make product development an attractive and even necessary approach for root crops in developing countries.

First, we examine the agronomic and biochemical characteristics of roots and tubers, highlighting the features that permit, if not require, transformation to increase utilization of these crops. Then, we analyze production trends to pinpoint tendencies in output, area, and yield that represent opportunities (signaled by growing production) and needs (where area planted is declining) for alternative uses of these crops.

Subsequently, we discuss recent changes in the prevailing patterns of utilization, emphasizing how experiences at specific locations might be put to wider use. We briefly mention developments in markets beyond those for root and tuber crops that, nonetheless, influence trends in these crops. Finally, we comment on trends affecting the future prospects of roots and tubers.

Characteristics of Roots and Tubers

This manual focuses mainly on the three major root and tuber crops—cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), and potato (*Solanum tuberosum*). We also give some attention to yams (*Dioscorea* spp.), cocoyams (taro, yautia = *Colocasia esculenta*), and tannia (*Xanthosoma* spp.).

Collectively, these crops occupy about 50 million hectares worldwide (Horton et al., 1984). Annual production exceeds 550 million tons, about two-thirds of which is harvested in the developing world. Cassava alone is an important food crop for some 500 million people in developing countries (De Bruijn and Fresco, 1989). Cassava, sweet potato, and potato are grown in roughly 100 of those countries under a wide range of growing conditions.

Agronomic traits

Root crops can adapt to diverse environments, partly as a result of their agronomic characteristics.

Growing cycle: Potato and sweet potato fit particularly well into complex cropping systems, because they have a shorter vegetative cycle than other root crops, such as cassava, whose growing period ranges from 9 to 24 months, depending on soil fertility and ambient temperature (Table 1).

Temperature: Although potato yields best under cool conditions, the crop is grown extensively in areas (e.g., in Tunisia and Bangladesh) with high daytime temperatures

Table 1. Main characteristics of root crops.

Characteristics	Cassava	Sweet potato	Potato	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 swampy, waterlogged 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

n.a. = Data not available.

SOURCES: Derived from Kay (1973), as presented in Horton (1988).

(Horton and Monares, 1986; Scott, 1988). But when nighttime temperatures exceed 20 °C, potato does not tuberize well (Midmore and Rhoades, 1987). In contrast, sweet potato, cassava, and other root crops are best cultivated under higher temperatures.

Rainfall: Potato requires less total rainfall than cassava, but rain must be fairly continuous, particularly at the beginning and during the tuberization phase of the vegetative cycle. Consequently, drought can devastate potato crops but is much less damaging to cassava and sweet potato.

Crop management: To produce high yields, potato needs ample fertilizer and organic matter. These inputs are less important for cassava and sweet potato, which can give good returns even in poor soils. In general, cultural practices for those crops (e.g., seed handling, weeding, and pest control) are less demanding than for potato. Moreover, potato crops can normally be left in the ground for only a short time after their prime harvesting date, whereas cassava can be "stored" in the ground, unharvested, for many months.

Biochemical traits

The fact that root and tuber production is generally confined to particular seasons is one major reason why these crops require some sort of transformation to permit continuous use throughout the year. Another is their physical and biochemical characteristics, the most singular of which are their bulkiness and perishability.

Fresh cassava has a dry matter content of about 40%, sweet potato 30%, and potato 20%. Physiological deterioration of fresh cassava roots begins 1-3 days after harvest (Ospina and Wheatley, 1992). Sweet potato and potato have a much longer shelf life. Even so, their harvested roots and tubers are living organisms that require adequate respiration and proper handling to prevent sprouting, spoilage, or pest damage.

If some biochemical traits of roots and tubers present serious obstacles, others—much less frequently mentioned—offer compelling reasons to expand utilization of these crops.

Horton (1988) points out that "root crops are often thought of as 'starchy staples' that provide low-cost energy but little else to the human diet." Contrary to this misleading generalization, the content of protein, essential vitamins, and minerals varies considerably among roots and tubers. On average, cooked potato and yam have about 2% protein, twice that of cassava (Table 2). Cassava, sweet potato, and potato all provide ascorbic acid, whereas cereal-based foods have

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

Food[a]	Water (%)	Protein (g)	Food energy (kcal)	Protein/ calorie ratio (g/000 kcal)	Fats (g)	Ash (mg)	Ca (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)	Thiamine (mg)	Riboflavin (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
Potato	80	2.1	76	27	0.1	0.9	7	53	0.6	3	407	0.09	0.04	1.5	16
Plantain	80	1.3	77	17	0.1	0.7	—[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
Yam (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
Sweet potato	71	1.7	114	15	0.4	1.0	32	47	0.7	10	243	0.09	0.06	0.6	17
Common bean	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	—	—	—	—	—	—	—	—	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

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.

SOURCES: USDA (1975) and Wu-Leung et al. (1968), as presented in Horton (1988).

none. Sweet potato and potato also contain the important amino acid lysine, in which commodities such as rice are deficient (Woolfe, 1987; 1992).

Furthermore, cassava, sweet potato, and potato significantly outyield the cereals in dry matter (i.e., calorie) production per unit area. Potato is particularly productive in terms of carbohydrate per hectare per day (Table 3).

Production Trends

Developing countries produced 149 million tons of cassava, 122 million tons of sweet potato, and 79 million tons of potato in 1988-1990 (Table 4). Between 1961 and 1988, production of the three crops increased 100%, 31%, and 173%, respectively, although output of sweet potato actually declined by 14% in the latter half of this period. The area planted to sweet potato has also fallen sharply in recent years, but this was more than offset by a near doubling of yields. Area planted in potato grew steadily over the last three decades—up 79% since 1961 (more, in fact, than any other major food crop except soybean and tomato)—even though it started from a much smaller base than coarse grains or beans. Area in cassava production increased by about 50% and yields by 32%.

Within these overall patterns, which broadly influence the prospects for product development of roots and tubers, production trends vary greatly, not only among 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, sweet potato, and potato all originated in Latin America, the bulk of production has shifted away from this region. Asia currently accounts for two-thirds of the output of these crops in developing countries. The high concentration of root crops on that continent mainly reflects its large share of sweet potato (93%) and potato production (76%). China alone produces over 85% of the developing world's sweet potatoes and nearly 40% of its potatoes (Tables 5 and 6). Africa produces nearly half (44%) the developing world's cassava (Table 7). Since 1961 output of cassava and potato has grown much faster in Africa and Asia than in Latin America, where production of sweet potato has actually declined by nearly 22%.

Africa has the most producers of cassava (38 countries) and sweet potato (36). Asia has the largest number of potato-producing countries, with 33, and the heaviest concentration of big producers (Table 8). In Latin America there are numerous minor producers (<10,000 t per year) of cassava (12 countries) and sweet potato (also 12).

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

Dry matter production	(kg/ha)	Energy production	(MJ/ha per day)	Protein production	(kg/ha per day)
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
Sweet potatoes	2.1	Maize	159	Dry peas	1.4
Rice	1.9	Cabbages	156	Eggplants	1.4
Carrots	1.7	Sweet potatoes	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, 1961-1990.

Crop	1988-1990			Percent change in:[a]								
	Production (000 t)	Area (000 ha)	Yield (t/ha)	Production			Area			Yield		
				1	2	3	1	2	3	1	2	3
Rice (paddy)	484,379	143,000	3.4	52.3	52.6	132.4	17.7	6.6	25.5	29.5	43.1	85.2
Wheat	224,612	100,450	2.2	79.5	94.0	248.3	19.8	12.9	35.3	49.8	71.8	157.4
Maize	196,916	83,213	2.4	73.1	65.1	185.9	22.0	14.7	40.0	41.9	43.9	104.3
Cassava	149,193	15,074	9.9	41.2	41.3	99.5	28.4	17.8	51.3	9.9	19.9	31.8
Sweet potato	122,057	9,063	13.5	52.2	-14.1	30.6	-4.1	-24.9	-28.0	58.7	14.3	81.4
Potato	79,066	6,363	12.4	73.8	56.8	172.5	31.9	35.7	79.0	31.7	15.6	52.3
Soybean	48,857	30,255	1.6	130.7	169.2	521.0	27.6	104.7	161.3	80.8	31.5	137.3
Banana	44,766	4,004	11.2	43.7	45.4	108.9	41.0	25.7	77.2	1.9	15.6	17.9
Sorghum	42,288	38,600	1.1	38.7	3.4	43.4	-0.8	-5.7	-6.5	39.9	9.7	53.4
Tomato	33,881	1,848	18.3	78.0	118.8	289.4	48.0	59.0	135.3	20.3	37.6	65.5
Millets	26,894	34,994	0.8	17.9	2.0	20.3	2.3	-12.5	-10.5	15.3	16.6	34.4
Barley	25,156	18,401	1.4	-7.0	35.3	25.9	-15.6	6.8	-9.9	10.2	26.8	39.7
Groundnut in shell	21,907	19,687	1.1	19.0	34.5	60.0	14.8	4.5	19.9	3.6	28.7	33.4
Yam	18,083	2,087	8.7	53.6	36.2	109.2	34.3	31.0	76.0	14.4	3.9	18.9
Cabbage	15,774	816	19.3	65.9	71.4	184.3	27.8	18.7	51.8	29.8	44.3	87.3
Bean, dry	13,324	23,889	0.6	17.9	24.4	46.7	15.4	15.1	32.9	2.1	8.1	10.4
Chickpea	6,294	9,204	0.7	-18.3	9.4	-10.6	-16.3	-4.2	-19.8	-2.4	14.2	11.5
Broad bean, dry	3,657	2,822	1.3	-22.4	2.6	-20.4	-23.7	-19.9	-38.9	1.6	28.1	30.2
Lentil	2,093	2,900	0.7	24.5	108.9	160.0	22.2	61.1	96.8	1.9	29.7	32.1

a. 1 = 1973-1975 vs. 1961-1963, 2 = 1988-1990 vs. 1973-1975, and 3 = 1988-1990 vs. 1961-1963.

SOURCE: FAO Basic Data Unit, unpublished statistics.

Table 5. Sweet potato production, area, and yield in selected developing countries, 1961-1990.

Country	1988-1990			Percent change in:[a]								
	Production (000 t)	Area (000 ha)	Yield (t/ha)	Production			Area			Yield		
				1	2	3	1	2	3	1	2	3
Africa[b]	6,492	1,315	4.9	44.5	-29.7	87.4	73.0	18.3	104.6	-16.4	9.6	-8.4
Madagascar	479	91	5.3	14.2	81.3	55.6	0	57.8	57.8	-14.2	14.9	-1.4
Sub-Saharan Africa[c]	6,401	1,311	4.9	46.1	29.5	89.3	73.6	18.3	105.4	-15.8	9.5	-7.9
Uganda	1,718	412	4.2	201.2	3.7	212.4	209.1	-15.1	162.4	-2.6	22.2	19.0
Rwanda	817	147	5.5	12.0	43.1	60.2	9.0	81.9	98.2	2.7	-21.3	-19.2
Burundi	655	91	7.2	-11.3	57.3	39.4	-0.5	36.5	35.8	-10.9	15.2	2.7
Kenya	561	57	9.8	80.0	107.7	273.8	23.4	81.1	123.4	45.9	14.7	67.3
Tanzania	526	245	2.1	92.3	29.1	148.3	367.4	70.9	698.9	-58.9	-24.5	-68.9
Asia[d]	113,380	7,453	15.2	53.7	-15.4	30.1	-8.9	-29.5	-35.7	68.6	20.0	102.4
China	104,824	6,304	16.6	58.0	-15.7	33.2	-10.5	-31.8	-39.0	76.5	23.7	118.3
Indonesia	2,118	232	9.1	-20.9	-12.8	-31.0	-26.6	-31.9	-50.0	7.8	27.9	37.9
Vietnam	1,920	328	5.9	-4.6	74.6	66.6	-5.1	50.1	42.5	0.5	16.4	16.9
India	1,262	159	8.0	56.2	-18.4	27.6	49.5	-26.7	9.7	4.5	11.3	16.3
Philippines	675	140	4.8	11.8	-21.2	53.7	64.1	-19.3	32.5	18.8	-2.3	16.0
Bangladesh	538	52	10.4	95.0	-17.1	-7.3	17.6	-19.6	-5.4	-4.9	3.1	-2.0
South Korea	528	23	22.6	45.2	-68.8	-54.7	18.8	-74.3	-69.4	22.2	21.4	48.4
North Korea	501	35	14.4	38.4	57.8	118.3	42.9	48.6	112.2	-3.1	6.2	2.9
Papua New Guinea	460	101	4.6	37.9	12.8	55.6	21.6	12.2	36.5	13.4	0.5	14.0
Latin America[e]	2,185	295	7.4	14.5	-31.6	-21.6	12.5	-23.2	-13.6	1.8	-11.0	-9.3
Brazil	683	68	10.1	15.5	-59.2	-52.9	6.0	-55.9	-53.2	8.9	-7.6	0.7
Total	122,057	9,603	13.5	55.2	-14.1	30.6	-4.1	-24.9	-28.0	58.7	14.3	81.4

a. 1 = 1973-1975 vs. 1961-1963, 2 = 1988-1990 vs. 1973-1975, and 3 = 1988-1990 vs. 1961-1963.
b. Not including South Africa.
c. Not including Algeria, Egypt, Libya, Morocco, Tunisia, and South Africa.
d. Does not include Israel and Japan but does include Oceania (except Australia and New Zealand).
e. Including Central, North (except Canada and the USA), and South America.

SOURCE: FAO Basic Data Unit, unpublished statistics.

Table 6. Potato production, area, and yield in selected developing countries, 1961-1990.

Country	1988-1990			Percent change in:[a]								
	Production (000 t)	Area (000 ha)	Yield (t/ha)	Production			Area			Yield		
				1	2	3	1	2	3	1	2	3
Africa[b]	6,166	650	9.4	75.0	91.1	234.3	86.7	48.0	176.4	-6.3	29.1	21.0
Sub-Saharan Africa[c]	2,282	381	6.0	70.3	40.8	139.9	83.3	31.4	140.9	-7.1	7.2	-0.4
Egypt	1,719	80	21.4	90.7	131.7	341.9	75.0	91.3	234.7	9.0	21.1	32.0
Algeria	903	106	8.5	81.3	113.5	287.0	161.4	73.8	354.3	-30.7	22.8	-14.8
Asia[d]	60,073	4,695	12.8	89.7	58.3	200.4	39.9	46.0	104.3	35.6	8.4	47.0
China	31,597	2,801	11.3	99.9	22.5	144.8	41.9	37.6	95.3	40.8	-11.0	25.4
India	14,558	925	15.7	82.1	181.1	411.9	41.8	69.7	140.7	28.4	65.6	112.7
South Korea	2,042	155	13.2	55.2	82.7	183.6	36.4	54.7	110.9	13.8	18.1	34.4
Bangladesh	1,144	117	9.8	127.4	44.8	229.3	49.4	38.2	106.5	52.2	4.8	59.5
Latin America[e]	12,877	1,018	12.7	29.2	38.8	79.3	1.4	-1.7	-0.3	27.4	41.2	79.9
Argentina	2,656	112	23.6	7.4	57.5	69.2	-30.7	-5.1	-34.2	54.9	66.0	157.0
Colombia	2,560	168	15.2	68.5	128.4	284.8	56.0	67.4	161.1	8.0	36.4	47.4
Brazil	2,222	163	13.6	37.9	42.9	97.1	-2.6	-14.5	-16.7	41.5	67.2	136.6
Peru	1,651	192	8.6	17.1	-2.4	14.2	2.9	-26.9	-24.8	13.8	33.6	52.0
Mexico	1,044	72	14.4	76.5	61.8	185.6	16.9	30.7	52.8	51.0	23.8	86.9
Chile	880	60	14.7	-3.3	11.2	7.5	-15.9	-22.4	-34.8	15.0	43.3	64.8
Bolivia	695	131	5.3	45.2	-9.9	30.9	10.0	8.3	19.1	32.0	-16.8	9.9
Other countries												
Turkey	4,237	191	22.2	55.0	82.5	182.8	28.1	5.5	35.1	21.0	72.9	109.3
Iran	1,984	124	16.0	64.6	280.5	526.4	63.9	271.0	508.2	0.4	2.6	3.0
Total	79,066	6,363	12.4	73.8	56.8	172.5	31.9	35.7	79.0	31.7	15.6	52.3

a. 1 = 1973-1975 vs. 1961-1963, 2 = 1988-1990 vs. 1973-1975, and 3 = 1988-1990 vs. 1961-1963.
b. Not including South Africa.
c. Not including Algeria, Egypt, Libya, Morocco, Tunisia, and South Africa.
d. Does not include Israel and Japan but does include Oceania (except Australia and New Zealand).
e. Includes Central, North (except Canada and the USA), and South America.

SOURCE: FAO Basic Data Unit, unpublished statistics.

Table 7. Cassava production, area, and yield in selected developing countries, 1961-1990.

Country	1988-1990			Percent change in:[a]								
	Production (000 t)	Area (000 ha)	Yield (t/ha)	Production			Area			Yield		
				1	2	3	1	2	3	1	2	3
Sub-Saharan Africa[b]	65,344	8,440	7.7	35.2	49.6	102.3	25.3	18.4	48.3	7.9	26.4	36.4
Zaire	17,333	2,256	7.7	29.1	51.6	95.6	22.4	36.9	67.5	5.5	10.7	16.8
Nigeria	16,363	1,504	11.1	30.1	68.6	119.4	23.5	49.4	84.5	5.4	12.9	18.9
Tanzania	7,230	671	10.8	54.4	61.5	149.3	35.1	-14.3	15.7	14.3	88.5	115.4
Mozambique	4,019	941	4.3	23.1	25.6	54.6	6.7	17.7	25.5	15.4	6.7	23.1
Uganda	3,393	375	9.1	125.5	36.2	207.0	82.9	-29.1	29.6	23.2	92.2	136.8
Ghana	3,115	364	8.6	50.3	83.2	175.3	67.2	48.8	148.7	-10.1	23.2	10.7
Madagascar	2,252	339	6.6	30.5	82.0	135.3	19.5	74.6	108.6	9.3	3.2	12.8
Angola	1,817	500	3.6	28.6	10.8	42.5	25.2	4.2	30.4	2.7	6.3	9.2
Asia[c]	52,836	4,013	13.2	61.4	74.7	181.8	27.0	36.5	73.4	27.1	27.9	62.6
Thailand	22,424	1,543	14.5	221.3	254.0	1,037.5	283.3	235.4	1,185.6	-16.2	5.6	-11.5
Indonesia	16,139	1,341	12.0	6.0	33.3	41.3	-3.9	-7.5	-11.1	10.3	44.1	59.0
India	5,308	269	19.8	240.3	-16.7	183.4	42.4	-28.0	2.5	139.0	15.6	176.4
China	3,271	230	14.2	99.1	38.5	175.9	93.4	18.2	128.5	3.0	17.3	27.0
Vietnam	2,650	293	9.1	-0.7	134.4	132.8	0.4	90.9	91.7	-1.1	22.8	21.5
Latin America[d]	31,013	2,621	11.8	33.4	-2.1	30.6	39.1	-3.7	33.9	-4.1	1.7	-2.5
Brazil	23,209	1,856	12.5	28.7	-10.1	15.8	37.5	-9.5	24.4	-6.3	-0.7	-7.0
Paraguay	3,806	235	16.2	31.4	190.5	281.8	25.9	164.0	232.5	4.4	10.0	14.8
Total	149,193	15,074	9.9	41.2	41.3	99.5	28.4	17.8	51.3	9.9	19.9	31.8

a. 1 = 1973-1975 vs. 1961-1963, 2 = 1988-1990 vs. 1973-1975, and 3 = 1988-1990 vs. 1961-1963.
b. Not including Algeria, Egypt, Libya, Morocco, Tunisia, and South Africa.
c. Does not include Israel and Japan but does include Oceania (except Australia and New Zealand).
d. Including Central, North (except Canada and the USA), and South America.

SOURCE: FAO Basic Data Unit, unpublished statistics.

Table 8. Distribution of developing countries by volume of cassava (C), potato (P), and sweet potato (SP) production, 1988-1990.

Production	Number of countries											
	Africa			Latin America			Asia			Total		
	C	P	SP	C	P	SP	C	P	SP	C	P	SP
0 or no info.	16	24	18	18	25	25	44	32	40	78	81	83
< 10,000 t	4	6	10	12	4	12	6	6	8	22	16	30
< 50,000 t	6	11	11	5	6	13	3	6	4	14	23	16
< 250,000 t	8	7	7	4	4	5	4	9	4	16	20	16
> 250,000 t	20	6	8	8	8	4	8	12	9	36	26	21
Total	54	54	54	47	47	47	65	65	65	166	166	166

SOURCE: FAO Basic Data Unit, unpublished statistics.

Cassava

Five countries (Brazil, Thailand, Zaire, Nigeria, and Indonesia) produce 64% of the developing world's cassava (Table 7). In Latin America the crop ranks second in annual production (on a fresh-weight basis) among the 19 major food crops, though 74% of the regional total is harvested by just one country—Brazil. Zaire and Nigeria account for about 50% of Africa's production and Thailand and Indonesia for over 70% of Asia's. Trends in cassava production, like those for potato and sweet potato, have been highly uneven across countries.

Among the eight largest cassava producers in sub-Saharan Africa, six increased their output by 90% or more from 1961 to 1990 (Table 7). According to Dorosh (1989), this growth was largely a consequence of the crop's "low labor input requirements, ability to produce a crop on degraded soils, and drought tolerance." Unlike Asia, Africa mostly has a low ratio of population to agricultural land. In addition, African farmers tend to engage in a more diverse set of farm and nonfarm occupations. Cassava is an attractive option for these growers, because its cultivation requires relatively little labor and its cultural practices are fairly flexible. Other factors that account for the popularity of this crop are growing population pressure, shorter fallows, and scarcity of fertilizers (Dorosh, 1989).

Cassava is popular in Thailand because of its drought tolerance, stable yield, and flexible planting and harvesting dates (Konjing, 1989). Largely to satisfy strong demand for dried cassava in the European Union (EU), this country has expanded production significantly (Phillips, 1979; Sarma and Kunchai, 1989). In the Philippines the favorable agronomic traits of cassava have also contributed to growth in output (Cabanilla, 1989). But in contrast with developments in Thailand, growth in the Philippines has been driven by strong domestic demand for cassava (the country exports only negligible quantities), which is used as food in rural areas and in animal feed and manufacturing. In Indonesia farmers cater both to export and domestic markets. Cassava exports are considerable in terms of volume and value.[1] But roughly 35% of production goes to local industries producing starch for human consumption (Kasryno, 1989).

In Brazil growers have responded to weak demand for cassava by switching to other, more profitable crops. As a result, production declined 10% and area planted by the same percentage between 1973 and 1990. More recently, good prospects for expanding utilization of cassava in Northeast Brazil appear to have slowed, if not reversed, this trend (Ospina and Wheatley, 1992). Brazilian experience with cassava and similar developments in Colombia and Ecuador (Best and Wheatley, 1990), along with trends in Thailand and Indonesia, have stimulated renewed interest in utilization of roots and tubers generally.

1. Exports of *gaplek* (based on dried cassava chips) have fluctuated between 149,000 and 710,000 t since 1970. In 1986, 97% of these exports were to Germany (Kasryno, 1989).

Sweet potato

Although cassava, sweet potato, and potato are grown in many countries, production is concentrated in a relatively small number of them. For example, the 16 largest sweet potato producers account for nearly 97% of total production (Table 5) and also for 98% of the change in output since 1961.

Recent trends in area planted and production have been highly uneven. In some countries (notably Burundi, Kenya, Madagascar, North Korea, and Rwanda), sweet potato output expanded rapidly over the last decade. Often, this was primarily the result of rapid population growth, which increased the pressure on farmland, as in Rwanda (Von Braun et al., 1991). Another contributor to expansion was the minimal production costs of the crop and its ability to do well even on marginal soils (Ewell and Kirkby, 1991). In a number of countries, however (e.g., Brazil, China, Indonesia, and the Philippines), sweet potato output and area have fallen since the mid-1970s.

Reasons cited for this include the expansion of infrastructure (mainly irrigation) for production of other crops and a switch to higher value vegetables in response to growth in urbanization, income, and the associated demand for a more diverse diet (Calkins, 1979; Chin, 1989).[2] In 7 of the 16 largest producers, output of sweet potato has dropped since 1973-1975. In the absence of detailed information, most observers attribute this to weak demand or to the lack of alternative markets (CIP, 1988a; 1988b; 1989b). In a recent survey, national program scientists cited these two circumstances as, by far, the most important production constraints (CIP, 1989a).

Potato

Eighteen of the largest producers grow nearly 90% of the developing world's potatoes (Table 6) and account for 90% of the increase in production since 1961. Most of this growth has taken place in China, South Asia (Bangladesh, India, and Pakistan), North Africa (Algeria, Egypt, and Morocco), and the Middle East (Iran and Turkey).

In all these regions, the introduction of improved, short-duration varieties of wheat and rice has created a new niche for potato 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 permitted rapid increases in yields and area planted (Chowdhury and Sen, 1981; Kokab and Smith, 1989; Scott, 1988). The huge increase in Colombia's potato output is partly attributable to rapid expansion in the processing subsector (Rodríguez and Rodríguez, 1992).

Other contributors to growth in potato production are strong domestic demand for food, the desire of most low-income consumers to diversify their diets, modest per capita consumption of potato, the lucrative European market (which has helped the North African countries in particular), and expansion of cold storage facilities in South Asia. In several Latin American countries, on the other hand, potato production has been hurt by drought, cheap imported cereals, and in Chile a shift to higher value fruit and vegetable crops for export (Fu, 1979; Scott, 1985).

Other less important producers (e.g., Syria) have substantially increased potato output over the last three decades. In these countries, as in those mentioned above, policy makers and potato scientists are increasingly interested in developing alternative uses for this commodity to prevent a collapse in prices resulting from abrupt saturation of the domestic market. In a recent survey, researchers in national programs cited unstable prices and supplies as the most important constraints to increased potato production (Scott, 1991).

Trends in Consumption and Utilization

Roots and tubers are generally considered food crops, first and last. More than half the production in fresh form is for human

2. Little research has been done on the relationship between changes in income and the consumption of fresh sweet potato roots in developing countries. Studies in the Philippines (Alkuino, 1983; Bouis, 1991) and Peru (Collins, 1989) show that this relation is much more complex than previously believed. Consumers' response depends on various factors, including their income, place of residence, and the sweet potato variety (Watson, 1989).

Table 9. Percent changes in utilization of cassava (C), potatoes (P), and sweet potatoes (SP) in developing countries, 1961-1990.

Utilization	1961-1963[a]			1973-1975[a]			1988-1990[a]		
	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	2.2	3.8	0.1	3.9	4.0	0.7	5.4	4.4
Seed	0	13.3	3.7	0	10.3	2.4	0	9.4	2.9
Waste	13.8	7.9	7.0	14.0	7.9	8.2	13.8	8.9	8.6

a. Totals may not add up to 100 due to rounding.
b. Includes other uses.

SOURCE: FAO Food Balance Sheets, unpublished statistics.

consumption. Nonetheless, other uses of these crops are also important, although the share of output devoted to them varies considerably across crops, regions, and countries. Patterns in the utilization of sweet potato and, to a lesser extent, cassava have changed significantly over the last 30 years. Processing for animal feed, for example, has assumed major importance in a number of countries. As a result of this trend and good prospects for similar developments in the future, patterns in the mean consumption and utilization of roots and tubers are receiving closer scrutiny.

Estimates of "processing" or "waste" as a percentage of root and tuber production are difficult to interpret, however. In many countries waste in the form of damaged roots and vines is processed or fed to livestock. Production is also lost to physical or autolytic processes, microbiological attack, and pest damage (NAS, 1978). Furthermore, because of the higher water content and bulkiness of roots and tubers, postharvest losses appear to be higher than for cereal crops (Coursey, 1982). Even so, reliable data on production losses are scarce. The information we have is based on inferences (e.g., since sweet potatoes are perishable, a certain percentage of the harvest is lost) or "guesstimates." The statistics available must therefore be interpreted with caution.

Potato

An estimated 60% of potato production in developing countries is for human consumption, 15% for feed, 10% for seed, and 5% for processing; about 10% is lost to waste (Table 9).[3]

In the tropics potato performs one of four different functions in the human diet, serving as a 1) basic staple, 2) complementary vegetable, 3) seasonal vegetable, or 4) delicacy to be consumed on special occasions (Poats, 1983). In most countries it performs the third or fourth function; consumers like the taste of potato but cannot afford to eat it daily. Potato is the centerpiece of the diet only in the highlands of South America and parts of Central Africa. The crop is rapidly gaining importance as a complementary vegetable in South Asia (e.g., in Bangladesh, India, and Pakistan), North Africa (e.g., in Egypt and Tunisia), and eastern and southern Africa (e.g., in Kenya, Madagascar, and Rwanda).

Traditional or simple rustic processing of potato for human consumption is common in Peru, Bolivia, and to a lesser extent, Ecuador. Typically, potato is solar dried (Yamamoto, 1987). A modernized version of this practice has been tried in Colombia (Mantilla, 1988) and Guatemala (Esquite and Pérez, 1991). Simple processing of potato is also practiced to a limited extent in Madagascar (Rasolo et al., 1987) and is being tested experimentally in Cameroon (Nave, 1989) and Zaire (Ravuna, 1990). Potato is processed at the village level in Bangladesh, India, and Pakistan (CTI, n.d.; Sikka, 1988).

The potato is a relatively costly commodity in most developing countries. One exception is China,

3. According to the FAO Food Balance Sheets, these percentages have remained constant over time.

where a growing proportion of production goes to noodle-making, flour, and snack foods (Gitomer, 1987). When value is added to potato through transformation, the resulting product is either prohibitively expensive for all but the highest income households (as are processed foods) or simply cannot compete with cheaper substitutes in industrial uses (e.g., as starch) and livestock feed (Gómez and Wong, 1989). In general, producers have received quite favorable prices for potato in relation to unit production costs, as evidenced by the sharp increase in area planted in Asia, sub-Saharan Africa, and parts of Latin America. Only in the last decade or so, have bumper crops of potato in a number of countries stirred serious interest in developing alternative markets.

In an important exception to the general pattern, the fast food industry has experienced remarkable growth in Southeast Asia, Central America, Mexico, and parts of South America (especially Colombia and Brazil). Strong demand for potato in this particular market niche apparently overrides cost considerations in the short run and in the medium term offers growers an attractive financial incentive to expand the local supply for industrial use (Scott et al., 1992a).

The substantial use of potato for pig feed in China—a purpose served mainly by small, decayed tubers and vines (Gitomer, 1987)—accounts in great measure for total feed use of the crop. Potato is used only to a limited extent for feed in Africa and Latin America, and this is largely confined to on-farm utilization of unmarketable tubers.

Sweet potato

Patterns in the utilization of sweet potato have changed markedly over the last three decades, particularly in Asia (Scott et al., 1992b). Although more than half the output in fresh form still goes for human consumption in all regions of the developing world, nearly 40% now serves as animal feed (Table 9). There is also growing interest in processing sweet potato for human consumption and industrial use.

Much more is known about patterns in the consumption of cassava and potato than about sweet potato (Horton et al., 1984). The latter is considered a "poor man's food" or a survival crop in many parts of Latin America, Africa, and Asia (Collins, 1989; Watson, 1989). But it is also eaten as a seasonal vegetable. Under certain market conditions, sweet potato commands an even higher price than potato (Maggi, 1990).

Sweet potato is most commonly boiled in developing countries. In China, for example, it is peeled and cooked with rice to make a breakfast porridge; it is also served fried, roasted, or mashed. Sweet potato leaves or "tips" are a delicacy in the Philippines and at certain times of the year provide an important supplementary source of essential vitamins and minerals.[4]

Sweet potato processing for human consumption is remarkably diverse and widespread (Woolfe, 1992). Some 5%-10% of China's annual production is processed into noodles, starch, chips, and candy (Tang et al., 1990). In the Philippines sweet potato is used to make ketchup, a soft drink, cakes, and candies (Van Den, 1989). *Dulce de batata,* a cheese-like sweet, is among the most popular dessert dishes in Argentina (Boy et al., 1989). Substitution of grated, fresh sweet potato for imported wheat flour has gained a foothold in the Peruvian bread market (Cavero et al., 1991).

Wherever sweet potato is produced in developing countries, it is almost always used in some form as animal feed (Table 10). According to estimates made by the Food and Agriculture Organization (FAO), 40% of total output is devoted to this purpose in China, 35% in Brazil, 30% in Madagascar, 17% in Korea, and 5% or less in the remaining 11 of the 15 largest sweet potato producers. These estimated percentages have remained stable during the last three decades in all countries except China (12% in 1961-1963) and Korea (2% in 1961-1963). Even so, recent estimates from China indicate that as

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

Table 10. Use of sweet potato as animal feed in Asia, Africa, and Latin America.

Country	Plant part	Form	Animals
Asia			
Bangladesh	Vines	Green	Cattle
China	Roots	Sliced, dried ground, cooked	Principally pigs but also for cattle, poultry
	Vines	Green, from silage	Ibid
	Waste from process-starch, noodles	Waste water	Pigs
Taiwan	Roots	Sliced, dried	Pigs
India	Roots	Sun-dried chips	Pigs
Indonesia:			
Java	Roots, culls, vines	Fresh	Cattle
Irian, Jaya	Roots	Fresh	Pigs
South Korea	Roots, culls, stored roots	Fresh, stored, limited quantity for high-carbohydrate feed	Pigs, composite feeds for pigs, poultry, other domestic animals
Papua New Guinea	Vines, foliage	Silage	Livestock
	Roots	Fresh stored	Pigs
	Leaves, vines	Green	Pigs
Philippines	Roots	Cooked, dried chips, composite feed	Pigs mainly but also poultry
Vietnam	Vines	n.a.	Pigs, water buffalo
	Roots	Fresh, sliced, dried	Pigs
	Vines	n.a.	Pigs
Africa			
Egypt	Vines	Green fodder	Cattle
Kenya	Vines	Green fodder	Cattle, pigs
Mozambique	Vines	Green fodder	Small animals
Rwanda	Damaged roots, vines	Fresh	Livestock
Uganda	Surplus roots, vines	Fresh	Livestock, pigs
	Leaves	Fresh	Fish
Latin America			
Argentina	Roots, vines	Fresh	Pigs, cattle
Brazil	Roots, vines	Fresh	Dairy and beef cattle
	Vines	n.a.	
Dominican Republic	Roots	Fresh	Pigs
	Vines	Green, ground	Cattle
Ecuador	Roots	Fresh	Pigs, goats, beef cattle
	Vines	Green fodder	Beef cattle, goats
Haiti	Culls, roots left in field after harvest	Fresh	Pigs
Jamaica	Roots	Fresh	Pigs
	Vines	Fresh	Pigs, cattle, other farm animals
Peru	Roots	Fresh	Cattle, pigs, rabbits
	Vines	Fresh	Fodder for dairy cattle, small ruminants
Venezuela	Roots, vines	Fresh	Livestock

n.a. = not available.

SOURCES: Boy et al. (1989); CIP (1988a; 1988b; 1989b); Mackay et al. (1989).

much as 35% of the country's sweet potato output now goes to animal feed.[5]

Explanations for this sharp increase since the early 1960s include growth in cereal production (which lowers the amount of sweet potato needed to supplement cereals for human consumption); rising demand for meat products (principally pork), for which sweet potato serves as a feed component (Ge, 1992); and changes in government policy (e.g., the introduction of the "responsibility system," which permits the sale of agricultural surpluses for profit). Another contributor was China's bilateral agreement with the EU, which allowed the country to export up to 600,000 t of dried sweet potato chips duty free to member countries during the 1980s (Calpe, 1992).

When using sweet potato as animal feed, farmers in Africa, Asia, and Latin America most commonly give the roots to pigs and the vines to cattle, as indicated in Table 10 (Scott, 1992; Woolfe, 1992). In northern China many farmers slice and then dry the roots before using them as pig feed (Lu et al., 1989). This type of simple processing is often done in the field. Slicing and then sun-drying the roots is a well-known procedure for producing pig feed in Taiwan (Calkins, 1979; Tsou et al., 1989). It has also been practiced, though on a more limited scale, in the Philippines (Palomar et al., 1989) and Vietnam (Hoang et al., 1989).[6] Virtually all production of feed from sweet potato takes place at the farm or village level. Only limited quantities of composite feeds are produced industrially.

Cassava

About 70% of the cassava produced in Africa and Asia is for human consumption; less than 50% is eaten fresh in Latin America. According to FAO estimates, these percentages have remained stable over the last three decades (Table 9). Fresh cassava is a basic foodstuff for rural households in Central and West Africa, parts of South Asia, Latin America, and the Far East. But it's also a high-priced vegetable in the urban markets of many of these same regions (Horton et al., 1984). The form in which people consume cassava varies considerably.

In Latin America, Lynam (1989a) has observed that the roots are traditionally eaten in one of three principal forms: 1) fresh (boiled or fried); 2) as a roasted flour called *farinha de mandioca*, particularly in North and Northeast Brazil and neighboring territories; and 3) as an unleavened bread, called *casabe*, in the Caribbean basin.[7]

In sub-Saharan Africa, the roots are a major staple, consumed in processed form in many areas and as a vegetable in others (Dorosh, 1989). Cassava leaves are also eaten as a vegetable, particularly in Central Africa. In West Africa the crop is most commonly consumed as *gari*, a dry granular meal made from fermented cassava. 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." Cassava is also consumed in the form of a sun-dried flour (called *lafun* in southwest Nigeria) and a sticky puree or heavy soup made from fermented cassava (Nigerian *fufu*). In East Africa cassava is commonly made into a flour from dried roots or root chunks.

According to George (1989), cassava is consumed principally in the form of baked roots 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 are also processed into *gaplek* (dried cassava chips) and starch.

Cassava has three other important uses in developing countries: 1) animal feed for the domestic market, 2) industrial purposes (such as starch and glue production), and 3) processing into dried chips for export.

5. Personal communication, Prof. Z. Tang, Crop Research Institute, Sichuan Academy of Agricultural Sciences, China.

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

7. For a detailed review of traditional cassava processing for human consumption, see Lancaster et al. (1982).

In sub-Saharan Africa only negligible amounts of cassava are used for these purposes.[8] In Latin America they account for almost half of the output, with 37% going to feed and 7.6% to other nonfood uses. About 10% of cassava production in Asia is for local feed and processing. The region also exports 20 million tons (fresh weight) annually in the form of dried cassava—nearly the equivalent of regional production—primarily to Europe. Although the domestic use of cassava for animal feed has attracted much attention in Asia (Phillips, 1979; Calpe, 1992), it is not nearly as common as in Latin America. There six and a half times more cassava, on a fresh weight basis (11.2 million tons vs. 1.7 in Asia), is used for feed.

The highly lucrative EU market for dried cassava has given rise to huge production increases most notably in Thailand. There and in other Asian countries, it has also helped create a strong profit orientation in the cassava processing industry. The EU market has been the most dynamic, with annual demand increasing from an average of 1.7 million tons of fresh roots in 1961-1963 to 20.3 million tons in 1981-1983 (Sarma and Kunchai, 1989).[9] Impending changes in trade agreements—under negotiation in the Uruguay Round of the General Agreement on Tariffs and Trade (GATT)—have diminished the prospects for increased (if not continued) cassava exports to Europe and other developed countries.

In Latin America the continuation of price supports and subsidies on locally produced feed inputs, along with cheap imports (also largely the result of government policy), have dampened the effect of mushrooming demand for meat products as a stimulant to cassava production and processing (Lynam, 1989b). The lesson from these experiences is that one must be cautious about relying on special trade arrangements to stimulate the emergence and growth of cassava utilization. Partly for that reason, many developing countries are now focusing more on the internal market for cassava-based products.

8. According to the FAO Food Balance Sheets, less than 2% of cassava production goes to feed use or processing.

9. Thailand alone accounted for 17.6 million tons, China for 1.5 million, and Indonesia 1.1 million in 1981-1983.

Over the last 10 years, rural development projects in parts of Colombia, Ecuador, and Northeast Brazil have shown that processing of dry cassava for concentrated feed rations is an effective means of stimulating growth (Best and Wheatley, 1990; Ospina and Wheatley, 1992). The extent to which this success can be repeated in other parts of the developing world depends partly on future developments in a number of key areas.

Future Prospects

Many factors that lie beyond the realm of cassava, potato, and sweet potato production and utilization will influence the prospects for root and tuber product development. These factors include demographic patterns, growth in incomes, availability of substitute food and feed sources, evolution of the market for derivative products (e.g., meat and processed foods), government policies on agriculture and trade, and improved technology for production and processing.

Demographic patterns

With few exceptions (China, Brazil, India, Indonesia, and the Philippines), population growth rates in the developing countries are expected to remain well over 2.0% during 1989-2000 (World Bank, 1990). Since the majority of households in these countries are located in rural areas, this growth will greatly increase pressure on farmland. That in turn will have important implications for both the production and utilization of food crops. Farmers will be compelled to place greater emphasis on higher yielding commodities, to bring more marginal land into regular cultivation, and to seek ways of converting raw materials into higher value products.

To meet the rising demand for food—both on and off the farm—rural families will have to exploit the production potential of their crops to the utmost, partly by reducing postharvest losses caused by dehydration, spoilage, and pest damage. Farmers will also have a strong incentive to convert what cannot be readily sold or consumed at harvest into marketable products. In the search for new products, notes Coursey

(1982), there is great potential for enhancing traditional practices with knowledge derived from modern science.

Urbanization will have a strong influence on product development. Nearly one in three consumers in the developing world now resides in urban areas, and rates of urbanization are two to three times population growth rates. If roots and tubers are to compete with alternative commodities (e.g., through reduced transportation costs), they will have to be processed in larger quantities. Urban consumers will increasingly demand food items that are easier to prepare and preserve. They will also shift to a more diverse diet that depends less on plants and more on livestock products, particularly meat. As a result, roots and tubers (which already occupy a niche in the market for animal feed) could become an even more substantial source of ingredients for feed concentrates.

Increased incomes

This has a more complex effect on the outlook for product development. Where incomes increase rapidly, fresh roots and tubers become less attractive to certain types of consumers, while processed food products, such as French-fried potatoes, become more affordable. In addition, rising incomes typically increase the demand for livestock products. Unable to supply enough feed by expanding cereal production, many developing countries have satisfied this demand with processed roots and tubers. China is a prime example (Gitomer, 1987).

Government policies

In many countries governments have drastically altered their policies on food and feed imports over the last few years. This is partly the result of changes in world markets but is also a way to cope with debt burdens and to create more opportunities for domestic agricultural production. In the years ahead, changes in policy will strongly influence the potential of root and tuber crops as processed products.

It will take time for some of the agrobiological and socioeconomic factors discussed here to exert their full impact. In the meantime the countries with the best prospects for expanding the use of roots and tubers as processed products appear to be the ones that already have a substantial supply of the commodity; are experiencing shortages of food, feed, or both; and cannot (for economic or political reasons) continue or expand imports of food or feed. A number of countries in Asia and some in Latin America appear to meet these criteria, at least for increased use of roots and tubers as animal feed. In China, for example, there are good prospects for more intensive utilization of sweet potato (Gitomer, 1987) and in Brazil for cassava (Ospina and Wheatley, 1992). In addition, markets for processed potato appear to be emerging in Central America and Southeast Asia.

Technical change

Improvements in the yield, dry matter content, and digestibility of cassava, potato, and sweet potato should make them more attractive as primary materials for processed products.

In developing countries average potato and cassava yields are well below their potential. Potato yields are about half those in most developed countries, and cassava yields in sub-Saharan Africa are half those in Asia (Table 7). Average yields of sweet potato have doubled in developing countries over the last 25 years, mainly because of increases in China (Table 1). The increase has apparently resulted more from improved cultural practices (mainly higher plant density) than from improved varieties or chemical fertilizers and pesticides (Mackay, 1989). That is to be expected, since until recently only limited resources for research and development have been committed to sweet potato.[10]

Most varieties of this crop cultivated in developing countries have a dry matter content of around 30%. Results of research at the Asian Vegetable Research and Development Center (AVRDC) show that "the mean dry matter content of breeding lines improved from 25.9% to 35.1% in five years. Theoretically this program increased

10. Relative to the value of production, funding for sweet potato research worldwide has been lower than for any other major food commodity (Gregory et al. 1989).

chip yield for animal feed by 40%" (Tsou et al., 1989). The international collection of sweet germplasm includes varieties whose dry matter content is as high as 45%.[11] Materials with similar advantages are available in the cassava and potato collections. Such varieties have much potential for making root and tuber crops better suited to processing.

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Unit 2

An Integrated Approach to Product Development

This unit gives an overview of product development, based on the authors' experience in root and tuber projects over the last decade. Here we focus on general concepts underlying the whole process. In Units 3-6, we provide details on each of its four phases.

In this unit we first define product development and explain its relationship to the concept of integrated projects for roots and tubers. Then, we explain the importance of clearly spelling out objectives, constraints, and other key considerations in project design. Another factor is the choice of beneficiaries. But because of its special importance, we treat this issue in a separate section of the unit. Next, we talk about integration of project activities, which is key to the success of product development. Then, we briefly describe four distinct phases in that process, setting the scene for Units 3-6. We conclude with some final tips on project design.

Product Development and Integrated Projects

To realize the sizable potential of root and tuber crops for contributing to socioeconomic development in rural areas requires a combination of efficient, sustainable crop production with new or improved products and markets. Projects that work toward this goal should be organized on a scale that is appropriate for developing country farmers. Most of these growers have small or, in some cases, medium-sized operations, limited access to processing technology, and weak links to nontraditional markets.

Product and process development (often abbreviated to product development) may be defined as generating ideas for new or improved products, selecting the best ideas, and developing these into commercially successful products. The entire procedure consists of four distinct phases:

- Identification of product ideas
- Research
- Pilot phase
- Commercial phase

Product development for root and tuber crops requires a high level of commitment, broad social participation, and effective administration. You need to take particular care in designing the organizational strategy. Its ultimate goal is to transfer the administration of a self-sustaining agroindustrial enterprise to competent farmer organizations or agroentrepreneurs. If the project has been well conceived and executed, the enterprise should contribute to rural development. To reach that goal requires active cooperation among the various public and private institutions that provide support in technology generation, product design, extension, training, farmer organization, credit, marketing, and product promotion.

As shown in Figure 1, product development is a key part of the broader concept of integrated projects for production, processing, and marketing of root and tuber crops (abbreviated here to integrated projects). Such projects combine research and development in those three areas with other activities to achieve community-based rural development in a specific region. Integrated projects take place in four phases:

- Macroplanning
- Microplanning
- Pilot phase
- Commercial phase

The purpose of macroplanning at the national level is to ensure that the most appropriate region of a country and the most promising markets are selected. Through microplanning the project then gathers enough information to define market characteristics, production practices, constraints, and so forth in the target region.

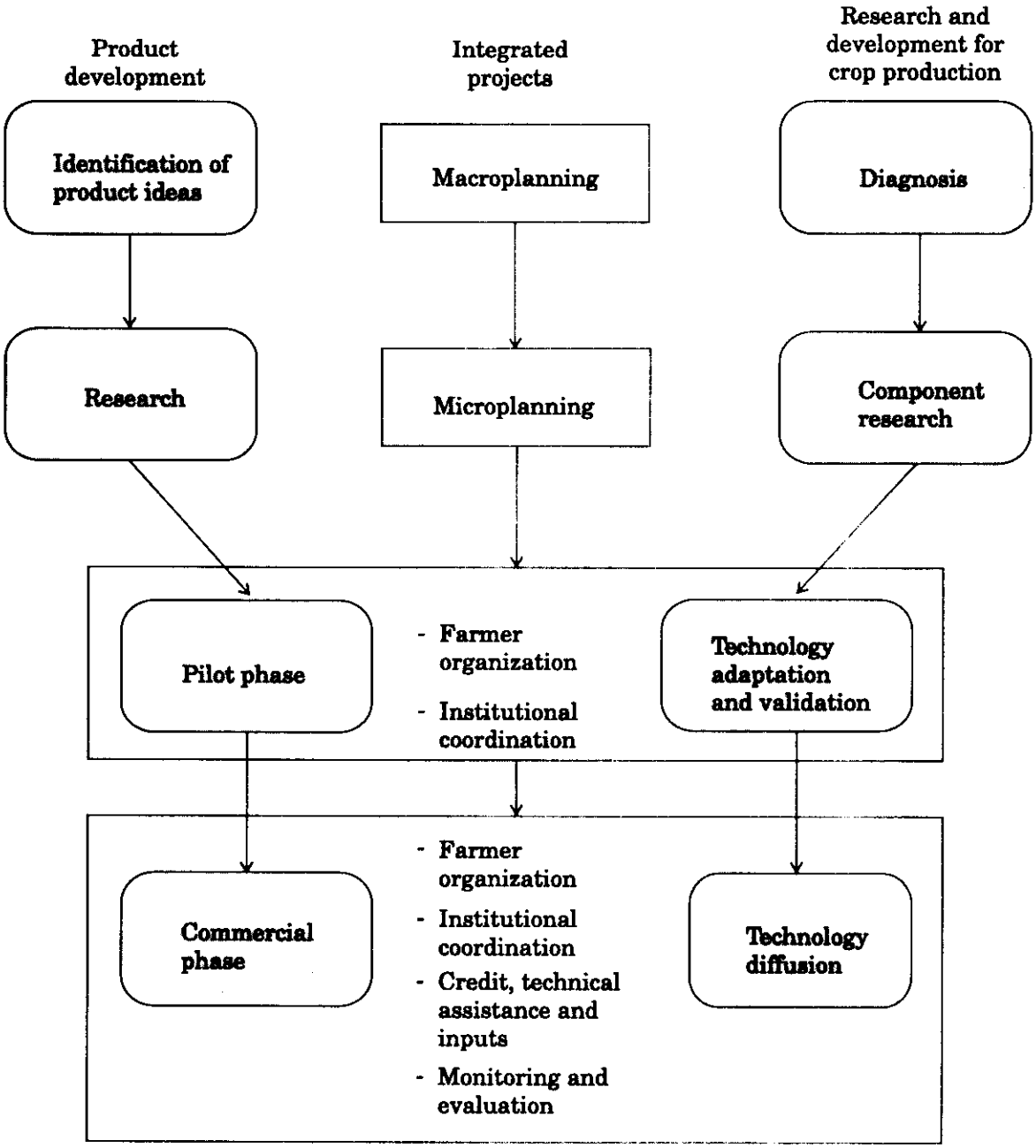

Figure 1. The relationship between product development and integrated projects for root and tuber crops.

Integrated projects have proven highly successful in facilitating the agroindustrial transformation of crops. They accomplish this by linking improved production technologies with product development and social organization through interinstitutional cooperation. You cannot achieve product development through technological innovation alone. It also requires farmer organization and training (technical, administrative, and organizational), provision of credit, establishment of efficient distribution channels, and interinstitutional coordination. These activities are especially important when product development reaches the commercial level. At that point they can best be carried out through links with integrated projects.

Integrated projects of the sort described here ought not be confused with the well-known integrated rural development projects sponsored by the World Bank. The former operate in smaller areas and have more limited objectives. More important, they are distinguished by their emphasis on technology—as opposed to the infusion of capital for infrastructure or operations—as the key means of triggering development. Technological innovations allow rural people to benefit from previously underused resources, especially local ones. No doubt, product development and integrated projects on roots and tubers should be part of some integrated rural development projects.

The Elements of Project Design

Good project design starts with a thorough analysis of the local situation: the actors and their agendas, constraints, and opportunities. Having identified constraints, you should then determine which ones lend themselves to change. Based on a preliminary assessment of possible solutions, you can start to determine the project's institutional requirements and technological and market options.

The actors and their objectives

Product development involves a variety of actors—from farmers to scientists—who often have quite different objectives. Unless there is some overlap between their aims, the project is doomed to failure. In finding a common ground among participants, you need to determine carefully the relative weight the project will give to different objectives, since this issue can be a major source of conflict. The goal of generating foreign exchange, for example (which is sometimes the overriding national priority), may be difficult to reconcile with the objective of improving the well-being of small-scale farmers.

To avoid difficulties at this early stage, project participants must state their own objectives explicitly and then agree upon the main objective of the project. Below we list three main groups of actors and describe the objectives to which they generally assign high priority:

- *National research and development institutions* seek policies and solutions that contribute to the country's socioeconomic development by increasing foreign exchange earnings, permitting import substitution, or both. These institutions may seek to slow or reverse migration to urban centers, increase the incomes and well-being of small-scale farmers, lower the cost of basic foods, and improve the nutritional status of the population.
- *Local development and extension agencies and farmer groups* work at the regional level to provide solutions to problems affecting particular segments of the rural population. They may seek to provide employment for landless laborers, increase the incomes of small-scale farmers by introducing new crops or diversifying markets for traditional ones, reduce postharvest losses, protect the environment, and improve the position of women and youth in agriculture.
- *Commercial enterprises* are primarily profit oriented. They may consider it in their long-term interest to promote concern for the environment and help improve the general well-being of local communities.

Anticipating constraints

Every project is faced with an array of constraints. If not dealt with specifically, these

may make it difficult, if not impossible, for the project to achieve its objectives. Here we divide constraints into five broad categories:

- The *institutional mandates* of participating organizations may impose limits with respect to location and target group, farm size, type of processing organizations involved (co-op, small business, or agrarian reform group), and crops or raw materials used. This problem is especially serious when the mandate does not permit an institution to engage in technology transfer at the local level.
- *Financial* constraints affect both institutions and farmers or processors. Institutions may lack the necessary research facilities, technical expertise, and operational funds. Small-scale farmers and processors rarely have much capital, generally do not meet the conditions for credit, and may be unwilling to risk their land in a new venture.
- *Legal* constraints include restrictions on the use of public funds for certain target groups, licencing requirements, and the need to comply with government regulations on product nutritional and sanitary standards, which may be designed more for urban than rural conditions.
- *Infrastructure* may not be adequate for transporting raw material to the processing plant, or there may be no appropriate market structure for the processed product.
- Common *environmental* constraints are unreliable rainfall, low soil fertility, and high ambient relative humidity.

Seizing opportunities

In their initial assessment, project planners tend to focus on the negative—i.e., on problems and limitations in a given country or region. Obviously, you should also be on the lookout for opportunities in the form of undeveloped resources and institutions that are not directly involved in the project but might contribute knowledge, expertise, and other resources.

Who Benefits and How?

Product development projects are undertaken to benefit target groups of people. The technology employed is a means toward that end, not an end in itself. Benefits may be:

- Economic (increased income)
- Nutritional
- Time-saving (e.g., beneficiaries can spend time saved in processing on other income-generating or family-related activities).

These benefits accrue to various groups:

- Small-scale farmers who are directly involved in the project
- Small-scale farmers who supply raw material for processing
- All farmers, regardless of farm size or capital holdings
- Rural intermediaries and assembly agents
- Urban wholesalers
- Rural and/or urban retailers
- Rural and/or urban consumers (divided by income strata)
- The rural community in general (through improved infrastructure, spillover effects in the rural economy, and stronger community spirit)

Among farmers and consumers, you can further characterize project beneficiaries by gender and age (e.g., dependant children may be the primary beneficiaries of a project focusing on nutritional improvement).

The following developments can generate monetary benefits:

- Improved prices for raw material (fresh roots) benefit all farmers producing the crop.
- The labor required for processing, marketing, etc., provides a source of income for people directly involved in the project.

- Profits generated by the enterprise benefit its stakeholders.
- Reduced prices for the final product benefit consumers and can lead to increased demand for the product, benefiting farmers and processors.
- Improving the quality of the final product benefits consumers and, if demand rises, farmers and processors as well.

Institutions participating in the project may also benefit, as their staff gain more experience, which they can apply in other projects.

In addition to analyzing potential payoffs, you have to confront the possibility of failure. Should this happen, who will suffer and how much? One of the strengths of the method presented in this manual is its emphasis on weeding out bad product ideas at an early stage. Despite this precaution, though, the product and process may still fail, even in the pilot phase. But since the venture is operating on a small scale at that point, the resulting losses should be minimal.

Choosing target beneficiaries

It may not be possible to benefit all needy groups at the same time. For example, unless marketing margins are reduced, you cannot help farmers through higher prices for fresh roots and simultaneously aid consumers through lower prices for the end product. Target beneficiaries must therefore be selected with care. A project in Peru dealt with this issue (as described in Box 1) by shifting its market focus from low-income

Box 1

Defining the Beneficiaries of a Potato Project in Peru (Case 7)

The original objective of Centro IDEAS in Peru was to benefit small-scale potato farmers and low-income consumers, primarily those participating in state food programs. A pilot plant was set up to produce a multiple-use food product based on a mixture of precooked potato and uncooked cereal (rice, barley, and maize) and legume (broad bean) flours. The most important property of this natural product (intended as a substitute for rice, noodles, and flours) was its nutritional quality. Project planners carried out little market research, since they aimed to introduce the product through state institutions.

A number of problems arose. The processed product had a higher price than the substitutes, and certain characteristics (e.g., bitterness, nonuniform presentation, and long preparation time) made it less acceptable. Low-income consumers preferred a less expensive product (grains or simple flours), even if it was also less nutritious. Given these circumstances, farmers had no incentive to participate in the project.

Consequently, project planners had to abandon their initial goal of producing a low-cost, high-quality nutritional product and at the same time benefiting potato farmers. Instead, they decided to develop a more sophisticated product, which could be sold to higher income groups through supermarket chains. But in attempting to do so, the project ran into cash flow problems and was unable to utilize its processing capacity properly. To remedy the latter difficulty, the project had to modify the pilot plant and purchase different equipment. Meanwhile, cottage industries adopted the project's idea and purchased about 50 hammer mills from the manufacturing firm that had built the project's original equipment.

If project planners had conducted a prefeasibility study and analyzed the market, they would have realized that in this case the goal of benefiting small farmers was incompatible with that of helping low-income consumers. They might also have built the pilot plant on a more appropriate scale.

consumers, who were very price conscious, to high-income consumers, who could pay a premium for a quality product.

Size and distribution of benefits

The size and distribution of benefits depends in part on the type of organization doing the processing. Cooperatives tend to emphasize social benefits for their members but may also try to improve the welfare of other groups (such as nonmember farmers). The central goals of small business, on the other hand, are to capitalize the enterprise, improve the efficiency of its operations, and maximize profits for individuals. In the long run, cooperatives need to strike a balance between the potentially conflicting goals of redistributing profits to members and nonmembers (by maintaining high prices for raw materials) and ensuring the viability of the enterprise (by capitalizing it, making it less dependent on credit, and so forth).

Integration: The Key to Successful Product Development

Based on a wide range of experience in process and product development for root and tuber crops, we have found that, if any single characteristic is vital for effectiveness, it is thorough integration of project activities and participants.

Actors and activities

Any commodity system has three main components: production, processing, and marketing. Integrating them is the key to successful product development. To accomplish this the project must build strong ties with a wide range of institutions—both public and private—engaged in research, extension, and social development. The exact character of these linkages will vary according to the stage of the project in technology generation and transfer.

Below we comment on specific groups with which product development must be closely linked:

- It is essential that *farmers* expand production fast enough to keep pace with projected demand for the processed product. Given that roots and tubers are long-cycle crops, farmers will respond only if there is a sure market and good price for their output. Another issue is the quality of the raw material. Are farmers' traditional varieties and cultural practices suitable in this respect? Plant breeders can contribute importantly to better productivity and quality, agronomists to improvement in cultural practices and cropping systems, and agroecologists to the proper analysis of resource management issues.

- To obtain appropriate equipment, the project must seek the services of local *designers and manufacturers*, who can develop prototypes for testing at an early stage in the project.

- Project staff must ensure that *policy makers* are informed about product development and integrated projects and grasp their importance for national development. This could reduce the possibility that government officials will create policies with adverse effects on project activities.

- *Consumers* should participate in integrated projects from the very beginning of product development. Unless this process is closely linked to consumer requirements and preferences, the project will fail when it attempts to place production on a commercial footing.

Other important actors are government institutions involved in research and development, NGOs working in rural areas, producer cooperatives, and small-scale agrobusinesses. Their participation is especially critical during the pilot phase. That is when researchers are still testing and adapting the technology; extension workers can still modify their organizational schemes (in collaboration with farmer groups) to facilitate technology transfer; input from the private sector can help the project adapt technology generated by research institutions to the demands of commercial production; and producers can be

connected with consumers of the end product for their mutual benefit.

Multidisciplinary cooperation

To analyze the potential role of root and tuber crops, you need to determine production potential, cost structures, and competitive prices and potential demand for the crop and its products. You should also identify local farmer groups and other cooperating institutions and examine additional factors that will affect project activities.

Rarely does a single institution have enough staff to supply the wide range of expertise needed to carry out these tasks. For that reason project participants, from the public and private sectors, must resort to creative institutional arrangements. As illustrated in Box 2, these can be built around working groups, designed to accomplish specific tasks by drawing on all the disciplines available. To be effective these groups need appropriate leadership and plenty of teamwork, based on a clear understanding of the distinct perspective of each discipline.

Planning and participation

To integrate multiple actors is easier said than done. The first step toward this goal is to establish common objectives and plans of work. In the absence of a good general strategy and clear guidelines for project management, the assistance offered by others is unlikely to be effective, particularly where various organizations are involved, each with different resources, loyalties, objectives, and strategies.

All participating institutions, including farmers groups, should be involved in planning the program. But the number of participants in planning meetings should be kept as small as possible, and decisions should be made by the people actually working in the project, not by those at a higher, more political level. Although the project needs political support, decisions about its activities should be taken strictly on a technical basis.

Genuine integration comes from meaningful participation in project activities. Producers, administrators, and technicians must interact in specific ways, sharing perspectives, needs, and organizational capacities. As mentioned above, consumers need to be involved early on, so that the project can take into account their concerns from the start. You should also determine what motivates farmers to participate and how much labor and money they are willing to sacrifice in working toward project objectives.

For farmers and processors, participation is a kind of apprenticeship, in which they learn to:

- Operate and maintain the processing plant.
- Discuss issues constructively, speak in public, negotiate, and identify and solve problems.
- Understand the technology and the market.

Box 2

Multidisciplinary Teamwork in the Philippines (Case 9)

When the Visayas State College of Agriculture (ViSCA) developed a sweet potato beverage, it entered into a contract with a large food and beverage company. The two institutions created a multidisciplinary team with all the expertise needed for successful product development. The team consisted 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. Leadership was rotated among team members, depending on the task at hand.

- Administer resources and keep accounts.
- Make sound investments.
- Plan future activities.

They acquire these skills gradually through daily involvement in solving problems, working in groups, and training new members.

Training

A product development project cannot operate without qualified human resources. Project staff must learn how to work on multidisciplinary teams, communicate with groups of farmers and processors, apply project methodologies, monitor and evaluate activities, and so forth. The farmers, many of whom may be functionally illiterate, need training to improve both their technical and administrative skills. In developing an effective training program, the project may benefit from links with institutions that specialize in working with groups of small-scale farmers.

Another good approach is the farmer-to-farmer training model (described in Box 3), in which experienced processors train new ones. First used to transfer dried cassava technology from Colombia to Ecuador, this model is now an important feature of a product development project in the latter country.

Culture and gender

The outcomes of product development can be affected in important ways by these two factors.

Culture gives people a distinct identity with respect to communication, dress, food habits, time consciousness, values, norms, relationships, reward systems, learning processes, beliefs, and attitudes. These factors, particularly attitudes and habits related to food, can have important implications for project design. In some regions of Africa, for example, male and female members of a household may operate totally separate economic units. Consequently, to increase the income of the male may not improve the quality of life of other family members, who depend on the income of the female. At the outset of project design, planners should explore cultural factors in consultation with farmers, consumers, and others.

Box 3

Farmer-to-Farmer Training in Ecuador (Case 4)

Colombian farmers with much experience in cassava drying traveled to Ecuador's Manabí Province, where they explained and demonstrated the process to farmers who were just getting started. They also helped construct a drying plant. The training and technical assistance were effective because the Colombian trainers understood the viewpoint of their Ecuadorian counterparts and communicated with them in terms they could understand.

To train additional groups of farmers, Ecuador's Unión de Asociaciones de Productores y Procesadores de Yuca (UAPPY) prepared several outstanding local farmers to promote the new technology. They also developed a special promoters' manual (Romanoff, 1989).

Promoters must be members of a local Asociación de Productores y Procesadores de Yuca (APPY) and have ample experience in cassava production and processing (including construction of processing plants). They also need to be able to read, write, and use a calculator. Their appointment must be approved by the head of promotion, by the administrator of UAPPY, and by the APPY to which they belong. In addition to training, promoters examine any problems that arise, propose solutions to the APPY, and communicate this information to UAPPY. They dedicate up to 3 days a week to their duties as promoters; their per diem expenses are paid by the UAPPY and the APPY that is being trained.

Socially determined attributes of men and women define to a large extent what is or is not an "acceptable" role or responsibility for them in agriculture. Failure to take gender issues into account has often resulted in the development of inappropriate solutions to local problems. Mechanization of processes that have traditionally been done manually is a classic example of how product development can displace female labor by introducing male-operated equipment.

The last United Nations development decade was dedicated to gender issues and the current one to cultural issues and their implications for development (see the list of publications on such issues at the end of this unit). In recent years agricultural researchers and project designers have become more sensitive to those concerns and more adept at incorporating them into integrated projects. This new awareness is partly the result of a growing recognition that the principal actors and end users must be full participants in project activities and that to achieve this requires a larger role for social scientists on research and development teams.

A Model for Product Development

The kind of integration required for successful product development does not normally occur spontaneously. Most often, it is the result of deliberate efforts within the framework of a well-designed project, in which the objectives, activities, and responsibilities of each participating institution are clearly defined.

The whole process of product development can be divided into four distinct phases, as shown in Figure 1 (page 24) and described below. These are not theoretical or abstract categories but specific events, which we've watched unfold in the various projects with which we've been associated.

A project focusing on dry cassava in Colombia (see Box 4) provided much of the experience on which the methodology we present here was originally based. Since that project started before the methodology emerged, not all the activities were carried out in the order we now recommend.

Phase 1: Identifying product ideas

The approach we outline here is market or consumer oriented. The first step is to identify unsatisfied consumer needs (reflected in problems with existing products) or opportunities for developing new products (evident from gaps in existing markets).

To identify an opportunity for product development, you must first generate a large number of ideas and then select the best options for further investigation. In coming up with ideas, you should consider both market and technological factors. But the choice of best product alternatives ought to be based largely on market conditions.

Phase 2: Research

Although research may be conducted in all phases of product development, it is the main activity of phase 2. Market studies and consumer research at this point determine the demand for and required characteristics of the selected product. Technical research focuses on the product and the process for manufacturing it. By the end of this phase, you should have developed a prototype product and process and formed some idea of demand for the product and the costs of manufacturing it. With this information, you can prepare a prefeasibility study.

In phase 2 the project must use its institutional contacts to harness technological developments in production and processing as well as expertise in the social sciences. Usually, national agricultural research programs carry out production research, while universities and food and feed research institutes investigate processing and utilization. Universities and specialized institutes may be engaged in market and consumer research as well. NGOs can also contribute importantly to research. It may even be necessary to obtain specialized assistance from institutions in other countries.

Box 4

The Four Stages of Product Development—Dried Cassava in Colombia (Case 1)

1. *Identification of product ideas (1979-1980):* Ex-ante analysis indicated that dried cassava could compete with imported grains as an energy source in animal feed. A project was established on the Atlantic coast of Colombia, since this is the country's most important cassava-producing zone (accounting for 40% of production). Based on the results of a microeconomic study, project planners decided to work in Sucre department with small-scale farmers who were already organized and were receiving adequate support from national research and development institutions.

2. *Research (1976-1980):* CIAT had already developed appropriate cassava chipping and drying technology, based on experience in Thailand. Center staff refined different aspects of it during the pilot stage.

3. *The pilot phase (1981-1983):* During this period the project expanded from a single pilot drying plant to seven. The feed hopper of the chipping machine was redesigned to achieve a more even flow of roots; this modification almost doubled the machine's capacity. The process was economically viable with cassava yields of 8 t/h (the average in the project area) and a conversion rate of 2.5.

4. *The commercial phase (1984-1989):* On the strength of success in the pilot phase, the number of processing plants rose quickly from 7 to 36. Further adjustments were made in the equipment (e.g., the capacity of the motor was inadequate for continual use). Farmers received intensive training in administration, so that they could eventually assume full responsibility. Since the end of a formal interinstitutional project in 1989, cassava drying has expanded significantly in the region, particularly as private individuals have gotten involved. By 1992 over 150 drying plants were operating in Colombia. This model is also being adopted in other parts of the country where there is potential for producing dried cassava chips.

Phase 3: The pilot phase

Once the processing technology has been thoroughly tested and if market and consumer studies show a demand for the product, it is time to proceed with the pilot phase. The objective is to introduce a new product or process on a limited scale in a specific region where roots and tubers are grown. This step may be associated with the introduction of improved technology aimed at increasing crop productivity and reducing production costs. If so, an integrated project can provide the framework in which production, processing, and marketing activities are linked in the same region.

During the pilot phase, you should evaluate the technical, economic, and operational feasibility of new technology under realistic conditions. Much experience has shown (see Cases 4 and 5 in Part II) that many problems arise at this stage, which are not apparent in the more controlled environment of a research center. For that reason the pilot plant should be operated, not by researchers, but by the project's intended beneficiaries. Any difficulties in marketing, organization, etc., will become evident. Once these problems have been resolved, the project can start to market the product commercially on a small scale.

By the end of the pilot phase, you ought to have enough firsthand information to confirm or deny most of the assumptions made in the prefeasibility study. With solid data derived from the pilot experience, you can determine with

confidence whether the project is justified in proceeding to the commercial phase.

The pilot phase involves significant risks. The product and process are still unproven, yet farmers and others are investing time and resources in the project. It is only fair that the project cover most of the costs incurred at this point, especially that of any untested equipment. Donor agencies recognize the importance of pilot operations and are generally willing to fund them, at least judging from the experience of many of the projects described in this manual. Assuming that the pilot phase gives positive results, further project activities should entail only minimal risk. The project should then be able to finance additional plants on credit.

Phase 4: The commercial phase

On the foundation of its experience in the pilot stage, the project can replicate or expand the use of new technology and its products. Once you know what the technology costs commercially, you can calculate the resources needed to meet the following requirements for widespread technology adoption:

- Credit for crop production, establishment of a processing capacity, and working capital
- Training and technical assistance for farmers and processors
- A plan for product distribution and promotion
- Formation of a second-order organization (i.e., a co-op or federation that supports a number of first-order farmers groups or co-ops) to coordinate marketing, farmer training, and provision of credit

Primary processing of root and tuber crops should be done in rural areas either by cooperatives, associations, or small businesses. To expand operations from a pilot to a commercial scale, the project will need to establish several plants rather than one or two large ones. Special enterprises located near each large urban market or second-order organizations can handle distribution of the products or carry out any secondary processing.

It takes time to develop and consolidate rural enterprises and also to legalize them—a necessary step for obtaining commercial credit. A frequent condition for legal registration is that all members of the cooperative have titles to their land, something that few possess. Since the managers of these enterprises generally have little formal education, they are poorly prepared to deal with these matters on their own. To get around such obstacles, the project must rely on its links with other institutions involved in rural development.

As the project starts to expand, it should establish a system to monitor commercial success and to determine whether the size and distribution of benefits are as planned. This system can employ mechanisms created during the pilot phase to gather information for the feasibility study.

The outcome of this phase should be a self-supporting rural agroindustry. As the enterprise grows stronger, it should gradually take over the functions of project institutions. This is a slow and difficult task—one that few projects have accomplished fully. Nevertheless, project personnel need to realize that they are not a permanent fixture, that the project framework is temporary.

Decision points and checklists

Each of the four phases in product development has a concrete outcome:

- Phase 1: one or more products selected for one or more regions
- Phase 2: a prefeasibility study
- Phase 3: a feasibility study
- Phase 4: a self-supporting rural agroindustry

The product selected at the end of phase 1 determines how the project will develop in subsequent phases. The products of phases 2 and 3 will, in the first instance, decide whether the project should even proceed; if so, they will then help shape the activities of phase 4. The product of this last phase is a measure of the project's success.

In this manual we provide checklists of important elements you need to consider at each critical stage in the four phases of product development. We don't mean for you to adhere to these strictly, since not all items are relevant to all situations. We've made the lists as complete as possible to ensure that nothing is overlooked or taken for granted. Particularly in the earlier units of the manual, we hope the checklists (such as the one for final idea selection in Unit 3) do not require that you generate a lot of new primary information. As the project reaches the pilot and commercial phases, though, your decisions should be based on precise primary information, with a minimum of assumptions.

Final Tips on Project Design

The project's ultimate success hinges on commercial acceptance of its final product. That is why product development must start with the consumer and a clear definition of product characteristics that make consumers want to acquire it. Once the project gets underway, however, other components of the whole endeavor—production, utilization, and commercialization—will each become temporarily preeminent, as the project advances from one phase to another in product development.

Since project design is complex, we recommend that you start even before the project begins. It is helpful to prepare a document outlining the project's aims and plans, particularly if you intend to seek external funding. If not, the document still helps define project activities and ensure that they are related to its objectives. (See the list of publications on project design.)

Given that product development can be divided into four distinct phases, each ending with a concrete product, the whole undertaking could be similarly organized into four projects. The first would identify the product and target region, the second would conduct research, and so forth. Unfortunately, though, few donors recognize the first phase as a concrete activity requiring their support. So, often, project planners will have to identify opportunities before submitting a research proposal.

One purpose of this manual is to highlight the importance of this first phase and the need to assign it sufficient time and resources. Unless phase 1 is taken seriously, the project may waste valuable resources on products that have no commercial prospects and should never have been selected.

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Unit 3
Identifying Product Ideas

This unit explains how to generate and select ideas for products based on root and tuber crops. As shown in Figure 2, the outcome of this phase is selected product ideas. Project staff then study these in the research phase, as described in Unit 4.

In that and all subsequent units, we assume research is being carried out under a project with specific objectives and outputs. Even where this is not the case, you should organize the research as if it were a project to increase efficiency and the chances of success.

At the start of the project, only its objective is defined. As indicated in Table 11, you may have decided on related matters as well, including the beneficiaries, the region where the project will be located, or others, such as the raw material to be used (i.e., which root crop) and the type of enterprise that will produce and market the product. At the end of this and subsequent units, we present revised versions of Table 11, noting progress made in resolving major project issues.

How to Generate Product Ideas

Ideas may come from a variety of sources, including:

- Consumers
- Traders
- Market researchers
- Technical researchers
- Managers
- Policy makers
- Development agencies
- Extension workers

You can also generate ideas through various techniques, such as:

- Brainstorming sessions with multidisciplinary groups
- Interaction of researchers with a small number of consumers, traders, and others selected according to certain demographic or social characteristics
- Visits to markets and stores
- Analysis of secondary information (e.g., on food consumption, purchasing habits, agricultural trends, and prices)

To identify a successful product, you need to take into account the objectives, constraints, assumptions, and beneficiaries of the project. You should also make sure that there is a market for the product, that the crop provides suitable raw material for it, and that this material can be processed cost-effectively.

Finding a market niche

Root and tuber products are sold in a wide range of markets (see Checklist 1), each with distinct characteristics and requirements. In food markets, low- and high-income consumers often differ in their consumption habits and expectations of food products. High-income consumers tend to value convenience, quality, and long product shelf life, whereas low-income consumers are likely to be more concerned with price. Roots and tubers have enormous potential as low-cost, locally available raw materials for a wide range of processed products, provided these crops can compete with cereals in price, quality, and availability.

In developing countries consumption of animal products (meat, milk, and eggs) and their derivatives is increasing rapidly. So is the use of root and tuber crops as low-cost carbohydrate sources for livestock production.

In the many industries that use starches and flours, there is potential for replacing imported wheat and other cereals with locally produced root and tuber products. Over the last two decades, government policy in many countries has favored imported cereals at the expense of those crops. The withdrawal of subsidies in many countries should enable roots and tubers to

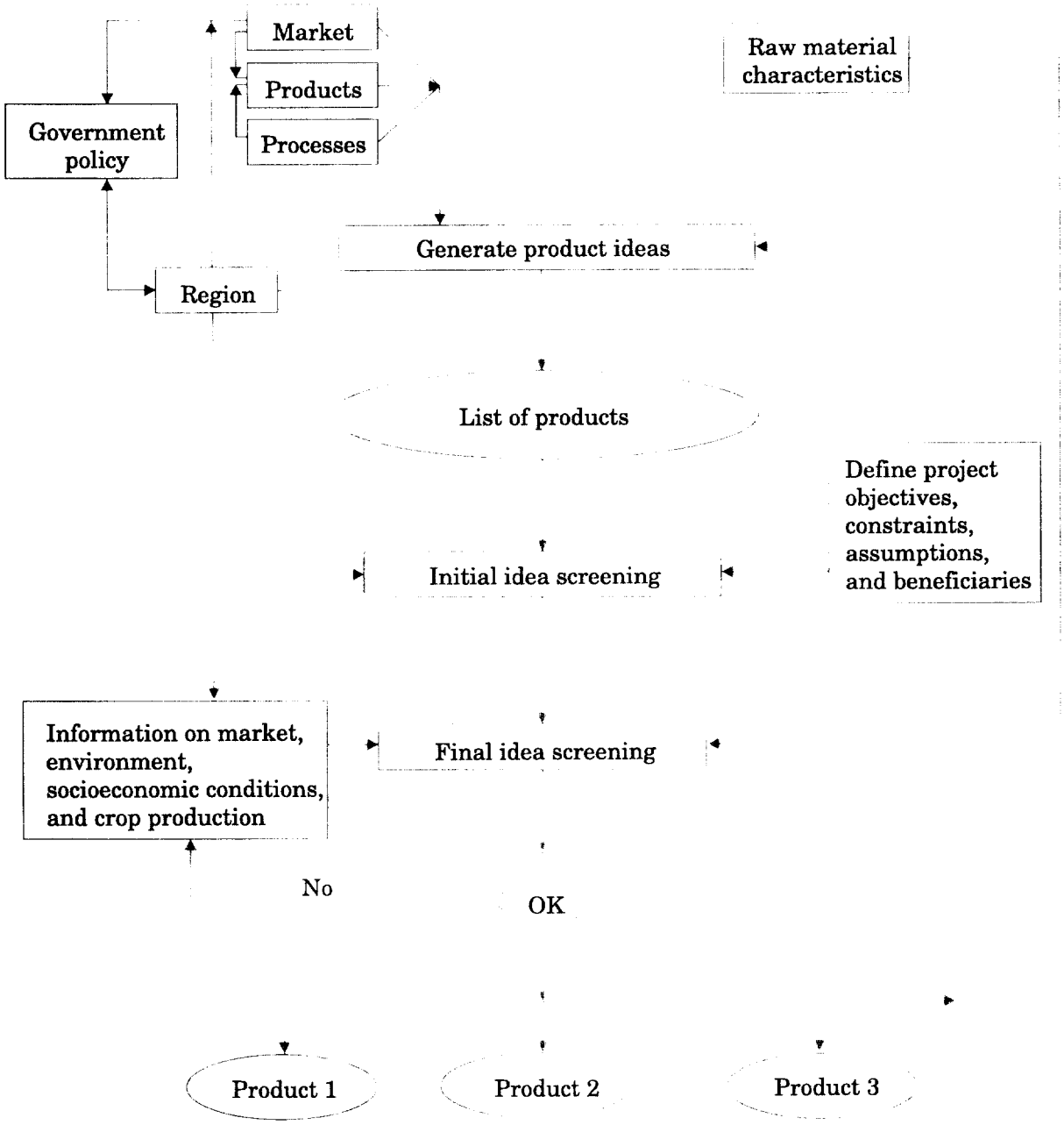

Figure 2. Stages in generating and selecting ideas for products based on root and tuber crops (phase 1)

Table 11. Status of a product development project at the outset of idea identification (phase 1).

Why (objective)?	Defined
Where (region)?	—[a]
What (product)?	—
How (process)?	—
How much (market)?	—
By whom (type of enterprise)?	—[a]
For whom (beneficiaries)?	—[a]

a. Possibly implied by project objective.

compete against imported cereals on a more equitable basis.

A cornucopia of root and tuber products

Because root and tuber crops are so versatile, they offer many opportunities for product development (see Checklist 2). Although some of these crops are relatively rich in protein or certain vitamins, they are mainly used as a carbohydrate source in a wide range of products—from traditional foods to sophisticated food and industrial products.

Many industries that could use root and tuber crops maintain rigid standards for specific raw material qualities (such as purity and hygiene, physicochemical composition, and functional properties). Some options for product development will simply not be feasible unless farmers and processors can meet those standards. In general, improving quality of the raw material or end product increases its market potential.

Options for processing

Products of root and tuber crops are manufactured through a wide range of processes, as indicated in Checklist 3. Some products, such as beverages made from sweet potatoes, may acquire additional processing.

For each process there are generally various options that differ in technological sophistication. Starch, for example, can be extracted either

Checklist 1

Markets for Root and Tuber Crops

Food

- Export
- Urban consumers (upper, middle, and low income)
- Rural consumers (many of whom produce these crops and consume them on-farm)
- Food industries, small (e.g., local bakers) or large scale (e.g., producers of starch for packet soups)

Animal feed

- Export or domestic use
- Source of carbohydrate (roots and tubers) or protein (leaves and vines)
- Functions related to specific properties (e.g., use of cassava as an agglutinant for shrimp feed)
- Animal feed companies or livestock producers
- Integrated livestock systems based on roots and tubers

Industrial

- Functions related to properties of starch, product purity, particle size, and price
- Production of starch, flour, and modified starches used as raw materials
- Major industries (e.g., paper, textile, glue, plywood, cardboard, oil, and pharmaceutical)

Checklist 2

Root and Tuber Products

Primary

- Fresh roots and tubers:
  - At harvest
  - Cleaned and graded
  - With improved shelf life
  - Prepared
  - Noncommercial quality (for animal feed)
  - Boiled (tubers) to remove antinutritional factors
  - Ensiled (roots) for storage as animal feed
- Fresh leaves and vines
- Sun-dried pieces, chips, and slices of roots and tubers
- Flakes, granules, and cubes
- Flour
- Native starch
- Fermented starch
- Modified starches
- Leaf meal
- Fresh leaves and vines (ensiled)

Secondary

- Starch and flour:
  - Bakery goods, soup and sauce bases, processed meats, pastas, noodles, beverage bases, and snack foods
  - Textiles, paper, glue, plywood, oil, and pharmaceuticals
  - Animal feed rations
  - Alcohol
  - Glucose, mannitol, sorbitol, etc.
  - Dextrin
  - Monosodium glutamate
- Fresh roots and tubers:
  - Frozen, canned, and vacuum-packed
  - Protein enriched via fermentation
  - Used in beverage, jam, and sauce production
  - Snack foods (chips, crisps, etc.)
- By-products:
  - Animal feed
  - Products of industrial processing

manually with rustic equipment or by means of high technology in a fully automated factory. The type and complexity of the technology you use depends on several factors:

- Scale of operation
- Capital investment
- Operators' level of education
- Value of product
- Conversion or extraction rate
- Product quality or purity
- Raw material characteristics
- Raw material cost
- Availability of services (water, fuel, and electricity)
- Cost of labor

This is not the appropriate place to discuss the details of specific types of equipment. To select product ideas, you need only a general idea of the scale of your operation and the complexity of the technology. (See the list of publications on products, processes, and markets at the end of this unit.)

Raw material characteristics

In identifying opportunities for product development, keep in mind the characteristics of roots and tubers as raw materials, including their chemical composition, functional properties in specific products (especially those containing

Checklist 3

Processes for Transforming Roots and Tubers

- Selection/grading and cleaning
- Peeling—manual, mechanical, chemical (lye), or steam
- Sulphating to prevent enzymic browning
- Reduction of size by slicing, chipping, or grating/rasping
- Blanching to prevent enzyme action and partially cook or sterilize
- Drying—solar or artificial, using batch or continuous processes
- Starch extraction by separation of starch in solution from other root components and sedimentation of soluble starch, by separation using fine mesh or centrifugal action, or by sedimentation in tanks or settling channels
- Fermentation, usually in a solid state with natural inoculum
- Milling (in hammer, pin, or roller mills) and grading by mesh size according to the end use
- Boiling and cooking of fresh roots for prepared foods, purees, or drying
- Frying for fresh roots, snack foods, etc.
- Extrusion of starch or flour for snack and other foods
- Baking for flours and starches

starch), and some of the storage and other traits of fresh roots. Some of these features are listed in Table 2 in Unit 1; Table 12 gives others. (For more information on this subject, see the list of publications at the end of this unit.)

The chemical composition of root crops can suggest potential products. In the Philippines, for example, scientists at ViSCA decided to develop a fruit-juice-like beverage from sweet potato because of its high content of sugar and vitamin C and because some varieties are yellow or orange. Likewise, the high starch content of cassava makes it a good candidate for starch-based products.

Raw material characteristics also affect your options in processing. The high dry matter content of cassava, for example, allows it to be sun-dried easily. For potato, in contrast, solar-assisted or artificial drying is more suitable (except where ambient humidity is very low and solar radiation is high, as on an altiplano), because a greater quantity of water must be removed from this crop to obtain a stable product.

Some raw material characteristics of root and tuber crops vary considerably and may also be affected by environmental conditions. The data in Table 12 are averages. If possible, obtain more specific information about the chemical composition, etc., of locally available varieties in the project area.

Selecting the Project Region

At this early stage in product development, many project activities can go forward even before you have decided where the final product will be marketed. Even so, it is helpful to have a rough idea of the target region.

This is defined automatically where product development is associated with a rural development project in a specific region. But if it is part of a national or international project, you will need to select one or a few specific target regions. This will help you identify potential products by narrowing the geographical focus of your study of existing products and their raw

Table 12. Raw material characteristics of root and tuber crops that are relevant to opportunity identification.

	Cassava	Sweet potato	Potato	Yam	Aroids
Dry matter (%)	30-40	19-35	20	28	22-27
Starch (% FW)	27-36	18-28	13-16	18-25	19-21
Total sugars (% FW)	0.5-2.5	1.5-5.0	0-2.0	0.5-1.0	2.0
Protein (% FW)	0.5-2.0	1.0-2.5	2.0	2.5	1.5-3.0
Fiber (% FW)	1.0	1.0	0.5	0.6	0.5-3.0
Lipids (% FW)	0.5	0.5-6.5	0.1	0.2	0-1.5
Vitamin A (µg/100 g FW)	17	900	Trace	117	0-42
Vitamin C (mg/100 g FW)	50	35	31	24	9
Ash (% FW)	0.5-1.5	1.0	1.0-1.5	0.5-1.0	0.5-1.5
Energy (kJ/100 g)	607	490	318	439	390
Antinutritional factors	Cyanogens	Trypsin inhibitors	Solanine	Alkaloids, tannins	Oxalates
Starch extraction rate (%)	22-25	10-15	8-12	n.a.	n.a.
Starch grain size (micron)	5-50	2-42	15-100	1-70	1-12
Amylose (%)	15-29	8-32	22-25	10-30	3-45
Max. viscosity (BU)	700-1,100	n.a.	n.a.	100-200	n.a.
Gelatinization temp. (°C)	49-73	58-85	63-66	69-88	68-75

n.a. = Data not available.

materials. It will also help screen product ideas, as discussed below. Here are some criteria for selecting target regions:

- There is enough root and tuber crop production to establish an agroindustry.
- Fresh root prices are low enough to permit processing if the project aims to manufacture a low-value product.
- Harvest is spread over several or many months.
- One or more institutions in the region is engaged in crop production research and extension.
- For food products, there is a major urban market within or close to the region selected.
- The distances over which both raw material and final or intermediate products would have to be transported are acceptable.
- For products that require other raw materials or inputs (e.g., for packaging or fuel), these are available at reasonable prices.
- It is advantageous if the rural population has experience in root crop production and processing.
- It is helpful if institutions in the region have successfully supported the formation of cooperatives or small enterprises in the past.
- Credit or other sources of finance are available for replicating project activities.
- Policy makers in the region clearly support the improvement of rural welfare through product development for root and tuber crops.

How to Screen Product Ideas

Having developed product ideas, you should now screen them to pinpoint those with the best chance of success. This is a two-stage process, consisting of an initial and final screening.

Initial screening

First, screen your product ideas for their compatibility with project objectives, assumptions, and constraints (as described in Box 5). Suppose,

Box 5

Initial Screening of Cassava Product Ideas in Colombia (Case 1)

In the country's Atlantic coast region, fresh cassava is a major staple for both rural and urban populations, although consumption in urban areas is declining. Cassava is grown exclusively by small-scale farmers in the region, which provides 40% of Colombia's total supply of the crop. Because of sharp fluctuations in price, cassava production became risky in the 1970s. Output declined, and farmers had little incentive to adopt new production technology. There were few alternative crops for this seasonally dry area with infertile soils.

In the 1980s opportunities were identified for developing alternative uses of cassava (starch extraction and drying for animal feed) and for improving storage of fresh cassava in traditional markets. These options were screened in light of the project's:

Objectives

- Improve cassava markets and link small-scale farmers to them.
- Increase the incomes of small-scale farmers and landless laborers.

Constraints

- The Programa de Desarrollo Rural Integrado (DRI) was relying exclusively on farmers groups and cooperatives for small-enterprise development.
- Little capital was available for investment.
- The options were limited to small-scale processing, using locally manufactured equipment.

Assumptions

- External financing was available for building a pilot plant.
- Local financing was available for institutional support.

Sun-drying of cassava chips was found to be an economically viable option, and several other processes and products showed potential.

for example, that the project aims to improve the welfare of small-scale farmers by adding value to root and tuber crops through rural processing. You would eliminate processes such as freezing, canning, and vacuum packing, since these involve relatively complex technology and are capital intensive, making it difficult for small-scale rural industries to adopt them.

Similarly, if the project's objective is to improve the nutritional status of low-income urban consumers, you would reject this same group of technologies, because their high cost will result in a product that only higher income consumers can afford. Based on the project's social objectives and financial limitations, you can thus reduce the product options to a manageable number for more detailed study.

The remaining options will normally be products that require relatively simple, low-cost processes and have a large potential market. These will tend to be fresh, prepared, or stored products as well as flour, starch, and products derived from them. Since flour includes items suitable for animal feed, human food, and industrial use, you can subdivide this category of product. For each potential product, indicate a distinct quality or specification. This in turn determines the process required and the cost of the final product.

Final screening

You can screen the remaining products or market categories (using Checklist 4), on the basis of potential demand, raw material supply, and

Checklist 4

Final Screening of Products

Potential demand

- What is the target market (city, region, etc.)?
- How large is the market (as a percentage of the total number of consumers)?
- How much product will each client consume per year?
- Is the potential market expanding?
- Are consumption or food purchasing habits changing?
- Does the product fit these changes?
- If the product is novel, will consumers accept it?
- If the product is competing against others, will its price and quality be better?
- For industrial markets, what are the volumes and prices of competing raw materials?

Raw material supply

- What is the volume of production in the target region?
- How much demand is there for this production in other markets?
- Is production and demand in other markets seasonal?
- Are there price fluctuations or cycles?
- What are the main characteristics of available varieties (growth cycles, quality, and yield)?
- Are other (improved) varieties available?
- What is the potential for increasing production (by increasing area or yield)?
- What are the constraints to increased production (diseases, erosion, drought, etc.)?
- What are the main handling and storage factors?
- If the crop is to replace another source of raw material, what will be the effects of reduced demand for this other crop?
- What environmental effects could result from expanding or intensifying crop production?

Physical factors

(These determine harvest times and the feasibility of natural drying.)

- What is the rainfall pattern (dry and wet seasons)?
- Does the dry season coincide with harvest time?
- What is the temperature pattern?
- What is the pattern of relative humidity?

Utilities

- Does the target region have access to:
  - Electricity, gas, coal, etc?
  - Clean water (especially for starch extraction)?
  - Sewerage or other waste disposal systems?
- Are there adequate roads and access to transport?

Organizational aspects

- Are farmers linked to markets?
- Are farmers willing to experiment?
- Does the target region have a history of positive experience with co-ops?
- Is institutional support available for co-ops or small businesses?
- Is credit available?
- Are capital requirements manageable?
- Is a separate distribution entity needed, and are technical and financial support available for this?
- Will many institutions be involved? Is interinstitutional coordination satisfactory?

(Continued)

Checklist 4. Continued.

Existence of similar activities

- Would processing by small-scale farmers be new or merely a continuation of current practices?
- What are the strengths and weaknesses of existing operations?
- What is the scale of existing operations?
- How can weaknesses be corrected?
- Could you use existing facilities to reduce capital outlays?

Capital requirements

- How much money would you have to borrow and under what conditions (interest rate, grace period, etc.)?
- What are the collateral requirements (landholdings, etc.)?
- Would you have to obtain the loan under standard banking arrangements, or is there a special loan scheme for small businesses or co-ops?

Labor

- Costs
- Availability (seasonality)
- Educational level (including literacy)
- Gender issues

Technology

- Has it already been developed, or is further research required? If so, how much, and what are the chances of success?
- Is the technology imported or local? If imported, are spare parts and so forth available?
- Can farmer groups manage the technology?
- Is training required (process operation, business, marketing, etc.)? If so, who can provide and finance the training?
- Can local labor and materials be used in construction?
- How will the process and its wastes affect the environment?

Consumer acceptance

- Is the crop (fresh or processed) already part of the local diet?
- Is its image good or not?
- Is the product already being made? If not, why not?
- If the product is already available, how can it be improved?
- If the product is novel, is the crop used in other foods or with other ingredients?

Benefits

- How well will the product meet project objectives?
- Who will benefit and how much?
- What is the risk of failure? Who will suffer if the project fails?
- How great will the benefits be (large enough to make the project economically feasible)?

various other factors. This brief, but systematic, analysis is preferable to a long-term, costly research project. How long it takes to work through Checklist 4 will depend on the amount of data available. You should be able to fill any gaps in the information by consulting secondary data sources and by making a brief visit to the project region. There is no need to conduct an elaborate formal survey.

Be sure to review all your assumptions with care, since common knowledge is frequently mistaken. For example, in areas originally considered to have excessive rainfall, cassava drying is now commercially successful.

The next step is to decide which of several initial product ideas to study in more detail, based on your responses to the items in Checklist 4. Be

flexible in using the checklist. For some products, a single negative response to a crucial question may be enough to eliminate them. For others, negative responses to several questions may not matter, if they relate to conditions that can be changed, given sufficient funds, training, or time.

One advantage of using the checklist is that it can help you generate additional product ideas. As you consider each item in the list, suggestions or observations may occur to you for modifying the original product idea (e.g., selling a powder-like potato product to industrial clients rather than a dried wafer or chip directly to consumers) or for replacing it altogether (e.g., with a product for animal rather than human consumption).

Tables 13 and 14 give the results of using Checklist 4 in particular cases. A project in northern India screened four ideas for potato products, as shown in Table 13. The most favorable option was to store potatoes for sale in the off-season, when prices are higher. But since the project's objective was to maximize rural employment, not farmer incomes, it opted to develop several processed products for human consumption as a means of creating jobs.

Table 13. Final screening of ideas for potato processing in northern India (Case 6).

Checklist	Product ideas			
	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 consumers (10% of population)	Depends on price, unlikely to be competitive	Depends on price of raw material and starch yield; uncertain
Raw material supply	Excellent; buy at low price and sell when high	Limited to June-March, at main harvest, when price is low		
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 crop	Small business	Family level or crop	Small business
Existence of similar activities	Storage of other crops carried out	Processing well known and 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 work but simple	Needs work; rather complex	Simple	Known; relatively simple
Benefits:				
Farmers	+++	+	++	+
Processors	None	+++	++	+++
Consumers	++	+	None	+
Economy	+++	++	+	+

Note: Size of benefits: +++ = many, ++ = some, and + = few.

Table 14. Final screening of ideas for cassava product development in the Atlantic coast region of Colombia.

	Dried cassava (animal feed)	Cassava flour (human consump.)	Fresh storage	Starch
Demand	+++	+++	++	?
Raw material supply	+++	+++	+++	+++
Climate, water, electricity	+++	++	++	No
Farmer organization	Some	Some	Some	Some
Existing activity	No	No	No	No
Consumer acceptance	+++?	++?	?	++
Capital needs	Low	Medium	Low	Medium
Labor availability	+++	+++	+++	+++
Technology existing	Yes	No	No	Yes?
Benefits farmers	+++	+++	+++	?
Benefits landless labor	+++	++	+	?
Benefits urban distributors	No	+	++	No
Benefits consumers	No	No	+++	No
Conclusion	Proceed to pilot stage	Research processes and markets	Research processes and markets	Develop elsewhere

Note: +++ = excellent potential, ++ = good potential, and + = some potential.
No = constraint identified.
? = uncertain, more research required.

In the Atlantic coast region of Colombia, where there is a sizable market for fresh cassava, project planners perceived a need for new market options (Table 14). Because of drastic fluctuations in the price of this commodity, its production had become risky for small-scale farmers. The project elected to produce dried cassava for animal feed, because it requires only simple sun-drying technology and offers promise as a substitute for imported feedstuffs. Another option—production of flour for human consumption—required more applied research. So did the development of a more storable fresh root to supply urban markets. Project planners ruled out starch extraction, because it would have been difficult to obtain a reliable supply of good water in this seasonally dry environment.

Ideas Define Action

We cannot overstate the importance of correctly identifying product opportunities at the outset. All too often, projects are started on the basis of a cursory evaluation of the processing technologies available. The danger in this approach is that considerable resources may be committed to developing a product with only a minimal chance of success.

By taking time to generate a large number of product ideas and then evaluating them, you can identify quite efficiently the one or more products that are most likely to succeed. The screening procedure need not be time-consuming or expensive. In most cases you can obtain all the necessary information from secondary sources rather than generate a lot of new information through research surveys and other means.

In addition to generating one or a few product ideas, this stage in product development leads to the identification of a target region, where the product will be tested and eventually commercialized (Table 15). As the project moves through successive phases, more of its activities will take place in the target region rather than a research center.

In selecting the product idea, you will also define the general processes to be used in its manufacture (issues such as equipment needs and scale of the operation are dealt with in the research phase). Even though you may not have quantified demand for the product, you will at least have determined that it exists. You should also have a clear idea of the project's potential beneficiaries.

Table 15. Status of a product development project at the end of idea identification (phase 1).

	Phase 1—Start	Phase 1—Finish
Why (objective)?	Defined	Better defined as project progresses
Where (region)?	—[a]	Identified (general area)
What (product)?	—	Idea selected
How (process)?	—	General process determined by type of product
How much (market)?	—	Not quantified but good potential seen
By whom (type of enterprise)?	—[a]	
For whom (beneficiaries)?	—[a]	Defined

a. Possibly implied by project objective.

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Unit 4

Research for Product and Process Development

By now you should have formed a general idea for a product and decided in which region it will be developed. The next steps are to define the characteristics of the product as well as the process for manufacturing it and to quantify more precisely its market demand and potential profitability. To complete these tasks requires more information, which you can generate through two types of research:

- ***Market, consumer, and farm-oriented research*** to characterize existing patterns in production, marketing, and consumption of the selected commodity and of products that may compete with your own. Information gathered through these studies will highlight socioeconomic, cultural, and technical constraints that must be overcome to make the product a success.
- ***Technical research*** to develop a product that satisfies consumer demands and preferences and to design appropriate processing technology.

In this unit we first discuss the notion of an ideal system for producing and commercializing a root and tuber product (see Figure 3). Then, we describe how to examine the system's various components and links to determine whether any of these are missing. The missing elements provide the basis for an agenda of market, consumer, and farm-oriented research.

The next step is to develop a product brief, which gives the characteristics of the product. The technical research needed to develop the product and process consists of two stages: The first takes place in the laboratory, while the second focuses on prototypes of new equipment (assuming that existing equipment is unsuitable). With the information generated through research, you can prepare a prefeasibility study, which indicates whether the project is justified in proceeding to the pilot phase.

Designing an Ideal System

The first step in research planning is to design an ideal system for converting the raw material into the desired product. Using Checklist 5, you can break the system down into its component parts, which must be linked if the project is to succeed commercially.

It is important at this stage to analyze government policies that may affect the project. The existence of state-run marketing boards and monopolies, for example, may determine the marketing channel you use.

Some components of the ideal system may already exist. For example, farmers in the target region may already be producing the target crop. If the project's objective is simply to improve traditional products, all the components and links may be in place. To diversify the market for these products by improving their quality, you will need to establish new links to different markets and consumers. If the purpose is to develop a novel product, you may have to establish all the components and links of the system—from processing to consumption.

Having designed an ideal system, you need to investigate various socioeconomic, marketing, and technical issues to determine whether the system is viable and to identify specific constraints.

Take the case of a project in Colombia, whose objective was to link small-scale cassava farmers to the urban market for bakery products through rural processing of cassava into flour. To facilitate production of a composite wheat-cassava flour, it was proposed that wheat mills do the mixing for subsequent sale to bakeries through the wheat mills' distribution channels. To determine the feasibility of this system, the project researched a wide range of issues (as indicated in Figure 4), using a holistic approach.

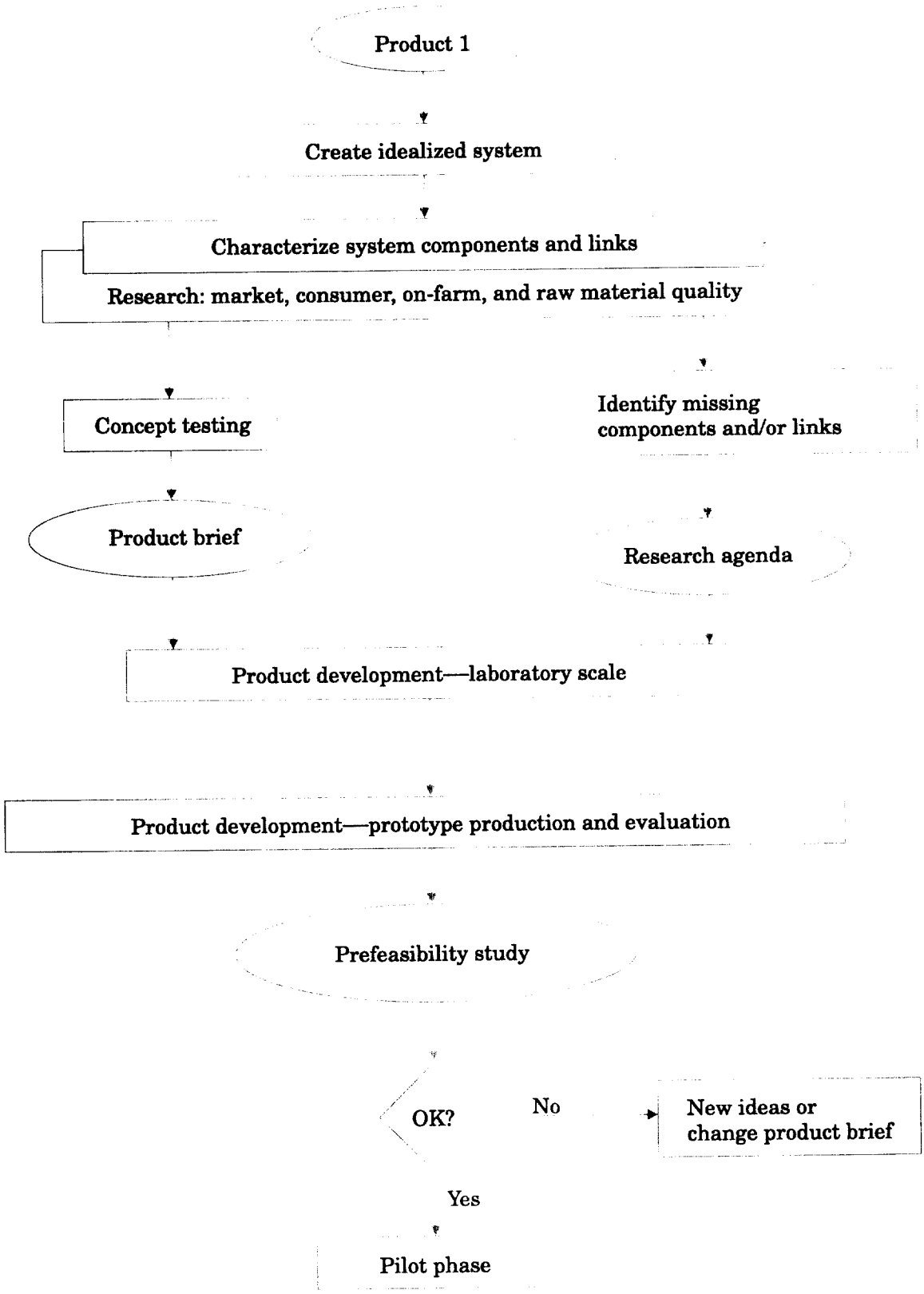

Figure 3. Stages in research for product development (phase 2).

Checklist 5

Components of an Ideal System for Producing and Commercializing a Root and Tuber Product

- ***Production*** to supply the raw material.
- ***Processing*** to transform the raw material into an end product. Often, processing has more than one component. For example, the raw material may first be transformed into a primary product, such as flour or starch, from which the final product is manufactured through further processing.
- ***Marketing*** (which includes distribution and promotion) to make the product available to consumers or clients. This consists of two components if wholesale and retail marketing are distinct.
- ***Consumption*** of the product by consumers, industrial clients, or both.

Market, Consumer, and Farm-Oriented Research

At this stage the technical problems associated with developing a new product and process may seem predominant. Yet, the commercial success of simple processing depends, not just on its technical feasibility, but on its attractiveness and utility for consumers. It is therefore essential that research on technical questions be balanced by a thorough investigation of socioeconomic issues.

What's in the market?

The aim of this research is to supply information on the components and links that are missing from your ideal system. It does so by defining the existing market structure, identifying products already on the market, and determining their costs. Checklist 6 can help guide your search for this information.

An easy way to prepare a list of processed products of a particular type or from a given food crop is to visit representative sales points in the target city or region. As indicated in Checklist 6, the list should include information on product characteristics. Intermediate users (e.g., bakeries and restaurants) and industries (such as flour mills and confectionery companies) can add to the list and pinpoint problems in the quality, cost, and availability of products or their raw materials. This information may suggest market opportunities.

To determine whether different products are marketable, it is helpful to talk with retailers, wholesalers, and industrial users. Could traders sell more of the product if they were supplied with more? Is price the key factor influencing sales?

Specialized libraries and documentation centers are a good source of useful secondary information. In addition, try to obtain feasibility studies on projects similar to yours from agroindustrial institutes, departments of food technology or business studies at local universities, regional offices of the agriculture ministry, rural development agencies, or credit institutions. Statistics on urban or rural food consumption habits may also be available.

Ask the consumer: Concept testing

Consumers' opinions should be taken into account as early as possible. Their tastes and preferences will indicate the type and quality of product that is most likely to succeed commercially. The quantity of product you can sell will depend on consumers' purchasing power.

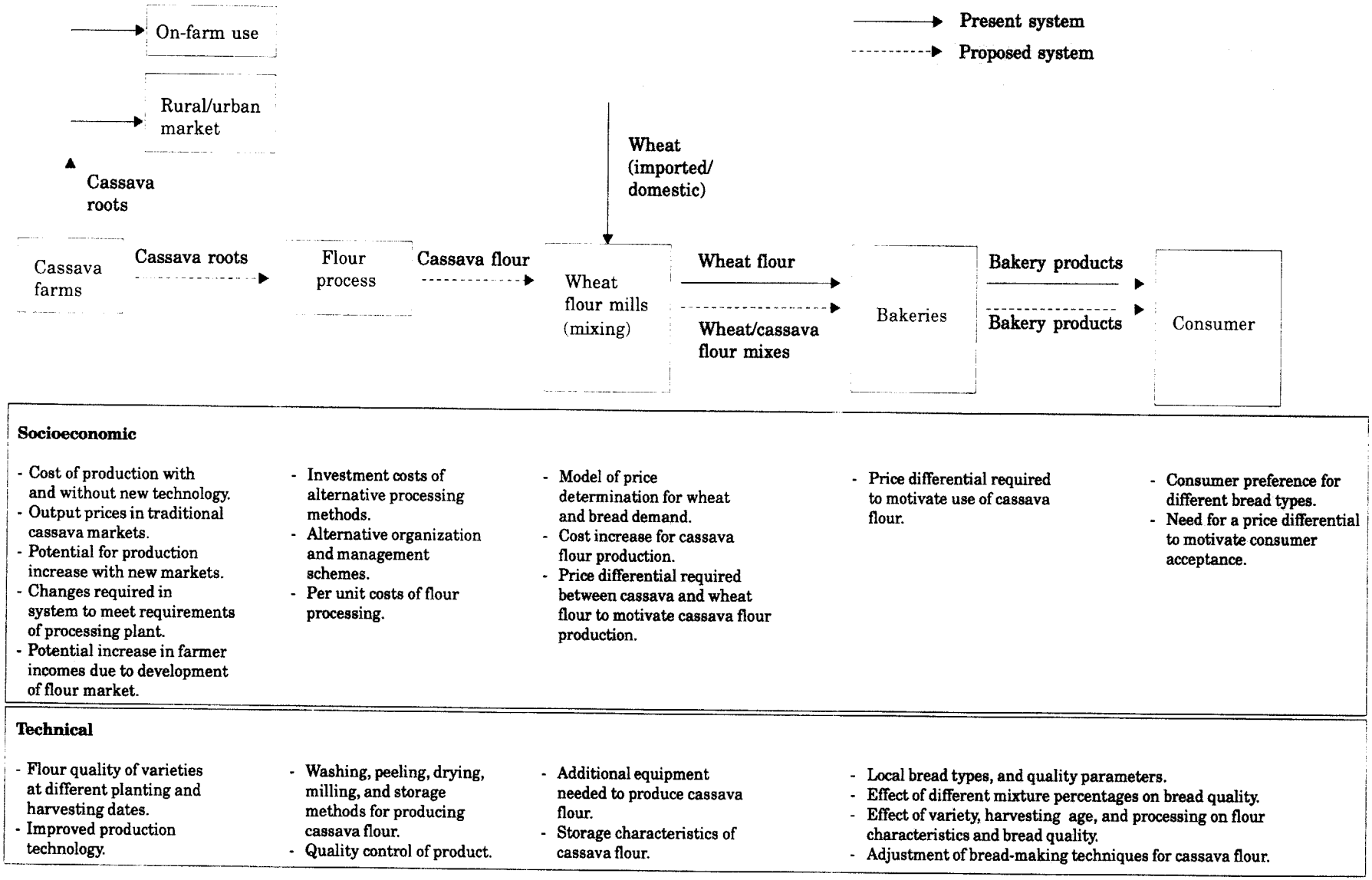

Figure 4. An ideal cassava flour system and major issues for research.

Checklist 6

Information Gathered Through Market Research

- **Market structure and costs from farm gate to consumer. This includes the number of intermediaries, volumes handled, margins obtained, frequency of purchase, quality problems, and product waste.**
- **Proposed or similar products in the marketplace.**
- **Characteristics of relevant products already on sale: color, size, form, unit size/weight, taste, package type, and storage properties.**
- **Sales volumes of relevant products, including growth trends.**
- **Locations where relevant products are sold (e.g., small stores, markets, and roadsides).**
- **Product characteristics (such as price and quality) that are critical for improving sales and consumer acceptance (from the viewpoint of retailers and wholesalers).**
- **Technology used by industry to produce the desired product or similar products and problems with the raw materials used currently.**

Central objectives of consumer research are to determine the characteristics (such as color, shape, and size) that consumers desire in a product—as well as those they dislike—and to determine which products are the most and least affordable. You can obtain this information by asking consumers about their food preferences and habits in purchasing and preparing food (see Checklist 7).

Consumer research separates the products that have high potential from those with limited possibilities. See Box 6 for an example of how market surveys and consumer interviews are used to evaluate the commercial potential of processed products.

Based on the information you have gathered through market and consumer research, form a series of concepts about how different consumer groups might use root and tuber products. Suppose, for example, that you want to market fresh cassava, packed in polyethylene bags, with good eating quality and a 2-week storage life (as described in Case 2). The product concepts might be as follows:

- 4-kg units for sale to middle and upper income groups who shop weekly in supermarkets
- 15-kg units for sale to restaurants and institutions
- 15-kg units for sale to neighborhood shopkeepers, who sell the product to low-income consumers in smaller subunits

For a more complex product—high-quality cassava flour for human consumption (as in Case 3)—some likely options are:

- 25- or 50-kg units for sale to industrial concerns, which would incorporate the flour into a range of food products
- 2.5-kg units for sale to flour wholesalers, who would mix it with wheat flour and sell the composite flour to local bakers
- 250- or 500-g units for sale through local retailers to consumers for household food preparation

Checklist 7

Questions for Consumer Research

Food preferences

- What product size, color, weight, use, storage life, preparation time, and price is acceptable to consumers?
- Do they consider the product to be nutritious, tasty, filling?
- How does the product compare with substitutes in terms of price, quality, and availability?
- Is the product of good hygienic quality?
- Is there a need for new or different products?

Habits in purchasing food

- Where do consumers purchase food products, how often, and in what volumes?
- How aware are consumers of processed products in the market?

Background information

- What is the level of consumption of root crops and processed foods (by income group and season)?
- What are the principal types of processed foods available in the market (identify gaps)?

The next step is to test these concepts by presenting them to consumers through a combination of text and photographs. Try to get answers to the following questions:

- Do consumers comprehend the product concept?
- Are its benefits relevant to them?
- How would they use the product?
- Given the suggested unit price, would they purchase the product?

Concept testing is a rapid, cost-effective method of defining important product characteristics, based on consumer needs. It helps eliminate uses or ways of presenting a product that are unattractive to consumers.

A stable supply of raw materials

Whereas agricultural supply is naturally cyclical, the demands of processing are mostly stable. That is one reason why satisfying the raw material requirements of a processing plant can be a major challenge.

In some cases, depending on operating costs and returns per production unit, it may be profitable to carry out processing during only a few months of the year. But in others processing may not be economically viable unless it can be kept going year-round. To further complicate matters for processors, growers may already have a ready outlet for their produce, even in the peak harvesting period, or they may have only occasional difficulty in selling their crops.

Given these uncertainties, processors must seek answers to a number of questions. Can I obtain reliable supplies of raw materials? Can I get enough to justify establishing a processing facility? Are the raw materials of adequate quality? Is the price acceptable? To answer these and related questions requires production research.

The results should define current patterns of supply and determine whether price movements are such that growers will be interested in selling to a processor or engaging in processing themselves. Important issues for this research are the quality and uniformity of supply and the costs

Box 6

Consumption of Processed Potato Products in Peru (Case 7)

The problem

By 1987 technical and market research on potato in Peru had yielded valuable information on simple processing technology (Keane et al., 1986), traditional 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 products into the diets of low-income people in the capital (Benavides and Rhoades, 1987).

Nevertheless, not much was known about consumption of various processed potato products by different income groups in Lima. To gather this basic information, a team of social scientists was formed at the Universidad del Pacífico in 1987 (Gómez and Wong, 1988). The approaches they employed and the outcomes of their work are outlined below.

Methods

- Literature review
- Participant observation
- Informal interviews with potato processors and traders
- Pilot consumption survey, using a structured questionnaire

The survey covered consumers (n = 199) with high (n = 19), medium (n = 81), and low incomes (n = 99). They were interviewed in supermarkets, shops, stores, and markets. The preliminary findings were presented to a group of processors and traders.

Results

- The following processed potato products were available:
  - Potato starch
  - Traditional dehydrated potato (*papa seca*)
  - Imported instant potatoes
  - Potato bread
  - Potato crisps
  - Bleached, dehydrated traditional potato (*papa chuño*)
  - Peeled, precut potatoes for restaurants
- The total annual requirement of fresh potato for the Lima market alone was estimated at 36,000 t.
- Consumers were not aware of the range of products available in Lima and were interested in knowing more about them and their uses.
- Consumers' perceptions of product attributes and defects were as follows:
  - Potato starch: tastes good but tends to go lumpy.
  - Potato crisps: practical and readily available but are greasy and salty and spoil quickly.
  - Instant potatoes: easy to prepare but have an acidic taste.
  - Dehydrated potatoes: filling but have a bitter taste and are of uneven quality.
  - Bleached/dehydrated potatoes: nutritious, but the pieces are too small.
- Demand for snack foods and convenience products (such as crisps and instant potatoes) was more responsive to simulated declines in price than that for products with specific uses (such as potato starch and traditional dehydrated potato).
- People of different income groups varied markedly in their knowledge of particular processed products. High-income consumers knew much less about traditional bleached and dehydrated potatoes than did middle- and low-income groups.

Impact

Based on the results of this survey, product quality was improved with respect to color (specifically, yellow and gold were found to be the most desirable colors for dehydrated potato) as well as purity and cleanliness. Later, these improvements led to successful contracts for test marketing of an improved product by two major supermarket chains in Lima.

of assembly and transportation. The topics indicated in Checklist 8 can serve as a guide to planning production research.

It is particularly important to determine at this stage whether the quality of the raw material is adequate for manufacturing the desired product. To enhance quality requires a significant investment in research (on genetic improvement or agronomic practices), which tends to have a long lead time. For that reason problems with quality can greatly diminish the feasibility of a project.

In assessing raw material quality, consider the factors indicated in Checklist 9. Obviously, the relevance of each depends on the end product.

To obtain information of the sort described in Checklist 8, you can synthesize secondary data, review the available literature, and collect primary data. In accumulating primary information, it is particularly important that you interview different types of representative growers. Try to measure the interest, not just of large-scale growers who seek to maximize profits, but also of subsistence farmers who may have minimal surpluses to sell and hence a limited interest in commercial processing.

Data on the annual volume of crop production in a particular region can generally be obtained from the Ministry of Agriculture or National Bureau of Statistics. Most commodity research programs have information on planting and harvesting dates. You can estimate the output of different categories of farmers and determine particular groups' share of total production from agricultural census data or by synthesizing the results of formal farm surveys. Producer prices for specific crops (by calendar year or month to month) are often available from the Ministry of Agriculture.

Analyzing information on production may be sufficient by itself for gauging the potential of certain crops or regions for processing. For example, if an area produces only a small amount of sweet potatoes for the fresh market and prices are always high, farmers are unlikely to be interested in sweet potato processing.

On the other hand, if your analysis suggests that there are good possibilities for producing a particular product at a given location, check with research centers (such as university libraries and agroindustrial institutes) for information on past, farm-level attempts to introduce or improve processing. Examine closely the objectives, track record, and major constraints of previous or ongoing experiments or projects that have proven unsuccessful.

Checklist 8

Essential Information on Raw Material Supplies

- Varieties planted, planting and harvest times, and seasonality of supply
- Experience of farmers in producing the crop
- Postharvest grading by size and quality and use by grade of produce
- Reasons farmers prefer particular varieties
- Rural marketing channels, seasonal stability, typical traders, volumes traded, and forms of payment
- Potential for changing the existing system with regard to variety used, harvest times, marketing arrangements, etc.
- Farmers' potential or limitations for producing and/or marketing processed products

Checklist 9

Factors Determining Raw Material Quality

- **Physical: root size, shape, and uniformity; peel thickness and color; parenchyma color and hardness**
- **Chemical: dry matter, fiber, starch, etc.; presence of antinutritional factors or toxins**
- **Organoleptic: aroma, taste, and texture**
- **Functional properties (of starch and flour): viscosity, etc.**

Formal or informal methods?

In general, you can make sound decisions about product development on the basis of indicative, as opposed to definitive, information. For that reason unstructured survey techniques are usually adequate for market, consumer, and production research. They are also faster and cheaper than formal surveys.

Only in certain cases (e.g., a consumer survey in which it is important to differentiate among income groups) is the extra precision of a formal survey warranted. A sample of 50-200 consumers should be adequate. Pretest formal questionnaires with a small group of target respondents.

Formal methods may also be necessary for sampling farmers' opinions and getting at the underlying reasons for them. The larger the number of alternative products and processes, the more precise the quantitative information required and the more important it is that you conduct a formal survey. If you can reduce the possibilities to one or two (e.g., through analysis of secondary data), informal interviews may be sufficient.

If you need information from consumers of a particular product, interview purchasers of these products at the point of sale rather than conduct a general consumer survey through household visits. The type of consumer you interview depends on the product. For example, if you are studying the prospects of intermediate products (flours, starch, etc.), industrial clients, restaurants, and bakeries should be the principal sources of information.

Interviews should take place at the convenience of the respondents, not the interviewers (busy traders and tired housewives have little time to spare and under pressure may give inaccurate replies). Conduct interviews in a low-key, nonaggressive fashion to gain the confidence of respondents (this is especially important for market agents and industrialists); they will then be more likely to answer supplementary questions aimed at resolving contradictions.

Whether you are preparing structured or unstructured surveys, phrase each question carefully to avoid ambiguity. Collect only the essential information to reduce costs and improve the quality of the results. To make the best use of survey results, the project must be able to process and analyze the data rapidly.

If you have little experience in this kind of research, it may be helpful to memorize a list of the topics you wish to cover during informal surveys. Compare the results with the opinions of technical specialists.

Where possible the same team of researchers that compiles the secondary information should also carry out the market and consumer surveys. The team should consist of technical as well as social scientists. We cannot overemphasize the importance of getting technical researchers out of

the lab or workshop and into the market. This interdisciplinary approach can open new avenues for technical research and help sharpen its focus on the most relevant problems and opportunities.

Box 7 illustrates the use of a formal questionnaire to evaluate the potential of a particular process. (For more information on survey techniques, see the list of publications at the end of this unit.)

Box 7

Assessing the Potential for Potato Processing in Colombia (Case 8)

The problem

Potato researchers in northeastern Colombia decided to explore the potential of simple potato processing in an effort to develop alternative uses and markets for the crop and thus stabilize prices and improve growers' incomes. They set up a small pilot plant in the Pamplona region to demonstrate that processed potato products could be produced, using simple technology and local varieties, infrastructure, and technical personnel. Afterwards, a research project assessed the socioeconomic feasibility of the technology, emphasizing the needs and interests of local producers. The outcomes of this study are outlined below.

Methods

- Review of available studies and secondary data on potato production and marketing in the region
- Demonstrations for local producers of products and dishes prepared with them (e.g., cakes and soups)
- Formal survey of 81 growers from five districts in the region. Information on technical aspects of potato production was collected, and farmers' interest in processing was assessed.

Results

- Sixty-three percent of the farmers interviewed had produced potato for over 20 years. In 1986 average potato production per farmer was 52.7 t, of which only 9% was sold.
- Most potatoes were sold from September to January, when supplies are abundant, and less than 40% in April-May, when supplies are lower and prices higher. Farmers rarely stored the crop for sale at a later date.
- Growers reported that, although prices had fluctuated somewhat, they had not been low for several years.
- Seventy-three percent of farmers relied on family labor; shortages at harvest time were common.
- Most farmers (72%) were familiar with potato crisps, but 28% knew of no processed potato product.
- Almost all growers were interested in processing part of their production to improve prices, diversify the family diet, and provide employment for household members. They mentioned such products as potato chips, potato flour, and French fries.

Impact

Though interested in processing, farmers lacked a compelling incentive to pursue it, since they generally had little difficulty in selling their harvest at reasonable prices. Moreover, the shortage of labor at harvest would have made it practically impossible for them to adopt a labor-intensive technology. If this survey had been conducted earlier, researchers could have located the pilot plant in a more suitable region.

Developing the research agenda and product brief

The research agenda comprises the topics you must investigate to supply missing components and links in the processing system and to provide information for a prefeasibility study. The research needed for the first purpose should be evident from your analysis of components and links (discussed above). The elements of a prefeasibility study are listed in Checklist 11 on page 70.

Based on the results of market, consumer, and product research, you should be able to prepare a product brief (see the examples in Table 16). This document gives the specifications of the final product as well as its raw material and processing requirements. Some products require more than one process or a combination of raw materials. Processing more than one root crop (assuming that their harvest times differ) or other crops, such as plaintain, with similar processing requirements may help you increase the number of months per year the plant can function.

Technical Research on the Product and Process

In this section we describe technical research, whose purpose is to ensure that the product meets the expectations—in terms of price and quality—of consumers or clients. This research focuses both on the product itself and on the process by which it will be made.

There are two types of product: first and second generation. The former results from what we describe as *primary transformation*. Examples of first-generation products of roots and tubers are flour and starch as well as fresh roots that have been selected, treated, and packaged to improve their presentation and prolong their shelf life.

Products such as flour and starch are often used as raw materials in *secondary transformation*, which gives rise to second-generation products. In some processes of this type, other ingredients are added to the raw materials (as in the production of balanced animal feed rations and composite flour) without altering

Table 16. Product briefs for two cassava products.

	Dry cassava for animal feed (Case 1)	Fresh stored cassava for human consumption (Case 2)
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 high-quality fresh cassava root product with a storage life of up to 2 weeks.
Raw material	Cassava roots with high dry matter and low/intermediate cyanide content.	Cassava roots, selected by size and eating quality.
Processing	Roots washed, chipped, and dried by either natural or artificial means; processing to be carried out by farmer co-ops or small- to medium-scale agroentrepreneurs.	Roots treated to suppress physiological and microbial deterioration; treatment and packing to be done by farmer co-ops or assembly agents.
Packaging	The dry root chips to be packed in 50-kg sisal or polypropylene sacks; closure of sacks to be done manually or by machine.	Roots to be packed (in polyethylene bags, plastic crates, or wooden boxes) according to market outlet.
Marketing	The dried chips to be sold directly to animal feed concentrate companies or to livestock producers; promotion to emphasize high starch digestibility, availability and relative cost.	The stored cassava to be sold through supermarkets and local neighborhood shops; promotion to emphasize freshness and storability.
Consumers	See marketing above.	Families from all socioeconomic groups, favoring those with poor market access.

their physical characteristics. Other processes modify the raw materials, biochemically or physically, through cooking, extrusion, fermentation, and so forth.

Investors in processing

One vital question that may still be unanswered at this point is who will invest in manufacturing the product. Though in any situation you will have various options, it may not yet be possible to select one. This is not an issue if your purpose is simply to improve the marketability of an existing product by reducing production costs or improving quality. But if you intend to establish a new product, look seriously at the following candidates:

- *Existing agro- or food industries:* This alternative, which you can explore while conducting market research, is most appropriate for making second-generation products, since a certain level of skill and experience is required to achieve the desired quality.
- *Entrepreneurs:* You may be able to identify interested parties through groups of entrepreneurs, such as food manufacturers associations or growers federations. The entrepreneur need not have previous experience in agroindustry but should be involved in the project from an early stage.
- *Farmers organizations:* Producer associations or co-ops may be the ideal candidates, since they have direct control over raw material supplies and may also have the necessary managerial and administrative capability. In some cases, though, it may be necessary to form such an organization to get processing established. If so, it should normally focus on first-generation products, at least initially.

Your choice among these alternatives will greatly influence the technology selected for manufacturing the product.

Two stages of research

Technical research takes place in two stages. In the first your principal aim is to develop, on a lab or bench scale, a prototype product with acceptable physicochemical and, in the case of foods, organoleptic characteristics. A taste panel is essential for checking the acceptability of a food product. In the second stage, you select and develop prototype equipment for manufacturing the product under experimental conditions. This equipment can then be incorporated into the pilot plant. Consult Checklist 10 for ideas in planning technical research.

Raw material quality

In Unit 1 we discussed the physical or mechanical characteristics and chemical constituents of root and tuber crops. These traits determine to a large extent the type of processing technology used.

The end product results from the interaction between raw materials and processes. To take a simple example, a root crop with a high dry matter content (> 40%) can be dried at low cost through natural drying, whereas a root with only 15% dry matter will take longer to dry and require more sophisticated drying procedures and equipment to achieve comparable product quality after drying. In general, process economics improve with increasing dry matter or starch content; that is, fewer tons of raw material are required to make a ton of end product.

If the raw material has toxic or antinutritional factors, extra processing or increased processing time may be required to eliminate or reduce them to acceptable levels. Table 17 shows how particular standards in end-product quality can be met through processing or improving raw material quality.

The nonuniform size of some roots and tubers reduces the efficiency of processing, particularly during initial operations, such as peeling. One solution is to grade roots by size before peeling, but this adds to labor costs. Another option, hand-peeling, is also labor intensive and in some areas possibly uneconomical. It may still be justified, though, as a source of employment.

The right raw material specifications are those that, in combination with the appropriate processes, give a product of the required quality. If only a small percentage of the

Checklist 10

Main Activities of Technical Research for Product Development

Laboratory research

- Make the product in small quantities.
- Have taste panels and consumers test the product.
- Test product quality, using chemical and functional methods.
- Define raw material standards.
- Define, select, and test process options on a small scale.

Prototype development

- Determine the scale on which processing will take place.
- If necessary, develop and test equipment.
- Determine the layout of process operations.
- Test product quality, process efficiency, etc.
- Revise raw material and product quality specifications.
- Determine process operating parameters, such as conversion rates and amounts of inputs (fuel, labor, water, and raw material) required per ton of product.
- Determine packaging materials and storage conditions and times.
- Establish the costs of equipment and infrastructure and amount of working capital needed.

Table 17. The relationship between end-product quality, the process, and raw material.

End-product quality	Process	Raw material
Dry matter < 14%	Natural or artificial drying	High dry matter content needed
Low microbial count	Hygienic conditions, water treatment, rapid drying	Absence of preharvest rots, etc
Fiber content < 3%	Peeling, sifting	Age at harvest, variety, environmental conditions
Protein content > 5%	Fermentation	Variety
White color	Sulphating, rapid drying, removal of impurities, water treatment, rapid processing	Variety

harvested roots and tubers meet those specifications, farmers must have a good market for rejected roots or receive a price that encourages them to cater for such a demanding market.

If locally available varieties fail to meet quality standards, you can consider introducing new ones. Where promising varieties are available, they will need to be evaluated on-farm. For some crops, such as cassava, multiplying enough planting material can take considerable time. If no suitable varieties can be found, it may be necessary to initiate a breeding program.

If so, should new varieties be developed specifically for processing, or must they satisfy the requirements both of processing and the traditional market? In varieties aimed at the fresh market, organoleptic and other factors related to consumer preference are important. To breed these traits into new varieties that have improved processing attributes may be complex and time-consuming.

On the other hand, farmers may resist the introduction of an "industrial" variety that is unacceptable to the fresh market, unless they are provided with price incentives, a secure market, or both. Farmers prefer a variety that can be sold in several markets. Being overly dependent on a single market is risky for them, because it exposes them to the danger of price fluctuations. If you plan to introduce an industrial variety, you must also find a way to compensate farmers for increased risk.

Product quality

The results of consumer and market studies should give you a clear idea of the end product's characteristics and quality. The product may also have to meet certain legal standards (such as those established by governments for foods). Since both the raw material and process determine end-product quality, you need to identify the aspects of both that are crucial for meeting quality requirements economically (see Table 17).

At the outset of technical research, monitor the quality of the end product as well as the efficiency of the process. The most important quality traits are chemical composition, functional properties, and use characteristics (e.g., storage time), which affect the product's appearance, organoleptic properties, hygiene, and performance.

Selecting technology and equipment

Your choices should be based on various factors, including:

- ***Scale of the operation:*** If the value added by processing roots and tubers is to remain within rural communities, small-scale processing is preferable. Many processes are designed to operate on a larger scale than is feasible for rural enterprises. Even so, small-scale processing is carried out in many parts of the world, and much research has been conducted in support of this activity. If you are introducing a novel process or scaling down a large operation, research will be needed to develop suitable equipment.

- ***Capital investment:*** The more capital the enterprise requires, the more likely it is to fail. This is especially true for small-scale farmers organizations that depend on credit for investment in infrastructure and equipment. As a general rule, new enterprises should start with simple processes requiring little capital investment. Only after gaining some business experience, should they expand into more complex processes requiring greater investment. In a cassava project in Colombia, for example, a cassava flour process was introduced to a group that was already managing successfully a simpler, natural drying process for producing animal feed.

  Wherever possible, use equipment that is or can be manufactured locally. This not only creates jobs locally and reduces costs but simplifies maintenance and repairs. If at all possible, avoid using imported equipment.

- ***Conversion or extraction rate:*** This is probably the single most important variable affecting the financial feasibility of the process. It depends both on the raw material and process. Choose the process that offers the best conversion or extraction rate and incurs reasonable energy and labor costs. If none of the available equipment meets these criteria, you may have to develop new or modified equipment.

  In the cassava flour project mentioned above, this was necessary in two cases. First, to achieve a good fresh-to-flour conversion rate, root peeling had to be dropped in favor of peel removal during milling and separation of dried chips. Second, a small-scale mill had to be developed that could convert chips into flour at a rate of 80%-85%.

- ***Amount of value added:*** If the cost of the raw material is high relative to the value of the final product (i.e., if the amount of value added is low), costly processing is not viable, unless the volume of production is high. In constrast, an end product aimed at high-income or export markets requires a certain type of processing and equipment to meet high standards in quality and packaging.

For example, in producing dried cassava for animal feed, natural drying of the cassava chips is essential for keeping the price of this product low. Only when chips are to be milled for human consumption—and thus sold at a higher price in a different market—is artificial drying a viable option.

- ***Availability of services and utilities:*** Many processes require potable water, electricity or natural gas, or good communications infrastructure (such as roads, telephone, and radio). But roots and tubers are frequently produced in the poorest areas with the least access to basic services. Under these circumstances, the project's options are to:

  - Develop a process that can be carried out only in those limited areas where utilities or services are available—and thus restrict the benefits to communities that are already better off than most.
  - Develop a process that is suitable for all areas (e.g., by using biogas energy, water power, natural drying, etc.).
  - Divide the process into two stages. The first would require few, if any, external inputs. The material would then be transported to a centralized secondary processing plant that has the utilities and services required to manufacture the final product.

  Bear in mind that some services, such as telephones, may be essential for marketing the product.

- ***Managers and operators' level of education:*** The process should not be so complex or require such precise control over certain variables (such as drying temperature and the chlorine content of the water) that rural people will have difficulty carrying out or monitoring it. Literacy is essential for certain processes and for maintaining business records. Even so, illiterate farmers are quite capable of performing many tasks (e.g., judging the moisture content of dried cassava chips based on empirical measures, such as chip texture).

Here are a few other points to consider in deciding what equipment to use:

- The different items of equipment should be compatible in terms of capacity. Look for potential bottlenecks and decide how you might expand capacity: by duplicating the original process or by increasing the capacity of one or more items of equipment.
- Some processes (e.g., root peeling and slicing and starch separation) can be carried out either manually or mechanically. An important advantage of mechanized processes is that they give uniform throughput and product quality. Manual labor, on the other hand, generates employment, especially among women and the elderly. But if labor is expensive it may also greatly increase costs. Where gender issues are particularly important, it may be valuable to use manual labor in at least one stage of a process. Keep in mind that mechanization often means replacing many women with one man.
- If the project requires a new type of equipment, try to pick up useful ideas (e.g., about design, power sources, and construction materials) from other agricultural processes in the area or from processing equipment employed for roots and tubers in other parts of the world before embarking on prototype development.

Designing equipment is a specialized task requiring the services of qualified mechanical engineers. Few national agricultural or development institutions have such specialists. But they may be found in universities, industrial research centers, and technical colleges. It may also be useful to link up with local metal workshops that have experience in manufacturing small equipment. Designing and testing prototypes of small equipment has proved to be an excellent subject for student thesis projects. See Box 8 for an example of equipment selection.

Laboratory taste panels

Laboratory analysis of an end product can indicate whether it meets certain quality

Box 8

Selection of Equipment for a Cassava Flour Project in Colombia (Case 3)

The production of high-quality cassava flour for use in food products is a simple process, involving washing and peeling roots; chipping or cutting them into uniform pieces; and drying, milling, and sifting the chips or pieces. Much research has been conducted on the design and development of small-scale equipment for processing root crops. Sometimes locally available equipment is suitable for milling and other purposes.

The first steps in selecting equipment for this project were a literature search and visits to local agricultural engineering companies and other agroindustrial enterprises that operate on a fairly small scale (such as coffee drying and maize processing plants in Colombia).

Root washer/peeler: Equipment based on designs from the literature were built and tested. Although it removed the peel effectively, this equipment caused a large amount of the root parenchyma to be lost. Project staff selected instead a local washer used in small-scale plants to extract cassava starch. This equipment removed much of the outer bark but not the peel itself.

Root chipper: Prototypes based on designs from Brazil, Malaysia, and Thailand were built and tested. The best features of the Thai and Malaysian designs were incorporated into a composite design.

Root chip drying: Artificial drying was found to be more suitable than natural drying, both for reasons of product quality and because it would permit year-round processing. Through-circulation bin driers for cassava, developed at the University of Viçosa in Brazil, were adapted to Colombian conditions.

Coal-fired burner and fan: Initial economic studies suggested that coal, which is abundant and cheap in Colombia, would be the best fuel. A customized version of a local proprietary design was built through a student project. The fan was purchased locally.

Dry chip milling and flour sifting: Local hammer and other mills were tested but could not provide high enough extraction rates for cassava flour. A local machine shop developed a small-scale sifter, based on a larger Swiss design. Local wheat flour mills also milled chips in the standard roller mills, with an extraction rate of more than 85%, from washed, unpeeled roots (the peel was removed in the by-product).

specifications. But only tests with human subjects can tell whether it also possesses more subjective traits, including an appealing taste, aroma, feel in the mouth, texture, etc. Since these traits are essential for gaining consumer acceptance, it is critical that you evaluate the product for them during the research phase.

For each product attribute (e.g., sweet taste and hard texture), taste panels can provide two types of information: an intensity rating and an acceptability rating. Only a trained panel can provide the first type, because this is more or less objective information; it has no relation to consumer likes and dislikes, which can vary by region, income group, etc. The second type of information, in contrast, is directly related to the preferences of taste panel members. You cannot assume that other sectors of the population will give the same responses. For this type of testing, relatively untrained panelists and less controlled conditions are suitable.

Laboratory taste panels can test products fairly objectively under controlled conditions. For this purpose it is not enough just to gather the lab

workers for half an hour every week. You need to select panelists who are representative of the target population and have a good sense of taste, smell, etc. (You can screen candidates for this latter ability by asking them to identify and rank sweet, salty, bitter, and acid solutions of differing concentrations).

Though you need not construct a special facility for testing products, it is important that the panel meet in a quiet place with controlled lighting and that samples be presented in random order. This will keep human and other errors to a minimum. Early on, the group should hold discussions to reach a consensus on the quality characteristics it will evaluate. The rating scales used should be easy to understand.

Some general evaluation criteria and sample rating scales are listed below:

- Intensity of particular quality characteristics (e.g., for sweetness: low to very intense)
- Intensity of quality characteristics relative to a standard (e.g., much sweeter than X)
- Acceptability (very acceptable to not acceptable)
- Preference relative to standard (prefer X to Y)
- Hedonic evaluation (like or dislike)

The literature contains many examples of product testing (see Watts et al., 1990, in the list of publications at the end of this unit). To ensure proper interpretation of the results, subject them to statistical analysis; the method you use depends on the evaluation scale and experimental design.

Consumer testing of products

Evaluating food products in the lab is not enough. At some point in the latter stages of research (certainly no later than the pilot phase), they must also be tested by ordinary consumers in their own homes. Consumers' methods of preparation (including use of other ingredients, cooking times, etc.) vary greatly, as do their perceptions and food preferences. As a consequence, the results of this evaluation will reflect various factors, giving an overall measure of consumer acceptability or intent to purchase.

Because consumers' opinions are so variable, your sample should be relatively large. It should also represent the target population accurately, with respect to income level, proportion living in rural and urban areas, family size, etc. In urban areas census data can help you determine the proper composition of the sample.

To organize and conduct tests in the consumers' homes can be very time-consuming. You may have to visit some participants repeatedly; drop-out rates will tend to be high; and some consumers may not follow the instructions properly (e.g., on food preparation dates). If the objective is to gauge the response of high-income consumers, you may have difficulty getting enough people to participate. Because of such difficulties, only a limited number of different products can be tested in this way.

Packaging and shelf life

Near the end of the research phase, you will need to decide on packaging and determine the appropriate shelf life. You can obtain much of the information needed for this purpose from consumer and market research. Inquire about the length of time that consumer goods normally remain in shops and homes and industrial goods in storage before further processing. Through consumer surveys, you can gather other useful information, such as appropriate package sizes and storage conditions at home and in stores.

Next, you should evaluate a range of packaging materials under typical storage conditions for changes in chemical composition, functional properties, appearance (especially color), and organoleptic characteristics (using taste panels) as well as for signs of insects or contamination by microbes.

Based on the results, you can then design the best package, taking into account the product's

stability over time and the cost of materials. In preparing the prefeasibility study, be sure to indicate packaging costs, including that of printing logos, instructions, and so forth.

Product name

Even in the research stage, it is not too soon to select a name for the product and have it legally registered. Often, researchers give little thought to this task, using names that have little consumer appeal. The product name should:

- Highlight the benefits of the product for consumers.
- Suggest product attributes (such as color, use, and taste).
- Be easy to pronounce and recognize.
- Be distinct from names of similar products.

A well-chosen name will make the final product more marketable by associating it with characteristics that consumers like. A fast and easy way to test product names is to interview consumers who purchase similar products (see the results of one such survey in Box 9). Repeat this exercise in each of the product's potential markets.

As is evident from the survey described in Box 9, legal registration of a brand name is important. The first step is to search the lists of registered names for the one you have selected (many names are registered but not used commercially). If the name is not listed, a lawyer will be needed to register it. This will prevent others from using the same name once the product is established.

The product name must have an owner. Some options are the project's executing agency, a farmer group or cooperative, or a small business. An even better candidate is some second-order organization that supports the project, since it can represent all the organizations involved.

The prefeasibility study

The purpose of a prefeasibility study is to determine whether a particular product and process should go on to the pilot stage. This decision should be based on a careful analysis of technical, economic, financial, and commercial information (see Checklist 11). Although much of this information may still be tentative, it should be adequate for making reasonable assumptions about such matters as the production capacity of the plant, the processing technologies to use, the raw material inputs and total investment costs, production costs, sales revenues, and returns on investment.

Based on these assumptions, you can determine rates of return and other financial information by means of a simple financial model (Ostertag and Wheatley, n.d.). At this stage or even earlier, the model can help you assess the merit of different options in processing. For example, if several drying systems show potential, you can feed the investment and operating costs of each into the model to determine which is best. Another use of the model is to determine the minimum size at which the pilot plant can operate profitably. If the proposed operation appears unprofitable, the model can help identify ways to improve the process, reduce costs, and so forth.

The types of research described in this unit should generate enough information to prepare a prefeasibility study and decide whether to set up a pilot plant in the target region. (For more information on feasibility analysis and related topics, see the list of publications at the end of this unit).

A Preliminary Status Report

By the end of the research phase (as indicated in Table 19), the product has been produced on a small scale, using prototype equipment. It has also undergone a preliminary consumer evaluation. You have determined the approximate costs both of capital and operations and selected the target region. Market research has helped define the product's potential. If the results of the prefeasibility study are positive, you can proceed to the pilot phase, in which the product and process will be tested on a small scale in a commercial environment. At this point you need to identify the enterprise or group that will manage and operate the pilot plant.

Box 9

Selecting a Name for Fresh, Storable Cassava in Colombia (Case 2)

In preparation for marketing storable cassava roots, packaged in polyethylene bags and treated with a thiabendazole-based chemical, project staff interviewed consumers in supermarkets as well as neighborhood shops and markets in three Colombian cities. Each participant was asked to select one product name from a list of five. The results are given in Table 18.

Consumers showed clear preferences for some names over others. Interestingly, two names that are virtually identical, Yucarica and Ricayuca, received very different scores. The two highest scoring names, Yucafresca and Superyuca, both suggest the special character of storable cassava. Superyuca was selected, since Yucafresca had already been registered by another enterprise.

Table 18. Consumer responses to product names.

Name	English translation	Percentage of consumers interviewed			
		Bogota	Cali	Barranquilla	Average
Yucarica	Tasty cassava	20	24	20	21
Superyuca	Super cassava	18	22	36	29
Ricayuca	Tasty cassava	10	12	10	11
Yucafresca	Fresh cassava	41	26	26	31
Deliyuca	Delicious cassava	8	14	4	9

Table 19. Status of a product development project at the end of the research phase (phase 2).

	Phase 1—Start	Phase 1—Finish	Phase 2—Finish
Why (objective)?	Defined	Defined	Well defined
Where (region)?	—[a]	General area identified	General area identified
What (product)?	—	Idea selected	Idea and concept tested
How (process)?	—	General process identified	Options considered, tested and best selected
How much (market)?	—	—	Loosely identified
By whom (type of enterprise)?	—[a]	—	—
For whom (beneficiaries)?	—[a]	—	Defined

a. May be defined in project objective.

Checklist 11

Elements of a Prefeasibility Study

- ***Technical feasibility:*** Whether the product can meet quality standards and be made efficiently depends on various aspects of the:
  - Raw material—time between harvest and processing, variety, time to maturity, levels of damage caused by root rots and other diseases or pests, dry matter content, and other root quality attributes
  - Process—conversion rate for fresh root to final product, raw material rejection rate, time and labor requirements for all stages of the process, amount of other inputs (e.g., water, electricity, fuel, and other raw materials) required per ton of final product, and parameters affecting product quality (e.g., drying and fermentation temperatures and pH)
  - End product—moisture content, chemical composition, purity, microbial standards, color, particle or unit size, and storage life
- ***Commercial feasibility:*** Whether a product of the required quality can be sold at the price offered depends on marketing variables:
  - Product—quality and availability throughout the year
  - Price—ability to compete with similar products and potential market response to increases or decreases in price
  - Distribution—potential channels and size of margins
  - Promotion—approach used, expected effect on demand, and cost-effectiveness
- ***Financial feasibility:*** Whether the product can yield the required rate of return on capital invested depends on:
  - Size of capital investment—estimated costs of infrastructure and equipment
  - Working capital needed—for raw material and other inputs
  - Scale of operation—plant capacity and utilization rate
  - Processing costs—number of units and cost per unit of each input (e.g., raw materials, water, fuel, labor, etc.) per ton of final product
  - Margin expected—sale price of final product and any by-products (weighted average price)
- ***Business feasibility:*** Whether the enterprise can be run profitably without outside support in the medium term depends on:
  - Type of business proposed—cooperative or commercial enterprise
  - Managers and workers' level of education
  - Training needs and capacity to supply training
  - Complexity of the process
  - Other aspects of the business—raw material supply, market development, accounting, etc.

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Unit 5
The Pilot Phase

In this unit we describe the pilot stage of research and development, focusing on an experimental product and process. The purpose of this stage is to generate enough information to determine whether the project is justified in expanding to a commercial scale.

The pilot stage cannot be undertaken within a research institution. It must be located in the environment where the project's beneficiaries—the people who will use the technology—live and work. The idea is to test the product and process under the conditions in which it will eventually have to survive commercially, though on a smaller scale. If the aim of the project is to increase farmers' incomes by getting them involved in processing roots and tubers, the pilot stage is the time for them to start. Farmers can gain valuable experience by operating and, if possible, managing the pilot plant.

Pilot testing of a new product and process must not take place in isolation. Rather, it should be closely linked to research and extension aimed at improving production of the target crop as well as to systems that provide institutional support (supplying credit, helping processors acquire business skills, and so forth). These activities are key components of integrated projects, which we described in Unit 2. The pilot phase is when product development should become part of an integrated project in the target region.

This is also the time for the project to make contact with local manufacturers of equipment. If you have developed new or modified processing equipment during the research phase, it is important to verify that large- or small-scale metalwork shops can replicate this equipment at a reasonable cost.

In this section we first discuss key issues and tasks involved in setting up the pilot plant. One of the early steps, as indicated in Figure 5, is to select a suitable site. Then, we cover key aspects of plant operations, which should first take place on an experimental basis and then on a larger scale under semicommercial conditions. If the product is aimed at the consumer market, you may want to evaluate it in a test market. Finally, you need to prepare a feasibility study, which concludes the pilot phase of product development.

Setting Up the Pilot Plant

In the following sections, we describe the steps leading up to the start of processing. Though some of these, such as construction, are quite complex, they mostly involve knowledge and skills that are commonly available. Instead of describing those steps in detail, we comment here on important decisions and measures that have particularly to do with setting up a processing plant.

Organizational models

Processing roots and tubers usually demands a good deal of teamwork. To market the final product calls for additional effort and skills. A basic accounting system is needed to control the purchase of inputs and sale of outputs. To ensure that both the work and income of the enterprise are distributed efficiently requires careful organization.

Here are several alternative models for organizing workers:

- Individual worker or family/household enterprise
- Cooperatives or associations
- Small businesses, consisting of one or more owners with employees
- State-owned enterprises

Co-ops and associations are socially oriented. By providing services and generating employment, they can distribute significant

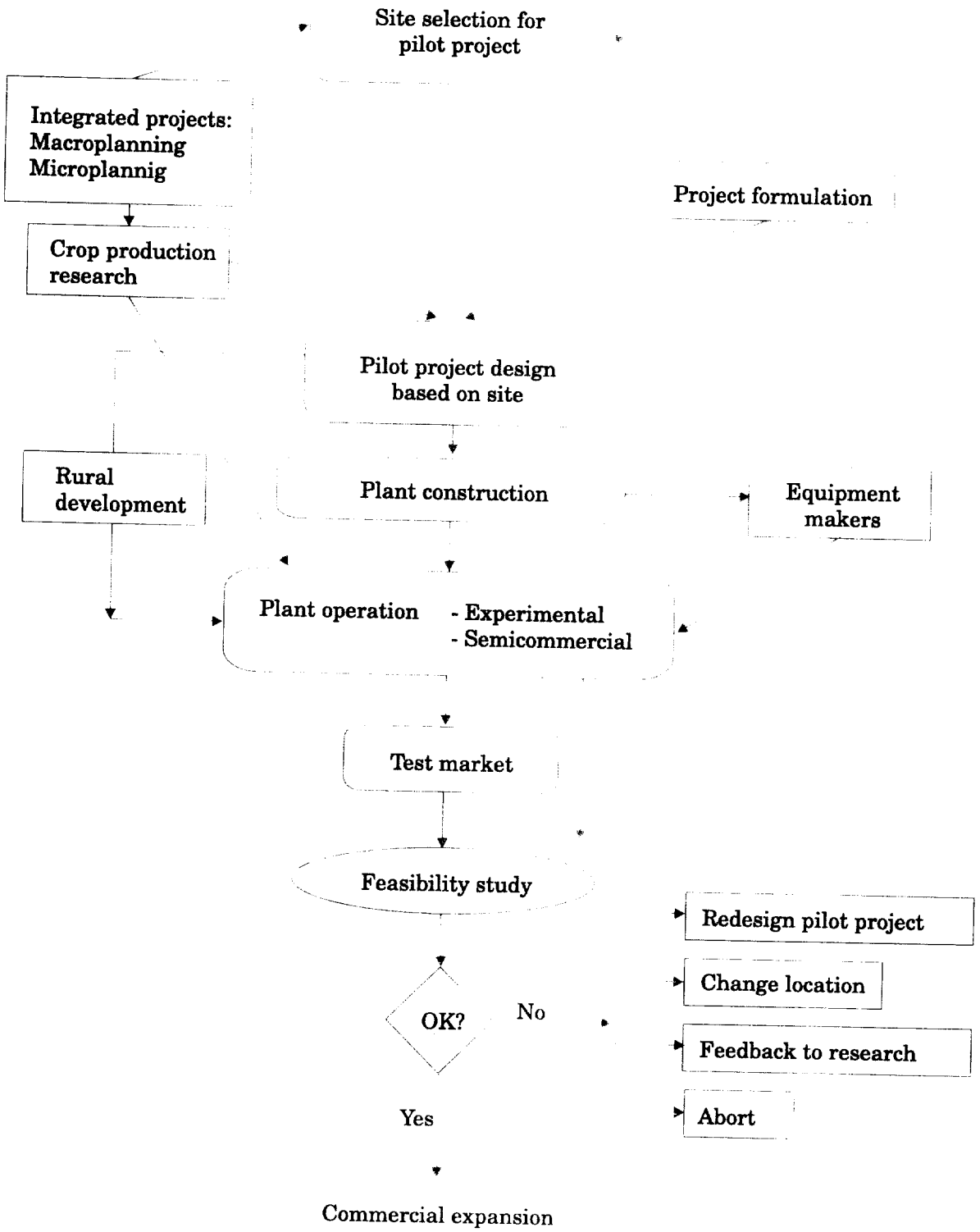


Figure 5. Flow diagram showing stages involved in pilot phase.

benefits to target groups. In many countries, though, these organizations have a history of absolute or relative failure. Even promising co-ops have had difficulty consolidating and expanding their gains. One reason is that in some places cultural factors favor individual rather than cooperative action.

Businesses, in contrast, operate for profit, much of which is divided among the owners or shareholders according to their stake in the enterprise. Provided that the rate of return on investment is attractive, business may offer the fastest means of developing a rural agroindustry. There is a risk, though, that a large share of the returns may not reach the project's intended beneficiaries.

State-owned businesses, marketing boards, etc., have a sad history of inefficiency and cumbersome bureaucracy. Frequently, political pressures adversely affect their decisions on commercial matters.

One alternative is an intermediate model, in which a small business functions within the organizational framework of a cooperative. Managers are given sufficient freedom and incentives to operate the business efficiently at its full market potential. The profits accrue to the co-op, which in turn transfers social benefits to its members.

A further possibility is to create different types of organizations for successive stages in processing and marketing. For example, one or more co-ops might produce an intermediate product for further processing by a second-order federation of cooperatives. A small distribution enterprise could then market the final product in a specific urban area.

It may seem premature to discuss the organization of second-order federations and so forth at the pilot stage. Yet, much experience has shown (see Box 10) that mistakes made at this point are difficult to correct later on.

For that reason it is risky to initiate a pilot project with a group or enterprise that has been formed only recently. Since its members have little experience in working together, they are ill prepared to handle the complex task of introducing new processing technology and making it a commercial success. The pilot project cannot achieve this goal, even with a potentially profitable technology, unless it builds on a strong farmer organization or small enterprise and provides it with appropriate technical, organizational, and financial assistance.

The scale of pilot operations

Choosing the size of the pilot plant is not easy. On the one hand, it must be large enough to provide reliable data on the efficiency of the process and its labor requirements, costs, etc. The plant must also make enough product to allow a meaningful assessment of its marketability, based on significant levels of sales.

But since there is a considerable risk of failure, you need to keep the amount of capital invested in the pilot plant to a minimum. For the same reason and because the pilot plant is unlikely to make a sufficient profit to permit repayment of a loan until it expands to a commercial scale, this investment should consist of a donation or soft loan. If weighed down with heavy loan repayments from the start, an otherwise successful pilot project may be doomed to failure.

Data derived from the pilot plant provide the basis for a financial feasibility study. Its results indicate the plant size that is most attractive financially. With that information you can seek commercial credit for plant construction (as described in Unit 6). One exception to this general pattern may be an existing enterprise that wishes to take on a new process or product. Since the plant already has facilities that can be assigned, at least temporarily, to pilot testing, the new product should require little additional investment, which can be financed with commercial credit.

There is no point in establishing more than one plant in the pilot phase. To do so will merely increase the financial risk without increasing the chances of success. It is better to concentrate on solving the inevitable problems of one pilot plant rather than dividing your efforts among many.

Box 10

Organizing Farmers in Colombia (Case 1)

Experience in Colombia has shown that conflicts can arise when cooperatives and private enterprises engage in the same process in the same area. In this case both groups belonged to a second-order marketing organization, which was responsible for recommending raw material prices. The co-ops wanted a high price to benefit the largest possible number of farmers (members and nonmembers), whereas the private sector plants wanted a low price to maximize their profits. As a result of this and other conflicts, the second-order organization split in two and lost its power to negotiate with the animal feed companies that purchase the end product.

The first farmer co-op for drying cassava was formed in 1981. Even though the project was limited to forming and financing co-op plants, many additional organization models evolved spontaneously in the region over the next decade:

- Small-scale co-op or association with about 20 members, consisting of small-scale farmers or landless laborers
- Large co-op with 100-400 members
- Association with 2-4 members, mainly large-scale farmers with their own capital for plant construction
- Privately owned plant that purchases cassava from local farmers
- Private business that rents drying floor space to farmers
- Private business that carries a mobile chipper to farmers and dries cassava on plastic sheets
- Small, on-farm drying plant located on a cattle ranch
- Starch producers, who switch to drying cassava when the price is low
- Individual farmers, who chip cassava manually and dry it on any surface when the price of fresh cassava is low or where access to the fresh market is poor

Site selection

The location of the pilot plant should be based on various criteria, as indicated in Checklist 12 and illustrated in Box 11. A major requirement is that an adequate supply of raw material be available at a reasonable distance from the plant (transportation of bulky fresh roots is costly). Good roads are also important for transporting the raw material as well as shipping the final product to its principal market, which ideally should also lie within a reasonable distance. If the plant operates only during the dry season, road conditions in the rainy season are obviously not important.

If at all possible, locate the pilot plant near a group of farmers who have some experience working together. This will reduce the risk of organizational problems, which could make it impossible to give new technology a valid test. To further ensure that the group functions well, it is essential that the pilot plant have ready access to institutional support in both technical and organizational matters.

Obviously, you will not be able to find one site that offers all these advantages. Nor is it possible, or even necessary, to assign all the selection criteria equal weight. For example, having electricity at the site may be absolutely

Checklist 12

Site Selection Criteria

Raw material

- Availability (harvest months per year)
- Current and future surpluses
- Existence of competing markets (e.g., for fresh roots)
- Quality factors (e.g., dry matter and starch contents)
- Concentration and distance from plant (which affects transportation costs)
- Price

Processing

- Infrastructure (e.g., water, electricity, and roads)
- Local capacity to build the processing plant
- Local capacity to build and maintain equipment
- Suitability of climate (e.g., for natural drying)

Farmer organization

- Presence of farmers organizations or small rural enterprises
- Farmers' level of education
- Interest in the project
- Resource availability (e.g., labor, capital, and land)
- Organizational capacity (e.g., leadership, level and quality of participation in decision making, and management of conflict)

Institutional support

- Institutions present and their relative strength
- Interest in the project
- Delineation of responsibilities
- Availability of funds
- Technical knowledge of technicians and field staff
- Availability of credit
- Existence of mechanisms for interinstitutional coordination

Markets

- Prices in different markets
- Cost and accessibility of transport
- Ease of commercial contact
- Stability (constant versus seasonal)
- Size and future growth potential

Environmental factors

- Prospects in the area around the site for increased crop production
- Waste disposal or treatment facilities near the site

essential but a paved road less so. The weight assigned to each criterion will depend on the product and process.

Designing the pilot project and constructing the plant

The next step is to draw up a plan for adapting the design and other aspects of the processing plant to the site where it will be constructed. For this purpose refer to the points in Checklist 13.

Building a pilot plant is much the same as any type of construction for agroindustry. It starts with preliminary land preparation and ends with the testing of equipment. Other important steps are to obtain water and electricity, build access roads, and manufacture and install equipment.

Once the equipment has been installed, make several trial runs to improve its functioning, efficiency, etc. Some minor modifications may be needed.

Box 11

Selecting the Site for a Pilot Plant in Colombia (Case 3)

Production of cassava flour involves relatively complex technology. For that reason planners of a project in the Atlantic coast region of Colombia decided to integrate the pilot plant into the work of a co-op already producing dried cassava for animal feed. In preliminary screening, four co-ops were identified for further consideration. Each was rated according to the criteria considered most important. The results are given in Table 20.

Since the project planned to dry cassava artificially, it needed a year-round supply of roots. Access to electricity and water was essential. Strong institutional support was also considered vital to the project's success. Visits to all four co-ops confirmed that Chinú was the best option, especially because of its continuous supply of raw material.

Table 20. Rating sites according to their suitability for cassava processing.[a]

Selection criteria	Cooperative			
	Chinú	Betulia	Palmar	Pivijay
Availability of land for cassava production	3	3	3	3
Potential for yield improvement	3	3	2	2
Availability of fresh roots for processing	3	3	1	2
Continuity of supply during the year	3	1	2	2
Infrastructure (electricity, water, and roads)	3	3	3	2
Distance to major markets	3	3	3	3
Institutions in the region	3	3	3	2
Socioeconomic importance of cassava	3	3	3	3
Current institutional support to co-op	3	3	2	2
Total	27	25	21	21

a. Maximum score of 3 per criterion.

At the same time, you can start selecting personnel to work in the pilot plant. If it will be run by a co-op or association, ensure that the members identify operators with sufficient skill to handle the processing equipment and keep their number to a minimum so as not to inflate operating costs. It is not a good idea to include an administrator or secretary at this point. The volume of production simply does not justify the expense. Once the personnel have been selected, you need to draw up a training plan.

Refining Plant Operations

Your central task in the pilot phase is to get the processing plant going. The first step is to try out the equipment, raw material, operators, and so forth under experimental conditions. Once the plant is working efficiently and turning out a final product of consistent quality, it can be run on a semicommercial scale. In this stage the product should be sold regularly in the target market to obtain information about its acceptability to consumers or clients. In the following sections, we discuss important issues that you need to deal with in the experimental and semicommercial stages of pilot processing.

Raw material

In Unit 4 we described the challenge of securing a stable supply of raw material and raised the issues of quality and price. During the pilot phase, you need to move beyond assumptions

Checklist 13

Elements in the Design of a Pilot Plant

- **Adjust the capacity of the plant to the production of roots and tubers and the market for them in the area around the plant as well as to the funds available.**
- **Prepare the building site (this includes studies of the topography and soils and may involve land levelling), and obtain permits for electricity, water, or both.**
- **Design the pilot plant, infrastructure, and equipment according to the capacity and characteristics of the site. Where the construction requires the services of architects or civil engineers, initiate a bidding process.**
- **Develop a plan for training plant operators, with emphasis on concepts and procedures in quality control, hygiene (especially for foodstuffs), and bookkeeping.**
- **Plan for experimental and semicommercial operation of the pilot plant.**
- **Design a marketing plan that identifies the most attractive markets in terms of margins, proximity to plant, etc.**
- **Analyze the institutional support available, and take measures to ensure adequate support in all areas.**

about these matters and decide how exactly they will be dealt with.

Supply. To speed capital flows and avoid loss of quality, roots and tubers should be kept in the plant for as short a time as possible before processing. This is especially important for cassava, which can be stored safely for only 1-2 days. If the plant requires a daily supply of fresh roots, you should try to organize daily deliveries. This may result in some unused raw material, especially at the beginning of the pilot phase, when the volume of raw material needed tends to be small. Although other root crops are less perishable than cassava, it is still important to minimize their storage times before processing.

Since fresh roots contain 65% or more water (which is eliminated in many processes), they are always expensive to transport. That is why the processing plant should be built in an area where sufficient raw material is produced within a short radius. If only limited amounts of raw material are available nearby (perhaps because the plant was built on the basis of future production potential), you will have to cover the cost of transporting raw material over longer distances in the early stages of processing.

There are several ways to organize raw material supplies. You may want to integrate crop production with processing, at least to some extent. This can help make up for shortfalls in supplies from other sources. If the processing is a cooperative venture, the entire co-op or individual members can also produce the raw material. Another option is to have intermediaries identify farmers with harvestable roots and tubers. The intermediaries may also transport raw material to the processing plant, although this could add considerably to the cost of their services. Another arrangement is to contract farmers to produce roots and tubers. As illustrated in Box 12, it might be worthwhile to provide them with inputs (such as planting material and fertilizer) to ensure good yields and quality.

All these options entail risk. Small-scale farmers in particular are liable to break their agreement with the processing plant if offered a higher price for their production in another market.

Harvest periods. To organize raw material supplies, you need to determine local harvest times. These can vary greatly from one area to another, depending on the months in which

Box 12

Obtaining Raw Material for Cassava Processing in Nigeria

The Nigerian government set up a processing plant to produce 11 t of gari per day. In 1985 the company's own plantation supplied 53% of the raw material, small-scale farmers 36%, and other state farms 11%. The company plantation provided of better quality and cheaper cassava.

Even so, for lack of raw material, the factory was able to work at only 25% capacity. Problems arose from:

- **The perishability of fresh cassava**
- **High and fluctuating raw material prices**
- **Small-scale farmers' lack of control over planting and harvest time as well as land and labor shortages**
- **High transport costs**
- **Pest problems**

The solution recommended was to initiate an outgrowers scheme, in which an association of small-scale farmers would produce cassava, while the company would provide inputs and carry out the harvest.

rainfall is adequate for planting and initial crop development. In some places two harvests a year are possible, while in others root crops can be harvested continuously, either because rainfall is evenly distributed or irrigation is available. Under some circumstances (e.g., where the product must be dried naturally), the processing can be done for an even shorter time than the harvest period.

Price. The price of fresh roots may vary greatly during a normal year, being lowest at harvest. A preliminary study of patterns in the price will give you an idea of how much the plant can expect to pay for raw material. Unless this price is comparable to that of the fresh market, you may have difficulty obtaining raw material, except at harvest time, when supplies peak.

Competition for raw material supplies between fresh and processing markets has caused several large-scale cassava processing plants to fail in Latin America. One way of avoiding this problem is by locating the plant in an area with limited access to markets. In general, a processing plant whose viability depends on low-cost raw material should be located away from major consumption centers, where the fresh market is important.

Quality. In general, processing plants are less demanding with respect to raw material quality than the fresh market, where intermediaries and consumers normally express strong quality preferences. In fact, it may be possible to supply a pilot plant with roots and tubers that are not acceptable for the fresh market. But indiscriminate use of noncommercial or poor-quality raw material is not an option for processes and products that require high dry matter or starch content.

Determine as early as possible in the pilot phase whether the raw material required for processing is different from that destined for other uses. If the differences are significant, it may be necessary to include a selection stage in the process, during which suitable roots and tubers can be identified. If a large percentage have to be rejected, you will need to determine an alternate use for them. Box 13 gives an example.

Early in the pilot phase, it should be obvious whether the raw material factors discussed here (quality, price, etc.) are favorable for securing a continuous supply of raw material of adequate quality.

Box 13

Dealing with Raw Material Quality in Colombia (Case 3)

Production of cassava flour for human consumption requires a high-quality end product. To meet quality specifications, a processing plant in Colombia had to reject a significant percentage of roots during the selection stage. The farmer cooperative that operated the plant used the rejected roots to make dried cassava chips for animal feed, a product for which roots of lower quality are acceptable. Later, the cooperative shifted its selection process to the farm level. This measure saved labor at the processing plant and reduced transport costs.

Processing

During the experimental stage of pilot plant operations, you need to adjust the equipment to maximize efficiency. In some cases this may take only a few days. In others it may take more time and money to modify defects in construction (above all, in prototype machinery). Moreover, you may have to test several options for a process to determine which is most efficient, easiest to manage, and produces the best quality product.

One of the most important factors determining the profitability of many processes is the conversion factor (or tons of raw material required to produce a ton of final product). How good, or low, the conversion factor is depends on the quality of the raw material (e.g., dry matter content and percent peel) as well as the efficiency of the process. For each step in the process, establish realistic specifications for all important variables (such as use of labor and fuel, process times, and product characteristics).

When the supply of raw material permits continuous processing without further modifications or adjustments, the plant is ready to operate on a semicommercial scale. At this stage you need to evaluate the following aspects of plant operations:

- Ease with which operators handle the process
- Labor efficiency
- Effectiveness of operator training
- Performance of equipment under continuous use, including energy consumption and efficiency
- Need for further research on equipment or its handling
- Bottlenecks in the process
- Actual operating costs
- Raw material supply, price, and quality throughout the period processing is expected to take place

By the end of this stage, you will have completed all necessary adjustments in the process, including management and labor use. Often, the plant workers themselves can find practical solutions to problems and offer valuable suggestions. Try to establish mechanisms for incorporating their contributions into the evaluation of pilot plant operations.

The product

In the experimental phase of plant operations, it is not enough just to improve the efficiency of the machinery. The process is not ready for further testing until the quality and quantity of the final product are right as well.

Product quality—a result of the interaction between the raw material and the process—consists of three main groups of traits:

- Chemical, physical, and microbial composition of the product

- Traits perceived by consumers (organoleptic factors, etc.)
- Features, such as shelf life, that are related to uses of the product

The most important chemical parameters for primary processed products (flours, starches, etc.) are usually dry matter and starch content, followed by other nutrients, such as protein and vitamins. All food and feed products should be free of mycotoxins. For many foods microbial counts are another important measure of hygiene. In some root crops, it is also important to monitor toxic or antinutritional components (e.g., cyanide, alkaloids, and trypsin inhibitors) throughout processing and in the final product. In cassava products, for example, maximum acceptable levels of cyanogens have been determined.

Food products must comply with any legal limits on microbial counts, etc. It may also be necessary to obtain a sanitary license from the Ministry of Health. Some clients have even stricter quality standards than those of the national standards institute or those required by law.

Identify a laboratory that can analyze critical quality factors routinely. This will ensure that you have selected the correct process during the experimental stage of plant operations and allow you to monitor product quality during the semicommercial stage. The project should cover the costs of these analyses as long as the plant is operating on an experimental basis.

If the product does not meet quality standards consistently in the experimental stage, you need to find out why. The problem must lie either in the raw material or in the conditions under which processing takes place, which may vary from those of the research station or research phase of the project. It is especially important that rigorous standards be maintained in personal hygiene and in the cleanliness of the processing equipment. In contrast, many traditional root crop products are made in the complete absence of sanitary controls and, as a result, have high levels of contamination.

In products destined for human consumption, organoleptic characteristics are extremely important (see the discussion of consumer testing of these traits on page 67).

Though normally associated with the food industry, quality control is just as applicable to other industrial uses of crops. To maximize production without sacrificing the quality of the final product, plant management rather than the production section should be directly responsible for quality control. This consists of the following tasks:

- Establish specifications for raw materials, other supplies, processing operations, and the final product, together with its packaging.
- Develop procedures to measure each quality factor (often, official methods are suitable).
- Develop sampling procedures that give reliable results at minimum cost.
- Design recording and reporting forms for use by production operatives.
- Train production operatives in the use of quality control tests.

Quality control should take place in three stages:

- Raw material control
- Process control
- Inspection of the final product

Theoretically, if you do a thorough job in the first two stages, the third should be superfluous. In practice, though, it is still a good idea to inspect the final product, especially since many root and tuber processing plants operate under less than ideal environmental conditions. If the raw material and process are carefully controlled, the proportion of final product rejected should be relatively small.

Shelf life and packaging

No matter how short a product's journey down the market chain, its quality must hold up for some length of time. It also has to resist significant changes during storage. The following factors can affect the product's useful life:

- Moisture content
- Relative humidity and temperature during storage
- Contamination by fungi, bacteria, and insects during processing
- Type of packaging
- Size of packaging (product weight per unit)

Packaging serves as a barrier between the product and its environment. Even so, being porous, it permits the interchange of moisture and gases (CO_2 and O_2) and can be penetrated by insects and rodents, which in turn facilitate contamination by microorganisms. For that reason the packaging must be, not only reasonably priced and easy to obtain, but also adequate to protect the product after purchase until it is used or consumed.

Fungal growth and mycotoxins are not a problem in products that are dried to moisture levels suitable for long-term storage. For some primary processed products, packaging is not a major consideration, since the industrial user will mill or otherwise process the product further shortly after purchasing it.

In contrast, processed products for human consumption, such as flours, noodles, and cookies require packaging that resists insect attack and changes in moisture content, particularly if the turnaround time is slow. Some products require a specific type of packaging to preserve their distinctive characteristics (e.g., fresh cassava in polyethylene bags).

Finding a Niche in the Market

There are two types of markets for the pilot plant's products: industry and individual consumers.

In industrial markets enterprises buy a primary product, which they transform or incorporate into another product. This market is relatively simple. Since it generally consists of few clients, you can establish direct contact with their heads of purchasing, whose decisions are based on logic, price comparisons, availability and suppliers' performance. A further advantage of dealing with these markets is that the monthly unit of purchase can be very large, equaling or exceeding the plant's production capacity.

In consumer markets a primary or secondary product is sold through a wholesale distribution channel. This is quite complex. To be successful the product must be purchased by thousands or millions of consumers, who are daily bombarded with publicity about competing products.

Whether consumers buy a given product depends on many illogical factors, such as its image and status. To reach large numbers of consumers requires an efficient distribution system at terminal markets as well as resources and capacity for mass promotion.

Small-scale farmers organizations can seldom meet these requirements on their own. So, you may have to contract or create other organizations to handle product distribution and promotion. This, of course, involves additional costs.

Target markets

Having selected a site for the pilot plant, you need to identify target markets and then carry out a marketing study. Here are the main groups of options:

- Local: rural areas around the pilot plant
- Regional: the nearest large urban center
- National: the capital and other major cities
- National: all locations of the target industrial market
- Export: neighboring countries, the USA, Europe, Japan, etc.

You should normally tackle local and regional markets first and only later consider export markets. Unless the product can compete locally, it is unlikely to succeed internationally.

The relevance of national markets depends, not so much on their size, as on the type of product. If the plant is producing for industrial markets, it should adopt a national strategy from the start, since clients will probably be located far from the zone where root and tuber crops are

produced. Usually, there are only a few such plants, so transportation ought not pose too great a problem. On the other hand, if the pilot plant caters to consumers, it should avoid breaking into national markets until it has first passed the test of a well-defined local or regional market.

The design of the market study will naturally vary according to the target market. If focused on consumer markets, the study should cover intermediaries, final outlets, and consumers. Studies of industrial markets include only potential clients, as illustrated in Box 14.

Easing into the market

Based on the results of the marketing study, you can draw up a plan for selling the product. This should be implemented after the experimental stage of pilot plant operations. By then you will have fine-tuned the process and should be turning out an acceptable product. It is crucial that the first samples clients purchase be of optimal quality.

Production that does not meet quality requirements can be disposed of in other markets with less exacting standards. For example, the cassava flour project described in Box 13 initially sold to the animal feed market until it could consistently provide the food industry with a product of acceptable quality. Until then the project covered the resulting losses.

After making the first sales to an industrial market, inquire in detail about the following:

- Satisfaction with the product
- Use of the product
- Evaluation of its quality
- Comparison with other raw materials
- Attractiveness of the price
- Estimate of demand and potential for increased purchases
- Consumers' reaction to the final product
- Desired unit of purchase and frequency of delivery

For sales to consumer markets, it is preferable to begin in a limited geographical area, distributing to several nearby shops or to a chain of supermarkets. This will enable you to gather a considerable amount of information with a minimum of resources.

Once the pilot plant is operating on a semicommercial basis, product quality and operating costs should be stable. That is the time to proceed with your plan for developing a

Box 14

A Study of the Market for Cassava Flour in Colombia (Case 3)

Cassava flour poses a special marketing challenge, because it is a new product intended to serve as a substitute for a well-known raw material—wheat flour. There are numerous potential buyers among manufacturers of foods, such as crackers and cookies, pasta, processed meats, and breads. But they are unfamiliar with the main characteristics of cassava flour and with its differences from wheat flour.

A study of the prospects for overcoming these obstacles was conducted in two stages. The first was a preliminary survey on the use of flours in general. In the second, industries were given samples with which to conduct partial substitution trials in various products. Then, a survey was made of the trial results and interest in purchasing the new product. The study yielded concrete information on the potential use of cassava flour in a wide range of products. And it was a good deal less trouble than extensive laboratory trials.

market. Explore several options for presenting the product (as described on page 68). To select the best, it is helpful to test the reaction of the market to different alternatives.

Product pricing and terms of payment

There are two ways to set the price of a new product: by calculating production costs plus a profit margin or by determining the price the market will bear, based on the prices of competing products.

A new product should be better, more readily available, or cheaper than those already in the market. Be cautious about promoting a product whose sole advantage is lower price, since this is often equated with low quality. If the product is of higher quality than others, it should cost at least as much as inferior competitors.

Although it is important to cover costs, they are not the only basis for determining a product's final price. When introducing a product in the market, for example, it may be helpful to offer discount prices for a limited period to encourage first-time sales.

The terms of trade offered to purchasers of the product should be at least as favorable as those of competing products. But they also depend on the financial situation of the enterprise. For example, if cash flow is a problem, you might consider offering discounts for cash purchases, bulk orders, or regular contracted deliveries. Payment after 30 days is the norm in some industries or where state marketing organizations are involved. If you allow sales on credit, expect a small percentage of nonpayers. If such sales are common, the associated costs should be built into the enterprise's financial projections.

Training Processors

In most cases the pilot plant will be located in a rural or periurban area. The people who manufacture the product will either be farmers, landless laborers, or traditional root crop processors who want to expand their product range or improve existing processes or products. Most will have little formal education or previous training and experience. For that reason a major activity in product development must be to train workers, not just to operate the processing equipment, but also to maintain high product quality—a task involving hygiene, raw material quality, etc.

During the pilot phase, the project is the logical candidate to offer training on technical aspects of processing, based on its experience in the research phase. It is unrealistic to expect the extension service, for example, to mount a formal training program on a product and process that may or may not succeed. If extension or other services do help with training at this point, the project must be prepared to finance their participation. If the pilot project is successful, it is then reasonable to expect that extension and other training agencies will incorporate the new products and processes into their portfolio of technologies for the region.

The processing operation must be managed like any business but without neglecting social aims that led to its formation. To do this requires many skills farmers normally do not possess, especially if the product is aimed at urban markets. Thus, even in the pilot phase, you may need to provide a relatively small number of people with intensive training in business, marketing, and accounting.

If project staff are not qualified to conduct training on these subjects, you need to find an agency that is. In addition to training, the agency can perhaps give ongoing support in the commercial aspects of the processing operation. Some likely partners for training are:

- University economics or business departments
- NGOs supporting small businesses (often in urban areas)
- Private sector businesses

It may seem surprising that the private sector would assist possible competitors. Yet, in Asia and Latin America, large companies actively support the establishment of small businesses, particularly those having commercial interests outside, but related to, their own. Business skills are, after all, independent of the product manufactured and sold.

Here are some useful approaches to training:

- Practical training at the prototype plant constructed in the research phase of the project
- Formal instruction on basic principles of food manufacturing (e.g., hygiene, product handling, etc.)
- In-service training provided by the private sector on topics such as business skills, marketing, and quality control
- Formal courses in accounting and so forth
- Visits to other projects

Given that a wide variety of training must be provided for a fairly small number of people, it is probably necessary to involve various institutions. Since not all will be project participants, you will have to contract some of them for specific functions.

By the end of the pilot phase, the project will have invested heavily in training for farmers and others involved in plant operations and management. For that reason you need to select both the site for the pilot plant and the participants very carefully. If you have people who are strongly committed to the project, they can help train other farmers when the operation starts to expand.

Test Markets for Consumer Products

To guarantee the success of a product in consumer markets, you must make a considerable effort (much more than is required for a product used by industry) to organize its distribution and promotion. Since these tasks are quite complicated and costly, it is a good idea to introduce the product in a test market before launching a full-scale project to commercialize it.

A test market is typical of the total potential market but smaller. It enables you to test the distribution system and promotional activities at low cost within a reduced area. From the results it should be clear whether the product can succeed on a wider scale.

To test market a product, the pilot project must satisfy the requirements indicated in Checklist 14.

To identify a suitable urban test market, consider the following options:

- Shops (small, local concerns or larger ones either in low- or high-income areas)
- Institutions (schools, hospitals, army bases, etc.)
- Supermarkets

Checklist 14

Requirements for Test Marketing

- A continuous supply of the product or enough inventory to meet expected market demand
- A product of the specified quality
- An attractive promotional price
- Promotional materials, together with an advertising campaign based on them
- A distribution system that is adequate, not only for the initial volume, but for expanded sales within a short time
- A system for obtaining feedback to judge the product's chances of success (including weekly data on volumes delivered and sold, by shop, and on purchases by a sample of consumers, information that indicates the rate of repeated purchases, compared with initial purchases)

- Shopkeepers' co-ops
- Restaurants
- Stalls in wholesale or retail markets

It is easier to deal with a market consisting of only a few high-volume clients than one with numerous clients purchasing small amounts. But since the latter may be the largest markets, it is worthwhile to examine these options for widening product distribution:

- Set up an enterprise that specializes in distributing products in urban centers.
- Contract a private distributor on a nonexclusive basis.
- Distribute the product to a central warehouse operated by a shopkeepers association (possibly one organized expressly to facilitate distribution).
- Obtain warehouse space in a wholesale market where shopkeepers purchase other food products.

Each of these systems has advantages and disadvantages. Select the one that keeps distribution costs to a minimum and thus allows you to sell the product at a competitive price.

To design and execute a promotional campaign—even with simple, low-cost media—you need the help of individuals or firms that have experience in advertising and know how to gain maximum publicity with scarce resources.

The key to promoting a product in consumer markets is to have an attractive, legally registered brand name that reflects the product's advantages, together with a logo and slogan. Advertising media include:

- The package (with logo, slogan, recipes, instructions for use, packing or expiration dates, name, and sanitary license)
- Promotional materials (such as posters and leaflets) at the point of sale
- Supermarket promoters and sales representatives
- Newspaper advertisements
- Billboards
- Radio and television commercials

An advertising campaign that uses all those media is beyond the budget of most projects. Even so, you can still achieve significant impact with limited resources by:

- Clearly identifying the target market, such as low-income housewives from the poorest residential districts, and using only the media that reach them (e.g., a commercial on the favorite radio station of these consumers)
- Promoting the product on the news and other programs of public interest, above all to consumers
- Organizing special campaigns for shopkeepers (e.g., using leaflets that explain the benefits of the product), aimed at getting them to promote the product among their clients

As shown in Figure 6, the product is a success if numerous buyers make initial purchases and a large percentage buy it again. If initial purchases are high but only a few people buy a second time, the product is based on a good concept but does not live up to its promises. In other words, consumer are disillusioned with it. When initial purchases are low but repeat sales are high, you have a good product but poor distribution or promotion. If both initial and repeat sales are low, the product is a failure.

Test market trials are difficult but quite effective for detecting problems early, before anyone has made a major investment. For products aimed at the consumer market, these trials are an essential part of the pilot phase in product development.

The Feasibility Study

The semicommercial stage ends when you have collected enough information to complete a feasibility study—the main output of the pilot phase. The key items of information are the same as those needed for a prefeasibility study (see Checklist 11, Unit 4). The results indicate whether the project should proceed to the commercial expansion phase or be abandoned.

Initial purchases	Repeat purchases: High	Repeat purchases: Low
High	Successful product	Good product concept but poor product quality
Low	Distribution or promotion problem	Failed product

Figure 6. Illustration of Kotler's hypotheses regarding product success (Kotler, 1986).

Normally, it takes a full year to gather information on raw material supply and product demand across seasons. But you may need more time if problems such as poor rainfall or pest attacks are so severe as to affect raw material supply, price, or quality. If the experimental stage in plant operations takes longer than expected, avoid shortening the semicommercial stage correspondingly, since this may leave too little time to collect information.

If the pilot phase has gone well, the supply, price, and quality of the raw material will be adequate; the process will be functioning efficiently; operators will be trained and working efficiently; the product will meet specifications and be of uniform quality; and the market for the product will be expanding.

The feasibility study essentially documents all this experience. Based on the outcomes of semicommercial plant operations and test marketing (if this was necessary), the study examines the financial feasibility of the new product, given the investment required to produce and market it. For help in deciding whether the product is an attractive investment, you can apply financial models, which, in addition to determining profitability, indicate how it can be increased through improvements in processing and other aspects of the enterprise.

Models for estimating financial rates of return

Using a basic microcomputer spreadsheet program (e.g., Lotus 1-2-3), you can construct a model that describes the process and other operations. You can easily adjust it to changes in costs and process parameters and carry out sensitivity analyses quickly to determine how rates of return are affected by changing costs, improvements in processing efficiency, and so forth.

There are numerous measures of financial feasibility. One is the *financial rate of return* (FRR), which is defined as "that rate which discounts annual cash flow to the project start (time 0) in such a way that its present value is equal to the initial investment" (Gittinger, 1982). The FRR takes the point of view of the business (i.e., the processing unit), not that of society in

general, which is measured by the *economic rate of return* (ERR). Differences between these two measures are summarized as follows:

- ***Economic rate of return***

  Takes society's point of view.

  Does not consider taxes as costs; views subsidies as costs to society.

  Does not take into account financial costs.

  Does not always use market costs and prices.

- ***Financial rate of return***

  Takes the business's point of view.

  Considers taxes as costs and subsidies as income to the business.

  May take into account financial costs.

  Always uses market costs and prices.

Before developing the model for a given process, you need to make basic decisions about:

- ***Project life.*** The longer the life of the project, the higher the FRR; the higher the profitability, the less impact project life has on FRR.

- ***Production capacity.*** Because of the seasonal availability of raw material and the high cost of storing fresh roots, processing plants often operate for fewer than 12 months a year. The maximum production capacity of a plant will therefore be less than the theoretical capacity of its equipment during a full year. On the other hand, the plant may operate at more than 100% capacity if it processes during a greater part of each year than originally planned.

- ***Capacity utilization.*** For a number of reasons (problems in the supply or quality of raw material, power failures, breakdown of equipment, etc.), processing plants do not normally operate at full capacity. Based on experience in the pilot stage, you can estimate more or less accurately what percentage of its capacity the plant will utilize.

- ***Inflation.*** In many countries inflation is a serious problem for small enterprises. If the model does not take this factor into account, then the minimum acceptable FRR value is that of the opportunity cost of capital minus the inflation rate. If inflation is taken into account, you need to decide whether or not to use a constant rate, and the same rate for costs and income, throughout the life of the project.

- ***Salvage value of the capital investment.*** At the end of the project, the plant will presumably be sold and all working capital returned. The model must assume a value for the plant, as some percentage of the investment cost. If the model includes inflation, it must take this into account as well.

The model has various components, each dealing with a key aspect of the finances of the processing operation:

- ***Investment***

  Preliminary estimates of costs of equipment and infrastructure. Initial working capital is also included. The amount required depends on:

  - Production costs
  - Volumes produced
  - Time taken to distribute, store, and sell the product
  - Payment schedules, especially for industrial clients

- ***Maintenance***

  The cost of keeping equipment and infrastructure in good working condition is divided by the production volume and represented as a fixed cost per ton of product.

- ***Basic information***

  - Plant capacity
  - Capacity utilization
  - Processing parameters (e.g., conversion factor for fresh roots to finished product, labor requirements in worker-hours per ton, energy and water use per ton as

well as the unit prices of each of these elements in the cost structure)

- ***Variable costs***

  Those that vary according to the scale of production, such as cost per ton of:

  - Raw material (including transport costs)
  - Labor
  - Packaging
  - Fuel and other energy
  - Water
  - Transport
  - Commissions and contingencies

- ***Fixed costs***

  Those that do not vary with the volume of production:

  - Investment in infrastructure and equipment, reflected in finance costs
  - Administrative costs
  - Plant maintenance

  (Be sure to include all costs so as not to overestimate financial feasibility.)

- ***Sale price of products***

  The model uses a weighted average of the costs of the principal product and any by-products. To calculate this you need to know the:

  - Sale price of each product and by-product
  - Percentage of each produced
  - Processing losses (e.g., in milling and transport)

  The model's outputs are the:

- Financial rate of return
- Gross margin (sales price less variable costs)
- Net margin (sales price less variable and fixed costs)
- Cash flows (income from sales minus variable and fixed costs plus increases in working capital due to inflation)
- Net present value
- Sensitivity analysis to determine which component most affects the FRR
- Product cost and price structure

  The model can help you:

- Optimize the process.
- Set maximum acceptable prices for purchased inputs.
- Assess financial feasibility.
- Select the best option for financing the business.
- Provide solid information for donors, banks, project advisors, and the owners and operators of the enterprise.
- Determine the sales price.
- Identify improvements in the plant and process that could increase FRR.

Box 15 shows how a cassava flour project in Colombia applied the financial model. Even without a computer-assisted model, you can learn a lot simply by calculating all costs and returns carefully and by looking at net returns per unit of output, as illustrated in Box 16.

Timing the Transition

In this unit we have described how to move a product from small-scale, experimental production through the pilot stage and market testing to a feasibility study. If the outcome is favorable, you can proceed to full-scale commercial production, with the aims of meeting a significant proportion of demand and making an attractive return on investment. To reach these goals, you can expand the existing plant, construct more units, or both.

How do you determine when the pilot stage ends and the commercial phase begins? This is a very important decision. If the operation expands too soon, before enough information is available, it may fail because of unforeseen problems. On the other hand, if the pilot phase is prolonged unnecessarily, you run the risk of losing commercial opportunities or prolonging the life of a bad product and multiplying financial losses.

For help in timing the transition correctly, consult Checklist 11 (Unit 4), which indicates the information required to assess feasibility. As soon as you can replace all important assumptions with solid data obtained under commercial conditions, it is time to assess feasibility.

Even if the results are encouraging, you cannot launch the commercial phase immediately. It takes time to develop plans, obtain financing for expansion, and so forth. In the meantime the pilot plant should continue operating to keep the market already obtained. The plant may still not be operating on a large enough scale to earn a profit. In that case you may need to obtain a bridging loan or make a small investment to boost capacity to a commercial scale.

If the outcome of the feasibility study is negative, you have several options:

- ***Redesign the pilot plant.*** By replacing equipment or redesigning the infrastructure, you may be able to overcome problems identified in the pilot phase. This means backtracking, repeating certain pilot activities, and conducting a new feasibility study. If funds are not available to cover the costs or provide extra working capital, this option may not be viable.
- ***Move the pilot plant to another location.*** This may help if there are problems with raw material supply or quality or with the organization operating the plant. This option may not be feasible, though, if you have made a significant investment in one site, which cannot be transferred easily to another.
- ***Do more research.*** If a problem arose in the pilot phase that was not investigated in the preceding stage, you may need to conduct more research. This could lead to modifications in the process, improvements in product quality, etc. In this case the pilot stage has fulfilled its function, but it is still too early to determine the feasibility of the enterprise.
- ***Abort the project.*** The pilot stage gives you the option of discarding an unsuitable product before making a significant investment in its manufacture. Since the project—not the processors—should absorb most, if not all, the risk involved, aborting the project should have few negative consequences. Keep in mind that in the food industry only a very small percentage of product ideas ever reach the market and succeed. You should not hesitate to kill a product at this stage if you are convinced that it has no commercial future. That is the best way to ensure that all projects reaching the commercial phase stand an excellent chance of success.

By the end of the pilot phase, after you have completed the feasibility study, the status of the project should be as indicated in Table 21.

References

Gittinger, J.P. 1982. Economic analysis of agricultural projects. 2nd ed. The Johns Hopkins University Press, Baltimore, MD, USA.

Kotler, P. 1986. Principles of marketing. 3rd ed. Prentice Hall, Englewood Cliffs, NJ, USA.

Table 21. Status of a product development project at the end of phase 3 (pilot phase).

	Phase 1—Finish	Phase 2—Finish	Phase 3—Finish
Why (objective)?	Defined	Well defined	Well defined
Where (region)?	General area identified	General area identified	Pilot site selected
What (product)?	Idea selected	Idea and concept tested	Product trial marketed
How (process)?	General process identified	Options evaluated and best selected	Process feasibility evaluated
How much (market)?	—	Identified	Market potential evaluated
By whom (type of enterprise)?	—[a]	—[a]	Enterprise evaluated
For whom (beneficiaries)?	—[a]	Defined	Defined

a. May be defined in project objective.

Box 15

Applying a Financial Model to Cassava Flour Production in Colombia (Case 3)

After operating for a year on a pilot basis, a project set up to produce high-quality cassava flour for human consumption in Colombia used a financial model to estimate the financial feasibility of the enterprise. The following information was available:

- Amount of investment in plant and equipment
- Data on plant operations (e.g., capacity and costs of labor, raw material, and energy)
- Variable costs of labor, energy, and transport per ton of product
- Fixed costs per ton of product
- Sale price of final product

It was assumed that the project would have a life of 8 years, that inflation would be 25% per year, and that the plant would operate at 90% of its capacity.

The model predicted an FRR of 22%, which was less than the opportunity cost of capital (35%) and slightly less than the assumed inflation rate. Sensitivity analysis of several key variables showed that the project could increase FRR by:

- Increasing the plant's capacity (a 75% increase boosted FRR by 10%)
- Milling chips in the plant rather than contracting out this step (increased FRR by 10%)
- Reducing total investment by 20%
- Improving the efficiency of drying to reduce the use of coal by 50%

If future processing plants were to apply all these quite realistic measures, their FRR would be an attractive 60%. The following year the pilot plant took all the steps except reducing investment cost.

Box 16

Costs and Returns in Simple Potato Processing in India (Case 6)

Dehydrated potato chips and potato flour were identified as potential products for human consumption. Initial trials demonstrated that both processes were technically feasible, even if conducted on a very small scale, producing 200 kg/day.

Project planners needed to determine the minimum scale of operation that would cover the costs of equipment. First, they inventoried all infrastructure and equipment and then monitored each process carefully to determine the amounts of labor, material, and fuel used as well as the costs of all inputs and outputs. With this information, they calculated operating budgets for processing on different scales. Some of the key results were as follows:

- Units costs are 25% lower at 1,000 kg/day than at 200 kg/day.
- Variable costs are 80% of total costs.
- Although the purchase of equipment requires large cash outlays, the amount is still only 5% of annual operating costs.
- As the scale of the operation and length of the processing season increase, so do profits.
- Increasing conversion rates by 1% improves profitability by 6% when production is 200 kg/day for 90 days/year.

Based on the results of this analysis, the project focused on improving conversion rates, rationalizing the use of labor, and lowering transport and marketing costs rather than on reducing drying costs. Plants were encouraged to produce at least 600 kg/day. And efforts were made to prolong the processing season.

Unit 6
The Commercial Phase

Assuming that the pilot phase demonstrates the feasibility of a new processing enterprise, you can take one of two approaches in expanding it to a commercial scale. The first is simply to add extra plants in a more or less ad hoc fashion as demand for the product increases. The other is to prepare a plan of action for the commercial phase before expanding the operation.

In this unit we strongly recommend the second course, as indicated in Figure 7. The plan of action describes a series of activities aimed at reaching specific commercial targets. Its goal is to ensure that supply and demand grow at the same pace. The plan can pay high dividends if based on careful examination of all aspects of commercial processing. Since any plan is fallible, though, it should be executed with flexibility.

This unit deals mostly with the planning process. (For further details on planning for the commercial phase, see the list of publications at the end of this unit.) First, we describe options for organizing farmers and the various institutions involved in the commercial phase. Next, we discuss various aspects of plant operations, including:

- Raw material supply
- Processing
- Product packaging, distribution, and promotion
- Farmer training

Then comes a discussion on sources of funding and approaches to evaluating progress.

The end product of this phase should be a growing rural agroindustry that is commercially viable and meets project objectives. Once the enterprise is reasonably well developed and has the capacity to develop new products, institutional support should be withdrawn.

This manual draws heavily on cassava projects in Latin America. In all of them, the commercial phase of product development has taken place within the framework of an integrated project. As explained in Unit 2, such projects deal with a wide range of activities, including crop production, institutional support, and credit. In this unit we refer to those activities but deal with none in detail. Some are complex enough to merit a manual of their own. To improve crop production, for example, requires a major effort to disseminate better varieties and crop management practices. Any product development project should take such activities into account, even if it is not part of a larger integrated project.

Getting Organized

If small-scale farmers are to benefit from economies of scale, learn to carry out specialized functions, and obtain credit for root and tuber processing, it is essential that they be organized into groups (either cooperatives or small businesses). In deciding how to do this, take into account farmers' traditional forms of organization as well as the laws of the country. (For further information on farmer organizations, see the list of publications at the end of this unit.)

Patterns of farmer organization

In Latin America many integrated cassava projects have worked with village-level farmer associations or cooperatives. Most of these have 15-30 members, who live near one another and may or may not produce roots for processing. Groups are typically structured so as to invest maximum authority in the general assembly of members. Their central purpose is to generate social benefits for processors as well as producers. Toward that end they tend to set the price of the raw material at higher than commercial rates.

In some countries larger cooperatives with many other activities have also taken up cassava processing. Both this and the village-level

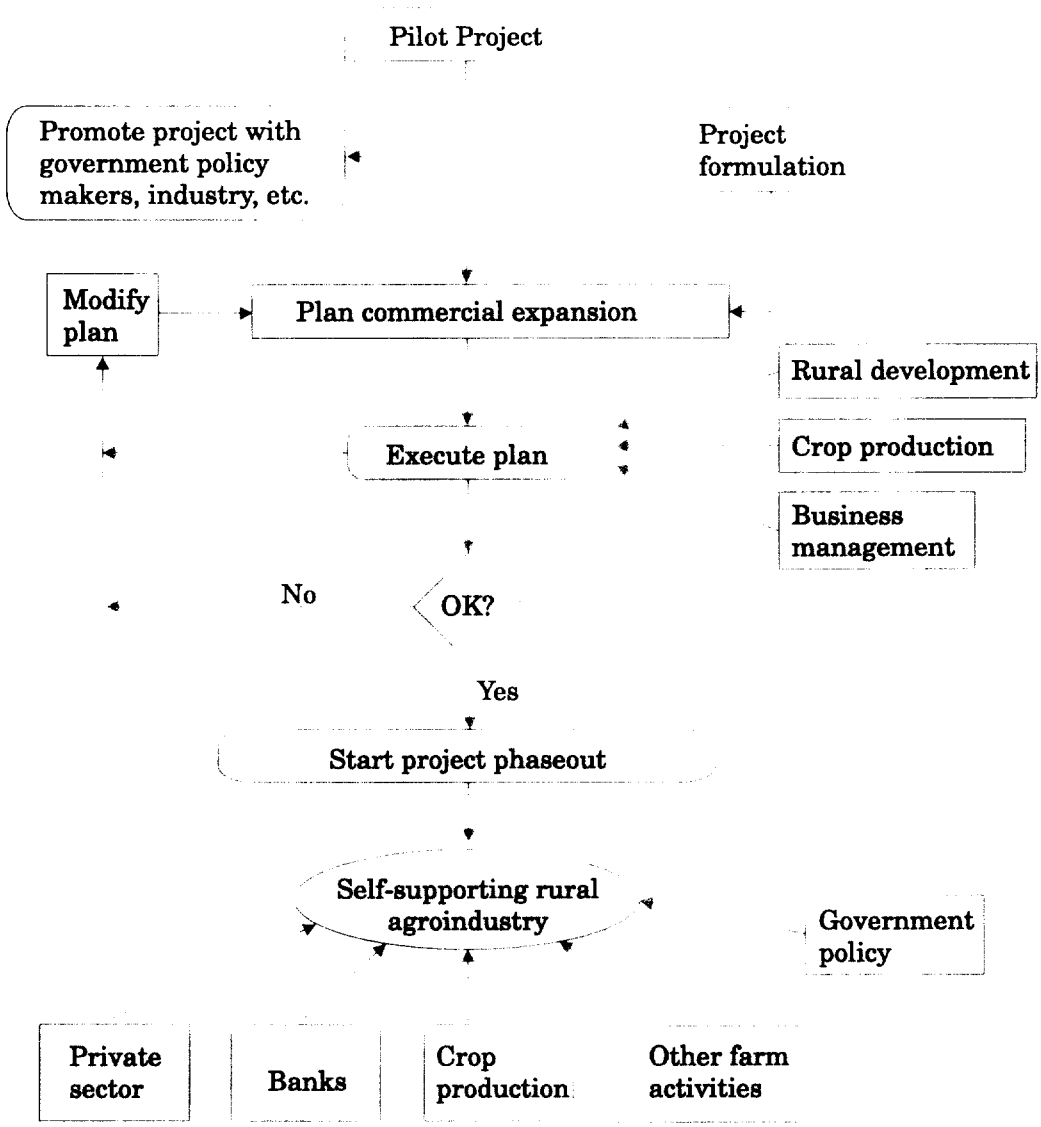


Figure 7. Steps in the commercial phase of product development

organizational model are applicable to processing of cassava and other root and tuber crops.

As noted in Unit 2, private sector organizations distribute benefits quite differently from cooperatives. Rather than spread benefits widely, the joint owners of an enterprise try to maximize profits by seeking raw material at the lowest possible price, among other means. As a consequence, privately owned enterprises have an easier time building up capital and reducing their dependence on credit.

One type of private sector enterprise is the family or household processing operation. It is somewhat like a co-op, in that members share responsibility for decisions and work. But the distribution of benefits is relatively limited, as in any private business. If such an enterprise expands (e.g., by employing labor from outside the family), its character may change radically. For that reason, some family or household enterprises may not be interested in processing on a larger scale.

Regardless of how a farmer association is organized, it needs to obtain legal status. Often, this is a prerequisite for obtaining inexpensive credit or technical assistance from the public sector. In some countries there are legal restrictions on the sale of produce for profit. These force loosely organized associations to form cooperatives, a step that involves considerable bureaucratic red tape.

When local groups or enterprises attempt to market their products outside the region, they generally run into problems with pricing, volume, and transportation. They also incur high costs for promotion and face the difficulty of negotiating with high-powered, private sector enterprises. To strengthen their position in the commercial world, it is a good idea for these groups to form second-order organizations of the type described in Boxes 17 and 18.

The functions of a second-order organization are to:

- Conduct further processing to convert an intermediate into an end product.
- Package and store the product.
- Distribute, market, and promote the product.

Box 17

Second-Order Organizations in Colombia (Case 1)

The Asociación Nacional de Productores y Procesadores de Yuca (ANPPY), founded in 1986, is open to individuals and legally constituted groups engaged in cassava production and processing. By 1988, 53 of the country's 59 drying plants were affiliated.

ANPPY negotiates the sale of dried cassava, based on recommendations from the managers of co-ops and from regional cassava technical committees, who meet with association management to discuss production costs, etc., and reach a consensus on the sale price. Members are also free to engage in commercial contracts outside this structure.

An important objective of ANPPY is to represent and protect the interests of its members before the government and other public and private entities. It is concerned particularly with policies that affect production, agroindustry, prices, markets, imports, and exports. In addition, the association has established marketing channels for dried cassava and developed an information system dealing with prices and markets. It can also provide training and technical assistance in production, marketing, bookkeeping, and financial and legal matters.

Since ANPPY is not a co-op (members do not contribute any capital), it has only a limited capacity to carry out many of those activities. The association is supposed to receive 1% of sales to cover its expenses. But since ANPPY is not actually engaged in selling, it depends entirely on members' willingness to pay the commission.

Another problem is management of the general assembly. Because its social base is widely dispersed, the association has no organizational background, and members have little sense of belonging. Recently, tensions between farmer associations and the owners and operators of private sector drying plants—groups with quite different objectives and social outlooks—have further weakened the organization.

In 1991 a new second-order association of cooperatives—ASOCOSTA—was founded. As nonvoting members, individuals benefit from services but have no influence on policy. Increasingly, ASOCOSTA is seen as representing farmers groups and ANPPY the private sector.

Box 18

Second-Order Organizations in Ecuador (Case 4)

The Unión de Asociaciones de Productores and Procesadores de Yuca (UAPPY), founded in 1986, coordinates cassava production, processing, and marketing for 18 associations (360 farmers). Its functions are to:

- Seek funding (which enables members to obtain loans for three purposes—capital investment in land and processing plants, working capital, and cassava production—at interest rates set yearly by the general assembly).
- Market members' products, with the aim of increasing their profits.
- Further process the associations' products to increase their worth and profit margins.
- Train members and offer them high-quality, low-cost technical assistance.
- Participate in research for the development of new technology.
- Try to diversify the associations' products.
- Stimulate the socioeconomic progress of members.

UAPPY set up a demonstration center to test new technology, mill dried cassava chips and produce refined flour, carry out quality control, maintain machinery, and train members. The union handles five products (whole cassava flour, cassava flour, industrial starch, starch for human consumption, and starch bagasse), of which a total of 1,750 t were manufactured in 1990. The general assembly of representatives meets monthly to decide such matters as product prices.

UAPPY has established strong links with other institutions to execute an ambitious plan of work in four areas: 1) research dealing with production (including seed), socioeconomic issues, and processing and utilization; 2) extension; 3) education; and 4) institutional support.

- Provide first-order organizations with technical assistance and training in crop production, processing, accounting, etc.
- Identify new opportunities for products.
- Coordinate research and development, focusing on new products.
- Manage interinstitutional relations.
- Obtain funds through donations and credit and operate rotating funds, which provide credit to first-order organizations.
- Monitor and evaluate first-order organizations.
- Represent the processing sector before government policy makers.

Third-order organizations have not emerged in Latin America, although Colombia's ANPPY and the Brazilian National Cassava Congress have attempted to shape policies at the national level. ANPPY was instrumental in price setting until it split into regional groups, as a result of diverging opinions between farmer groups and private processors.

Organization of cooperating institutions

Successful product development results from the collective work of various institutions. The ideal arrangement for such efforts has been called an "interorganizational collectivity," in which two or more institutions make decisions and act on behalf of others. Their purpose is to promote and protect common interests and obtain and allocate much larger resources than could any single participant.

Finding organizational mechanisms to accomplish these goals has proved difficult. Here we examine two models. One is the interinstitutional committee, an approach discussed in Boxes 19 and 20.

The second model is the technical team, whose purpose is to coordinate the work of field staff in different disciplines and institutions. In a project for cassava drying on the Atlantic coast of Colombia, state-level technical assistance teams were established for this purpose. First, they conducted a study to identify production surpluses and then suggested alternate markets.

Other functions of the teams were to carry out feasibility studies (a requirement for obtaining group credit), define production strategies (covering seed, inputs, machinery, labor, and credit), plan for expansion of processing, and coordinate training. In this work the teams received support and in-service training from local and national institutions.

You might expect the private sector to show strong interest in root crop processing once a pilot project has demonstrated its economic feasibility. Yet, this is often not the case.

In Colombia, for example, individuals did not invest in cassava drying plants until 7 years after the initial success, by which time more than 50 cooperative plants were operating. One reason for the private sector's reluctance may have been the low status of cassava as a poor man's crop. Investors tend to focus on other options, such as cotton, even if these entail greater risk.

In other countries, such as Indonesia and Thailand, where the private sector has a better record of agroindustrial innovation, it has not only taken the lead in large-scale processing but also encouraged small-scale intermediate processing, sometimes involving farmer cooperatives.

Even though the private sector may have different objectives from those of a project for developing root crop products, the two have many common interests. On that basis they can explore the possibilities for a private sector role in the project. In doing so it is important that they identify potential areas of conflict at an early stage.

The Product and Process Revisited

Resolving basic issues of farmer and institutional organization is the first step in planning for commercial expansion of the processing enterprise. The next step is to review carefully the whole range of topics—from site selection to training—that were dealt with in the pilot phase.

Site selection

In the pilot phase, you made a list of criteria for selecting the pilot plant site. If necessary, revise the checklist in light of subsequent experience with the processing operation. Give particular attention to the following criteria:

- Rural versus urban locations
- Infrastructure needs
- Environmental impact (the effects of wastes, etc.)
- Farmer groups that have a sufficient price incentive to plant more than they require for on-farm consumption

It is useful to separate essential criteria, such as availability of electricity or water, from merely desirable ones (e.g., existence of a farmer group or other enterprise at the site). Since some new plants built in the commercial phase will be located at less than ideal sites, it is also helpful to identify the minimum set of conditions that must be met to justify building a plant.

Raw material supply

To estimate accurately the availability of raw materials within a reasonable distance of the processing plant, you need to:

- Identify actual and potential production regions.
- Identify farmer groups or other enterprises in each region that can ensure an adequate raw material supply of the appropriate quality and who wish to participate in primary processing.
- Study competing markets to ensure that the price the plant can pay for raw material gives farmers a sufficient incentive to sell.

Box 19

Interinstitutional Committees in Brazil (Case 5)

A primary objective of a pilot project for cassava development in the state of Ceará, Brazil, is to strengthen community organizations, with heavy emphasis on participatory management.

Brazil has national, state, regional, and local institutions concerned with production and processing of this crop. In the original project design, it was proposed that an advisory council be established at the national level to provide general guidance. But planners later decided that this was unnecessary.

To coordinate work on cassava at the state level, several agricultural institutions formed the Ceará State Cassava Committee, as shown in Figure 8. It is composed of technical and administrative representatives of four agencies and at one time included the CIAT project leader. The committee is chaired by the state secretary of agriculture and meets monthly. To ensure effective coordination, it appointed an executive leader and established channels of communication with the offices of research and extension services. The Committee also helped identify institutions to participate in working groups that coordinate local action.

The Ceará Cassava Committee is now generally recognized as the coordinating body for all activities related to cassava development in the state. It received increased support as a result of a tour in project areas, which was organized by CIAT in mid-1989 for policy makers from Northeast Brazil (including the Ceará secretary of agriculture).

At the regional level, the organizational plan calls for Regional Cassava Committees in each project zone. Composed of representatives from technical support agencies and farmer organizations, these committees are intended to decentralize project administration and facilitate local participation in decision making.

At the local level, the Regional Committees coordinate the work of technical teams, composed of extension workers and subject-matter specialists from various research and extension agencies. The purpose of these groups is to stimulate the formation of community-based farmer groups for integrated cassava production and processing. Initially, progress was hampered by the slow development of the State and Regional Committees. In the first year, 12 existing but dormant farmer groups were reorganized or reactivated and another 12 were organized. By the end of 1990, 59 groups were engaged in cassava drying.

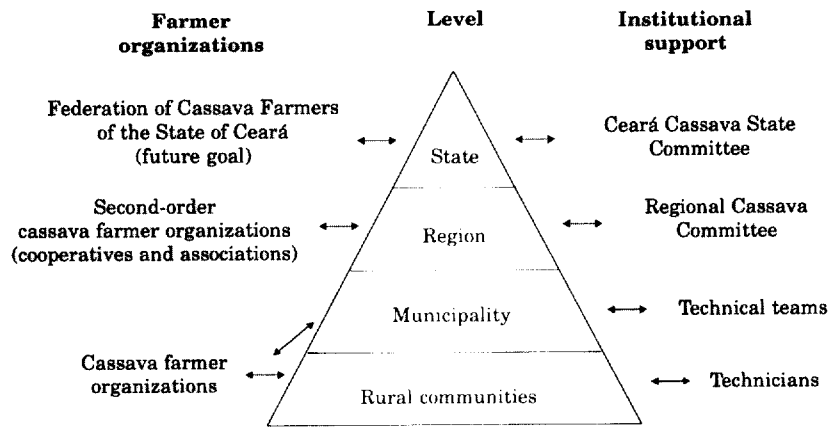


Figure 8. Farmer and institutional organization in an integrated cassava project, Ceará, Brazil.

Box 20

Interinstitutional Committees in the Philippines (Case 10)

The mission of the Philippine Root Crop Research and Training Center (PRCRTC) and the Postharvest Technology Section of the Visayas State College of Agriculture (ViSCA) is to adopt, modify, or develop new postharvest technologies, products, or uses to increase root crop production and utilization in the country.

In 1984, PRCRTC and ViSCA implement-ed a project to produce a soy-flavored sauce based on root crops; develop and adopt suitable processing equipment; and devise utilization and marketing schemes. Recognizing that the project called for a multidisciplinary approach with close integration of its various components, the two organizations formed a team composed of a postharvest technologist, an economist, and an agricultural engineer.

Each member was assigned specific tasks and given responsibility for making a program of activities for each project component. The entire team then collated and discussed these programs to define strategies and plan activities. Project leadership was rotated according to the activity under consideration.

The team held a series of meetings with local support agencies to organize a project management board. A memorandum of agreement was drawn up, defining the tasks and responsibilities of each participating agency and specifying the terms and conditions under which farmer groups could become owners of the venture. A core team of eight farmer leaders was organized to build up their management capacity; this team also included two representatives of a local foundation.

Where there is a competing market for fresh roots and tubers, try to obtain data on historical trends in prices, so you can identify seasonal patterns. Creating a new market for a root crop should help stabilize prices.

It is also critical that you take into account seasonal variation in production. Since roots and tubers are highly perishable, it is rarely economically feasible to store fresh produce for later processing. As a consequence, the plant will probably be able to operate only during harvest periods. If the process involves sun drying of raw material, you need to check whether the dry season coincides with harvest time. Experience in Latin America suggests that planting and harvest times as well as dry season months vary considerably, even within one region of a country. Thus, you cannot safely extrapolate results from the pilot plant site to the whole region.

It should be easier to answer questions about raw material supply once various international agricultural research centers have completed a project underway now to map root and tuber production areas by edaphoclimatic zone. With more detailed information about target production areas, you will be able to identify and prioritize them more accurately.

Processing plants

The size of the processing plant affects the complexity of the operation as well as its ability to obtain an adequate raw material supply and deal with equity issues. In general, many small plants offer more advantages than a few large ones.

Members of co-ops and other rural enterprises generally have little education and experience in operating and maintaining machinery. These people will need substantial technical assistance and training in primary processing, even if the procedures and equipment tested in the pilot phase are appropriate for a small-scale plant in an urban area.

When a processing enterprise shifts from the pilot to commercial phase, the process itself should require few changes. This is particularly true if the commercialization strategy is to replicate the pilot plant at other sites rather than expand its operations at the original location. Nonetheless, you may have to increase the scale of the operation somewhat. If so you need to identify stages in the process where bottlenecks could form as the plant's capacity grows. It is also important to make sure that processing capacity does not exceed the managerial ability of the small association or co-op.

Timing is crucial in the construction of new plants, especially where processing seasons are well-defined. Even so, the timetable must be flexible. In deciding on a completion date, allow plenty of time to get the operation started and to finish training before the main harvest season. Also take into account the inevitable delays in construction, resulting from such problems as shortage of labor at the harvest times of other crops, shortage of building materials, and delays in obtaining credit.

If the new plant is to be operated by a co-op, its members should help with construction as much as possible (under the supervision of an experienced journeyman or master workman). This will not only help reduce costs but also consolidate the group by focusing its energies on a joint task.

The existence of many small processing plants can complicate quality control. To ensure that product quality remains consistent as the operation expands, you need to standardize as many aspects of processing as possible across co-ops. The way raw materials are received and selected and storage time before processing have especially pronounced effects on product quality. Both managers and operators of small plants need to understand the importance of establishing and maintaining strict quality standards. If a second-level organization is responsible for commercializing the product, it too should be actively involved in quality control.

With products for human consumption and, to a lesser extent, those used as animal feed, sanitary and hygiene regulations are especially critical. It may be difficult to comply with some of these either for technical reasons (e.g., inadequate water quality) or lack of knowledge. Before the plant starts to operate, you need to deal with any shortcomings through technical adjustments in the process or training. Before the plant is even built, it is a good idea to check local, regional, and national health regulations and licensing requirements.

To ensure that new plants operate efficiently and economically, managers need extensive training and support in administration and accounting. The agency providing credit for expansion should help provide these services, since it has a strong interest in seeing that the funds are well used. State entities and NGOs can also contribute importantly. Some training functions could be performed by a second-order organization of co-ops, created specifically for this purpose.

The pilot plant can be quite useful for training and demonstration. Operators of new enterprises can spend some time working there to gain practical experience. In addition, people who have worked in the pilot plant can spend time helping those who are starting new ones. It's a mistake, though, to overburden experienced processors with training responsibilities.

Draw up a training plan to ensure that enough operators and managers are available for the number of plants required to meet expected demand for the products.

Product distribution

As noted in Unit 5, processors themselves can distribute a product aimed at the industrial market. But to reach consumers they need a specialized distribution network. In marketing an improved version of a traditional product, you may be able to use the existing network. Chances are, though, it will have several levels of intermediaries, each requiring a marketing margin to cover expenses and provide income. As the processing enterprises evolve, they will almost certainly want to increase their participation in the marketing chain, taking over some of the intermediaries' functions and margins.

You need to decide at this point how far to take product distribution. Do you rely on independent wholesalers, create a second-order enterprise to take charge of wholesale activities, or expand the scope of distribution to include sales at the retail level? The answer depends on the characteristics of the product and market as well as consumers' purchasing habits. See Boxes 21, 22, and 23 for examples of different approaches to product distribution.

If you opt for a distribution enterprise, it must operate on a purely commercial basis. If it is under the umbrella of a second-level co-op, it should be administratively and financially separate. Only then can the enterprise be truly competitive and maximize profits for members.

The main responsibilities of a distribution enterprise are to:

- Coordinate the supply of products from different enterprises according to market demand.
- Oversee quality control of finished products and, if necessary, divide them according to different quality standards.
- Manage warehousing, stocks, and inventories.
- Sell and distribute the product to wholesalers and retailers.
- Coordinate promotional campaigns with distribution.

Box 21

A Three-Tiered System for Distributing Potato Products in India (Case 6)

In Uttar Pradesh, India's largest potato-growing state, nearly all of the 6 million tons produced are harvested in just one month. Since farmers need cash and cannot afford to put the tubers in cold storage, they are forced to sell at very low prices. These growers could increase their incomes by creating links with alternative markets through village-level processing.

In 1985 the Society for Development of Appropriate Technology (SOTEC) was established and received a three-year grant from CIP to work on problems with drying potatoes and using them in Indian foods. Project staff realized that a processing plant, by itself, would be incapable of handling all the activities needed to make village-level processing a success. For that reason SOTEC established a three-tier structure with:

1. Village-level drying plants.
2. A unit that sorts chips from 8-12 nearby drying units (quality control), grinds them into powder, packages the powder in bulk or for retail, stores the product, and fills orders.
3. A unit that handles sales and marketing, advertising, package design, distribution of products to retailers, billing, and collection. It also establishes production targets for tiers 1 and 2 and may obtain bank loans for purchasing products.

Initially, SOTEC operated at all three levels. In 1988 it turned over most of the sales activities to independent companies and by 1990 was able to withdraw from sales altogether. Currently, SOTEC is establishing a federation, which will eventually assume all the responsibilities of tier 2 as well as equipment supply. It will also help procure raw materials and financing.

One problem with this system is in the collection of dried chips. Villagers lack adequate storage facilities. And transport costs are high, because the product is of low density and is shipped in lots of less than a truckload. There are also difficulties with storage of the final product. Currently, it is taken to SOTEC headquarters for sorting and storage and then reshipped to the market as required.

Box 22

Dividing and Conquering with Potato Products in Peru (Case 7)

The agroindustrial program of the Centro de Investigación, Documentación, Asesoramiento y Servicios (IDEAS) established a pilot plant at Concepción, Junín, to promote small-scale manufacture of processed potato products in rural areas. The products were to be sold in the principal supermarkets of Lima under the brand name Abril. The project encountered several problems:

1. ***Target group.*** The products were originally intended to improve the nutrition of low-income urban consumers, who would be reached through official food programs or institutional markets. Afterwards, other products were to be developed for middle- and high-income consumers. Although no detailed marketing surveys were conducted, project planners did learn that low-income consumers preferred cheaper products (such as grains and simple unprocessed flours) to processed products. As a result, the project had to alter its strategy.

2. ***Pricing.*** The first product developed, a flour mixture, cost more per kilogram than simple unprocessed flours and showed no apparent advantage over other processed products. Its only benefit was low cost per nutrient and ration. And since consumers cannot readily perceive this, the product would have been difficult to market. Changes in government policy on subsidies for imported foods put the product at an even greater disadvantage. Consequently, project staff decided to modify it.

3. ***Marketing strategy.*** Initially, the project had no strategy, because the original idea was that its products would be marketed through government and private institutions. Thus, even though recommendations were made about the name, packaging, etc., no action was taken on these issues.

Because of its difficulties in identifying a suitable flour mixture, the project decided to market three other products: precooked flours ("creams"); precooked, peeled grains; and specialized products (such as a milk substitute named Chicolac) based on potatoes, maize, quinoa, etc. The market was divided into three segments: 1) middle- and high-income consumers, who shop in supermarkets in Lima; 2) low- and middle-income consumers who would be reached through shops, markets, and special promotions in the area around the plant; and 3) the institutional market, principally government programs offering free meals for the poor.

The project eventually sold products through five of the six supermarket chains, distributing directly to 57 points of purchase. Advertising campaigns were considered unnecessary, because the package was attractive, the quality of the products was good, and prices were fairly low. Chicolac was introduced successfully in the municipal Glass of Milk Program in Huancayo and Concepción, which included 70,000 children and mothers. Project staff promoted this product by demonstrating its use for mothers and by letting children taste it. The project promoted other products by offering introductory discounts and distributing recipes.

Although the Abril products cost more than competing items, consumers were willing to pay the difference. The volume of sales was limited by lack of working capital. As a result, the project used only 50% of its production capacity.

Box 23

Distribution of Fresh Cassava in Colombia (Case 2)

In spite of its high consumer appeal, a conserved cassava product was trading at low volume—only 1.2% of the market (10 t/week compared with a total market volume of 800 t/week). Apparently, the problem was insufficient promotion. An advertising agency was hired to develop a brand name (Yucafreska) and slogan and design a promotional campaign. But the Programa de Desarrollo Rural Integrado (DRI) was unable to obtain funding to carry out the campaign.

Initially, each cooperative manufacturing the product also handled marketing. Then, as shown in Figure 9, the project proposed to establish a central marketing organization, which would coordinate regional supply and quality control. During the pilot phase, the Cooperativa de Producción y Mercadeo de Repelón (COOPROMERCAR), Atlántico, was selected for this purpose.

In the commercial phase, responsibility for marketing was given to the Federación de Organizaciones Agropecuarias de Colombia (FAGROCOL), a second-order federation of co-ops of cassava producers and shopkeepers formed in Barranquilla in 1989. Since ANPPY did not authorize this group to use the brand name Yucafreska, it adopted the name Superyuca in mid-1990 but has not yet registered it.

FAGROCOL has the capacity to sell 50 t of cassava weekly, of which 15 t are fresh cassava, conserved and sold in bags to supermarkets. From November 1989 to June 1990, the federation sold 102 t of bagged cassava. It has also improved the processing technology and product quality. Return of deteriorated cassava has fallen from 20% to 5%. Nonetheless, the operation is not profitable, since it must market 26.6 t a month to break even.

Currently, the project is trying to reduce costs. But to increase the volumes of production and sales, it will need additional support to establish a processing plant and carry out a large-scale publicity campaign. Some wholesalers have opted to store and sell untreated cassava roots packed in polypropylene bags. The roots can be stored for 1 or 2 days, which was previously impossible.

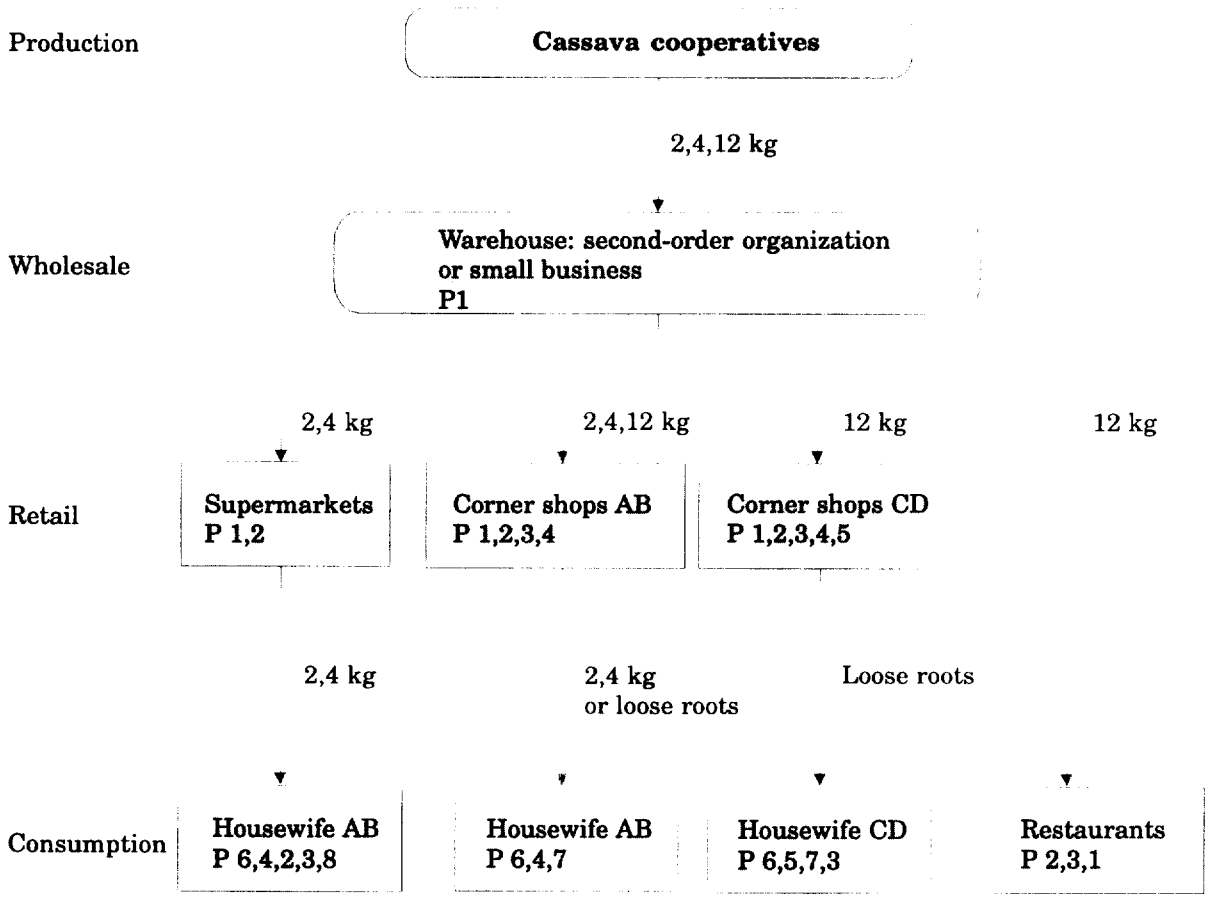
- Monitor the volume of sales, including those of competitors, as well as the profit margins of wholesalers and retailers.
- Give feedback both to processing groups and product organizations.

The location of the enterprise's central offices and warehouse is very important. If the product will be sold in small shops, the warehouse should be near the central wholesale market where shopkeepers purchase most of their goods.

Obviously, to manage distribution demands quite different skills from those needed in processing. The former requires a high degree of competence in marketing and business and a good knowledge of product storage. State agencies are not the place to look for these skills, since they do not operate on a commercial basis. Instead, you must seek input from organizations that support small businesses and can provide relevant training and technical assistance.

Product promotion

To meet the objectives outlined in the market plan, you need to make consumers aware of the product and its advantages and inform them where it can be purchased. Many publications describe how to plan and execute a promotional campaign (see the list at the end of this unit). Here we summarize a few basic principles.



Promotional materials:

- P1 - free sample
- P2 - visit by salesman
- P3 - pamphlet
- P4 - newspaper advertisement
- P5 - radio advertisement
- P6 - regional TV advertisement
- P7 - poster
- P8 - material distributed at point of purchase

Bag size (kg of roots per bag):

2, 4, 12

Socioeconomic standing of retailers and consumers:

AB - middle to higher income
CD - lower income

Figure 9. A scheme for distributing and promoting storable cassava in bags in Colombia.

When deciding what media to use, you need to take into account the characteristics of target consumers (e.g., newspaper advertisements will not reach barely literate people in the low-income strata). In developing promotional materials, avoid using regional expressions, dialect, and the like, since they may limit the geographical area in which the materials can be used. In all materials the brand name, logo, and slogan should figure prominently.

A small co-op cannot afford to launch a new product with the same degree of fanfare as large food companies. Even if it did have the resources to bombard consumers with publicity, the co-op would be hard pressed to satisfy the resulting sudden increase in demand. A safer alternative is to increase promotional activities gradually, as the distribution network expands and product supply increases. To create a market costs money. But in the long run it should pay for itself.

Training

To train farmers and other rural people in processing and product distribution requires a strong commitment from the institutions collaborating in the integrated project. In addition to dominating the technical aspects of plant operations, these people need to acquire new skills in business administration, personnel management, financial analysis, and bookkeeping. They must also learn how to negotiate, motivate employees, and work in groups. A big part of the challenge is to find appropriate training methods for the many farmers who may be quite astute but functionally illiterate. They may need extensive on-the-job training, until they acquire enough skill and confidence to manage the processing plants themselves.

Personnel from both the private and public sectors should receive training in the technical aspects of root and tuber production and processing as well as in methods for working with farmer groups and small-scale agroindustries. One problem to watch for is high turnover of personnel, which can greatly increase the investment required in training.

Investment and Impact

In addition to covering all aspects of processing and marketing new products, your plan of action for the commercial phase must answer two questions that have a direct bearing on the long-term success of the processing enterprise. First, how will the activities of this phase be financed? And second, how will investors or creditors be assured that the project is working steadily toward its objectives and achieving the expected impact?

Sources of financing

The pilot phase is normally funded through special projects, since no small business or cooperative can be expected to finance the development of a product that has not proven to be technically and economically feasible. But once the plant reaches the commercial phase, it should be able to obtain credit for replicating or expanding its manufacturing capability and providing sufficient working capital to cover initial expenses. Even at this stage, though, there is an element of risk, since the success of the project depends on its ability to develop a processing enterprise with small-scale farmers.

For that reason you will probably have to seek credit on relatively easy terms from a public sector organization. It is also important that credit be accompanied by a well-designed program of training and technical and administrative support, provided either by the public or private sector. Such activities can generally be financed by state organizations, assuming that their development priorities are in accord with those of the project. In countries where root and tuber crops receive low priority, a more likely source of funding may be NGOs that are active in rural development and are working with farmer groups.

Small-scale producers and processors rarely have enough capital to finance the promotion of a consumer product on a commercial scale. This is also the activity for which it is hardest to find outside financial support. By and large product promotion is not considered part of a rural

development project. That is why it is important to find a second-order organization willing to undertake this task. Possible candidates are institutions interested in improving the availability of staple foods in urban areas.

To reduce their dependence on external credit, processors need to build up capital. For co-ops this means finding a balance between distributing profits and reinvesting them in the business to finance growth and reduce dependence on credit. Poorer groups in particular are under a lot of pressure to distribute profits.

Monitoring and evaluation

If the project goes ahead with the commercial phase, it will need a system to monitor the progress of the product in penetrating target markets. Whether the project achieves its objectives depends to a great extent on the quality of the market plan, which must be both detailed and flexible. You may have to modify the plan in response to developments in production, processing, and markets. For example, if the growing season is so poor that the supply of roots and tubers falls dramatically, you will need to cut back processing or find other sources of supply.

If the enterprise depends on funds from the public sector, it is also important to monitor changes in government policy. In addition, the marketing plan should take into account probable delays in forming and consolidating co-ops, obtaining credit, and constructing processing plants. To ignore these possibilities may cause other project activities to get out of phase.

Make an effort to document experience gained at the outset of the commercial phase. This information may help you improve plans for breaking into other markets.

The monitoring system should focus in particular on documenting:

- Sales volumes (including totals as well as breakdowns by market outlet and by consumers' socioeconomic status), inventories, and stocks
- Consumer behavior with respect to first and repeat sales
- Consumer satisfaction with product quality, usefulness, and price

Checklist 15 indicates other types of information you should be able to obtain from the monitoring and evaluation system. It has to be in place when the project begins and must be maintained by the participating organizations. A large part of the monitoring can be based on the project's administrative records. It might also be useful to make an annual survey to obtain answers to specific questions.

To learn first-hand whether they have made a sound investment, the organizations that have supported product development ought to conduct an evaluation of its commercial impact. As illustrated in Box 24, they should judge this, not just by the financial viability of the processing enterprise, but also by its distribution of benefits. These can accrue to farmers, landless laborers, rural transporters, urban distributors, retail shopkeepers, and consumers. It is also important to determine whether the enterprise has had any adverse effects.

Data generated by monitoring and evaluating the project are a potential source of ideas for new markets or products. This information should be communicated to the technical research components of the project for further evaluation. (For more information on project monitoring and evaluation, see the list of publications at the end of this unit.)

Toward a Self-Reliant Agroindustry

Good planning must be followed by decisive action. In this section we outline the series of steps that you need to take after developing an action plan for the commercial phase.

Executing the plan

Executing a plan to expand the agroindustry is largely a matter of integrating its different components. For example, efforts to increase crop production must be geared to the construction of new processing plants. Proper integration depends in turn on close coordination of the activities of participating organizations (research

Checklist 15

Information Gathered by a Project Monitoring and Evaluation System

Raw material supply

- Origin
  - Distance to plant
  - Percentage brought by middlemen
  - Percentage supplied by village
  - Supply from co-op members in relation to break-even point
- Quality
  - Dry matter content
  - Variety
  - Planting period
- Regularity (quantity processed by lot)
- Value
  - Purchase price
  - Percentage of remainders

Processing

- Utilization of capacity (a measure of overall efficiency)
- Product quality
  - Moisture content
  - Conversion factor
  - Color
- Production
  - Cost structure
  - Costs in relation to selling price

Commercialization

- Packaging
  - Types of materials
  - Bulk
  - Sizes
- Utilization of warehouse (measured by the ratio of processed product to storage capacity)
- Rotation of capital (days of delay in payment)
- Ratio of inventory value to working capital

extension agencies, NGOs, farmer groups, the private sector, etc.). This is a highly complex task, for which a single entity ought to be given overall responsibility.

As the commercial phase moves forward, you need to make good use of feedback from the monitoring system to keep the project on track and modify the plan of action in response to unforeseen developments. This is also the time to prepare for the eventual withdrawal of project support. To avoid creating dependence, the project must ensure that farmer groups get enough training and experience to handle all aspects of the enterprise. Even if these groups have to contract out certain commercial or financial tasks, they should always keep these activities under their overall control.

Phasing out the project

The end product of the commercial phase is an economically viable agroindustry that requires no outside support to survive, fulfills the social objectives of the project, and is able to expand and adapt to a changing commercial environment (see Box 25 for an example). Whether the project achieves this objective depends on numerous technical, economic, and human factors.

If the agroindustry has expanded by building a large number of small processing units, rather than expand the original pilot plant, its production capacity will be fragmented. To achieve commercial success, the agroindustry will require close coordination in product marketing and distribution. This will depend on the strength

Box 24

A Comprehensive Strategy for Project Evaluation in Brazil (Case 5)

A pilot project for cassava development in Ceará, Brazil, is tracking progress toward key objectives through a comprehensive evaluation strategy. This involves monitoring the following activities:

- Daily progress in cassava processing
- Impact on cassava production
- Distribution of benefits

The project also assesses the socioeconomic status of participating farmers to determine impact on income generation and distribution, education levels, farmer organizations, access to the political support system, and social benefits. This monitoring takes place at three levels, with a different method at each:

- Specific project objectives: collection of baseline data on participating organizations.
- Target population: a survey of 150 participating cassava farmers.
- Target areas: small-group surveys and intensive follow-up with a limited number of farmers (sample populations for this level are drawn from the second level).

Information from the project's databases is reported in periodic bulletins. On this basis the technical team of the Cassava Committee gauges project performance, and the farmer groups evaluate their own performance relative to one other. Project staff have found that getting feedback to individual groups rapidly is critical for detecting and correcting problems. The databases have proved useful for preparing detailed project reports and demonstrating the size and distribution of benefits to the Kellogg Foundation, which is funding this project.

of the second-order organization formed to handle those functions.

Phasing out a project smoothly requires good management. This underscores the importance of training key people in the enterprise. One option is to hire managers working in other businesses. But there is a downside to bringing outsiders into a community enterprise. To avoid problems the outside manager would need to be under the supervision of well-trained personnel representing the target beneficiaries.

Training managers is complex, since by definition they must coordinate a wide range of functions (technical, financial, personnel, sales, etc.). Projects in Colombia and Ecuador have been developing managerial capacity for more than a decade. To consolidate this achievement takes a generation. The children of original members of farmer co-ops are just now completing their formal education. With the technical or business skills they have acquired in school, plus the experience they gain by working in processing enterprises, these young people will be well prepared to provide solid leadership in the future.

Institutional support should not be withdrawn before the enterprise is financially solvent and has reasonable prospects for continued success. Above all, it must have access to a sustainable source of credit. Some options are commercial bank loans, a special credit line established for small-scale agroindustries, or a revolving credit fund, which the enterprise manages, using funds left over from the product development project.

Finally, the enterprise needs to establish channels of communication with government policy makers. It can do this through local government or sectoral organizations operating at

Box 25

Versatile Processing Enterprises in Ecuador (Case 4)

For several years Ecuador's UAPPY, which supplied dry cassava for the shrimp feed industry, enjoyed steady growth in membership and volume of production. Then, in 1989 it suffered a major setback. The country's shrimp industry collapsed as a result of foreign competition and other problems. The demand for dried cassava fell sharply, and large stocks of product were left unsold at the end of the processing season.

The organization responded in two ways: first, by seeking other markets for cassava chip and flour products in Ecuador and, second, by starting to produce starch from cassava. UAPPY found demand in several industrial markets, specifically among producers of plywood, glue, and cardboard boxes. But to take advantage of these opportunities, processors had to raise the quality of their products. Some enterprises started producing flour from peeled roots and thus created many new jobs for women as manual laborers.

In the Manabí area of Ecuador, where the project was located, there is a tradition of small-scale cassava starch production. The UAPPY saw an opportunity to expand the market for this product by improving its quality. A women's group was formed for starch extraction and successfully established a profitable operation.

The union next conducted a market survey of food, feed, and other industries to estimate the potential demand for its various products. By that time cassava processors were turning out flour, starch, and by-products of different quality standards. Based on the results of the survey, UAPPY was able to allocate resources to the different processes according to their market potential.

Through this experience UAPPY members learned the importance of product and market diversification for ensuring the long-term viability of the processing enterprise. The union set up a special unit to develop new and improved processes as well as a demonstration plant for training. The organization's research capacity should enable it adapt to changing circumstances in the future.

the national level (e.g., associations of rural agroindustries and crop producers and unions of small-scale farmers). It is increasingly common for producers and importers of nationally significant raw materials and products to have political lobbies. These groups can achieve significant shifts in government policy, especially with respect to support prices, import tariffs, etc. The agroindustrial enterprise must have a representative at that level to ensure that its interests are taken into account.

Occasionally, policies formulated for one sector of the economy may unintentionally harm the interests of the processing enterprise. Or its competitive position may be weakened by the efforts of one interest group to gain advantages over another. In Colombia, for example, the microbial standard was set higher for cassava flour than for wheat flour, because the standards committee included representatives of wheat flour millers (importers) but not of cassava producers.

The sign of self-reliance

While some basic products have a long life span, consumer items tend to be relatively short-lived. No matter what market an enterprise caters to, it cannot expect to survive indefinitely by producing just one product.

This is especially true under current global economic conditions. Increasingly, the market determines raw material and product prices, and national economies are being opened up to international competition. World market prices

for many agricultural goods fluctuate widely. The resulting uncertainty makes the development of root and tuber products to compete with animal feed grains or wheat flour, for example, a fairly risky business.

Another reason not to rely exclusively on one product is that consumer tastes and habits change, though more gradually than economic conditions.

If the project's commercial phase has been successful, it must ensure (before institutional support is withdrawn) that the enterprise acquires a capacity for continued development of new or improved products. Here are several strategies for developing a more versatile agroindustry:

- Improve the quality of existing products, so they can enter new markets.
- Develop totally new products.
- Further process existing products (e.g., from chips to flour to feed rations for animal production).

This last strategy involves a series of increasingly complex processing procedures. Each must be built on a solid foundation established in previous steps. In other words, don't try to master all the procedures at once.

During the commercial phase, the project comes into close contact with the market. This can be an important source of ideas for new or improved products. To act on these ideas, the enterprise must repeat the process of product development, starting with research, as described in Unit 4.

At this point the project may be prolonged to support the exploration of new opportunities. But a better option is for the enterprise to build its own product development capacity. It may have to contract out research for which it lacks the necessary expertise (e.g., in equipment design or analysis of product quality). But assuming that the new product reaches the pilot phase, the enterprise should operate the pilot plant itself. An in-house capacity to develop new products is a sure sign of the agroindustry's self-reliance and vitality.

A Final Status Report

By the end of the commercial phase, the status of a product development project should be as described in Table 22. This final phase has two main outputs: a commercially successful product and a financially sound enterprise. If the project has done a good job of monitoring progress, you should be able to trace its effects on target beneficiaries. Since it takes time for quantifiable benefits to accrue, impact ought not be assessed prematurely.

Table 22. Status of a product development project at its conclusion.

Project component	Status at end of Phase 4
Objective	Defined, with good potential of being reached
Region	Industry spreading from initial to other regions
Product	Commercially successful; more ideas now generated
Market	True potential being realized
Enterprise type	Selected model successful, more appearing
Beneficiaries	Monitoring to ensure impact reaches target

Another output of the product is a set of ideas for new products. The enterprise should be able to develop these itself, even it has to contract out some tasks. The enterprise may need project funding for this purpose. If so it should be actively involved in formulating and executing the project. In Latin America two agroindustries have recently taken this step. In Colombia ASOCOSTA obtained government credit for a project to produce balanced animal feed rations using cassava. In Ecuador UAPPY has received credit and donations for various projects.

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Unit 7

A Review of Major Issues

In this final unit, we review important issues raised in Units 3-6 and conclude with a look to the future of small-scale agroindustries for root and tuber product development.

Key Aspects of Product Development

Here we discuss key aspects of product development, drawing lessons from the case studies to underscore important points.

Project objectives

Product development projects are complex, requiring careful integration of many diverse groups and tasks. A clear statement of objectives, with which all parties agree, can reduce the potential for confusion and conflict. It is especially important to be clear from the start about project beneficiaries, since you will probably have to choose between rural producers and urban consumers.

As the project proceeds, new experience may require that you modify the objectives. If so, do this explicitly and with the consent of all parties. If the private sector is involved in the project, as an investor in processing or as a source of funds, it is particularly necessary that the project work steadily toward common objectives.

Identifying opportunities

Public resources for research are scarce. To ensure that they are wisely invested in product development, you need to do a thorough job of identifying the best possible product. Resist the temptation to rush into the investigation of technical aspects of processing after considering product options only superficially. Extra time spent on this latter task will pay dividends later.

There are many examples of research that led nowhere, because it focused on a product that was unprofitable or technically difficult or had no market. In most instances a more comprehensive investigation of opportunities at the outset would have given the research a different focus.

Take the case of a project in the Chapare region of Bolivia, where five plants were built for natural drying of cassava to produce chips for animal feed. Once the plants were in operation, it became apparent that, because of high rainfall in the region, cassava required artificial drying. It also came to light that this product could not compete with low-priced maize in the local target market.

The project turned instead to producing high-quality flour (which requires artificial drying) as a substitute for expensive, imported wheat. If the project had made a more thorough evaluation of product options at the outset, it would have saved time and money in the long run and benefited small-scale farmers much sooner.

Putting the market first

In this manual we emphasize the importance of putting market factors first in key decisions about product development. We also take into account technology options but always in view of their prospects in the market.

Many research institutes do just the opposite, letting technology serve as the driving force behind product development. The main attraction of this approach is that it gives researchers maximum freedom to exercise their creativity. But they also run a high risk of dedicating scarce resources to processes and products with little chance of commercial success. We're convinced that research is more efficient and more likely to pay off if guided by market information from the start.

Market-driven research must be interdisciplinary. It requires that technical researchers learn to deal with the results of market and social studies and to interact with a wide array of project cooperators and beneficiaries. The value of interdisciplinary research is evident from the experience of the Visayas State College of Agriculture (ViSCA) in the Philippines. By participating in market and consumer surveys, technical researchers gained new insights into the needs and problems of consumers, while market researchers learned new ways to interpret their data.

If the institute responsible for technical research in your project has few economists or other social scientists, contact local universities. With them you can explore the possibilities of conducting market research through student thesis projects and other forms of collaboration. Universities should be able to provide low-cost, rapid methods of gathering market information that do not slow down technical research.

Pilot projects

The pilot phase is a central part of product development. Its purpose is to test the process and product on a small scale under "real life" commercial conditions.

In many research institutes, what passes for a pilot plant is more correctly termed an "experimental plant." The difference is that in the latter researchers control the process and frequently the raw material supply as well. Moreover, the product is marketed under artificial conditions; production costs are unrealistic, and the product is sold largely to employees.

An experimental plant may be essential for research and useful for training and demonstration. But it has limited value for judging the commercial feasibility of a processing plant. To examine the key factors that determine this (such as logistics, raw material quality, and energy and labor supply), you must establish a pilot plant under realistic circumstances. As illustrated in Box 26, the technical problems that may arise under these conditions provide a focus for adaptive research in the pilot phase.

Cooperatives or small businesses?

At an early stage in product development, you need to weigh the merits of different organizational models and decide which is the most appropriate vehicle for commercializing a particular product. As discussed in Unit 2, there are two main options: to organize the enterprise as a cooperative or association with primarily social ends or as a small business with chiefly commercial ends. Whether you choose one or the other or some combination of the two should depend on project objectives, on the social and political environment of the target region, and on the technology involved.

The advantage of cooperatives is that they distribute benefits over a wide social base. They are the obvious choice if the project's overriding concern is to benefit the rural poor. Small businesses are generally more effective and grow faster than co-ops but generate fewer social benefits. This shortcoming may not matter if the project's objective is to benefit urban consumers.

Whether participating institutions choose to work through cooperatives also depends on the track record of such groups in the target region. In some parts of the world, social factors or government policies work against cooperatives.

Another important consideration is the sophistication of the technology. If it is suitable for large-scale production, you might consider joining forces with a big food company. You can then share development costs and achieve greater impact more rapidly. A further advantage is that private enterprise can promote the product on a large scale, a task that is beyond the resources of public sector projects. In order for such an arrangement to work, however, it must be compatible with the project's objectives. Small-scale farmers will benefit only if the market for raw material greatly expands; they will gain nothing from processing or added value.

In the Philippines, ViSCA has taken several products (a sweet potato beverage, ketchup, and Delicious SP, a dried snack) as far as the research phase and then passed them on to private companies for manufacturing on a pilot and eventually commercial scale. In the first such

Box 26

Problem Solving at the Pilot Phase in Colombia (Case 3)

A pilot plant was set up in Colombia to determine if it would be economically feasible for a small-scale farmer cooperative to produce high-quality flour for the food industry. The plant was based on a design tested under experimental conditions at CIAT. The process was found to be efficient, especially in artificial drying of cassava chips, and the end product met Colombian quality standards for total and coliform bacteria levels.

Nonetheless, initial results from the pilot plant showed that the artificial drying system was not performing efficiently enough and that product quality was inadequate, especially with respect to microbial standards. Research conducted at the plant identified two major problems. First, there were delays of up to 2 days between harvest and processing. And second, drying time was long when the plant was run at full capacity (3 t of fresh chips per batch).

The solutions were tighter control over the supply of fresh roots to ensure that no more than 24 hours elapsed between harvest and processing and the purchase of an additional coal-fired burner to raise drying temperature, reduce drying time, and improve the quality of the dried chips.

With these improvements the plant was able to produce chips and flour for human consumption that satisfied quality standards. It obtained a license for food product manufacture and began selling flour to the local food industry.

This experience underscores the importance of the pilot phase. Without this step the project would not have identified and solved at an early stage problems (especially those relating to fresh root supply) that did not appear in the experimental plant at CIAT.

case, the college made an exclusive contract with a company, which never developed the product any further. Since then ViSCA has used nonexclusive contracts. One of the terms is that the college helps companies conduct pilot testing of products, and in return they donate equipment to the college.

Phasing out the project

Most of the recommendations in this manual are based on a wide range of experience in various parts of the world. The one step about which we can't speak with much certainty is the commercial phase of product development, during which the project framework is withdrawn. The problem is that there are still few cases in which this has happened. The only projects we can describe in the past tense are those established in Colombia for producing dried and fresh cassava. And even these are hardly perfect examples.

The cassava drying project, for instance, was not phased out through a conscious decision. This just happened as the agroindustry created by the project spread far beyond the original target region, making project activities essentially irrelevant. The private sector became increasingly involved in cassava drying, and government reduced its support of rural cooperative development.

The fresh cassava project suffered a similar fate. It lost support from the government's rural development agency because of changes in personnel and institutional mandate. At the same time, CIAT decided to terminate its work on this product as an outcome of budget cuts and strategic planning. The project thus came to a halt at the end of the pilot stage. Two years later businesses set up on a pilot basis for storing fresh cassava are still operating at a profit. By not proceeding to the commercial phase, we may have missed a valuable opportunity.

Institutional support to the Unión de Asociaciones de Productores y Procesadores de Yuca (UAPPY) in Ecuador, is currently being phased out in an orderly fashion over a two-year period. In preparation the union is building its own capacity to develop new projects in direct contact with international donors rather than through institutional intermediaries.

Root and tuber products under development in the Philippines are all in the pilot phase, except sweet potato ketchup, which is being manufactured successfully by private enterprises. Production on a commercial scale could spread to new locations with further support from researchers at ViSCA.

In India the potato processing enterprises now underway require further institutional support to guarantee their long-time profitability and diversify their range of products.

In Peru processed potato products are now available. A project aimed at expanding the market would be helpful.

Based on the limited experience we have so far, it seems clear that to phase out a project successfully two conditions must be met. First, the enterprise must have a product with a good profit margin. And second, it must be under sound management.

A good indicator of the strength of an agroindustry is its ability to develop new products. Cooperatives in Colombia, for example, are now commercializing maize, producing animal feed rations, and so forth. If the enterprise needs support (for example, in applied research on crop production or process development), it should contract other organizations to provide this service.

Future Prospects

In the 1990s two general trends have a direct bearing on the prospects of small-scale, rural agroindustries for developing products based on root and tuber crops. Markets are gradually becoming less distorted, and countries are opening up their economies to external trade and strongly encouraging exports.

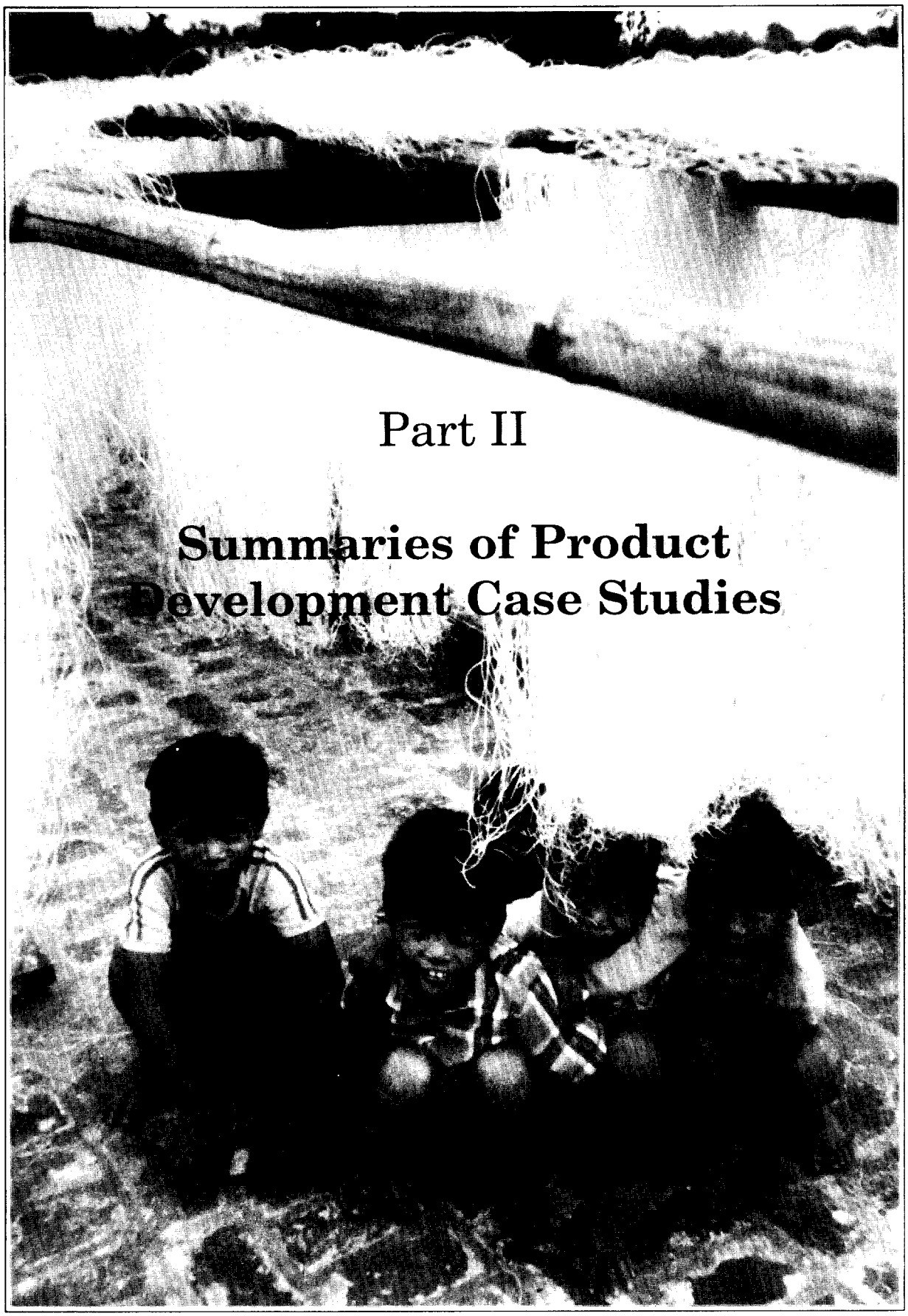
Agriculture is probably the sector with the most distortions. This is largely the result of heavy subsidies maintained by developed economies in Europe and North America and of the negative effects of politically motivated food aid on agricultural production in the developing world. It seems likely that developed countries will make some progress over the next decade toward reducing subsidies and allowing free-market conditions to prevail in agriculture.

Production of root and tuber crops in developing countries can succeed if it provides low-cost, high-quality, locally available raw materials for rapidly developing food, feed, and other industries. These crops will be used primarily in starch- and flour-based products (serving mainly as ingredients of animal feed), in processed foods, and for a wide range of other industrial purposes.

The central premises of this manual are that roots and tubers can perform this role and that small-scale rural processing (at least for manufacturing intermediate products, such as starch and flour) is a viable way for small-scale farmers to get a share of the benefits from value-added products. If these are sound assumptions, root and tuber crops could contribute importantly to sustained economic development.

In order for these crops to contribute significantly, though, it is vital that governments reduce or eliminate subsidies on imported industrial raw materials, that rural people receive training in both the technical and business aspects of operating processing plants, and that effective managers be selected for product development projects.

The key advantage of roots and tubers is that they are low-cost sources of carbohydrate. To capitalize on this advantage, rural people must add value to these crops through small-scale processing of products whose quality and price are comparable to those of cereals. If this happens equitable rural development could become a reality in the disadvantaged areas where roots and tubers are usually grown.

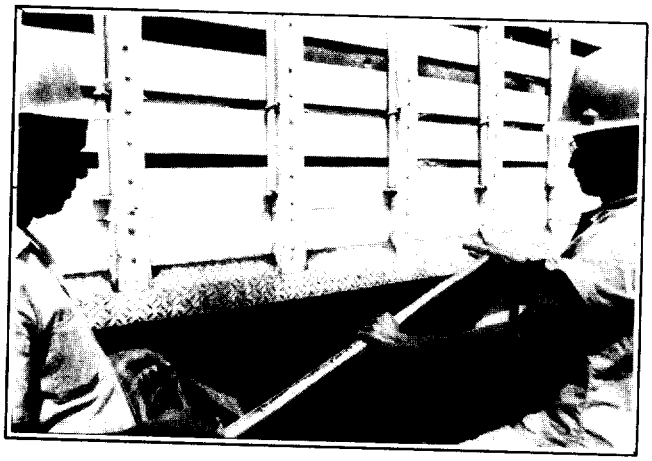


Part II

Summaries of Product Development Case Studies

Case 1

Dried Cassava for Animal Feed in Colombia



Objective: To raise the incomes of small-scale cassava farmers and landless laborers by introducing a new cassava product—dried, whole root chips—for sale to producers of animal feed concentrate.

Project area: The departments of Sucre and Córdoba on the Atlantic coast; the idea later spread to other departments on the coast and in other regions of the country.

Time frame: Pilot phase, 1981-1984; commercial phase, 1985-1989; phase-out started in 1990. The project drew on research conducted by CIAT in the mid-1970s.

Background

In the 1970s the country's Programa de Desarrollo Rural Integrado (DRI) tried to improve the welfare of small-scale farmers in this region by providing credit for cassava production. Although production increased, demand in the fresh market remained constant, leading to a price decline and widespread default on loans.

In an effort to diversify cassava markets, DRI joined CIAT and various national institutions to mount a pilot project in which cooperatives would produce dried cassava chips on a small scale, using natural-drying technology from Thailand. The idea was that this domestic product would compete with imported sorghum, which the Colombian government was purchasing in significant amounts and selling at support prices above those in the world market. Economic studies suggested the project's strategy was feasible, assuming that farmers could reduce production costs and increase yields.

Project Evolution

DRI organized small-scale farmers into community co-ops or associations, and interinstitutional teams coordinated by DRI gave the farmer groups integrated support in technical matters and credit. CIAT focused particularly on cassava drying.

The first pilot plant was set up with funds from the Canadian International Development Agency (CIDA). Other plants soon followed (mostly in Sucre and Córdoba); by the mid-1980s there were nearly 40. The number of plants increased again in the late 1980s and early 1990s because of continued support to farmer groups and increased interest among entrepreneurs outside the project. By 1992 more than 150 plants were producing over 25,000 t of dried cassava chips.

Technical and other challenges

The plants sold their product to the country's major animal feed companies, which incorporated the chips to varying degrees into balanced feeds for cattle, swine, poultry, and other livestock.

Although generally successful, this marketing approach did present problems for both processors and their customers. Because the farmer groups catered mainly to industries accustomed to paying for goods 30-90 days after delivery, they had difficulty maintaining working capital. The feed companies, on the other hand, often complained about inadequate chip quality, a result of poor drying, but detected no aflatoxins.

The farmer groups also faced challenges in plant operations. For example, scarcity of cassava fresh roots sometimes forced them to look outside the group for new supplies. And this reduced their processing efficiency, particularly in the commercial phase.

Since the cost of raw material accounted for 74% of processing costs, including transportation, the project paid close attention to its links with cassava production. It also improved the chipper developed in Thailand, increasing its capacity from 3 to 12 t/h. The project proved economically viable with a cassava yield of 8 t/ha and a conversion rate (for fresh to dried cassava) of 2.5:1. Delays between harvesting and processing and extended drying time had a negative effect on quality of the final product. Inadequately dried cassava chips (i.e., exceeding a maximum moisture content of 12% on a wet basis) were rejected by the feed industry.

In addition to technical support, the farmer groups received extensive training in all aspects of production, processing, commercialization, and administration. Some members needed literacy classes. Training in plant administration, especially financial management, was not successful. This and marketing required skills and communication channels that the farmer groups lacked.

Institutional support proved costly. In its first year, the project received 220 days of support from various groups; the requirement dropped to about half that amount after a few years. Farmers commonly complained that technical support was poor and inopportune, largely because they had no control over the technical teams.

Spreading the benefits

Despite its difficulties, the project generated significant benefits. To spread these as widely as possible, planners opted to replicate the farmer groups and processing plants rather than expand existing ones.

When enough groups had been formed, the project encouraged them to establish a second-order organization, which would handle product marketing (particularly negotiation of prices with animal feed companies), channel technical assistance and other services to farmer groups, and protect farmers' interests in the political arena. The Asociación Nacional de Productores y Procesadores de Yuca (ANPPY) was established for these purposes in 1986.

By 1992, however, the organization had split into regional factions. Between 1990 and 1992, private owners of drying plants took control of ANPPY, prompting the co-ops to form rival second-order organizations, the Asociación de Cooperativas de la Costa (ASOCOSTA) and Federación de Cooperativas de la Sabana (FEDECOSABANA).

Producers earned income from processing by various means: 1) selling raw material directly to the plant; 2) working in processing or its administration; 3) profits from the plant or other benefits of group membership, such as access to credit and training; and 4) income paid to family or contracted labor for producing raw material. Early results showed that small-scale farmers received a large share of the income from processing. Some also went to landless laborers.

The rate of return from processing was initially very favorable (more than 70% in 1990) but has declined in recent years because of increased competition from cheap imported maize and sorghum. Even so, in 1993 the price of dried cassava still exceeded production costs.

As a consequence of the project, cassava demand increased, farmers adopted improved production technology, and yields rose. The Instituto Colombiano Agropecuario (ICA) released two new varieties. But farmers resisted the idea of differential prices for roots based on dry matter content. And this has made it difficult to improve the processing plants' efficiency.

The loss of institutional support

CIAT terminated its involvement in the project in 1989. By 1992, DRI had also reduced its role in the work, as the government switched to a more free-market approach in agriculture, abandoned support prices, and restructured and reduced the size of public institutions. The interinstitutional technical teams were disbanded. Lines of credit

for small-scale farmers were reduced, and access to them made more difficult.

Once the project lost its institutional framework, technical support collapsed. Perhaps this would not have happened if the service had been established within a second-order organization from the beginning, as was done in Ecuador (see Case 4). Nonetheless, the groups continued to function, though often at reduced production levels and narrower margins. Some groups still receive institutional support through the new second-order organizations.

Future directions

Under the free-market economic policies the government has pursued since 1990, farmers must rapidly improve cassava productivity but without degrading the land. Farmer groups also need to diversify the market for this crop by finding products with higher value added, such as cassava flour for food and industrial uses (see Case 3). These two steps are essential for transforming cassava into an agroindustrial crop that benefits small-scale farmers and processors.

The success of this project prompted DRI and other institutions to launch additional projects. Their aim was to extend drying technology to farmer groups in other regions of the country and test other products, such as fresh, storable cassava for the fresh market and cassava flour for human consumption (see Cases 2 and 3).

Lessons Learned

- When production is dispersed among many farmer groups or cooperatives, an effective second-order organization is essential for increasing their bargaining power and concentrating product supplies.
- Farmer cooperatives seek to maximize benefits to their members by maintaining a high margin for crop production. The private sector, in contrast, aims to maximize the profits from processing. Where a second-order organization includes both co-ops and private sector processors, it must reconcile the different interests of these groups to avoid conflict. If the organization maintains a balance between groups, the private sector can spur the co-ops to achieve greater efficiency.
- Distance to the market is critical because of the high cost of transporting such a bulky product. Increasing the ratio of weight to volume by reducing the size of the dried product is important. When other cash crops are being harvested and trucking lines are operating at full capacity, cassava chips may not be collected on time, giving rise to cash-flow problems for the cooperatives.

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Case 2

Conserved Fresh Cassava for Human Consumption in Colombia

Objective: To demonstrate the technical and economic feasibility of new cassava storage technology on a pilot basis and study its impact.

Project area: Primarily the city of Barranquilla (population 1.2 million) and surrounding areas on the Atlantic coast.

Time frame: Pilot phase, 1987-1988; commercial phase, 1989-1992.

Background

Consumption of fresh cassava is declining in many urban areas of Latin America. Among the biggest losers are small-scale farmers, who seldom have alternative markets for this highly perishable crop. With no way to process and store the fresh product, they are forced to sell immediately at low prices.

In search of alternatives, this project examined ways to slow postharvest deterioration of fresh cassava, improve its quality, and reduce its price to consumers. The most promising option for preserving fresh roots was to treat them with an antimicrobial agent and store them in polyethylene bags.

In 1985 a pilot project (part of a DRI project in Bucaramanga, Santander del Sur) demonstrated the viability of the new storage technology. Consumers liked the bagged cassava and bought it from retailers in the main market and shopkeepers in several neighborhoods. Farmer groups earned net profits of just over US$10/t.

Project Evolution

A new project was set up in Barranquilla for three reasons: 1) small-scale farmers on the Atlantic coast were already developing associations for drying cassava; 2) this is the country's most important cassava producing region; and 3) it has the highest rate of cassava consumption per capita (54.3 kg/year vs. 25.5 kg nationally).

Institutional partners

Several co-ops took part in the project. One was the 82-member Cooperativa de Producción y Mercadeo de Repelón (COOPROMERCAR), some 90 km from Barranquilla, which was growing and marketing tomatoes, plantain, and cassava. Having gotten low tomato yields and prices for several years, the co-op was interested in the technology for conserving fresh cassava. Another participant, Cooperativa Agroindustrial del Nor-Oriente del Atlántico (COOAGRONOR), was already drying cassava chips and began selling bagged cassava to a supermarket chain. Several other co-ops got involved in the project as well.

DRI coordinated the activities of institutions supporting the farmer groups. CIAT provided technical assistance and training. The Servicio Nacional de Aprendizaje (SENA) gave training in co-op organization, administration, and bookkeeping. ICA developed improved varieties

and technology packages. Statistics on prices were obtained from the Central de Cooperativas de la Reforma Agraria (CECORA). The Corporación Fondo de Apoyo a Empresas Asociativas (CORFAS) provided the co-ops with technical assistance, along with credit for production, commercialization, and capital investment. Other organizations, including the Caja Agraria, Instituto de Financiamiento y Desarrollo Cooperativo de Colombia (FINANCIACOOP), and Instituto Colombiano de la Reforma Agraria (INCORA), also made available credit for production and processing.

Striving for a quality product

The success of the cassava preservation technology depends to a large extent on root quality and shape. Farmers must take care not to include damaged roots, since these can be stored safely for only 4-5 days. Initially, operators removed the stem from the roots with a machete. But since even experienced workers often damaged the roots, they switched to a garden pruner for this purpose.

Early on, large sacks of roots were immersed in a barrel containing a solution of Mertect (a fungicide), followed by a 15- to 30-minute wait to remove excess moisture. This was replaced by a faster method, in which the solution was sprayed with a backpack sprayer directly into the polyethylene bags of cassava. A small hole was cut in the corner of the bags to allow excess solution to drain out. This method used less solution and required that the roots be packed only once. Costs fell from US$12 to $4/t.

Storage conditions proved critical. Operators learned the importance of air circulation around the bags to prevent losses from microbial growth and internal rotting.

Despite these measures, product quality varies significantly, even among roots harvested from the same field. In addition, rain and poorly drained soils reduce the starch content of cassava roots, an issue that requires much further research.

Another difficulty is the limited correlation between chemical composition of cassava roots and easily measurable traits, except for bitterness and total root cyanogen content. Roots from tall, unstressed plants tended to have better chemical and organoleptic qualities than those from shorter, stressed plants. Since root quality can vary with soil and climate, roots must be taste-tested to ensure consistent quality. In some cases up to 20% of roots had to be discarded; normally the rejection rate should not exceed 5%. The rate was particularly high during the rainy season.

The prohibitive cost of aggressive marketing

Market and consumer tests documented the main characteristics of the fresh cassava market in Barranquilla. The city consumes about 32,000 t of cassava yearly. In the central marketplace, cassava is purchased both for wholesale and retail. Consumers buy the crop mostly from small shops (numbering 5,000 and accounting for 65% of the volume), supermarkets, and street vendors. Retail prices are 50% higher in urban than rural areas. Although marketing margins are extremely high (more than twice the farm-gate price), the profits go mainly to retailers, who buy and sell small quantities, rather than to intermediaries.

In consumer testing of potential brand names, the preferred name was one suggesting the product's freshness (Yucafreska). But since this name was already registered, the project settled for Superyuca. This and the marketing campaign slogan—*calidad por laargo rato* (suggesting "laasting quality")—were both registered in the name of the ANPPY. A bag was designed and posters printed for point-of-sale promotion in supermarkets.

Lack of funds prohibited a more ambitious marketing campaign aimed at creating general awareness of the new product and its advantages among consumers and traders. Even more modest measures (such as replacing the plain polyethylene bag with more sophisticated packaging printed in two colors) would have added 40%-80% to the current production cost of $0.01/kg. These steps would have been more affordable if the project had marketed larger volumes of product. But it was unable to do so because of limited financing.

A fragile distribution system

The Federación de Organizaciones Agropecuarias de Colombia (FAGROCOL) set up a central collection point and undertook urban distribution of cassava. In 4 months it sold 288 t of fresh, untreated cassava in polypropylene bags; 125 t of treated cassava (Superyuca) in 3-, 15-, and 50-kg bags; and 15 t of chopped waste roots for animal feed.

To facilitate treatment of roots at the collection center, they were packed in polypropylene sacks and shipped the next day for treatment with the antimicrobial solution and repacking in polyethylene bags for retail sale. In addition, cut roots were protected with sodium disulphate and calcium carbonate powder, which reduced the quantity of rejected roots.

Noting that FAGROCOL was able to move 72 t of cassava each month, other wholesalers adopted its approach to commercializing untreated cassava in polypropylene bags. This enabled wholesalers to store the crop in their warehouses for 1 or 2 days without losses. Granabastos, the central collection center for public sector wholesalers in Barranquilla, became interested in the storage technology as well.

The co-ops ran into serious economic trouble when FAGROCOL was liquidated as a result of circumstances unrelated to the project. The lack of a good distribution network and a centrally located warehouse that caters to shopkeepers has made it difficult to expand sales beyond 10 t/week, even though the total market volume is about 800 t/week.

Benefits for all concerned

Economic analyses of this technology in the pilot phase showed that it benefited all concerned. Producers received slightly more for their roots, and participating co-ops earned net profits ranging from US$13.50 to $72.75/t. The lower figure is for COOPROMERCAR, a commercial enterprise that pays administrative costs of nearly $0.02/kg of treated roots, and the higher is for a co-op that catered to the export market.

Consumers paid slightly more ($0.03/kg) for conserved cassava but received a more convenient, higher quality product. As the volumes of sales increase, supermarkets will be able to reduce their margins, particularly since product losses from deterioration are minimal. Margins should be further reduced, as continued spread of the conservation technology gives rise to competition. Narrower margins will benefit consumers.

The technology has already been adopted in other regions of the country. For example, at Socorro in the department of Santander, SENA has trained various co-ops, and they are treating roots to provide a product called Yucarica for the Bogotá market. They are also drying cassava for feed concentrate plants in Bucaramanga and Bogotá. The success of the new technology has prompted farmers to seek improved production technology and varieties with high starch content and desirable eating qualities.

Future directions

Since the co-ops are currently satisfying only 18% of potential demand, they have much room for expansion. DRI should take the lead in supporting and financing the efforts of co-ops and small processing businesses to meet the demand of current and new markets for bagged cassava. These processors urgently require financing for capital investment, working capital, and technical assistance.

A simple, low-cost system for monitoring and evaluating processing operations in the coastal region and eventually nationwide is needed so that decisions can be based on precise, current information. CIAT designed and installed a computerized system (Sysyuca) that covers production, processing, commercialization, and socioeconomic indicators of benefits. Implemented originally for a cassava drying project, this system has been operated by CORFAS and SENA since the Center's withdrawal from that project.

Lessons Learned

- In handling and marketing fresh produce where presentation and quality are critical, the co-ops must find alternative uses (such as drying or starch extraction) for rejected roots, which can account for up to 50% of the total weight of the harvest.
- Package design is very important for consumer products.
- As the co-ops expand their processing activities, they need to identify alternative sources of roots during the rainy season and maintain records of dry matter and starch content, as a means of ensuring acceptable product quality.
- It is considerably more difficult to penetrate a consumer market with a new product than an industrial market like that described in Case 1. Since the costs of product promotion and distribution tend to be high, the project should first target specific market niches. Experience suggests that only large-scale second-order organizations with some degree of economic power and know-how should attempt to enter consumer markets.

Source

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Case 3

Cassava Flour for Human Consumption in Colombia

Objectives: In research, to determine the technical and economic requirements of developing a rural cassava flour industry; in the pilot phase, to integrate cassava production, processing, and marketing under typical socioeconomic conditions; and in the commercial phase, to prepare for expansion by improving the profitability of the pilot plant.

Project area: Chinú, department of Córdoba, on Colombia's Atlantic coast.

Time frame: Research, 1985-1988; pilot phase, 1989-1991; commercial phase, 1992-1994.

Background

In the last 40 years, rapid urbanization in Latin America has changed people's dietary habits. Starchy staples, such as maize, plantain, and root crops, have given way to more convenient foods, such as rice and processed products of wheat (e.g., bread and pasta). Researchers are seeking alternative markets for the traditional staples, so that rural people can continue to derive a livelihood from these crops.

One promising option is to use cassava flour as a partial substitute for wheat in bread, pasta, and other foods. Three factors favor the use of this flour: 1) it is relatively cheap, costing 15%-20% less than wheat; 2) in some food products, it can be substituted at medium to high levels for other types of flour; and 3) it has functional advantages over wheat flour in some foods, absorbing more water and giving better crispness. Cassava flour is especially advantageous in processed meats, biscuits, cones, spices, pastry (for *empanadas*), and mixtures for breading and frying. The potential demand for cassava flour among industrial and small-scale food processors in Colombia is estimated at 40,000 t/year.

Project Evolution

In the past, large-scale cassava flour plants have failed, because they were poorly linked with production and often dependent on expensive fossil fuels. An alternative strategy is to establish small plants in important cassava-growing rural areas. Toward this end, the project used funding from the International Development Research Centre (IDRC) to design a system for producing and marketing cassava flour.

Institutional partners

CIAT conducted research on cassava production, carried out prefeasibility and feasibility studies, and designed and developed processing equipment. The Instituto de Investigaciones Tecnológicas (IIT) in Bogotá developed bakery products and performed economic studies. The Universidad del Valle at Cali designed and developed the processing plant and devised formulas for products based on cassava flour. In cooperation with ICA, on-farm trials were conducted to identify varieties for intercropping and second-semester planting (which would ensure a continuous supply of cassava for processing) and to find ways of increasing the productivity of current cropping systems.

During the pilot phase, DRI coordinated the integration of cassava production and flour processing and marketing into its program of cassava development on the Atlantic coast. Since the end of the pilot phase, the Natural Resources Institute (NRI) in the UK has supported research aimed at improving flour quality, focusing particularly on the use of varieties with high cyanogen content that are commonly grown in Brazil and Africa.

Developing prototype equipment and testing the product

The processing plant and equipment were developed according to a batch or semibatch modular design, with a capacity of 1 t of cassava flour per day. Flour yields from dry cassava chips ranged from 83% in a laboratory version to 98% in an industrial mill. Research showed that during milling fiber and lignified bark in the chips are separated from the flour by sifting. Results suggested that milling the chips in a roller mill would eliminate the need for peeling roots. The project developed a simple roller mechanism that could handle chips small enough to allow continuous feeding.

The prototype plant was designed for both natural and artificial drying of cassava chips. The chips are dried naturally for one day on inclined mesh-bottomed trays positioned on racks. Then they are loaded into a bin dryer, which has an indirect coal-fired burner, is coupled to a 5-hp centrifugal fan, and heats the air to 60 °C.

In an evaluation of composite flour produced with this equipment, bakers complained about the handling properties of the dough. In bread making the main drawback was loss of volume in the final product. To avoid this problem requires substantial adjustments in the bread recipe. Such changes are unnecessary with products, such as biscuits, cakes, and crackers, whose quality is less dependent on the use of wheat flour.

The project also conducted a blind test of bread made from wheat flour, compared with bread made from a composite flour, with 200 families representing different social strata in Bogotá. The panelists detected differences in appearance, aroma, and freshness. More than 80% liked the bread made from composite flour and 15% preferred it.

The pilot phase

After an economic evaluation of research results indicated that production of cassava flour is feasible, a pilot plant was established at Chinú, Córdoba. This site was chosen because land and raw material are available throughout the year, there is potential for increasing cassava yields, infrastructure is adequate, markets are nearby, and institutional support is available. Based on subsequent experience, the project added several items to its criteria for site selection, including the educational level of co-op members, the executing organization's entrepreneurial ability, proximity to fuel sources and machine repair shops, availability of transportation, and raw material quality.

The project began working with a farmer co-op, Cooperativa de Productores de Algarrobos (COOPROALGA), which operates a plant that produces chips for animal feed. The co-op's 41 members are relatively well educated. After several trials, adjustments were made in the process, and personnel selected by the co-op's administrative council received training.

The plant soon ran into problems with its water supply. The project had planned to obtain water from a well it constructed for two nearby villages. But the mayor refused to go along, maintaining that the well's capacity was inadequate. Consequently, the project had to build new wells 2 km away. And since it had not budgeted for extra pipe and a pump, the start of processing was delayed. The project's financial investment in the pilot plant, excluding the cost of obtaining a water supply, amounted to US$48,179 ($44,389 for infrastructure and processing equipment and the rest for working capital).

The pilot plant had the capacity to produce 200 t of cassava flour per year. In 1991 it operated for 9 months, but output was low (43 t of chips, with a conversion factor of 2.92) because of equipment breakdowns, energy cuts, and insufficient working capital. The chips were milled at a wheat mill in Medellín, with a flour extraction rate of 87%.

The financial rate of return or FRR (see explanation on page 88) to the pilot plant was calculated to determine its profitability. Given that the opportunity cost of capital in Colombia is currently 22%, the FRR would have to be a minimum of 30% to cover annual inflation of 27%. Based on data for 1992, the FRR was only 19%. Further analysis showed that it is very sensitive to utilization of plant capacity, price of raw material, the conversion factor, coal consumption,

and sale price. On this basis the project developed a strategy to raise the FRR to 31%.

During the pilot phase, problems with product quality emerged that had not been evident in testing of prototype equipment. One factor that lowers quality is the high moisture content of the roots during the rainy season. Others are the high incidence of bacteriosis, fungal infection, and termite attack. Some roots are contaminated with fecal coliforms under the poor sanitary conditions of small farms. As a result, the quality of the cassava flour did not meet industry's microbiological standards for food products and had to be sold to manufacturers of animal feed.

At the end of the pilot phase, the project had two options: to sell the chips to millers or subcontract the milling and sell cassava flour. It chose the latter and in promoting this product, the project concentrated on Medellín, the largest and most promising market. The wheat flour mill that milled cassava chips expressed interest in promoting cassava flour among its clients.

The commercial phase

To increase COOPROALGA's participation in plant operations, the project put the cooperative's manager in charge of the two processing plants, and plant operators' positions were stabilized.

In 1992 the project concentrated on improving the microbiological quality of its product. Sanitary conditions were raised by treating washing water with sodium hypochlorite, disinfecting roots, cleaning the equipment more thoroughly, enforcing high standards of hygiene among workers, and establishing specifications for raw material quality. To control the physical and biochemical quality of raw material, operators were encouraged to wash the roots adequately, adjust the distance between premilling rollers, and periodically measure the moisture content of the chips. In addition, chips were dried at higher temperature and for a longer time. Various modifications were made to reduce drying time. Another burner was added and the drying area expanded to improve air flow. As a result of these measures, the cassava flour now conforms to standards for wheat flour.

Given the high cost of milling in Medellín, a small-scale mill and flour classifying system was developed at the Universidad del Valle and incorporated into the process. The cooperative now sells flour directly to buyers. The project established a flexible price scheme for cassava flour, in which the price varied from 15% to 20% below that of wheat flour, according to the location and type of client (e.g., a bakery versus a processing firm). A price list was prepared with discounts for the initial purchase (5%), payment in cash (1.5%), and volume purchases.

Future directions

During much of the project's lifetime, cassava flour could be produced at a competitive price—72% that of wheat flour, assuming a 25% profit margin for both the cassava grower and processor. The future of this product depends very much on government policy, attitudes in the private sector, and trends in production.

The government's current emphasis on trade liberalization policy has severely damaged the ability of cassava flour to compete with imported wheat flour, whose price has declined in real terms over the last 3 years. Unfavorable policies are reinforced by vested interests in some sectors of the economy. As the volume and price of imported wheat decline, cassava growers will need to adopt improved production technology to keep cassava flour competitive.

In an effort to deal with these issues, the project established a consultative body with representatives from public and private organizations having direct or indirect interests in wheat, cassava, and bread. In general, public agencies responsible for rural development supported the project, while the private sector was noticeably cautious. Industrialists continue to largely ignore the nonfood uses of cassava flour, making it difficult to expand the market for this product.

Although the future of cassava flour is uncertain, there are some positive signs. For example, the Colombian government has recently developed a comprehensive plan to promote cassava. Moreover, COOPROALGA is taking various steps to improve its services to the local

community. Specifically, it seeks to gain greater community acceptance, stimulate cassava production, and help meet local needs for water, housing, and education.

To manage the processing operation on their own, staff of COOPROALGA need further training. For this purpose the project developed two reference manuals for the managers of cassava flour plants. Another challenge is for the plants to obtain the technical capacity to perform final milling of cassava flour.

Projects like this one have been launched in Bolivia, Brazil, Ecuador, and Peru. In addition, the NRI is studying the market potential for cassava flour in selected African countries. A new research project will identify flour properties related to end-product quality and novel products containing cassava flour.

Lessons Learned

- Varieties differ significantly in dry matter content. Venezolana, for example, has high dry matter content, which makes it well suited for processing into flour. Manihoica P-12, in contrast, has a lower dry matter content. Although farmers tend to plant several varieties in the same plot, they favor P-12. The project paid a premium price for high quality roots to give growers an incentive to plant varieties with high dry matter content.
- Correctly identifying the most promising market for a product is critical to its success. During the research phase, this project considered bakers of bread its main market. When they expressed concern about cassava flour's effect on bread quality, the project shifted its focus in the pilot phase to other foods, such as processed meats and biscuits. The functional properties of cassava flour confer desirable characteristics on these end products.
- During the pilot phase, a number of technical problems arose that were not evident from testing of the prototype processing equipment. This highlights the importance of having a pilot phase before investing heavily in commercial development of the product.
- Competitiveness of cassava flour is strongly influenced by raw material price. Research on crop production, by increasing productivity and lowering costs, can eventually complement projects on postharvest processing and marketing.
- To penetrate a market that is accustomed to conventional raw materials with a new product, like cassava flour, requires a thorough understanding of the physicochemical and functional properties of the new product. This information is fundamental in promoting the product among clients.

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Case 4

Diversifying Cassava Markets in Ecuador

Objective: To provide farmers with alternative markets by researching and promoting processing of cassava flour from chips, cassava starch for human consumption and industrial use, and preserved fresh cassava and by improving interinstitutional cooperation, with the aim of expanding integrated cassava projects.

Project area: Manabí province in coastal Ecuador.

Time frame: Pilot phase, 1985-1987; commercial phase, 1988 to present.

Background

During the mid-1980s, cassava production in the project area declined, mainly because farmers had difficulty disposing of extra production. Major barriers were the perishability of cassava roots, limited markets, and low prices. In the project area, there was considerable potential for involving small-scale cassava farmers in product development, because community development projects in Bijahual-Alajuela and Bellavista had already organized cassava growers into associations.

Project Evolution

The project in Ecuador was based to a large extent on experience in Colombia but with greater emphasis on building a strong second-order organization to provide key services to cassava processors. The challenge of this project was to repeat the technical success of the Colombian projects but at a lower cost in terms of institutional support.

Institutional partners

Participating institutions contributed as follows:

- Ministry of Agriculture and Livestock: In the pilot phase provided three staff, one to coordinate the project, another to serve on its advisory committee, and the third to oversee training and technology transfer and support the Asociaciones de Productores y Procesadores de Yuca (APPYs) in organization and extension.
- Fundación Ecuatoriana de Investigaciones Agropecuarias (FUNDAGRO): Provides administrative and technical assistance to a second-order organization, the Unión de APPYs (UAPPY).
- Instituto Nacional de Investigaciones Agropecuarias (INIAP): Supports on-farm research. As a result of the project, INIAP revived its research on tropical roots and tubers.
- Community development projects: Provide advisors to farmer associations at Joboncillo and Bijahual.
- CIAT: Provided an anthropologist to help farmers and rural institutions establish a small-scale cassava industry as well as agronomists and economists to give technical support and training. The Center also

arranged for a Colombian farmer to train Ecuadorian farmers in plant construction and operation and donated two chippers.

- British and Canadian embassies: Initially funded the APPYs' demonstration projects.
- US Agency for International Development (USAID): During 1985-1988 provided the APPYs' main source of grant funding and loans and paid the salary of the CIAT anthropologist through FUNDAGRO.
- IDRC: Funded maize and cassava research and monitoring of drying plants.

Farmer-to-farmer training

The project has put as much as possible of the responsibility for supporting project activities in the hands of the farmer organizations engaged in cassava processing. The objectives are to reduce the cost and increase the effectiveness of support provided by the above-mentioned institutions and foster independence among project beneficiaries from the start.

One effective tactic is farmer-to-farmer training and technology transfer, which CIAT has guided and fostered. Early on, Colombian farmers visited counterparts in Manabí to teach them how to dry cassava. Then, growers from Manabí visited Colombia to see the drying technology in action and learn how to organize and manage a processing plant. A Colombian farmer leader helped design and build plants in Manabí. At Bijahual and Jaboncillo, members of farmer groups that predate the project experimented with the new technology and formed additional groups to apply it and market the product.

Building a strong second-order organization

The number of cassava processing operations or APPYs grew quickly from 2 to 16. The APPYs buy fresh cassava from members and other producers, chip the fresh roots, dry the chips, put them in sacks, and sell the product to UAPPY. This organization evolved from a marketing union established by the first APPYs. It was assumed that UAPPY could support as many as 20 local chipping associations (each with 15-20 members) within a radius of about 70 km. Roughly 30% of UAPPY members are women, concentrated in four APPYs consisting entirely of women.

The local APPYs and the regional UAPPY share market risk and responsibilities. The latter provides portable milling equipment and marketing services to the APPYs in exchange for 30% of the markup between fresh cassava and flour (about 10% of the gross price of the flour). The remaining 70% covers the APPYs' operational expenses, capitalization, and distribution of profits to members. In addition to milling and marketing, the UAPPY manages loans and donations, provides credit to the APPY's for processing, exercises product quality control, and handles accounting and transportation.

Until 1993, UAPPY's administrator was a farmer and founding member of one of the first APPYs. He was assisted by representatives from CIAT and FUNDAGRO, who together formed a management and planning committee, which organized training for the UAPPY's assembly and board and involved them in planning.

By making good use of talented people within the organization, UAPPY has remained somewhat independent of supporting institutions. This has enabled it to negotiate with them on a more equal footing and obtain the services members require.

Even so, as the organizations that helped start the processing operation withdraw support, UAPPY faces major challenges. For example, it may prove difficult to find and keep good managers. It is therefore critical that the board of directors of the processing operation learn now to appreciate a good manager. Otherwise, they will tend to strictly limit his or her authority and salary. Turnover is generally high among managers who are also farmers. Another problem once institutional support comes to an end is that new APPYs are less likely to obtain grants for building processing plants and have to obtain loans at interest rates close to market rates.

The UAPPY assembly, which consists of APPY presidents, needs to provide training for its three commissions (responsible for member education, marketing, and auditing). In addition,

association members need training in financial management.

In addition, UAPPY should contract an accounting firm to improve its inventory system, depreciation schedule, and system of records for members. The Union also needs advice on minimizing taxes and maximizing member benefits.

An ambitious sales campaign

In its pilot phase, the project tested natural drying of cassava; evaluated cassava starch as a binder for shrimp feed, cattle feed consisting of dried cassava and chicken manure, and use of cassava silage for swine feed; and carried out trials to identify varieties with high dry matter content and drought tolerance. Based on the results, the project adopted a strategy in its commercial phase of promoting the use of cassava flour through an ambitious sales campaign aimed at the animal feed industry.

The first attempt focused on manufacturers of chicken feed in the Portoviejo area. This initiative was not as successful as comparable efforts in Colombia, because the industry was reluctant to try a new ingredient, even at a low price.

The second attempt, aimed at shrimp feed manufacturers in Guayaquil, was more successful. Ecuador's shrimp industry was seeking an alternative to formaldehyde to hold feed pellets together under water. US health authorities had banned the importation of shrimp raised on feed containing that ingredient. Cassava flour was an ideal substitute, because its high starch content makes it an excellent binder. Even though cassava comprises only 2%-14% of each pellet, the scale of shrimp production and feed demand was such that the demand for cassava flour exceeded 8,000 t/year. The shrimp feed industry paid a higher price for this flour, because of its agglutinant characteristics, than did producers of poultry and livestock feed.

Toward product diversification

From an early stage, UAPPY strongly encouraged product diversification. In 1987, for example, two APPYs experimented with preparing, packaging, and selling fresh cassava for export (see Case 2). At about the same time, two new APPYs, made up entirely of women, were established to produce cassava starch for human consumption. Their main clients were stores and food processors. In 1989, UAPPY sold industrial-quality starch to a large cardboard factory in Guayaquil, which substituted it for maize starch in glue for corrugated boxes. A 1989 study estimated high potential demand for industry-quality cassava starch, which is easier to produce than starch for human consumption.

Meanwhile, UAPPY had developed a milling capacity to produce cassava flour from chips for the shrimp feed industry. In 1988 several factories complained that cassava flour made from whole unpeeled roots contained too much ash. In response UAPPY began selling flour made from whole or peeled roots according to the clients' needs.

At first APPY members resisted peeling, because they were not accustomed to this practice and it involved much additional labor. Even so, peeling soon became an important source of additional income for the families of members and nonmembers. They could earn as much as a month's minimum wage in 2 weeks by peeling cassava in their spare time. In the 1990-1991 processing season, UAPPY paid more than US$16,000 in wages for cassava peeling. Most of the money went to poor women, children, and the elderly. For that reason, the UAPPY is now reluctant to introduce mechanized peeling.

A valuable lesson in the need for diversification

Despite its early moves toward diversification, UAPPY still catered primarily to a single market, the shrimp feed industry. In 1989 this began to change. Because of competition from Asian shrimp producers and a shortage of larvae to stock ponds, there was a slump in local feed production, which halted the purchase of cassava flour. To make matters worse, many APPYs had borrowed heavily to expand their drying capacity.

UAPPY responded by slashing expenses and launching an all-out campaign to sell cassava

flour to other industries. As a result of these measures and a recovery in the shrimp industry, the union was able to sell all production in storage by 1990. Although its economic balance for the year was poor, UAPPY had learned a valuable lesson. From then on it assigned high priority to diversifying the market for current products and building the capacity to produce new ones.

In 1990, for example, UAPPY began refining whole-root cassava flour by passing it through a mechanical vibrating sifter. The product can serve as a partial substitute for wheat flour. It was sold to factories that use it as a filler for resins in manufacturing plywood. Bran, the byproduct of sifting, is sold as a source of fiber to livestock feed industries in the highlands. UAPPY also uses the mechanical sifter to produce a white flour for making noodles. Although the union sells only a small amount of flour for human consumption, it is testing various methods, with a view to expanding production. As a result of such measures, UAPPY reduced its dependence on the shrimp industry by about 30% (Table 23).

Spreading and increasing the benefits

The demand for cassava flour and starch grew rapidly. UAPPY's sales quadrupled in 1988 and again the next year, with annual profits of 27%. Average payments to individual farmers increased from US$100 in 1985 to more than $300 in 1988.

Since some members provide more cassava than others, distributing the association's proceeds equally among members may not be acceptable. Larger producers are in effect subsidizing the smaller ones and may insist on proportional payment. By-laws must be specific with respect to management of members' capital, payment to former members and heirs, conditions for membership, etc.

Families engaged in cassava processing have a strong incentive to increase cassava areas. If they increase the area from 0.5 to 2.0 ha (as many APPY members have done since 1985), their income may grow by 10% to 100%, depending on their land holdings, other crops, management ability, and the weather. The opportunity costs of this increase are low, since pastures are the most common alternative use of cassava land and family labor is a key component of increasing costs.

Future directions

UAPPY has clearly demonstrated an ability to place cassava processing on a firm commercial footing. It is therefore not surprising that industrial interests are now asking how they can "create a UAPPY" to supply them with cassava products.

To continue generating benefits for members and nonmembers, UAPPY must expand its markets, diversify its array of products, and improve product quality. Processing research can support this effort, particularly by developing methods for quality control and monitoring market demand. Researchers must also address the problem of contamination caused by waste water from starch processing. Research on cassava production should concentrate on varieties that are suitable for dry zones and

Table 23. Market share of annual processed cassava production for 1989-1990 and 1990-1991.

Final product	UAPPY products	Total tons sold		Percentage of total amount sold	
		1989-90	1990-91	1989-90	1990-91
Shrimp feeds	White and whole industrial flour	974.4	1,207.2	96.0	69.3
Cardboard boxes	Industrial starch		209.1		12.0
Plywood	Refined whole industrial flour		226.5		13.0
Traditional cassava starch bread	Food starch	20.3	5.2	2.0	0.3
Pastas and noodles	Refined white food flour		6.9		0.4
Cattle and swine feeds	Starch bagasse and flour bran	20.3	87.1	2.0	5.0
Total		1,015.0	1,740.0	100.0	100.0

mixed cropping on hillsides and have high dry matter content, which makes them more suitable for processing.

Lessons Learned

- Farmer-to-farmer training is an effective approach to technical assistance. Colombian farmers were able to explain and demonstrate processing technology to Ecuadorian farmers in language they could understand. The project trained a team of outstanding Ecuadorian farmers and developed a manual to promote the technology among new groups.
- A strong second-order organization can reduce the cost of institutional support for cassava processing and foster self-reliance among project beneficiaries.
- Diverse markets and products are critical requirements for long-term commercial success in cassava processing.

Source

CIAT (Centro Internacional de Agricultura Tropical). 1992. Ecuador integrated cassava project. In: Cassava Program, 1987-1991, Chapter 5. Working Document no. 116. CIAT, Cali, Colombia. p. 273-295.

Case 5

An Integrated Cassava Project in Brazil

Objective: To improve the welfare of rural communities in major cassava production areas by applying a model for integrated production, processing, and commercialization of dried cassava chips for use as animal feed and by strengthening farmer organizations through participatory management.

Project area: Ceará state in Northeast Brazil.

Time frame: Pilot phase, 1989-1992.

Background

Brazil is the world's second largest producer of cassava, contributing 16% of the world total, and accounts for 75% of production in Latin America.

The crop is particularly important in Northeast Brazil, where a yearly average of 113,000 ha were planted to cassava during 1985-1987. Most of the region's production is used for *farinha de mandioca* (a toasted flour). Some is consumed fresh, and minor amounts are fed to animals. The crop is a major source of calories in the human diet, providing 27% of total caloric intake.

In 1990 the total population of Northeast Brazil was estimated at 43 million, 42% of whom live in rural areas. This region has the country's highest levels of poverty and unemployment. Land distribution is skewed toward large-scale growers. Even though holdings of less than 10 ha make up nearly half the total number of farms, they occupy only about 4% of the total cultivated area.

There is considerable potential for expanding the use of cassava as animal feed. Since Brazil is an important beef producer and the world's third biggest producer of poultry, the market for feed rations is large. Once a maize exporter, Brazil must now import 3.5 million tons of this commodity annually to meet demand. The Northeast in particular has a large deficit of maize and animal feed.

Project Evolution

The project was funded by the Kellogg Foundation and executed jointly by CIAT and the Ceará Secretaria de Agricultura e Reforma Agraria (SEARA), which acted through two agencies, the Empresa de Assistência Técnica e Extensão Rural do Ceará (EMATERCE) and Empresa de Pesquisa Agropecuária do Ceará (EPACE). Their work built on the experience of 11 farmer groups organized in the 1980s for cassava processing. The project also relied heavily on the Ceará State Cassava Committee, which was set up in 1988 to coordinate work on cassava state-wide and consists mainly of representatives from EMATERCE and EPACE.

Levels of institutional support

As a result of good initial results from this project, the State Cassava Committee gained considerable recognition and credibility. This helped it identify sources of financial support for project activities and establish useful contacts with state and national development agencies. The Committee was made a permanent member of the nationwide Câmara Sectorial de Mandioca (Cassava Sector Chamber), which represents producers, agroindustrialists, consumers, and government organizations and whose main purpose is to recommend policies to the Ministry of Agriculture.

Coordination of project activities was placed in the hands of Regional Cassava Committees, of which five were established by 1992, with two more planned. They are composed of representatives from the main agencies executing the project as well as farmer groups. The Regional Committees enabled the project to rapidly decentralize its activities and helped improve communication among extension officers.

Farmers get organized

The project concentrated on organizing farmer groups around agroindustries based on cassava drying. It reactivated the 11 groups established previously and set up another 135, with the total number of farmers involved exceeding 3,000. Nearly 60% of group members are smallholders (of whom 28% live in land reform settlements), 29% lease the land, and 13% are sharecroppers. More than half the farmers plant less than 1 ha to cassava; only 15% plant more than 2 ha.

Each group obtained a grant from local agencies to finance the installation of drying facilities, provide credit for production and processing, distribute planting material, and so forth. Few members availed themselves of credit, though, because the high inflation rate made it risky for them.

Farmers were trained in production, processing, and commercialization as well as community organization through more than 100 training events (such as field trips and courses), involving nearly 850 technicians and well over 2,000 farmers. Since more than half of group members are illiterate, the Kellogg Foundation funded a separate project aimed at increasing literacy.

In addition, the project stimulated the creation of three regional second-order associations to improve the farmer groups' bargaining power and participation in project planning.

Processing and its benefits

The farmer groups readily adapted to the new technology for processing dry cassava because of its simplicity and their ample experience in producing farinha de mandioca. From 1989 to 1992, the groups processed 7,094 t of fresh roots into 2,677 t of dry chips. The proportion of roots going to farinha production fell from 65% in 1989 to 38% in 1992. Even so, group members' consumption of this product increased from 4.6 to 6.2 kg/household per week, probably because of the extra income farmers generated by selling roots for dry cassava production.

The project was successful in opening and consolidating an alternative market for cassava production. In 3 years a total of 975 clients purchased dry cassava; 93% of them bought low volumes (less than 5 t/year), accounting for 32% of total output. Contrary to experience in other countries, less than 5% of the consumers purchased large volumes of product, which represented 59% of the total.

The financial success of new cassava agroindustries will depend largely on the dynamic relationship (with respect to prices, costs, etc.) between the two main outlets for cassava—farinha and dry chips. The project helped farmer groups build the capacity to choose the best option in a given year.

Farmer groups benefited by gaining a new market for cassava roots, additional employment opportunities, and a share of the profits from cassava processing. Of the total income earned, 59% went to smallholders, 32% to renters, and 9% to sharecroppers. More than 70% of the income went to farmers who planted only 1-2 ha.

From 1989 to 1992, earnings generated for farmers through processing totaled US$163,689. Of this amount 37% came from cassava sales, 10% from wages for processing, and 53% from farmers' share of annual profits. Smallholders received 59% of the earnings, renters 32%, and sharecroppers only 9%; 77% went to growers planting no more than 2 ha.

The project tried to attract credit sources in the public and private sectors. But it was unable to do so, largely because of the country's difficult economic conditions. Even so, the project grew as a result of strong support from local agencies, which provided farmers with grants to establish agroindustries. Growth would perhaps have been stronger, except that local agencies responsible for implementing the project are undergoing radical reorganization.

Limited adoption of improved production technology

To improve the efficiency of cassava production, the project sought solutions to two major

constraints, low adoption of improved technology and a lack of good planting material.

It addressed the first problem by establishing "preproduction trials" under farmer management. The improved technology showed a decided yield advantage over traditional practice. But it remains to be seen whether farmers will invest scarce resources in fertilizer and weed control.

Since small-scale farmers apply little fertilizer on cassava, they can maintain soil fertility only by extending the fallow period. Although organic manure is available in some areas, farmers cannot afford it. They urgently need new options for maintaining and increasing soil fertility (e.g., mulches and green manures) to raise production and preserve the agricultural resource base.

To deal with the scarcity of good planting material, the project established communal plots for cassava propagation, but this approach was not successful.

Monitoring and evaluation

A major activity of the project was to establish a system for monitoring and evaluating its activities. This involved collection of baseline data, annual surveys, and intensive monitoring of a small subsample of participating farmers. These data were collected by managers of the cassava processing groups and extension agents under the coordination of the Regional Cassava Committees. The information was then analyzed by the State Committee and the results distributed through monthly and annual reports.

The baseline data (on cassava production potential, farmer characteristics, etc.) helped identify areas for project expansion. Monthly reports on the performance of farmer groups in processing proved useful for planning project activities and calculating benefits and their distribution. Annual reports kept cooperators, donors, and decision makers abreast of project activities.

Future directions

Since the demand for dry cassava as a partial substitute for cereals in the production of animal feed concentrates far exceeds the supply, there is much potential for expanding project activities to other regions of the country. It is encouraging that the organizational structure of the project (particularly the State and Regional Committees) was widely accepted and worked effectively. Another positive sign is the success of the farmer groups in creating employment opportunities, opening an alternative market, stimulating local industry, and raising incomes.

Even so, to consolidate these benefits, important constraints must be addressed. It is essential, for example, that the organizational structure adopted under the project be made a legal part of the local institutional framework. It is also critical that researchers find ways to speed the adoption of improved technology, partly as a means of reducing costs. Whether farmer groups can secure their hold on the new market for dry cassava will depend largely on their ability to provide sufficient quantities of product at competitive prices.

Lessons Learned

- The formation of State and Regional Cassava Committees proved to be an effective means of coordinating project activities. The State Committee helped the project establish close ties with the country's agricultural policy makers. This was an essential step for ensuring that small-scale cassava farmers are represented.
- Although local markets can absorb relatively small volumes, they offer good opportunities for commercializing a new product. Prices are often higher, and quality requirements less strict than in large-scale industrial markets.
- It takes time to turn cassava farmers into small-scale agroindustrial entrepreneurs. Improvement of literacy and participatory techniques are essential for success.

- Interaction of project personnel with similar projects in other countries (see Cases 1 and 4) contributed importantly to human resource development and motivation.

Source

CIAT and Ceará State Cassava Committee. 1992. Cassava development: Pilot project Ceará, Northeast Brazil. Integrated production, processing and commercialization of dry cassava chips for animal consumption. Final Report. CIAT, Cali, Colombia. 55 p.

Case 6

Drying Potato in India's Villages

Objective: To give small-scale farmers an alternative for disposing of surplus potato production by introducing a simple drying process and by developing the infrastructure needed to ensure regular supplies of raw material as well as technical assistance, financing, and help with marketing.

Project area: Potato-growing areas in the Bareilly district of western Uttar Pradesh.

Time frame: Development of prototype equipment and product, late 1970s; establishment of pilot processing unit, 1985; expansion in number of processing units, 1986 to present.

Background

Uttar Pradesh produces an average of 6.4 million tons of potato annually. About every second year, the market is glutted at harvest, and prices are low. For that reason and because cold storage space is scarce and expensive, farmers leave some fields unharvested. Even in years when there is no glut, only 70% of the harvest can be stored until prices are more favorable.

Project Evolution

Various organizations joined forces to provide growers with the option of drying potato for urban markets.

Institutional partners

Compatible Technology, Inc. (CTI), a US voluntary agency dedicated to helping the poor establish viable rural enterprises, offered a vehicle and funds to set up processing units and cover operating costs. The Society for Development of Appropriate Technology (SOTEC) established a demonstration processing unit, along with simple storage facilities, and purchased 1 ha of land to develop the Research Training and Village Development (RTVD) Centre. CIP funded development of the storage facilities, equipment, and recipes for preparing foods from the dried potato products. Appropriate Technology International (ATI) in the USA provided funds to develop, test, and commercialize procedures for potato storage and processing. The Nonconventional Energy Development Agency of Uttar Pradesh made a grant to develop a solar drier.

Project organization

A noteworthy feature of the project is its three-tier organizational structure.

The first level consists of village drying units. After a prototype unit was established in 1985, another 21 were set up during 1986-1990. Training workshops were organized for staff of voluntary and government agencies to encourage them to establish the additional processing units in rural areas. About half of those units were still operating at the end of 1989.

It took time to determine the optimum size and output for drying units. At first the project's goal was for each unit to have 10 workers, processing 60 t of fresh potato in 60 working days. But this proved impossible except under unusually favorable conditions. Normally, 15 people can process 40 t in 60-70 working days. By 1990 village units were carrying out all of the processing and selling their product for 25%-30% less than some automated drying plants.

Since the village processing units are too small to handle their own marketing and lack storage capacity for large quantities of finished product, the project placed responsibility for these functions at two additional organizational levels. The second takes care of quality control (through sorting), grinding, packaging, storing, and despatching orders; while the third establishes production targets and handles sales, marketing, invoicing, and collection of payments for the second tier. In addition, the third tier may eventually seek loans to purchase the product, so that the lower tiers can receive payments more quickly. Initially, SOTEC was involved at all three levels. But by 1988 it had turned over 95% of the sales to two independent companies.

Since the drying units have chronic cash-flow problems, they often cannot deliver a full truckload of dried product. This, together with the low product density, contributes to high transportation costs. To deal with this problem, SOTEC collected the product from several neighboring units and took it to the RTVD Centre for inspection, repacking, storage, and dispatch.

SOTEC must comply with a variety of government regulations, including food and storage licensing requirements, sales tax and packaging laws, and labor laws controlling minimum wage, permanency of employment, and number of employees. Wages are high, particularly during wheat harvest.

To keep labor costs and taxes low, SOTEC has tried to keep the units small. This also helps them avoid competition with large-scale commercial operations. If village-level processing were to become conspicuously successful, groups with large amounts of capital might try to take over. The project has therefore emphasized the use of family labor and simple machinery, with low overhead.

Most low-income rural people in the project area have limited formal education and consider themselves capable only of menial tasks. To help overcome this limitation, SOTEC trains workers of the village drying units and visits them regularly to ensure that processing is going smoothly.

Searching for a marketable product

The project's original idea was to promote dried potato slices as a rehydrated vegetable. But it soon realized that consumers traditionally use chunks and do not like the flat slices. Dried chunks more than 7 mm thick give poor results in terms of rehydration and texture.

As part of an effort to create interest in dried potato slices, the project organized a contest to encourage the development of recipes using this product. In addition, staff of the Nave Technical Institute prepared 50 dishes from the dried slices. In all but one case, though, the slices had to be rehydrated, cooked, and mashed, making them just as time-consuming to prepare as fresh potatoes.

Subsequently, the project tried grinding dried slices into a coarse powder. This proved easier to use and improved the recipes. But since consumers were unfamiliar with potato powder, the project was unable to introduce this product for household use. Where SOTEC conducted product demonstrations, initial sales were good, but consumers continued buying the product only where SOTEC had personal contacts. Retailers wanted attractive, high-quality packaging. But there was little money for this, and it would have increased the price of the product.

The project was more successful in selling potato powder for reprocessing into extruded snacks. The introduction of extrusion cooking generated interest in potato-based snacks. The powder (finer than 60 mesh) and granules (40 mesh) produced by the village processing units proved satisfactory for this purpose and less expensive than factory-produced powder.

In conjunction with the search for a viable product, research was conducted on appropriate equipment for the drying units. The project first examined implements available in the kitchens of ordinary homes. But to increase productivity and make processing economical, it was necessary to develop sturdier equipment in consultation with local blacksmiths and carpenters.

Local industries, in contrast, proved uncooperative in sharing technical know-how. As a result, it took 2 years to develop a technique for applying abrasive grit to the surface of the potato peeler. Two experienced technicians made final adjustments in the equipment. Even so, the project continued improving the design of new implements to reduce their cost, which rose as a result of increased taxes on metals. Local artisans manufactured the equipment, sometimes with grants from SOTEC.

Several challenges remain to be met. For example, small rural industries often do not have the capital to purchase equipment, and spare parts are hard to come by. Moreover, since customers require products of differing particle sizes, processors need a proper screen mill. A motorized sieving machine would reduce labor costs and losses through dust.

Drying and storage

The project learned several useful lessons about drying and storage.

It found, for example, that white-skinned potatoes dry better than red-skinned ones and that certain varieties are more suitable for drying. It is also important to select appropriate tubers (large, uniform in shape, with shallow eyes, and free of damage and disease) and then cure them by removing the aerial part and leaving the tubers in the ground for 1-2 weeks.

Sun-drying can be done during only 4 months of the year. If farmers do not have enough tubers for processing, they have to buy them just after the main harvest, when prices are low, and store them. Potatoes can be stored for up 10-12 weeks and still give good dried products. The rate of recovery of dried chips or strips may reach 18% but depends on the variety and tuber quality. Some starch is recovered from the washing tubs (5-10 kg from the average 800 kg of potato processed daily), but it cannot be produced economically in this manner.

Since dried slices take up almost as much space as fresh potatoes, those that are to be sold in powder form should be ground at once. Discolored chips should be removed and those with visible insect damage or fungal growth used for animal feed. To prevent chips from absorbing moisture, they must be packed in sisal-type sacks lined with plastic.

The economics of potato drying

The project closely studied the economics of village potato drying.

To construct a cement drying floor, simple stores, and a water tank and obtain equipment (including a washer/peeler, slicer, and drying racks) requires an initial investment of US$3,850. The units can be economically viable if they operate for a minimum of 60 days/year. Assuming a product recovery rate of 18%, the dried product can be produced at a cost of $0.47/kg. If a unit processes 60 t in 60 days, it can repay a capital loan (at 12% interest) in 4 years and a loan for operating costs in 4 months, assuming the product is sold at $0.71/kg. But since most units process 800 kg/day, they would have to operate 75 days and sell the chips at $0.88/kg. Recovered starch earns another $88.25/year.

The sales record of the processing units is encouraging. By 1990 demand for the processed products was so great that 90% of the production was sold as soon as it was available. Approximate sales figures are as follows:

Product	Amount sold (t)		
	1987	1988	1989[a]
Chips	0.2	2.0	3.5
Strips	0.2	1.5	3.3
Powder	2.0	6.0	6.0
Starch	—	0.4	1.2
Total	2.4	9.9	13.7

a. March-August only.

A more disturbing element in the economic picture of the drying units is credit. As a result of production problems, most units have had to reschedule their payments on loans for equipment. SOTEC has not been able to charge interest on these loans. Payments are made when the product is delivered to the RTVD Centre.

There are clearly major obstacles to extending credit for rural processing. The people involved have no business experience and lack the resources to survive without immediate payment for the goods and services they provide. Yet, customers who purchase in bulk commonly insist on 30-45 days' credit and then further delay payment. Under these circumstances, credit for establishing and running a processing unit is more likely to enslave than liberate villagers.

Future directions

For the period 1989-1991, SOTEC received funds from ATI to develop, field test, and establish commercial operations for sorting, processing, drying, and grinding potato. During the first two years, a demonstration project built several potato stores, established three processing units, and set up a milling unit.

Depending on the outcome of the demonstration project, an expansion phase was planned to set up six more processing units with supporting facilities. This phase was also to include an economic evaluation of the processing and marketing of potato products. The results should indicate alternatives to the original project design that facilitate diffusion of the processing technology and adoption of particularly attractive components (e.g., storage).

Lessons Learned

- The development, as opposed to transfer, of village-level technology takes time. Even though the basic principles of potato processing are well known, it still takes several years of applied research to apply this knowledge at specific locations.
- Problems in management and motivation are just as important, if not more so, as purely technical constraints. Whereas the latter can be solved with temporary outside support, the former require on-the-job training and coordination with public and private organizations over an extended period of time.
- Small-scale processing can compete with large-scale operations, because the former pay lower overhead and taxes and have the necessary flexibility to extend or reduce the period of plant operations.
- Quality control is critical in marketing to industrial clients. In this case quality standards are met by undertaking grinding and sieving at a centralized location and checking products from the village units for moisture and foreign matter.

Source

Nave, R. and Scott, G.J. 1991. Village-level potato processing in developing countries: A case study of the SOTEC project in India. CIP, Lima, Peru. 40 p.

Case 7

Processing Dried Potato in Peru

Objective: To produce nutritious processed products for low-income consumers and raise the incomes of small-scale potato farmers through increased sales and reduced production costs.

Project area: The Mantaro Valley around Huancayo, Peru.

Time frame: Research on processing and marketing, 1977-1984; semicommercial and commercial production of dried potato products, 1984-1990.

Background

Potato production covers 10% of the cultivated area in Peru; only maize, covering 15%, is more extensive. Most of the country's potato production is concentrated in the central sierra. Because of the wide range of agroclimatic zones in this area, the crop can be harvested throughout the year. Potato production became more market oriented as the country improved its highway network and expanded intra- and interregional trade. There is growing interest in processing potato to reduce transportation costs and thus give farmers larger profit margins, to supply urban markets more regularly, and to store the product when markets are saturated, until prices increase. Peru's coastal cities offer a potential market for inexpensive but good quality potato products.

For centuries small-scale farmers in the southern sierra have used solar energy to produce three products: 1) *chuño*, which is used to prepare soups and *mazamorra*, a maize-based pap, 2) dried potatoes, and 3) starch. Traditional processing could be improved to give products that better meet the requirements of urban markets in terms of color, consistency, and purity.

Since the 1980s potato area and production have fallen dramatically. Average yield has risen from 6.5 to 8.3 t/ha, but this seems insignificant given that potential yield in the highlands is 30-50 t/ha. About 90% of farmers plant less than 1 ha to potato, mainly for on-farm consumption; 9% plant up to 3 ha, mostly for the market; and 1% are commercial growers who plant as much as 100 ha for seed production and urban markets.

Project Evolution

This project drew upon considerable previous research on potato processing. One group, for example, field tested an improved solar dehydrator, which consisted of a black wooden box with a removable plastic top. They hoped it would reduce the time required to dehydrate potatoes while preserving their nutritional and culinary quality, but this method did not give better results than traditional processing. One disadvantage of the black box was that it lacked ventilation, trapping moisture inside; removing the plastic did not eliminate this problem.

The Universidad Nacional Agraria supported a commercial-scale drying plant in Muquiyauyo, but it never functioned as planned because of the high price of tubers and limited market for dried potato. Moreover, administration and technical

assistance proved more demanding than expected, so finally the plant was abandoned. Scientists realized the importance of developing new processed products that would be less subject to fluctuations in the price of potato.

A nutritious product from local crops

Researchers at CIP focused on identifying combinations of local crops that could be processed into low-cost products of high nutritional value. Since low-income consumers make up a large share of the market, it was possible to lower costs by processing a larger volume of product. To explore the possibilities, CIP staff experimented with different crop combinations, constructed a pilot processing plant, and carried out taste trials, marketing studies, and an economic feasibility study.

Various crops grown by small-scale farmers (including quinoa, Andean lupine, faba beans, oats, and barley) were evaluated for their acceptability and compatibility with potato. Prototype mixtures were produced and evaluated according to their organoleptic qualities. The most acceptable were then analyzed for their nutritional value. The best product contained 30% dried potato mixed with rice, faba bean, oat, barley, and maize flours. Adding 1 L of water to 80 g of the mixture and then cooking for 25 minutes gives a thick porridge; the product can also be used as a thickener. It has 10.6% protein and 333 kcal of energy per 100 g of mixture. Its protein efficiency is 86%, compared to 82% for potato, 70% for rice, and 41% for faba bean alone.

A pilot plant, built near Huancayo, could dry 1-2.5 t of mixture weekly. After being cooked and mashed, moist potatoes were mixed with flour of the cereals and legumes.

The mixture, with a moisture content of 52%, was spread on wooden trays on shelves in the drying chamber (5 kg/m^2). A hundred trays containing 500 kg produced 250 kg of dried mixture in 48 hours. A ton of product gave 50,000 portions (250 g each), which when rehydrated, provide enough food for 396 families of six to have three meals a day for one week.

The drying chamber included a solar collector made of eucalyptus wood and adobe brick. The walls and floor of the drying floor were painted black to absorb more sunlight. The other walls had six windows 50 cm from the floor to permit air circulation; a fan extracted saturated air.

Too expensive for the poor

Demonstrations were organized to promote the product. A thousand potential consumers sampled it and were given half a kilogram to take home. The product was also served for a year at community kitchens in low-income neighborhoods. In both cases the product was well received. In addition, taste trials were conducted in 12 *pueblos jóvenes* (squatters' settlements on the outskirts of Lima), at another community kitchen, and in 2,000 schools across the central sierra. The product's flavor and consistency were found acceptable.

In calculating the economic feasibility of the product, it was assumed that the processing operation would require an investment of US$15,000 (not including land), with an annual interest rate of 12.5%. The product would be sold for $1 and cost about $0.60 to process, depending on the scale of production. A study conducted in the pueblos jóvenes determined that processed products like this one are too expensive for the poor. But scientists working on the process dismissed these findings as too pessimistic.

Trouble from the start

The technology's developers decided to help a local NGO, the Centro de Investigación, Documentación, Asesoramiento y Servicios (IDEAS), prepare a project proposal and identify a potential donor. The project was to consist of five phases: assimilation, development, investment, operation, and replication/impact. The original plan called for a pilot plant at Huancayo and three more in Puno, Cajamarca, and Piura, requiring a total investment of $295,000 in fixed assets and $10,000 in working capital. This estimate included the cost of land as well as construction, a hammer mill, and industrial potato press. Analyses suggested that the operation would be profitable under highly favorable conditions but show a net loss under more realistic circumstances.

The project was implemented by Industria de Derivados del Agro S.A. (IDEAGRO) with a loan from Centro IDEAS. Payments on the loan were to be deposited in a rotating fund that would enable other firms to repeat the process elsewhere. Even though the financial viability of the project was questionable, it was viewed as an experiment from which valuable lessons could be drawn.

An additional drying chamber increased the processing plant's capacity to 9.6 t of product per week. Its staff consisted of an industrial engineer or food technician, an administrator, head, secretary/sales assistant, and eight laborers. The operation was weak in administration and accounting, had no sales force, and made no arrangements to ensure that it met legal requirements in such matters as plant construction, municipal and health licensing, and registration of a trademark.

Marketing studies were conducted in two university cafeterias and three community kitchens. Although the product was generally well received, some people complained that it "smells bad, like oil," has a "rancid or bitter taste," "doesn't thicken," and "yields less than it's supposed to."

A change in strategy

After 6 months the project was clearly in trouble. The product didn't satisfy consumer tastes and was more expensive than some wheat products. To remedy these problems, IDEAGRO changed the project's strategy. It launched a search for new, better quality products that would appeal to urban consumers and, for financial reasons, permit a production increase from 9.6 to 16 t/week.

Oats were eliminated from the mix because they were not readily available, and peas were substituted for faba beans to eliminate the bitter taste. Cooking time was reduced from 25 to 15 minutes.

In searching for new products, IDEAGRO made profitability its main criterion. Consumers felt that two aspects of the original product needed improvement: its texture and taste. To accomplish this, project staff used precooked potato flour and left out the rice, which was too coarse. They also developed several new products, including Chicolac (4% potato, 70% maize, milk, and cocoa), a potato cream and semolina, and legume and cereal lines. The project purchased new equipment as well.

The price of Chicolac was higher than that of comparable products in Lima's wholesale and municipal markets but considered intermediate compared to prices in supermarkets. The project registered its products under the brand name Abril and promoted them by means of flyers distributed in supermarkets. Chicolac won a first prize at the Huancayo fair, where it was presented to committees responsible for distributing milk to children.

Sales of the products were low, apparently because housewives lacked information on preparing dishes with them. To remedy this problem, the project distributed recipes in supermarkets. The potential monthly market in Lima was estimated at 113 t of dried potato and 7 t of potato flakes. Nonetheless, average monthly sales in 1988 amounted to only 8.2 t, and only 50% of the pilot plant's processing capacity was used.

Working under difficult circumstances

The country's deteriorating economic situation in the late 1980s made it difficult for IDEAGRO to work effectively. Gross national product dropped 9% between 1986 and 1989, plunging 26% in 1988 alone. High inflation distorted prices, and government policies (such as reduced barriers to food imports, soft credit, fertilizer subsidies) along with drought destabilized the prices of key project inputs.

Problems arose in managing the project because of fundamental differences between IDEAS and IDEAGRO about project strategy. It proved difficult for staff to make decisions that satisfied both organizations.

Three factors eroded the potential profitability of the operation. First, money was lost through unpaid credit. Second, the project

had to pay workers even when processing was halted for adjustments in the product. And third, the prices of Abril products did not increase at the same rate as those for similar products. The firm's ability to pay its loan in the short term was restricted by two factors. First, capital investments absorbed much of the firm's resources (75% versus an ideal 25%), leaving too little working capital. Second, working capital was immobilized because clients delayed payment for purchased product by up to 2 months.

Future directions

Several agroindustrial enterprises have replicated the product of this project as well as some of the machinery and marketing strategies, including product presentation and points of purchase. Upon seeing the effects of competition from a better quality product, wholesalers began to implement quality control and segment the market according to sales expectations. There is potential for small-scale farmers to replicate the product and process, provided they have access to processing equipment and technical assistance.

Lessons Learned

- The experience of this project illustrates the vital importance of information about market characteristics, such as raw material supply and price, quality requirements for processed products, and potential demand. Trying to enter three markets at once was overly ambitious, and assigning highest priority to the low-income market was a mistake. Projects of this sort should concentrate first on the product with the most potential for profit to get the firm well established.
- This project underscores the need for continual modification of processes and products in response to changing market conditions. Small-scale commercial enterprises require technical support from institutions with the appropriate expertise.
- Availability and cost of raw material are key considerations. Purchasing raw material from wholesalers rather than producers proved less costly and more predictable.
- Estimates of cost and cash flow must be realistic. The high cost of credit to clients, which limited growth, should have been taken into account in estimating the amount of working capital the project would need.

Source

Wong, D.; Alvares, M.; Scott, G.J.; and Yupanqui, A.T. 1991. Papas, mezclas y cremas: Un estudio de caso del procesamiento de papa en el Perú. CIP and Centro de Investigación, Documentación, Asesoramiento y Servicios, Lima, Peru. 30 p.

Case 8

Simple Potato Processing in Colombia

Objective: To create new marketing alternatives for potato producers and generate rural employment by developing an industry that produces solar dried chips, cubes, and flour.

Project area: Areas of North Santander and Nariño departments where potato is grown on a small scale.

Time frame: 1987-1991.

Background

From 1970 to 1988, annual potato production in Colombia expanded from just under 1 million to about 2.5 million tons. Researchers at ICA were concerned about the effect of such a large increase on potato prices and producers' incomes. A sharp drop in the price during 1984-1985 prompted a decision to explore alternative potato products and markets more actively. Other good reasons for this initiative are the seasonal abundance, bulkiness, and perishability of potato, which greatly complicate marketing.

A Colombian technician was sent to Peru for training in simple potato processing. By 1986 a small pilot plant had been set up to determine the feasibility of producing solar dried chips, cubes, and flour. Colombian potato farmers, unlike their counterparts in Bolivia and Peru, where simple potato processing is centuries old, are unfamiliar with these techniques.

After successful trials in a pilot plant, marketing studies were conducted. One objective was to gauge the interest of farmers in producing, selling, and consuming potato products. Another was to get feedback from urban consumers on product attributes as a basis for improving processing methods.

Colombian policy makers and potato researchers had long been interested in the development of new processed products, such as potato chips, French fries, flour, and starch. Some saw these products as a way to expand potato exports, while others were more concerned about their prospects in domestic markets. The experts agreed that to diversify potato products and markets successfully would require a better understanding of market demands and rural-urban links.

Project Evolution

From 1987 to 1991, ICA undertook a project with technical support from CIP, aimed at developing markets for processed potato products. A large share of the operating costs were paid by IDRC as part of its support for a regional potato research network in the Andean zone. The goals of the network were to address high priority problems in member countries, train scientists to conduct marketing research, and facilitate the exchange of experiences and methods.

The project's approach was to explore the prospects for commercial potato processing, using different levels of technology (rustic, semi-industrial, and industrial). This involved regular interaction between researchers concerned with the technical aspects of processing and social scientists engaged in market research. Grower associations, women's groups, and the private sector also participated in the project. The strategy was flexible enough that the project could shift its focus as new opportunities emerged. Researchers were free to respond to the need for market information and also explore thoroughly the feasibility of technical options based on socioeconomic studies.

Obstacles to simple processing

The project concentrated initially on assessing the commercial potential of products intended for human consumption and involving simple processing methods. This work took place in the area around Pamplona in northeastern Colombia. In Pamplona simple processing was a response to the crash in potato prices during 1984-1985.

ICA now receives requests for germplasm with particular skin color and dry matter content; its plant breeders used to reject some such materials. These staff have formed a new perspective on increased potato production. Rather than fear a drastic fall in prices, they see higher production as necessary to meet rising demand for fresh and processed potato products.

Lessons Learned

- Although technology is central to a project of this sort, it must not be emphasized at the expense of other factors. The three experiences described here underscore the importance of analyzing the market first. Characteristics of the product and target market, along with sources of inputs and marketing channels for processed products, must be clearly identified at the outset.
- A related challenge is segmentation of markets. In Colombia three products were aimed at three different groups of users, although initially the emphasis was on people at the lower end of the income scale. This approach proved overly ambitious. Such projects should probably concentrate first on one product for one segment of the market.
- Experience in Colombia also underscores the importance of consumers' perceptions in product development. In Pamplona, for example, the processed products had an acceptable taste, but consumers were concerned about their color and texture.
- Product development may involve new processes and products, such as simple procedures for solar drying of potato to make flour or cubes. It may be more effective, however, to improve existing processes first (e.g., semi-industrial processing with improved raw material).

Source

Scott, G.J. 1993. Processed potato products in Colombia. CIP, Lima, Peru. 8 p.

Case 9

Development of a Sweet Potato Beverage in the Philippines

Objectives: To identify food products that can be made from sweet potato, develop technology for manufacturing these products, and transfer the technology to processors.

Project area: Baybay, Leyte, the Philippines.

Time frame: Identification of product ideas, 1985-1986; product development, 1986-1989; commercial phase, 1989 to present.

Background

Sweet potato is an important food crop in this country, ranking third after rice and maize. More than 800,000 t are produced on about 165,000 ha. But per capita consumption of sweet potato is declining, and few alternative markets for the crop have been developed.

Project Evolution

The Visayas State College of Agriculture (ViSCA) was seeking ways to increase sweet potato utilization and raise its value for producers. College staff found that a number of processed sweet potato products (e.g., fried chips, candies, flour, and local delicacies) were already being produced commercially and in households.

The project considered three possible approaches: 1) to improve existing processes, 2) adopt technologies from other countries, and 3) develop appealing, nontraditional products with good market potential. ViSCA chose the third, based on the hypothesis that roots could be processed into products traditionally made from fruit.

Sweet potato's appeal

Sweet potato has considerable appeal as a competitive substitute for fruits in some products. The crop is nonseasonal and inexpensive and offers excellent nutritional value. In addition to their high starch content, the roots show high levels of vitamin C. Moreover, varieties with orange root flesh contain as much B-carotene (provitamin A) as carrots and more than other vegetables and fruits.

In search of product ideas, project staff made an inventory of commercial fruit products, including dried fruits, jams, canned fruits, juices, and drinks packaged in various forms. Since fresh fruits are seasonal, these products tended to be expensive and thus accessible only to high-income consumers and export markets.

Product research

ViSCA developed three products on a trial basis: dried sweet potato with a sweet and sour taste, jam, and catsup. Consumer tests gave encouraging results, with 80% of the respondents saying they liked the products moderately to very much.

Based on these results and the interest of local food processors in such products, the college proceeded with research on a fourth product, a nonalcoholic sweet potato beverage (SPB). In evaluations of varieties with different root flesh colors, orange varieties were found most

appealing. Adding artificial orange flavoring or fruit juice or pulp from guava, pineapple, or Philippine lemon significantly improved the product's aroma.

SPB had a higher vitamin A content than commercial fruit drinks in cans and tetrapacks. An 8-oz or 237-ml serving satisfied the average Filipino's daily requirement of this vitamin. In addition, the drink was fortified with vitamin C, as is commonly done in fruit juice processing. As a result, it provided 40% of the recommended daily allowance of this vitamin. The phosphorus and calcium levels of SPB were significantly higher than those of Hi-C orange, mango, and pineapple juices, while its content of magnesium and potassium levels was comparable to that of fruit drinks.

A laboratory taste panel found no significant differences in sensory attributes between the new beverage and commercial products. In fact, it received higher scores for aroma and general acceptability than papaya nectar and pineapple orange drink. SPB with guava was rated higher than guava-flavored fruit nectar in cans. The natural orange color of the beverage, an indicator of high vitamin A content, gave it a marked advantage over commercial fruit drinks, to which artificial coloring and flavoring are added.

Samples of SPB, without flavoring and with ripe guava, were tested on four groups of consumers, each representing a different age bracket. They were asked to rate the products on a seven-point scale. The results generally confirmed those of the lab test. Even so, some consumers who were aware that the beverage is based on sweet potato, were apprehensive that it might cause flatulence, as a consequence of a large intake of undigested starch. But the starch content of SPB is only 0.8-1.0 g/100 g of product—lower than that of passion fruit. Ten volunteers confirmed that consuming one 8-oz bottle of the beverage daily did not cause flatulence.

Toward commercial processing

In 1989, ViSCA obtained a patent to protect its rights to the processing technology and strengthen its bargaining position with industry. The college also prepared a strategy for technology transfer, involving dissemination of information to the public through scientific reports, newspaper announcements, a Department of Trade and Industry investment forum, and science and technology fairs.

In the end, ViSCA offered the technology, on an exclusive basis for 5 years, to a group of businessmen who were establishing a food processing company. The college was criticized for this decision, because it seemed inconsistent with ViSCA's mandate to improve the welfare of small-scale farmers. Project staff hoped, however, that commercial processing of sweet potato would increase the demand for raw material, resulting in higher prices for the crop and boosting farmers' incomes. Unfortunately, the processors had little experience in marketing food products, and their facilities proved inadequate. When fire destroyed the processing operation, this arrangement was voided by mutual consent.

ViSCA next entered into an agreement with a large food and beverage company, which was exploring the potential of indigenous raw materials in the production of nutritious, inexpensive food products for poor consumers. The company intended to contract farmers to produce raw material, thus integrating production with processing and marketing.

ViSCA's alliance with local industry

Under ViSCA's agreement with the company, the processing technology was made available on a nonexclusive basis, with the understanding that any improvements the company made would be its property for 5 years from the time the product went into commercial production. Moreover, all trademarks developed for the product would belong to the company.

In return, it donated food processing equipment to ViSCA for research and development. The company also provided funds and the use of its facilities for production of SPB, first on a pilot basis and then semicommercially.

This work was done by a team consisting of the ViSCA scientist who invented the product, together with company specialists in product and process development, plant management, and agricultural extension. Their main tasks were to

raise product quality to company standards, carry out trials with local varieties of sweet potato and the improved cultivar VSP-1, identify the factors affecting quality and processing, evaluate the product for sensory attributes and shelf life, and analyze costs (taking into account fluctuations in the price of raw material).

To ensure a steady supply of high-quality raw material, ViSCA offered assistance in improving cultural practices, postharvest handling, and grading of roots. It also trained students at a local agricultural school to produce sweet potato planting materials.

Future directions

The project seems to have resolved the majority of its challenges in postharvest processing and marketing. Nonetheless, it will take a substantial effort to provide the company with a reliable supply of raw material. This could prove difficult, since the plan is to produce SPB only when certain fruits are not in season.

It remains to be seen whether, by placing the processing technology in the hands of a large private company, the project can achieve its original objective of benefiting small-scale sweet potato farmers. They may not be able to modify crop production practices to meet the processor's demands.

Even so, the arrangement with this company does offer a decided advantage. Since it is already producing beverages similar to SPB, the company can market this new product without much additional investment in advertising and distribution. That in turn increases the project's potential for impact over a wider area.

Lessons Learned

- Close analysis of the physicochemical and functional properties of the raw material often leads to a new product idea.
- Teams consisting of specialists from universities and industry can be effective in carrying a product from laboratory testing to pilot-scale production.
- Strong ties between production and processing are critical to successful product development and should be established before the product reaches commercial production. This step is just as important in a project like this one, which links small-scale crop production to large-scale processing, as in the other nine cases described here, whose main aim is to establish small- to medium-scale agroindustries in rural areas.

Source

Truong, V.D. 1991. Development of a sweet potato beverage in the Philippines. ViSCA, Baybay, Leyte, Philippines. 14 p.

Case 10

Development of Root Soy Sauce in the Philippines

Objectives: In research, to determine the technical and economic feasibility of producing a soy-flavored sauce from root crop flours; in the pilot phase, to refine the processing technology, transfer it to farmer organizations, and develop a marketing strategy.

Project area: Maasin, southern Leyte, the Philippines.

Time frame: Research, 1980-1987; pilot phase, 1988-1990.

Background

The Philippine Root Crop Research and Training Center (PRCRTC) and the Postharvest Technology Section of ViSCA develop and improve postharvest technology for root crops, with a view to increasing supplies of better quality food, feed, and industrial products for low-income people. A primary objective of both institutions is to increase commercial use of root crops.

One option PRCRTC has explored is to develop a soy sauce in which flour made from root crops (sweet potato, cassava, and taro) substitutes for wheat flour, a premium raw material that is often in short supply. Soy sauce is a popular condiment throughout the country. If manufactured from roots crops, the product would be cheaper, could be produced in larger quantities, and would provide farmers with a new outlet for root crop production.

Project Evolution

The project consisted of two phases: 1) research and 2) a pilot study conducted in a local community. The research was carried out by a PRCRTC/ViSCA team, composed of a postharvest technologist, food microbiologists, economist, nutritionist, and agricultural engineer. The pilot project was implemented by a PRCRTC postharvest specialist, agricultural engineer, and engineer. The pilot phase was funded by the Department of Science and Technology-Region VIII. The Department of Agriculture provided technicians, and the municipal government of Maasin supplied equipment and local staff.

Technical and market research

Soy sauce is normally prepared from a mixture of soybean and wheat, which is fermented through the action of the fungus *Aspergillus oryzae*. To manufacture this product from root crops involves three main steps:

1. Root crop flour is prepared by washing, peeling, chipping, and sun-drying, and grinding (the chips may also be cooked before drying). The dry ground flour is then roasted.

2. Starter is made by first soaking, draining, and sterilizing rice. After the resulting mash has cooled to room temperature, it is seeded with spores of *A. oryzae* or *A. sojae* and left to incubate for 4-6 days or until greenish spores form.

3. Soy sauce is derived by first mixing steamed soybean with roasted root crop flour and starter. The mixture is incubated, initially for 4-5 days to allow growth of the microorganism, and then for 3 months, with the addition of a brine solution, until the pH reaches 5.05-5.50. The resulting mash is pressed and strained to obtain a liquor, which is left to settle overnight. The soy sauce is then decanted. This process is repeated twice, after which the three liquors obtained are combined. Molasses is added to give the sauce a darker color and greater viscosity. The mixture is pasteurized at 80° for 3 minutes.

The research team examined various technical issues involved in this process. For example, it compared three methods of extracting the sauce: manual (in muslin) and mechanical (in

nylon cloth), using a screw- or lever-type press. The teams also conducted three laboratory trials to determine the most effective medium for fungal development.

Mold grew most abundantly on cooked sweet potato medium. In the first trial, cooked sweet potato and wheat flour gave the highest yields and cassava flour the lowest, especially uncooked cassava. Cooking gelatinizes the starch, making it more readily available for the microorganisms to act upon, and sweet potatoes have more digestible matter than cassava (88% versus 76%). In the second and third trials, production did not vary significantly, perhaps because of the manner in which the sauce was extracted.

Production costs were highest for wheat flour (US$0.37), followed by sweet potato ($0.18), and cassava ($0.14).

The properties of soy sauce made from cooked sweet potato flour are comparable to those of sauce made with wheat flour. One exception is the low salt concentration of the former, which can easily be adjusted.

The soy sauce was compared on the basis of organoleptic qualities with two locally available commercial brands (A, which is dark-colored and inexpensive, and B, which is lighter and more costly). PRCRTC researchers and laborers were asked to rate the sauces (on a nine-point scale) in pure form, as a dip for broiled fish, and as a marinade for beef. The panelists gave the sweet potato soy sauce the same rating as both commercial brands. They considered the cassava soy sauce as good as brand B but felt that both were inferior to brand A in terms of color, aroma, and consistency. Taro soy sauce received the lowest rating, although it was found comparable in aroma to brand B.

ViSCA identified 12 processing devices suitable for village-level processing and evaluated them in the laboratory. These included a root crop washer, pedal-operated root chipper/grater, a modified copra dryer, a portable Almeda attrition mill (designed for rice and maize), and a screw-press sauce extractor. Other devices were designed specifically for the project, including a flour roaster, mixer, crown cap sealer, and charcoal stove.

The name Root Soy Sauce was selected for the product through a contest. Consumer surveys were conducted at ViSCA and in four nearby communities. Samples (50 ml) were distributed among households, and a week later people were asked to comment on the product. Survey results indicated that the aroma was too strong, salt content needed to be increased, and color should be darker.

Marketing channels were identified through a study of retail stores and cooperatives in the area around Baybay and a survey of 300 consumers chosen at random. The preferred point of purchase was retail stores and the preferred size 12 oz or 320 ml (about the size of a beer bottle). Consumer preference was determined largely by availability, price, taste, and promotional activities.

A feasibility study was conducted in Leyte, because it has great potential as a source of raw material and is readily accessible from ViSCA. Data were collected through interviews, analysis of processing costs in the lab and on a pilot scale, and market testing. Potential monthly demand for root soy sauce was estimated at 1,814 L. The capital investment required to meet 50% of this demand was estimated at about US$3,220 and just over $4,140 for the whole project.

The pilot phase

A project management board was established to supervise and monitor the pilot phase. The board consisted of the ViSCA-PRCRTC team, the plant manager, and representatives from the Department of Science and Technology, a farmers' federation, and the municipality. Maasin was selected as the site for the pilot plant, because it has good crop production potential, farmers there showed strong interest in the project, institutional support is available, the infrastructure is good, and the municipality is under progressive leadership. The pilot plant was inaugurated in May 1989.

The project strongly emphasized institution building as a means of making the processing operation viable. A farmers federation (consisting of 40 farmer associations) was organized and made responsible for plant management. The plant's technical staff, all recruited from the local community, received training both in the lab and at the pilot site. Training was combined with testing of processing equipment and trials to determine optimum operational schemes.

After evaluating the operational viability and organizational and management structure of the pilot plant, the project moved into a transition phase in preparation for commercial production. The process and plant infrastructure were modified; a full feasibility study was conducted; and ViSCA staff began gradually to withdraw support. The farmers federation continues to improve produce quality, stability, and presentation. These changes will be followed by further consumer testing and marketing trials. Farmers are being encouraged to adopt improved sweet potato cultivars with high dry matter content.

Future directions

Assuming the transition phase described above gives satisfactory results, the project will embark on commercial production. To finance this venture, the project has submitted a proposal for external funding.

Lessons Learned

- Farmer groups that undertake agroindustrial processing need strong support in organization and conflict management.
- Process and product development can take a long time. In this case it took 10 years to assess the commercial viability of the product.
- A pilot phase is essential for laying the groundwork of commercial production. During this phase, it is critical that multidisciplinary teams conduct planning, that institutional linkages be established, and that local groups participate in management.
- Information gathered through consumer acceptance trials and marketing surveys is vital for orienting research aimed at improving product quality and presentation.

Source

Data, E.S. and Roa, J.R. 1991. Development of soy sauce from root crop residues: PRCRTC's experience. Philippine Root Crop Research and Training Center, Visayas State College of Agriculture, Baybay, Leyte, Philippines. 36 p.

To obtain source materials

Source materials for the 10 case studies included in this manual, as well as for six other studies not covered here, are available from the Cassava Program, CIAT, at US$0.10 per photocopied page (including postage). The six additional studies are:

Agroindustrial program for cassava in Mexico by Asunción Méndez. (Spanish, 6 p.)

Cassava root and leaf meal in balanced feed rations by Luis Fernando Gerhard. (Portuguese, 222 p.)

Development and utilization of nationally produced tuber and cereal flours to substitute wheat by Ahmed El-Dash. (English, 43 p.)

Nontechnical problems associated with improved village-scale gari processing technology by Aurea Almazan. (English, 15 p.)

Pilot testing of commercial formulations of root crop-based feeds by Guindolino Gerona. (English, 14 p.)

Thailand's experience in the development of the dried cassava industry by Alistair Hicks. (English, 19 p.)

Much valuable information is also contained in the set of workshop proceedings listed below. They present information on cassava production, processing, and marketing in the countries represented at the workshops and also describe research; processing methodologies; trade in roots and tubers; the work and experience of different entities, including commercial firms; and the regional potential for root and tuber processing.

Scott, G.; Wiersema, S.; and Ferguson, P.I. (eds.). 1992. Product development for root and tuber crops, vol. I-Asia. Proceedings of the International Workshop. CIP, Lima, Peru. 384 p.

Scott, G.; Herrera, J.E.; Espinola, N.; Daza, M.; Fonseca, C.; Fano, H.; and Benavides, M. (eds.). 1992. Desarrollo de productos de raíces y tubérculos, vol. II-América Latina. Memorias del Taller sobre Procesamiento, Comercialización y Utilización de Raíces y Tubérculos en América Latina. CIP, Lima, Peru. 375 p.

Scott, G.; Ferguson, P.I.; and Herrera, J.E. (eds.). 1992. Product development for root and tuber crops, vol. III-Africa. Proceedings of the Workshop on Processing, Marketing, and Utilization of Root and Tuber Crops in Africa. CIP, Lima, Peru. 506 p.

All three volumes are available from CIP. The price per volume is US$15 for developing countries and $30 for developed countries, plus $10 per copy for handling and shipping. A limited number of copies are available free to researchers in developing countries.

Appendix

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Acronyms

ACFOA	Australian Council for Overseas Aid
ACIAR	Australian Centre for International Agricultural Research
ANPPY	Asociación Nacional de Productores y Procesadores de Yuca (National Association of Cassava Producers and Processors), Colombia
APPY	Asociación de Productores y Procesadores de Yuca (Association of Cassava Producers and Processors), Ecuador
ASOCOSTA	Asociación de Cooperativas de la Costa (Association of Coastal Cooperatives), Colombia
ATI	Appropriate Technology International, USA
AVRDC	Asian Vegetable Research and Development Center, Taiwan
CECORA	Central de Cooperativas de la Reforma Agraria (Central Office of Cooperatives for Agrarian Reform), Colombia
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture), Colombia
CIDA	Canadian International Development Agency
CIP	Centro Internacional de la Papa (International Potato Center), Peru
CIUP	Centro de Investigación de la Universidad del Pacífico, Peru
COOAGRONOR	Cooperativa Agroindustrial del Nor-Oriente del Atlántico (Agroindustrial Cooperative for the Northeast of Atlantico Department), Colombia
COOPROALGA	Cooperativa de Productores de Algarrobos (Cooperative of Carob Producers), Colombia
COOPROMERCAR	Cooperativa de Producción y Mercadeo de Repelón (Repelón Cooperative for Production and Marketing), Colombia
CORFAS	Corporación Fondo de Apoyo a Empresas Asociativas (Corporation Fund for Support to Associations), Colombia
CTI	Compatible Technology, Inc., a US agency operating in India
DRI	Programa de Desarrollo Rural Integrado (Program for Integrated Rural Development), Colombia
EMATERCE	Empresa de Assistência Técnica e Extensão Rural do Ceará (State Technical Assistance and Rural Extension Agency of Ceará), Brazil
EPACE	Empresa de Pesquisa Agropecuária do Ceará (State Agricultural Research Agency of Ceará), Brazil
ERR	Economic rate of return
EU	European Union
FAGROCOL	Federación de Organizaciones Agropecuarias de Colombia (Colombian Federation of Agricultural Organizations)
FAO	Food and Agriculture Organization of the United Nations
FEDECOSABANA	Federación de Cooperativas de la Sabana (Federation of Cooperatives in the Savanna), Colombia
FIFAMANOR	Fiompiana-Fambolena-Malagasy-Norveziana (Malagasy-Norwegian cooperative project on potato, wheat, and milk production), Madagascar
FINANCIACOOP	Instituto de Financiamiento y Desarrollo Cooperativo de Colombia (Colombian Institute for Cooperative Finance and Development)

FOFIFA	Foibem-pirenena momba ny fikarohana ampiharina amin'ny fampandrosoana ny ambanivohitra (National Center for Applied Research on Rural Development, Department of Research and Development), Madagascar
FRR	Financial rate of return
FUNDAGRO	Fundación Ecuatoriana de Investigaciones Agropecuarias (Ecuadoran Fund for Agricultural Research)
GATT	General Agreement on Tariffs and Trade
ICA	Instituto Colombiano Agropecuario (Colombian Institute for Agriculture and Livestock)
ICTA	Instituto de Ciencia y Tecnología Agrícolas (Institute of Agricultural Science and Technology), Guatemala
IDEAGRO	Industria de Derivados del Agro S.A. (Agricultural By-Products Industry), Peru
IDEAS	Centro de Investigación, Documentación, Asesoramiento y Servicios (Center for Research, Documentation, Assistance, and Services), Peru
IDRC	International Development Research Centre, Canada
IFPRI	International Food Policy Research Institute, USA
IICA	Instituto Interamericano de Cooperación para la Agricultura (Inter-American Institute for Cooperation in Agriculture), Costa Rica
IIT	Instituto de Investigaciones Tecnológicas (Institute for Technical Research), Colombia
IITA	International Institute of Tropical Agriculture, Nigeria
ILO	International Labor Organization
INCORA	Instituto Colombiano de la Reforma Agraria (Colombian Institute for Agrarian Reform)
INIAA	Instituto Nacional de Investigación Agraria y Agroindustrial (National Institute for Agrarian and Agroindustrial Research), Peru
INIAP	Instituto Nacional de Investigaciones Agropecuarias (National Institute for Agricultural Research), Ecuador
INTA	Instituto Nacional de Tecnología Agropecuaria (National Institute for Agricultural Technology), Argentina
IRRI	International Rice Research Institute, Philippines
ISER	Instituto de Economía y Sociología Rural (Institute of Economics and Rural Sociology), INTA, Argentina
ISNAR	International Service for National Agricultural Research, The Netherlands
NAS	National Academy of Sciences, USA
NGO	Nongovernment organization
NRI	Natural Resources Institute, UK
ODNRI	Overseas Development Natural Resources Institute, UK (now NRI)
PRACIPA	Programa Andino de Investigación en Papa (Andean Program for Potato Research), Peru
PRCRTC	Philippine Root Crop Research and Training Center
RTVD	Research Training and Village Development Centre, India
SEARA	Secretaria de Agricultura e Reforma Agraria (Secretariat of Agriculture and Agrarian Reform), Brazil
SENA	Servicio Nacional de Aprendizaje (National Training Service), Colombia

SOTEC	Society for Development of Appropriate Technology, India
UAPPY	Unión de Asociaciones de Productores y Procesadores de Yuca (Union of Associations of Cassava Producers and Processors), Ecuador
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Fund
UNIDO	United Nations Industrial Development Organization
USAID	US Agency for International Development
USDA	US Department of Agriculture
ViSCA	Visayas State College of Agriculture, Philippines