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9. ABSTRACT

Assesses the feasibility of accurately estimating, and devising methods to prevent, the enormous post-harvest food losses in developing countries. While the report does review the significant effect of local culture and economy on food loss, it is primarily concerned with the methodology of loss reduction, the technology of primary food processing and storage, the control of food pests, and the physiological deterioration of food. The report's threefold strategy for reducing food loss includes the establishment of effective national committees to plan and implement conservation policies, the institution of conservation education programs at all levels of the post-harvest food system, and an increase in basic and applied research activities.

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# Postharvest Food Losses in Developing Countries

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Board on Science and Technology  
for International Development  
Commission on International Relations  
National Research Council

NATIONAL ACADEMY OF SCIENCES  
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1978

This report has been prepared by an ad hoc advisory panel of the Board on Science and Technology for International Development, Commission on International Relations, National Research Council, for the Office of Agriculture, Bureau for Development Support, Agency for International Development, Washington, D.C., under Contract No. AID/csd-2584, Task Order No. 23.

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This is a preliminary xeroxed version of the  
Committee's report prepared for AID use prior  
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6 x 9 printed format.



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## Summary

As the world's population grows, increasing the food supply continues to be an urgent priority. One vital--and neglected--step toward this end is to reduce the food losses that occur between harvest and consumption. Reliable studies and expert opinion indicate that postharvest losses of major food commodities in developing countries are enormous, in the range, conservatively, of tens of millions of tonnes\* per year and valued at billions of dollars. Programs for reducing these losses must be based on reasonable estimates of the losses, as must evaluations of program effectiveness. Yet it is very difficult to estimate postharvest food losses with precision. Partly, this is due to their inherent variability. But it is also a result of many cultural and economic factors that frustrate the smooth, efficient flow of food through the postharvest system from producer to consumer.

Useful food loss estimates are possible, however, as is improvement in food conservation. This study is devoted to assessing their potential and their limitations. It summarizes existing work and information about losses of the major food crops and fish, discusses some of the economic and social factors involved, identifies needs and suggests alternative policies and programs for developing countries and technical assistance agencies.

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\*Metric tonnes--are used throughout the report.

## Loss Estimation

Unlike production estimates, which are based on the measurable genetic potential of crops, loss estimates are location- and season-specific to a degree that makes the concept of average levels of loss almost meaningless. The low accuracy of loss-survey techniques on the one hand, and the limitations of extrapolating from even a specific, well-characterized loss situation on the other, make reliable and economically feasible loss estimates highly difficult. Losses can be better understood and assessed, however, and improved methods must be developed and standardized.

Improved loss estimation is essential for making policy decisions about the allocation of resources to reduce losses. Experts resist estimating national or global percentage losses of major food commodities because these figures are impossible to substantiate statistically, except on a limited, controlled experimental basis. When providing "indicative" figures for planning purposes however, the experts typically cite minimum overall losses of 10 percent for durable crops (the cereal grains and grain legumes) and 20 percent or higher for non-grain staples (yams or cassava, for example) and other perishables including fish. Accepting these estimates (with appropriate caveats) as conservative minimum values in support of allocations for food loss reduction, it is clear that worldwide food losses are staggering, justifying substantial investment of intellectual and financial resources to understand them better and to reduce them. This is reflected in the 1975 Resolution of the VIIth Special Session of the United Nations General Assembly, committing member states to reduce postharvest food losses by 50 percent by 1985.

## Loss Reduction

Loss reduction ultimately depends on economic exigencies. Given modern technology and sufficient resources, it is theoretically possible to conserve most food commodities almost indefinitely without loss. The expenditure on food conservation, however, must be justified by the particular need and circumstances. Before programs can be undertaken to reduce losses on a broad scale, more data is needed on the probable costs, manpower, and organization. Such efforts require political commitment by individual countries to carry through the actions required at the national level.

Given the complex coordination required to reduce losses, each country needs a national postharvest policy body with a fulltime professional staff to assess and monitor overall losses, identify acute loss priorities, and carry out research. This body should also provide decision makers with realistic policy options so that appropriate levels of investment in loss reduction can be made commensurate with the economic and social costs involved. The postharvest policy group must have access to the highest levels of government, since losses may result as much from disincentives to conservation caused by pricing, taxation, or other governmental regulatory policies as from biological or physical causes.

Regrettably, few countries have national postharvest groups responsible for developing and coordinating policy among the ministries involved. Establishment of such bodies is urgently recommended and technical assistance agencies should be ready to help developing countries with the process.

Current national efforts for food loss estimation and reduction are not only inadequate, but are also heavily biased towards storage of cereal grains. Given the seasonal character of grain production and the survival value of grain in many societies, this is understandable. However, the non-grain

staples, which are at least the main source of calories in the diets of a number of societies, should receive attention commensurate with their importance in the diet, as should vegetables and fruit. This concern, should not, however, be at the expense of efforts focused on the cereal grains.

In most societies, such importance is attached to eating fresh, known varieties of fish (because of the speed with which fish spoil and the dangers of eating either spoiled or toxic varieties) that increased consumption of unconventional varieties or processed fish products such as fish flakes or protein concentrate is unlikely to reduce present losses. Rather, efforts should be directed to (a) improving storage; (b) assisting fishermen in forming cooperative associations, which collectively could justify improved boat landing and fish handling facilities; and (c) improving marketing and processing (drying, salting, and smoking) of landed catches of conventional species. Non-conventional fish species on the other hand should be used wherever possible for animal feed and fertilizer.

#### Social, Cultural and Economic Aspects

Food losses are related to social phenomena. Cultural attitudes and societal practices form the inescapable and critical backdrop against which postharvest operations and loss reduction activities must occur. Among different cultures, even the perception of what constitutes food loss often varies greatly. The techniques of food conservation are frequently dictated more by traditional beliefs than by immediate utility. The roles of male and female, or relationships among individuals and families, may be reflected in the particular ways in which food is handled or stored after harvest.



Incentives are an important aspect of reducing food losses. Producers are unlikely to invest money or effort in loss reduction activities unless they foresee a good return, whether in income, security, or status.

National efforts to reduce food losses cannot rely solely on technology or information. Technology and information must be culturally and socially acceptable if they are to be useful, and incentives for the adoption of sound food conservation practice should be emphasized.

The lack of data about postharvest food losses is particularly acute with respect to economic and social aspects of loss; a corollary is that the cost effectiveness of food loss reduction cannot be adequately demonstrated. Yet there are simple improvements in conservation practices which require little monetary investment and could greatly reduce the risk of serious loss at the farm level. There are also indirect benefits that can derive from investment in postharvest loss reduction, especially in the traditional farm sector of poor countries where the bulk of the population produces and consumes the larger proportion of the food crops, little of which enters the market sector. Here, food loss reduction leads to greater food security against lean years. It may also offer possibilities for generating employment and surplus food for marketing, which may pay for an increased flow of goods and services to the rural area. Government action to reduce losses is probably more important in the traditional farm sector than other sectors of the economy where food commodities are mainly in the hands of commercial entrepreneurs who may respond to market forces with appropriate conservation measures.

## Education and Training

The lack of reliable general information on the extent, nature, and possibilities for reduction of postharvest food losses, combined with lack of recognition that this is a discrete technical area with opportunities for professional career development, has led to a critical shortage of qualified and experienced personnel. This can and should be overcome by educational efforts at many levels. These efforts should include informal programs to increase public awareness of the need for hygiene in food handling and storage, training courses for agricultural extension workers -- who have a particularly important role to play in the rural farm sector -- and for administrative personnel, and degree and postgraduate training in appropriate biological and engineering disciplines. Particular attention should be given to increasing training opportunities for women, who in many societies play a vital role in harvest and postharvest activities. Current technical assistance support for national postharvest training programs should be strengthened and should be matched by complementary research and training opportunities in the developed countries.

## Technical Information and Research

There is little precise published information about losses and loss reduction in developing countries. What there is concerns mainly grain storage, and there is particular need for more information about perishables, and the socio-economic factors affecting food conservation. The literature is scattered widely throughout the technical journals and frequently is not readily identifiable by title as relevant to postharvest losses. There is need for a postharvest loss documentation service, organized internationally and continually updated, with facilities for providing microfiche or hard copies of technical papers worldwide.

A great deal of general technological and scientific information about various aspects of food loss in developed countries is available and should be put to use. There is need for adaptive research to ensure that this information is technically sound and for socioeconomic research to ensure that it is socially acceptable and economically justifiable. The role of the private sector in developing countries is potentially very important because of information and experience in the postharvest conservation of commercial and export crops.

Further applied research is needed to improve food processing equipment so that it will work efficiently under tropical conditions. This applies particularly to drying, threshing, and milling equipment, which is often old, ineptly operated machinery designed for other purposes and causes much avoidable loss. There is also a particular need for low-cost simple cooling equipment, which could dramatically increase storage and marketing life of perishables.

There is a need for basic research, much of which should be conducted in cooperation with developed countries. It should include such topics as improved, biodegradable pesticides (insecticides, rodenticides, and fungicides) to be used in integrated systems of pest control, replacing toxic chemicals to which many pests are becoming resistant and which may be a threat to the health of people, livestock, and wildlife. The international agricultural crop research centers and national crop breeding programs should also consider the postharvest characteristics of new varieties when selecting crops for introduction to developing countries.

The study confirms that there is no known simple, inexpensive technology that by itself can make a profound impact on postharvest losses. On the contrary, postharvest food conservation can be achieved only through a

combination of location-specific organization, problem identification, training, information, and adapted technology. Good conservation practice must be applied on a sustained basis, with continual refinement as additional information becomes available. Significant worldwide reductions in food losses will result from the aggregate of these sustained national efforts, which should be given all possible support by the bilateral and international technical assistance agencies.

## Chapter 1

### Introduction

By the year 2000, world population is projected to increase from 4 billion to between 6 and 7 billion. Estimates indicate, however, that between 450 million and 1 billion people do not have enough to eat now and that this number is likely to increase by the end of the century (NAS, 1977).

To cope with current and future food demand, governments have traditionally emphasized two lines of action: reducing future demand by slowing population growth, and increasing food supplies by increasing production.

A third vital complementary measure, however--reducing the loss of food during and after harvest--has not been adequately emphasized.

In developing countries enormous losses result from spillage, contamination, attack by insects, birds and rodents, and deterioration in storage. Conserative estimates\* indicate that a minimum of 107 million tonnes of food were lost in 1976; the losses in cereal grains and legumes alone are an amount that would provide more than the annual minimum caloric requirements of 168 million people.

Billions of dollars have been invested to help developing countries produce food, but this has not been matched by investment--or by an awareness in developing countries of the need for it--either to determine what could be done to reduce losses, or to initiate measures to reduce loss.

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\*See Chapter 8.

Increased food production causes strain on present methods of handling, storing, and processing crops, and increased food losses will result unless developing countries and donors of economic assistance (a) establish and maintain adequate harvesting, storage, and handling practices, particularly in rural areas, and (b) create efficient policy and administrative infrastructures.

Neither the total magnitude of postharvest food loss, nor the extent to which it is avoidable are reliably known. Losses vary greatly and are a function of crop variety, pest and pest combinations, climate, the methods involved in the system of harvesting, processing, storage, handling, marketing, and the social and cultural setting. The importance of losses in particular localities varies according to the availability of food and the purchasing power of the various sectors of society.

Experts involved in the preparation of this report resisted extrapolating postharvest loss estimates to national or global levels because they cannot support general estimates with statistically significant data. When supplying information for planning purposes, however, the experts cite 10 percent as an average minimum overall loss figure for cereal grains and legumes, and about 20 percent minimum for perishables and fish. It is clear that food losses are important to poor countries not only in terms of quantities but also of nutritional and economic loss.

Many observers believe that a 50 percent reduction in postharvest food losses in developing countries would greatly reduce, or even eliminate some countries' present need to import large quantities of food. This reduction has been set by the VIIth Special Session of the United Nations General Assembly in 1975 as a target to be achieved by 1985. Annual production of

cereals by that time is projected to reach 450 million tonnes, and a 50 percent reduction of projected minimum losses might yield 22.5 million tonnes, valued at 3.7 billion 1976 U.S. dollars. Calculations for perishables and fish give additional minimum losses in 1985 valued at over 4 billion dollars, for total food loss valued at more than 11 billion dollars.

Food losses are highly locality-specific not only in amount, but also in impact: they must be evaluated in the context of the relative economics of food production, and of the relationship between food production and population growth. There is no doubt, however, of the importance of loss reduction to governments and technical assistance agencies as a means of increasing food availability at a time when constraints on production (land availability and costs of fertilizers and pesticides) are continually increasing.

Substantial postharvest losses also occur in developed countries. These losses appear to result from somewhat different causes than in developing countries, however. Many stem from consumer demand for a widely varied diet. Because of strict regulatory quality standards and consumer preferences, a large amount of food is not consumed because of slight changes in quality or appearance. Requirements for uniform packaging procedures result in heavy losses of irregularly shaped fruits and vegetables.

#### Charge and Objective

The United States Agency for International Development (AID) has identified postharvest food loss reduction as a key problem area to receive attention. In order to identify the most appropriate ways to allocate AID

funding, the Agency requested the Academy to undertake a study of post-harvest food losses.

The objectives of this study are:

1. To summarize existing work and information on food losses;
2. To discuss some of the social and economic factors involved in food loss and food conservation; and
3. To identify need for food loss assessment and food conservation, and to suggest alternatives for food conservation policy and programs for developing countries and development assistance agencies.

The study does not prescribe conservation projects or practices applicable to all developing countries, since remedies must depend on each country's particular circumstances and priorities. Rather, the study reviews alternative possibilities for reducing losses, presenting them in a way that may help decision makers to understand more fully the possible consequences of various courses of action.

The report is aimed primarily at the decision maker--in both industrialized and developing countries--who is responsible for resources that might be allocated to food conservation and who seeks a comprehensive overview of the postharvest system in developing countries. It, therefore, includes background and basic technical, socioeconomic, and cultural information.

The report is also designed to provide a basic introduction for the technical person not familiar with the field. References and suggested reading are included to indicate further sources of information.

To initiate and direct the study, the Academy appointed a Steering Committee whose members have experience with both the technical aspects of



postharvest food conservation in developing countries and the broader scientific, social, and economic context.

The Steering Committee met three times. The first meeting agreed on the outline of the study and identified key issues. With these guidelines established, compilation of a bibliography was begun and information solicited from large numbers of experts.

For the second meeting, an international group of experts was invited to join in an examination of the key issues and the roughly assembled study material. On the basis of these discussions, a final draft was prepared by NAS professional staff members for discussion at the third meeting, with subsequent review under the Academy's report review procedure.

#### Scope of the Study

Throughout this report, emphasis is given to the major food crops, identified on the basis of estimates of their levels of production in 1976 (FAO, 1977a). From the outset, the study focused on the basic categories of foods--cereal grains and grain legumes, nongrain staples, and perishables and fish--in rough proportion (60:20:20) to their relative importance and the amounts of information believed to be available about their postharvest problems.

Since Congress has directed AID to devote priority attention to the poorest people in developing countries, the study focuses on the needs of rural farm facilities. Emphasis on the farm sector, moreover, is logical in terms of production patterns; a large portion of all food crops in developing countries remains on farms and in rural villages and never enters the commercial market.

TABLE I:1. Major Food Crops, World and Developing Country\*  
 Ranked in Order of Estimated Production (from FAO, 1977a)

WORLD			DEVELOPING COUNTRIES		
CROP	'000 Tonnes	PERCENT	CROP	'000 Tonnes	PERCENT
Wheat	417478	15.67	Paddy	186230	21.36
Paddy	345386	12.97	Cassava	103486	11.87
Maize	334014	12.54	Wheat	95048	10.90
Potatoes	287554	10.80	Maize	73328	8.41
Barley	189654	7.12	Banana/ Plantain	55199	6.33
Sw.Potatoes	135855	5.10	Coconuts	32664	3.75
Cassava	104952	3.94	Sorghum	31173	3.57
Soybeans	62117	2.33	Yams, Taro, etc.	28777	3.30
Grapes	59204	2.22	Potatoes	26909	3.09
Banana/ Plantain	56805	2.13	(Pulses)**	25997	(2.98)
Sorghum	51812	1.95	Citrus	22040	2.53
(Pulses)**	51522	(1.93)	Millet	21452	2.46
Millet	51461	1.93	Barley	20775	2.38
Citrus	50843	1.91	Sw.Potatoes	17630	2.02
Tomatoes	40802	1.53	Soybeans	13842	1.59
Coconuts	32895	1.23	Groundnuts	13502	1.55
Yams, Taro, etc.	29530	1.11	Tomatoes	12755	1.46
Rye	27660	1.04	Grapes	12720	1.46
Groundnuts	18495	0.69	Mangoes	12556	1.44
Dry Peas	13427	0.50	Watermelon	10436	1.20
Dry Beans	12580	0.47	Dry Beans	8537	0.98
			Onions	6474	0.74
Percentage of Total World Food Crop Production		88.14	Percentage of Total Developing Country Food Crop Production		94.39

\* Developing market economies as defined in the FAO Production Yearbook (1977).

\*\* Pulses--total legumes except soybeans and groundnuts.

As a corollary to the AID emphasis on crops grown and consumed in the poorest farm sector, it was agreed to exclude primarily commercial food crops--the beverages (tea, coffee, cocoa) and other plantation and export crops such as bananas and sugar cane. All of these commodities are mainly the province of private enterprise; presumably, the entrepreneurs give postharvest loss appropriate attention, at least by comparison with the nonmarket food crop sector.

Meat and dairy products have also been excluded from the study. It was agreed that they pose special kinds of loss problems related to the provision of a storage and distribution system: if such a system exists, it operates more or less efficiently with pasteurization and refrigeration; if it does not, there is little incentive for production beyond immediate, usually modest, needs and the products are consumed quickly with minimal loss.

The study is directed toward losses occurring either in unprocessed food or in food commodities that have undergone "primary" processing. Primary processing is a series of steps (taken mainly on the farm with women taking much of the responsibility) by which the raw foodstuff is converted into a basic edible commodity by being treated or separated from inedible constituents. Rice, for example, is harvested, dried, stored as paddy, hulled and polished (rice hulls are not losses because they are not food, but rice bran may be), or parboiled. These steps involve weight loss that may or may not include food loss, depending on definition.

There are further processing steps--"secondary" processing--in which the basic edible commodity is converted into other forms before being consumed, such as baking, brewing, or canning. The study concentrates on the losses occurring from harvest through primary processing rather than on secondary processing, a decision made for two reasons:

- Secondary processing takes a large variety of forms. Keeping track of the commodity as it moves through various stages in this part of the food chain makes the estimation and quantification of losses a daunting prospect.

- In secondary processing, the commodity is normally in the hands of commercial, village, or domestic processors. Losses are likely to be relatively small (compared to storage losses, for example), and to the extent that commercial enterprise is responsible, they are probably minimized as much as the available resources and economic incentives warrant.

Though meat and dairy products are excluded from the study because of their perishable nature (except for cheese) and urgent storage demands, fish is included. This decision was made because of the importance of fish in the world diet (in which it supplies 17 percent of animal protein consumed) and because losses after "harvest" are similar to losses in other perishables resulting from problems of rapid deterioration, preservation and drying technologies and storage.

#### Definitions and Boundaries

Certain key words must be defined to avoid confusion. Perception of loss is highly subjective and location-specific and the formulation of unambiguous definitions difficult. The definitions that follow are the consensus of a large number of knowledgeable individuals who recognize the need for bringing some uniformity to the use and meaning of commonly used terms. The definitions are based on those articulated by Bourne (1977).

## Food

Food is any commodity eaten and produced or harvested to be eaten by a particular society. It is measured by the weight of edible material--calculated on a specified moisture basis--that has been harvested, gathered or caught intentionally for human consumption and that is consumed by the population of the area under consideration. For the purpose of this study, primary attention is focused on the major food crops--cereal grains, grain legumes (the "durables"), and root crops, with secondary consideration given to perishables and fish.

## Harvest and Postharvest

Harvest is the single deliberate action to separate the foodstuff (with or without associated nonedible material) from its growth medium--reaping cereals, picking fruit, lifting fish from water -- and all succeeding actions are defined as postharvest actions.

The postharvest period of time, thus, begins at separation of the food item from the medium of immediate growth or production. It is defined here as ending when the food enters the process of preparation for final consumption. This period also corresponds to the agricultural marketing and distribution period in which "crop protection" activities have ended, but before meal preparation activities begin.

Fruit becomes postharvest after it has been picked. Fruit that falls from the plant and is allowed to rot on the ground is not a postharvest loss because it was never harvested. However, if fallen fruit is collected for use, it becomes subject to postharvest loss assessment.

## Loss and Damage\*

Loss is the decrease measured as a reduction in weight in the amount of food available for consumption. We are concerned here only with losses that could be avoided or reduced given the right conditions under the constraints of the society in which they occur. Economic considerations may lead to situations in which it is not desirable to reduce loss that could technically be avoided.

Damage is physical spoilage, often a partial deterioration or one subjectively judged and very difficult to measure; it is usually reported as a percentage of the food sample. Damage of a crop sample is not usually the same as weight loss and is usually not as useful or precise a loss indicator as percent weight loss.

Unused foods that are taboo are not held to be lost; neither are foods used in ceremonial or religious rites. Nonutilization and underutilization of items not now recognized as food are not considered loss, though this is an important area of study that should be addressed elsewhere.

It is important that loss definition be location-specific. Cultural differences create problems in defining loss; what is considered edible, a delicacy even, in one area (fermented bean curd, for example) may not be viewed as food in another. Loss definition may even be time-specific, with items rejected in times of plenty consumed in times of want--for instance, spoiled-grain bread on the Trans-Saharan trade route.

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\*For a fuller discussion of this topic, see Chapter 3.

## Assessment, Estimation, and Measurement

These terms are used in the literature to describe different kinds of processes undertaken with varying degrees of confidence to determine losses. They are used here as follows:

Assessment is used to denote the rough quantitative approximation of food loss or for characterizing the relative importance of different points of loss in a particular food chain. Implicit in the use of this term is subjective judgement required because of insufficient information.

Measurement is a more precise and objective process by which quantitative facts about a loss situation are calculated. Implicit in this process is the belief that the same procedure applied by any observer under the same circumstances will yield the same result. This does not mean that the accuracy of the result is necessarily higher than that of an assessment--the accuracy will depend on the method of measurement itself, while the accuracy of an assessment can only be borne out by subsequent measurement.

Estimation is used to describe the process of interpretation of a number of scientific measurements, and thus requires that experience and judgement be brought to bear on the factual information under consideration.

## Waste

Waste or wastage are terms included here because they are commonly used elsewhere. However, they cannot be precisely defined since they involve subjective and even moral value judgments and depend on the context in which they are used. They should not be used as synonymous for loss and are probably better avoided.

## Bibliography

The need for a survey of bibliography material was recognized and is included in the study's terms of reference.

As collection of postharvest technology references proceeded, it became evident that, contrary to expectations, a large amount of material exists that in some way touches upon loss estimation, food preservation, or storage technologies.

This material was organized by major categories: Food commodity loss estimation, conservation technology, and loss vector. The limited time available and the volume of material precluded extensive cross-referencing, but country indexes are appended.

The present bibliography of some 2,500 entries and 250 pages is recognized to be a working document. Two hundred and fifty copies have been distributed to institutions actively pursuing research on postharvest technology. Additional copies are available through the National Technical Information Service (NTIS). The information has also been entered in the FAO AGRIS computerized information store and can be retrieved by referring to AGRIS catalogs.

To serve the needs of readers who may desire an overview of particular aspects of the postharvest food loss problem, but who have neither the time nor the interest in examining large quantities of information of uneven relevance or quality, selected reading lists have been provided at the end of the major sections of the report. These lists represent the opinion of experts on the various topics as to the items in the literature that are informative, comprehensive, and well-written.



## Chapter 1

## References

- Bourne, M.C. 1977. The Neglected Dimension in Increasing the World Food Supply. Cornell International Agricultural Mimeograph 53. International Agriculture, Cornell University, Ithaca, New York
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## Chapter 2

### Cultural and Socioeconomic Aspects

This report emphasizes the technical aspects of postharvest food losses. Much of the discussion, following the mandate of the study committee, concerns the methodology of loss reduction, the technology of primary food processing and food storage, and the body of knowledge on food pests and the physiological deterioration of food. The study committee is fully aware, however, that prevention of postharvest food losses necessarily involves more than technical issues. Cultural, economic and social factors strongly affect the nature and magnitude of food loss and the attitudes of farm families and governments to food conservation. Past experiences with agrarian reform have demonstrated that programs must be sensitive to the cultural, socioeconomic, and political characteristics of a society and that the technical and scientific components of change cannot be divorced from the social context within which they are applied.

The resources available to the committee did not permit a systematic examination of knowledge about cultural change and the conditions that facilitate it. This discussion does not represent, therefore, a thorough examination of the social, economic, and educational issues that need to be considered in an approach to food conservation. It is intended, rather, to emphasize the importance of these issues, to point out some of their

implications, and to stress the need for planning now to conserve food,

### Cultural and Social Factors in Food Conservation

The causes of food loss are linked in many complex ways to beliefs and attitudes which underlie traditional ways of managing the postharvest system but which also complicate change. These factors must be carefully examined and understood before new conservation technologies and practices can be successfully introduced.

Under traditional farming conditions, the postharvest system of storing and handling crops is suited to the type and level of crop production in which it has evolved, often through a harsh process of natural selection. The levels of production and conservation of food are constrained by the resources available to the farm family, and there may be limitations on the time or labor available on the farm or in the village for incorporating changes to the established seasonal cycle of events. Furthermore change may be perceived as a threat, and resistance to it may be strong. In many societies, for example, there may be much reluctance on the part of individuals or groups to relinquish established controls over food storage and other practices that are linked to security and status. Traditional practices, therefore, are not likely to be abandoned unless new technologies and methods are demonstrated and perceived to be effective improvements, and also do not result in intolerable strains on social structures, income levels and distribution.

Despite the understandable, and justifiable, conservatism about established postharvest practices, change is inevitable. Population increase may strain food resources, and lead to introduction of new crops or new varieties and other inputs for production. Such changes will strain the existing capacity to handle the additional food, and create possibilities for increased levels of loss at all stages of the postharvest system. What is required, therefore is to harmonize the perception of change and needs with possible approaches to satisfying them.

The conditions that foster the incentives necessary to stimulate change vary over time and between cultures. Past experience suggests, however, that certain conditions can turn people against technical "improvements" to food conservation. For example:

- Price depression that may result from increased availability of food;
- Taxation, especially tithes on amounts of food stored;
- Fixed quotas for commodities to be purchased after harvest;
- Inadequate means of storing or marketing surplus production; and
- Problems in reaching larger markets, such as lack of feeder roads or inadequate transportation arrangements for fish and perishables.

A list of conditions that mitigate against food conservation draws attention to the importance of national policies. Past experience suggests that the effectiveness of intervention depends on adequate communication between central governments and local communities. Governments must have adequate information for planning and decision making. It is for this reason that the committee places special stress on the need for national policy bodies concerned with postharvest food losses. Such bodies can take account of the large range of local interests involved and can examine

the technical and scientific considerations against local conditions and attitudes. It would then be possible for national governments to decide how postharvest losses rank in terms of national priorities. The decision to act to reduce losses involves not only complex social considerations, but also economic considerations, some of which are discussed below.

#### Economic Factors in Food Conservation<sup>\*</sup>

Postharvest losses can arise from a number of causes that fall into three main categories each of which has economic implications:

- Physical loss that can be measured by weight;
- Loss of quality (including presence of contaminants), with changes in appearance, taste, or texture that may cause the food to be rejected by potential buyers; and
- Loss of nutritional value; these may affect the subsistence farmer, the farmer who produces food for sale, and the consumer. Although any losses will ultimately be felt by society as a whole, individual groups are likely to experience the economic consequences to different degrees. Further, strategies to prevent or reduce food losses have economic effects on other groups involved in food preservation and processing, in addition to the producers or owners and final consumers of the food.

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<sup>\*</sup>Discussions on economic losses are based on work by Adams and Harman (1977)

Many kinds of costs may be associated with postharvest losses, and it is important to assess these costs as thoroughly as possible for an accurate picture of possible economic consequences.

Individuals or private organizations normally make decisions about dealing with food losses on the basis of economic consequences alone; governments, however, are faced with decisions about losses that will involve consideration not only of economic consequences, but also of social responsibility and national development goals. Clearly, there is no simple "right" answer for complex and changing situations, but understanding of the economic consequences of postharvest food losses can help illuminate feasible answers and eliminate unsuitable ones. These consequences differ at the production, or farm, level and the broader social level; both contexts will be discussed below.

#### Economic Loss at the Farm Level

For the individual farmer, economic loss is usually expressed in monetary terms and may result when physical, qualitative, or nutritional loss occurs. For example, a farmer may store grain to sell at a later date; if a portion is eaten by rodents or is damaged and becomes unsalable, the farmer loses income he would otherwise have gained. (It should be noted, however, that the example just given could result in an economic gain where the general availability of a commodity declines and the price rises as a result; in such a situation the total income of some individual farmers may be increased.) In a similar storage loss situation, a subsistence farmer might be forced to buy extra food to replace his lost supplies and the cost of this food would be a loss. His diet would also suffer if the food lost nutritional value.

It is also possible for the farmer to avoid an economic loss even though his commodity has suffered a loss of quality or nutritional value. If such losses are not detected or the consumer, for whatever reason, is willing to purchase the commodity at prices unaffected by the qualitative changes, the farmer experiences no loss of income.

For the farmer, costs related to postharvest food loss may be considered as direct or indirect and these costs are discussed in Note II-1.

#### Economic Loss at the Social Level

Food loss also has implications, of course, for the buyer and the consumer and thus affects the society or the nation as a whole. (Strictly speaking, the economic implications spread throughout the entire world, but they generally are analyzed at the national level.)

For purposes of this discussion, losses at the national level are defined as social losses. Although the economic implications of post-harvest losses will be considerably more difficult to appraise at the social level than at the farm level, the causes and consequences of social loss must be recognized.

The difference between postharvest loss consequences for the individual farmer and for the society as a whole can be shown through examples used earlier. A farmer may not suffer economic loss, for example, if he sells his crop at normal prices even though nutritional value has been reduced, but society incurs a loss through the possibility of poorer health because of nutritionally inferior food resulting in lower productivity.

Conversely, society may benefit when the individual farmer bears an economic loss. Farmers could, for example, take steps to improve grain

storage that involve substantial costs to each farmer. In the short term, there could be a surplus of grain and a lowering of prices so that the farmers, individually and collectively, would lose while consumers benefited. There may also be effects on secondary groups, other than farmers and consumers: e.g. basket-makers making storage containers may be displaced by the introduction of metal bins.

Social gains or losses also fluctuate in relation to external influences, notably the world market price for the commodity and the availability of food from external donors on concessionary terms.

#### Evaluation of Economic Costs

This report emphasizes the importance of knowing as much as possible about the actual quantitative or qualitative extent of postharvest food losses in any given situation in order to make reasonable decisions about corrective action. The requirement for intelligent decisions is knowledge about the costs involved in various losses; to the extent practicable, loss situations must be carefully evaluated in economic terms.

#### Farm Level Costs

Some illustrations of economic evaluation at the farm level may be helpful.

A subsistence farmer may become short of food before the next harvest and be forced to buy it for sustenance. The money spent or the goods bartered for the purchased food are a direct cost. If the money to buy food comes through a loan, the interest paid is also a direct cost. If food has been damaged in storage and the farmer must sell when the price is low because he lacks alternative storage, he incurs a direct cost equal to the price he would normally have received less the price received from



the forced sale. In some instances, a farmer who runs short of food may be helped by donations from friends or relatives. Although his own direct costs may be negligible as a result, the cost to the donors must be included in a complete evaluation.

Costs incurred through loss of quality in a commodity may be difficult to identify. If the loss of quality causes complete market rejection, then the extent of the loss is reasonably clear. In less clear-cut situations, the analysis may be aided if the crop happens to be graded, with different prices for different grades. In the case of quality loss in animal feed-stuffs, costs will vary depending on the value of the substitute feeds used or available.

Nutritional losses due to deterioration of food which is nevertheless still consumed are difficult to evaluate in economic terms, although it is recognized that they can have an adverse effect on health and productivity. It is possible to assess the protein and vitamin content of certain harvested crops in their premium or undamaged condition and assess later decreases against the premium standard. An evaluation of this nature, however, is essentially subjective, and interpretations based on such data should be presented separately from other aspects of a loss evaluation.

#### Social Costs

One farmer's postharvest loss will have little social consequence, but the total of all farmers' losses can represent a significant social cost. Typically, evaluation of these social costs follows a similar approach as that used for those of an individual farmer: the consequences of loss are analyzed as thoroughly as possible and appraisals are made on that basis.

The values assigned to postharvest food losses can be based on the prices (using international exchange rates) at which the commodity could be traded by the country concerned. If production of the commodity has been great enough to meet internal or domestic demand, then a surplus is available, at least in theory, for export. Losses that occur can be calculated to have cost the amount of foreign exchange sacrificed by the reduction of exports.

Conversely, if a commodity is not produced in sufficient quantities to meet domestic demand, some amount of the commodity, in theory, will need to be imported. Losses can be valued at the cost in foreign exchange of importing greater quantities of the commodity equal to the losses.

Just as individual farmers bear indirect costs in coping with or trying to prevent postharvest losses, indirect costs also can be incurred by society. Measures taken to prevent food losses, rather than those resulting from actual losses in a particular season, have indirect costs. The costs of extension staff who advise on improved postharvest handling and storage of crops are an example of indirect costs, as would be the costs involved in inspecting and grading produce to reduce losses. Indirect costs to society can present problems in economic evaluation, however, because they frequently involve multi-purpose activities and the costs cannot be attributed solely to loss prevention purposes.

#### Cost-Effectiveness Analysis

To the extent that prices can be attributed to postharvest food loss prevention or reduction activities, cost-effectiveness analysis can be a useful technique for evaluating the cost of reducing a unit of food loss and the quantity of units that can be affected within a fixed budget. This

analytical approach can indicate which activities could affect the most units within a fixed level of resources. An example is given in Note II-2.

While cost effectiveness analysis can be a useful analytical tool when reasonably good information is available on costs and anticipated results, it is only one factor that policy makers and program planners must consider. Other elements that must be included in the decision-making process are such factors as the socio-cultural acceptability of possible programs, overall national development priorities, and the impact of possible programs on social and economic matters beyond postharvest food losses. The next section discusses some of these additional impacts.

#### A Special Approach to Cost-Benefit Analysis

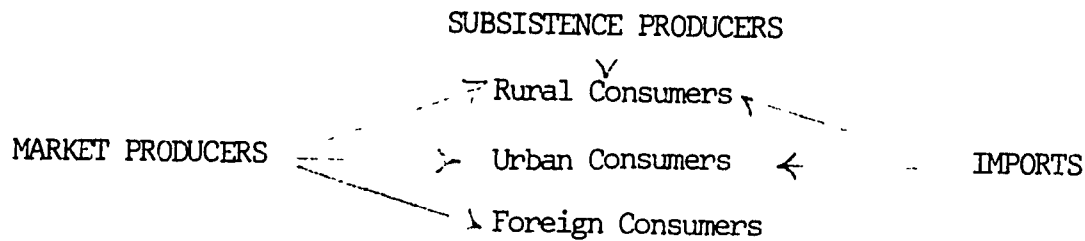
In a background paper commissioned for this report, Martin Greeley demonstrates the way in which social cost-benefit analysis supports concentration of loss reduction in the rural traditional part of the post-harvest system.

Greeley points out that differences exist in measuring costs and benefits for a private entrepreneur and for the public sector for an investment in loss reduction. The entrepreneur is concerned with private profitability. For public sector investment, the purely financial considerations are only one aspect of evaluating the investment.

In the public sector, investment in food loss reduction programs must be considered in terms beyond the primary objective of loss reduction and increased food supply. The secondary--but vitally important--objectives may include effects on employment (including employment of women who are often displaced by mechanization), income distribution, nutrition, social stability, and balance of payments. Their existence necessarily requires that the financial cost of achieving a given level of postharvest loss

reduction be only one element of evaluation. Poorly conceived programs of loss reduction can impose social costs that negate the benefits derived from the saving of food. Well-conceived programs, on the other hand, may not only save food, but also help to provide jobs and distribute income more widely (thus increasing food purchasing power) and to save foreign exchange by reducing food imports. The social benefits in such cases can often be of greater weight than the investment in loss reduction activities.

The postharvest food sector is depicted in the following diagram:



As shown, there are three major sources of food and three major types of consumer. Each arrow represents an element or sector of the total post-harvest system.

The sectors are not always independent in physical and operational terms; a rural miller, for example, may have as customers both subsistence and market producers. The sectors do, however, provide a useful division into target groups for program-planning purposes.

According to Greeley, the entire postharvest area has often been neglected in resource allocations and there is a need to improve operations at all levels.

For planning purposes it is helpful to establish priorities among the six sectors, which can be defined by the movements of food. These are discussed in Note II-3.

The use of social cost-benefit analysis suggests that, in general, governments should give greater emphasis to food conservation programs for the traditional sector. In many countries (especially in Asia), this sector has both the largest population and the highest total food production, meaning that with widespread food conservation techniques, substantial savings of food can be made even when percentage losses are relatively low. Furthermore, the producers and consumers in this sector comprise the largest poverty-level group in many countries, and therefore can provide a focus on the poor in national development activities. Because loss reduction activities may require some capital investment and must be perceived to provide practical benefits, governments may need to demonstrate and to subsidize these efforts. At the village level, good opportunities exist for using local raw material, labor, and artisan skills in loss reduction activities; these elements of a country's resources are relatively cheap and abundant, yet the opportunity cost--their value in alternative investments--is relatively low. Use of these rural resources, moreover, provides direct social benefits by generating employment and distributing income, in addition to reducing food losses for the benefit of poor farm families and consumers. Increased food availability in this sector can also provide the poorest farmers and farm women with access to, and perhaps integration into, the urban and export markets.

Thus, a persuasive case can be made that careful social cost-benefit analysis will support an increased emphasis on food conservation programs for the traditional sector. At the same time, it must be recognized that other demands will frequently have to be given short-term priority. Losses that affect urban food supplies, for example, are highly visible, often affect local political elements, and must be addressed with urgency. Other

short-term imperatives can take on equal priority. Moreover, in those countries where the majority of farmers are involved in market-oriented activities, a focus of postharvest food loss interventions in the subsistence or traditional sector assumes less importance.

Despite these cautions, social cost/benefit analysis is an important analytical methodology for evaluating postharvest food loss reduction activities in economic terms, whether or not those activities are directed toward the traditional sector. The results of such activities must be appraised in terms not only of the reduction in food losses and the costs of achieving those results, but also in terms of the effects of those savings on the beneficiaries and of the secondary and lasting impact on the country's overall development.

### Conclusions

Food losses are related to social phenomena, and ways should be found to incorporate governmental concern for food with the sociocultural implications of food loss and food loss prevention. Because food conservation bears similarities to other types of intervention into rural practices, the problems and successes of rural health delivery, agricultural extension, and other community development interventions at the village level should be taken into account by those who plan for food loss reduction.

The need to integrate new practices and revised technologies into village economies calls for a better understanding of traditional practices and, generally, of the conditions that facilitate or hinder corrective measures. Thus, there is a need for more research into the links among economic and cultural practices and food losses.

More understanding is needed of the effects of government financial policies (subsidies, price controls) on postharvest losses and incentives to reduce losses. Specific case studies are also needed that illuminate village-level problems, such as the impact of subsidies on the motivation to adopt new or changed technology.

There is a particular need for data on the costs of increasing the availability of food commodities through loss reduction. Such economic evaluation is essential for comparing food loss reduction strategies with other types of interventions as an aid to more effective planning and making decisions about development programs.

## Chapter 2

## Notes

## Note II-1.

In the examples given in the section, the losses are direct; the farmer has suffered a decrease in the quantity available for sale, his own consumption, or for barter. In all these cases a monetary value can be applied to the loss. Physical or qualitative losses may also cause other direct costs to be incurred by the farmer. A damaged grain crop, for example, may have to be re-bagged or re-sieved at additional cost.

Indirect economic costs result from measures taken to prevent physical losses. If a farmer takes steps to prevent future losses, he will normally make an investment of money and time in the expectation of a positive return. Or a farmer may prefer to plant an improved crop variety because of its good yields or marketing characteristics. If he is obliged to produce a different variety, however, because the improved variety does not hold up as well in storage, he may suffer some loss in satisfaction, which should be valued if possible. Indirect costs and losses are more difficult to estimate than direct losses and should be considered separately when evaluating food loss situations.



Note II-2.

In country X assume, for example, that the national postharvest policy unit wishes to know how to achieve the maximum amount of loss reduction for rice, working within a limited budget. Assume further that a program of introducing new rice milling machinery might reduce annual losses by 600 tons, on average, in each province affected, while a particular type of improvement in village cooperative rice storage facilities might reduce annual losses by 400 tons in each province. If the total budget available for loss reduction activities is \$2 million, and if the improved storage program costs \$200,000 per provincial project and the milling machinery program costs \$400,000 per province (assume equal rates of amortization), then cost effectiveness analysis would favor the storage program. This program could be used in ten provinces, reducing total losses by 4,000 tons, while the milling machinery program could be used in only five provinces, reducing total losses by 3,000 tons, as the table shows.

#### Cost Effectiveness of Food Loss Reduction Options

<u>Program</u>	<u>Loss Reduction Per Province</u>	<u>Cost Per Province</u>	<u>Provinces Affected Using Budget*</u>	<u>Program Effectiveness</u>
Storage Facilities	400 tons	\$200,000	10	4,000
Milling Machinery	600 tons	\$400,000	5	3,000

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\*Total Funds Available = \$2 million

Note II-3.

The sectors of the postharvest food system in order of importance for resource allocations are:

1. Subsistence producers to rural consumers. This can be called the traditional sector, in which the rural consumers are also producers themselves and labor and service employees are paid in kind. Inputs of capital are typically very low, and this sector is characterized by on-farm operations of crop processing and storage.

In many places in the developing world, however, there is an increasing trend toward market-oriented agricultural production, and many regions or countries have no identifiable subsistence or rural nonmarket sector in the strict sense. While small farmers may consume much of what they produce, they generally also market some portion to meet other requirements, often as barter. Even when farmers produce one crop entirely for their own use, they usually produce a second crop for the market. "Traditional," therefore, may be a more useful description of this socioeconomic situation than "rural nonmarket."

2. Market producers to rural consumers. This sector, called the rural private market sector, involves large-farmer commercial activities oriented toward monetary profit rather than subsistence food. More off-farm operations are involved than in the previous sector, and buying agents, millers and other processors, and wholesalers and retailers participate in the activity of this sector. Consequently, quantitative and qualitative food losses may be higher because of the additional transport and handling.

3. Market producers to urban consumers. This domestically produced urban sector represents the flow of surplus food from the rural production. In developing countries, distribution activities here are often dominated

by public corporations. Buffer stocks of foods are held within this sector and their size is a key variable determining the level of activity for the sector. Moreover, if the stocks are on occasion too large in relation to management capability and facilities, losses are likely to increase.

4. Market producers to foreign consumers. The export sector is generally the smallest of the six divisions and varies from small to non-existent, depending on the season and the country. Its importance is in the export of commodities to generate foreign exchange. The postharvest operations are generally similar to those of the domestically produced urban sector.

5. and 6. Imports to urban consumers and imports to rural consumers. Together, these two divisions are called the import sector. Food imports can be highly variable, and the organization of the required transport and handling facilities for imports may be redundant in times when they are not necessary. Long-range expectation for the mix between domestic and imported production thus requires high-level policy decisions based on risk calculations and other factors.

## Chapter 3

### Postharvest Food Loss Assessment and Estimation

#### Introduction

The United Nations General Assembly, reflecting international concern with ways to increase the world's food supply, in 1975 called for a 50 percent reduction in overall food losses by 1985. Progress toward this goal can be judged only through reasonable quantitative estimates of actual food losses. Loss estimation is also essential for establishing the programs that will reduce loss; at the national level, politicians and administrators must have reasonable information for their decisions on food conservation investment.

Yet, while the committee understands the need for quantitative estimates to justify budget allocations, we caution against undue emphasis on this aspect of the problem. Food loss estimation is a complex process with limited accuracy. Reliable average figures on losses for a region, nation, or period of time may be impossible to support with sound statistical evidence, for reasons to be discussed later in this chapter. Part of the problem is that standard methodologies for measuring and estimating loss are lacking for most kinds of food. A variety of estimation techniques do exist for grains, but considerable care must be taken both in choosing the descriptive terminology and estimation technique appropriate for a given situation and in using it.

Above all, care must be taken in extrapolating loss estimates from one situation to another, particularly in attempting to arrive at general national or global estimates. The dubious accuracy of food loss observations and their limited general applicability support use of an extrapolated average figure for loss estimates only under carefully described conditions.

In many cases, it may be unnecessary--or impossible--to make scientific estimates of loss. The sophistication of measurement required will vary widely in different situations, and assessment by experienced observers is often sufficient to justify loss reduction measures. In the commodity sections of this report, the opinions of qualified observers about average losses are included; these figures are conservative judgments of the specialists and should be used with caution.

At present, the greatest loss assessment need in many developing countries is for a coordinating body at the national level with an operating arm to identify where postharvest food losses are occurring and to undertake detailed loss assessment using standard methodologies. This structure will permit continuing review of the resources that should be allocated for reducing losses.

The personnel needed to carry on programs of food loss estimation in developing countries do not all require a high degree of technical skill. At the planning and supervisory level, however, it is important that responsible persons have a thorough grasp of the complexities of postharvest food processing and distribution, along with sufficient knowledge to call on the various disciplines needed for loss estimation programs.

Before we begin a more specific discussion, there are two general aspects of food loss estimation that deserve somewhat fuller treatment: the difference between "damage" and "loss", and the utility or applicability of loss estimates.

The distinction between what is considered to be damaged and lost food is often difficult to make and sometimes confusing. The subjective term "damage" denotes a condition that is not objectively measurable. It refers to apparent evidence of deterioration, and its importance to the consumer depends upon his affluence and cultural background. A poor family often has no alternative but to consume a certain amount of damaged food in its diet, whereas more affluent neighbors may be in a position to exercise selection.

With perishables, damaged portions of root, fruit or vegetables may be cut off and thereby actually lost for consumption. However, there will be stages of deterioration at which the consumer decides that the whole item should be discarded. It is clearly impossible to define the conditions under which a certain damage should in general be considered partial or complete. This is a culture-dependent decision.

"Loss," on the other hand, denotes disappearance of food and should be directly measurable in economic, quantitative, and qualitative or nutritional terms.

° Economic loss is the reduction in monetary value of food as a result of physical loss.

° Quantitative loss involves reduction in weight and, therefore, can be readily defined and valued.

° Qualitative loss can be difficult to assess because, like damage, it is frequently based on subjective judgements, but it can sometimes be described by comparison with locally accepted quality standards.

° Nutritional and germinative losses may be a combination of loss of quantity and quality, and thus is also difficult to measure.

Loss of food quality through deterioration, contamination, and changes in the composition of nutrients is important, and needs to be much better understood and measured. Presently identified quantitative food losses from whatever causes are of more immediate significance, however, since opportunities now exist to do something about the causes responsible for these losses.

As mentioned in the introduction to this report, quantitative food losses should be determined on the basis of the food's moisture content.

Quantitative estimates of food losses can be used to evaluate the potential of conservation activities:

1. To provide a basis for decisions made by developing-country governments and international agencies about the allocation of resources for food production, and postharvest activities such as storage, processing, and marketing;
2. To furnish information necessary in determining the locations and types of activities that may be effective in reducing losses; and
3. To increase knowledge and understanding of food supplies.

#### Relationship Between Usefulness and Accuracy of Loss Assessment

Despite the limitations inherent in the accurate identification of food losses, properly selected estimation methods can provide information essential for reducing losses. Widespread sampling procedures can be used, for example, in which untrained observers gather information according to a prescribed format. Although the accuracy of the individual loss estimates may be low, large numbers of such observations can provide a useful basis for more general estimates and for decisions involving extended geographical regions or a substantial number of food stores.

The example of large scale surveys raises the question of how much accuracy is necessary to make loss estimates that are generally useful. The answer to the question depends upon the purpose to which the estimates are to be put.

Using survey procedures, the range and level of confidence of the individual result is less important than the overall picture that emerges. If, however, the objective is to determine losses in specific large-scale food storage or processing facilities and to institute conservation measures affecting large amounts of food over a number of seasons, then the accuracy of loss assessment should be as high as possible. Technologies exist to store almost any food indefinitely, but economic, social, and political factors influence the selection of the technology for a particular commodity and place. Often the type of storage--and the consequent amount of loss--represents a compromise among factors of storage cost, desired food quality, and the anticipated storage period required.

On another level, for traditional on-farm storage situations the degree of accuracy of loss estimates is likely to be low, as are resources for available corrective measures. Here loss estimation is limited by the variety and dispersal of storage facilities among families and villages in a given area and by problems both in sampling procedures and in making generalizations based upon individual observations. These problems are likely to be exacerbated by the reluctance of farmers to provide information and by the efficiency of the traditional storage methods.

Experienced observers agree that in many developing countries storage losses of grain stored at the farm level are often relatively low, perhaps on the order of 8 to 10 percent. If losses at the farm-storage level are of the same order or smaller than the accuracy achieved by reasonable



estimation procedures, it is obvious that good estimates for a region or a sector of agriculture cannot be made with any degree of precision by generalizing from farm data until the number of observations is large and taken over carefully sampled areas. As amounts of grain stored become larger, the potential accuracy increases and there is less need of subjective judgement.

The limitations of food loss estimation at the farm level lead to the concept of "sound conservation practice" which says that, although it may not be economically sound or practical to determine precise food losses, certain food conservation practices nevertheless are justifiable and sound on the basis of common sense. These could include such things as making sure storage bins are completely cleaned out between seasons, or providing shade and appropriate containers for transporting and marketing perishables.

Food is such a vital resource in a world of growing population that reasonable measures to conserve it should be taken even though detailed information on exact losses may be lacking. Furthermore, although losses at the level of individual farms may be relatively low, in the aggregate the savings that result from improved food conservation can be considerable.

The complexity of procedures used in estimating food losses should be in relation to the risk of loss and the quantities of food involved in the situation under study. Further, existing data and the opinions of experienced observers may be useful in formulating a "commodity loss profile" in which loss problems for a particular commodity are approximated. The approximation can also help identify areas where losses are higher than would be expected with sound conservation practices and, therefore, require detailed attention.

These introductory paragraphs have described some of the limitations and choices involved in the estimation of food losses. However, a considerable effort has been made to develop specific loss estimation methodology and procedures. The remainder of this chapter will examine what is known, what is in the process of being developed, and, finally, what needs to be done.

### Loss Estimation Methodology

The production, processing, and distribution of food involve a system of movement that is always locality-specific and usually very complex, consisting of many stages. Regardless of the nature of the system, however, certain food losses always occur within a system.

Often there is a clearly apparent need to estimate food losses. It may be readily seen, for example, that rodents or insects are attacking stored grain, and the general extent of loss must be determined to decide whether pesticide treatment is warranted. In many other situations, however, intuition and observation may indicate that food is being lost in the system, but the specific weak points, loss causes, or quantities are not known.

The more that loss estimation is analyzed, the more it is apparent that there neither is, nor can there be, a simple technique, method, or procedure that can be universally applied. The movement and storage of commodities between production and consumption is seldom an easily analyzed flow. Irregular movement and mixing of various batches in postharvest operations make sampling procedure and generalizations difficult. Yet, sampling procedures must be defined precisely according to the particular situation.

Estimating losses in a given situation should be designed so that the methodology is meaningful, economically sensible, and culturally appropriate. Analysis of the results should be directly usable for decisions regarding loss reduction. It is reasonable and important, therefore, to integrate the process of reducing losses with the process of loss assessment. At the farm level, for example, the limited resources available for estimation should also be applied to reduction to be credible to the farmer; estimation must not be seen as an end in itself.

For a variety of reasons, more techniques have evolved for the estimation of grain losses than for other major food categories. These reasons will be examined in greater detail in subsequent chapters on specific commodities; suffice it to say here that these techniques reflect the importance of grains as staple foods, the relative physical uniformity of specific grains, and the relative ease of storing grain.

Grain loss estimation methodology has recently been the subject of a manual prepared by Harris and Lindblad (1978) for the American Association of Cereal Chemists and the League for International Food Education, supported by funds from the Agency for International Development. The manual is designed to be widely used in developing countries to encourage standardized loss assessment procedures so that results from observations carried out in different locations can be more easily compared. This valuable document has been written in consultation with grain loss experts involved in the major national and international programs around the world, many of whom were also involved in the preparation of the present study. Thus, these two AID-supported projects are complementary--the manual designed for those directly involved in grain loss estimation, and this study designed to cover a wider range of subject matter for a more general audience.

A number of useful techniques and approaches have been developed for problems of food loss estimation. These techniques can be applied in situations ranging from a broad analysis of where losses occur and at what rough levels of magnitude, to sampling and estimation procedures yielding rather precise loss figures. The techniques, described in the following paragraphs, include (a) overall assessment of the commodity movement system, (b) field investigation of losses, and (c) loss measurement (or "experimental estimate").

The following pages describe the major methodological aspects of loss assessment, including the inherent problems and limitations and future needs. Those seeking more detailed information on procedures for grains should consult the Harris-Lindblad manual directly.

#### Overall Assessment

Overall assessment of the commodity movement system means a search for the points where the most acute food loss occurs; it implies study of the whole physical and social system in which the food moves from producer to consumer, and will identify how the commodities are handled (size, number of steps, etc.) and the number of participating middlemen. Its objective is to permit judgements to be made about the possibilities for loss reduction interventions. From the loss assessment and reduction perspective, it may be helpful if a national policy body existed to deal with postharvest loss problems, to coordinate the efforts of national and international assistance agencies, and to gather and analyze loss information. Relevant loss information can be obtained from a variety of sources:

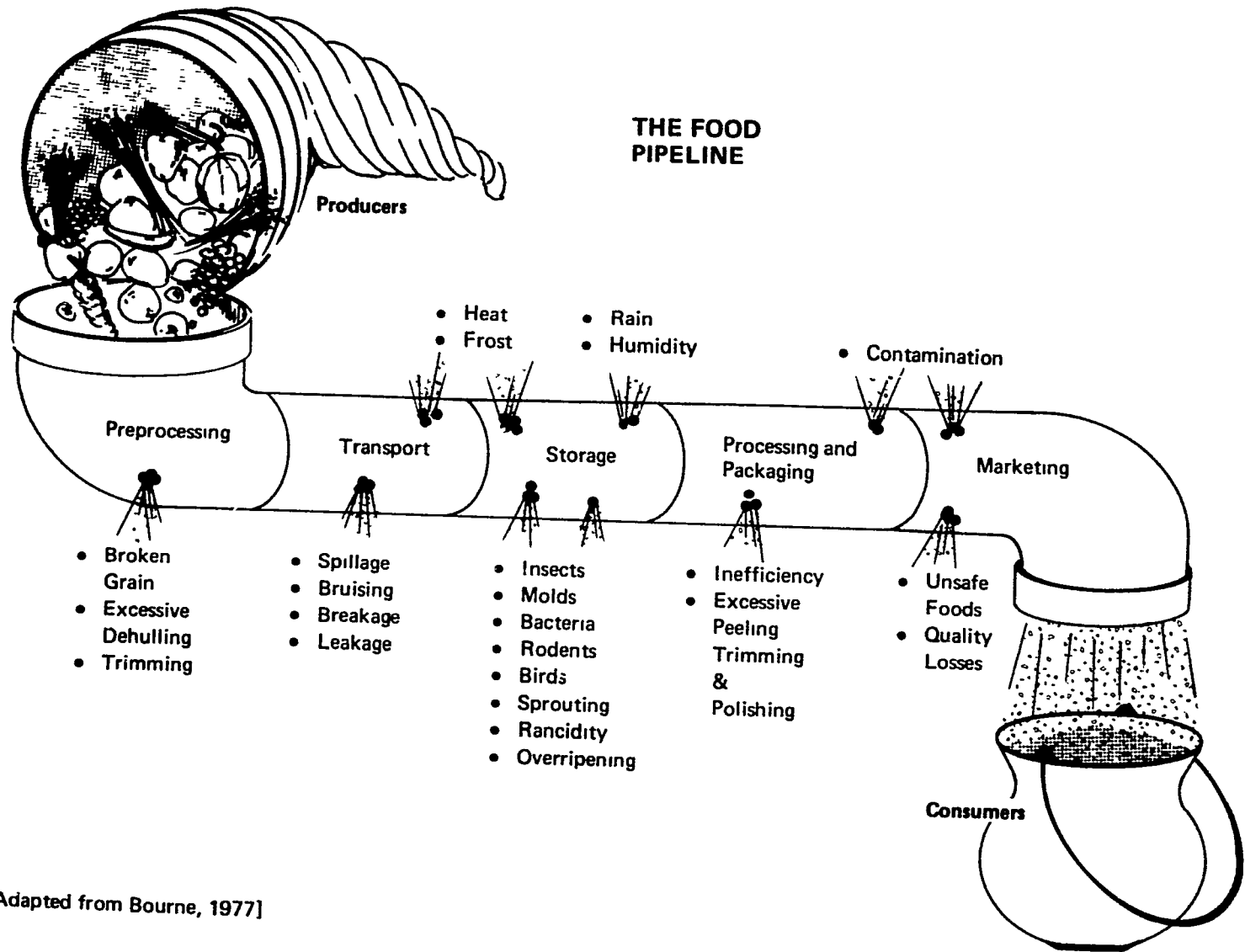
ministries of agriculture, central statistics organizations, university faculties of agriculture and economics, transportation agencies, marketing boards, commercial organizations, and farmers' cooperatives.

Locality- and commodity-specific information is needed to develop a "commodity loss profile" describing the movement of a commodity through the system and highlighting points of potential or actual food loss.

Figure 3:1 depicts in cartoon form the "food pipeline" and the physical and biological ways in which some losses occur. It must be emphasized, however, that the actual movement of food from harvest to consumer may be simple, or may involve a much more complex system than a cartoon can represent. Movement can be irregular or can be halted for long periods of time; batches of a commodity can be divided and routed through the system by very different paths and schedules; infusions of a commodity can be made into the system from different sources.

The "pipeline" also has a number of different kinds of materials. There are the human and the mechanical parts of the pipeline, the chain of hands and the line of transport vehicles down which the food passes with greater or lesser efficiency speed and ease; the food in the pipeline is propelled by socio-economic, and political forces; regulations and other bureaucratic procedures slow down or accelerate the food's passage from producer to consumer.

Despite the complexities of the system of commodity movement, experienced professionals can make useful estimates of losses and identify possibilities for loss reduction. Simple observation procedures, for instance, of such visual indices as insects, mold, leaking roofs, etc., may be all that is necessary. Further, such items as the use of pesticides or the type of storage facility can provide a knowledgeable person with a basis for judging where and what magnitude of losses occur.



[Adapted from Bourne, 1977]

The ultimate use of a commodity also bears on loss estimation. Harvested grain may be divided into several lots for different purposes, with each receiving different treatment--some dried and stored for long periods as seed, and some held only for short-term storage and consumption or movement off the farm. Different levels of risk of loss would be involved for the different uses; farmers frequently consume their low quality grain first, since it is known to be subject to the most rapid loss.

These observations enable the trained observer to develop a "commodity loss profile" for a particular commodity: such a profile would indicate the final uses of the commodity, the channels through which the commodity travels to final use, the points at which losses occur, and rough estimates of the relative magnitude of the losses. It should be pointed out that complete information on food handling frequently is not collected, but the data is critical, i.e., the number of handling steps involved, the number of middlemen handling the food (with inevitable losses) at each step. It is only this kind of complete information that will enable the expert to judge with confidence what should be investigated and where priorities are to be assigned.

#### Field Investigation of Losses

This kind of investigation typically results from analysis of critical points of potential or actual loss in the commodity loss profile.

The first step is to develop methodology for the particular objectives of the investigation. Loss assessment projects frequently have suffered from poorly defined objectives and from lack of experimental control. In addition to objectives, the project must have a pattern that

is replicable so that loss comparisons can be made. Comparisons must be statistically valid and must be undertaken within a logical framework of field investigation and scientific measurement.

There are two aspects to field investigation: the survey and sampling procedure.

First, a survey is made of farms, villages or areas to determine the locations at which the loss assessment will take place, the parts of the postharvest system to be investigated, and the farms or villages from which samples will be taken. A recognized statistical procedure should be employed for selecting farms or villages if it is intended to apply the resultant loss data to an estimate of loss over the area as a whole. Adams and Harman (1977), for example, recommended stratified random sampling in connection with their assessment of losses of maize in Zambia.

The method of sampling a commodity is the way in which the sample is removed from the location under investigation, such as farm or village store. Specifications of sampling procedures is frequently missing from the post-harvest literature, yet is a critical dimension of loss estimation procedures.

If the purpose of sampling is to estimate the loss in all the produce in a store at a particular time--for example, during one or two visits in the season--then the sampling must be carried out on all the produce in the store. If sampling is undertaken at regular intervals over a season, on the other hand, then each sample should be taken only from produce being consumed between samplings; to remove other samples would disturb the natural process of loss.

The size of a sample is limited by practical considerations, including whether or not the sample is being removed for analysis and returned to the store. (With maize, for example, Adams and Harman (1977) suggest samples of 10 cobs or 1 kg as a reasonable quantity.)



Sampling of stored grain also must take into consideration removal of the commodity from the store for normal consumption or sale. Large losses quoted in the literature often reflect heavy damage to a small amount of residual stored commodity at the end of a season, while in fact total weight loss of the original crop may be much smaller.

#### Estimation of Total Losses

After calculating losses in commodity samples, the investigator still faces the problem of estimating total loss in the entire lot under scrutiny. In making such estimates, it is important to relate losses to the pattern of consumption. If, for example, food is left untouched throughout the storage period and at the time of removal the estimated loss is 10 percent, then this represents the total loss over that period. However, in most cases food is removed at intervals during the storage period, and each quantity removed will have suffered a different degree of loss since it will have been exposed to deterioration for a different length of time. The total loss over the season can be obtained by accurately weighing all the grain in and out of the store and comparing the totals. This does not, however, indicate the relationship between loss and time; that is, whether the loss reached a peak or whether it was related to a particular part of the season.

Clear distinction, obviously, must be drawn between observations of loss made at different stages of the system, whether they are made on the same lot of grain experiencing all the losses cumulatively, or on different lots, or a mixture as grain is added or withdrawn (see Note III-1). Sophisticated methods are available to deal with these kinds of loss estimation problems (Harris and Lindblad, 1978); they do not yet exist

for perishables. The whole area of deterioration of stored perishables over time in developing countries, and the implications for cost of loss reduction, needs priority attention.

#### Interpretation of Results

As Adams (1976) points out, it is clearly impossible to avoid approximation in estimating storage losses of subsistence farmers unless enumerators can be used within each village to check and weigh each removal of stored grain. In most cases, provided the same method of estimation and similar approximations are used for a well-selected sample, the loss estimates will be comparable and will enable decisions about loss-reduction activities. The pattern of loss and factors influencing it should also be recognizable. If possible, loss-reduction activities are to be evaluated effectively using accurate weighing of food quantities, replication, and simulation of normal usage will be necessary. The data for this evaluation should cover the whole storage season and can best be obtained from the type of general loss survey described in the previous section.

The interpretation of loss estimation results is also related to the degree of potential effort for alleviating losses, as well as by the relationship between the investigator and the situation being studied.

Food loss estimation in developing countries is plagued by the inverse relationship between accuracy and extrapolation. At the one end of the scale trained observers who have the time, experience, trust and cooperation of the farmers whose losses are being estimated, can obtain and report results of reasonable accuracy, but with limited extrapolability for other situations. At the other extreme, large numbers of poorly instructed, untrained observers are likely to produce information of little value.

The inherent variability in postharvest food losses renders extrapolation of estimates from one loss situation or from one time period to another difficult if not impossible without being so misleading as to be counterproductive. Currently available information is so limited, even in the case of the cereal grains which have received most attention, that experienced observers agree it will not substantiate the use of single "average" or "representative" values for losses of food commodities at national, regional, or world levels. The available values for losses in particular situations should be used only where appropriate as indicative of the particular kinds of losses in those particular kinds of situations.

Until much more research and loss assessment is undertaken by trained observers on a planned, systematic basis using well-conceived standard methodologies aggregate estimates of loss which can be substantiated by statistically sound observations will not be possible. In the interim, where these values are required for planning purposes, the conservative judgement of experienced observers familiar with the local situation is the only basis for arriving at a particular figure. This figure is apt to be meaningful to the extent that it can be related to particular situations and backed up by experimental data. Again, it must be emphasized that there is a great danger that these "best judgement" figures will be taken out of context and quoted as authoritative, as it has so often happened in the past.

The committee is convinced that the magnitude of losses of all commodities justifies additional efforts to improve knowledge about their nature and extent, thus providing an information base that can lead to improved conservation of food. This is particularly so for the perishables, for which there is an almost total lack of reliable scientific data about losses.

The committee, therefore, recommends that additional resources be allocated by developing country governments and technical assistance agencies to improving knowledge of (a) the movement of food from source to consumer, and (b) the locus, nature, and extent of postharvest food losses. Priorities for these efforts should be assigned in proportion to the importance of the food in the local diet. This should not be interpreted to mean that the committee recommends the diversion of resources from existing efforts directed at cereal grains and legumes to efforts concerning other crops but, rather, the committee's recommendation aims at redressing the imbalance of effort that so far has been aimed primarily at the durable crops.

The critical shortage of trained observers for identifying and estimating food losses should be alleviated by appropriate short- and long-term training programs. Innovative approaches, such as use of rural high school and university students as observers under appropriate supervision, should be considered by the responsible national body as valuable supplementary resources for loss estimation and reduction studies. One source of expert skill which is sometimes to be found in a country lies within the marketing organization for valuable export crops such as cocoa, copra, coffee, etc. Diversion of some of these valuable skills to the subsistence economy should be encouraged.

Additional information on methodologies of estimating grain loss resulting from particular causes is given in Note III-2.

Postharvest loss estimation methodology for perishables (including fish) is much less advanced than for cereal grains and legumes. The development of a standard methodology is complicated by a number of factors intrinsic to the nature of the commodities. Differences such as the following have to be taken into account:

- The high moisture content of the harvested material makes estimation of weight loss on a dry matter or defined moisture content basis difficult, if not impossible.

- The lack of uniformity in weight and shape of individual food items as compared with rice, wheat, or other grains and legumes.

- The potential exists for partial loss. The size of the food and its susceptibility to mechanical damage and physiological and pathological deterioration, at different rates and in different parts, make it possible to divide the edible parts of an individual yam or banana into acceptable and unacceptable portions. Grains, by and large, are either edible or not.

- The rate and consequence of spoilage, which for fish is particularly rapid and potentially dangerous to the health of the consumer, is also important in other perishables.

- There is a difference in the relative value of each food unit, individual perishable items being much more valuable than an individual grain. The value is not only economic, but as food, particularly in the case of fish.

At present, all that can be reasonably recommended to bring some order to the estimation of postharvest losses of perishables--a new field--is that research workers be as explicit as possible when reporting what they are measuring. For example:

- For roots and tubers, weights should indicate whether the observations were made on fresh, cured, or aged material; whether with or without skins; and whether vegetative reproductive parts have or have not been removed.

- For fruits and vegetables, weights should specify whether observations were made on fresh whole material or whether skins, peels, and cores, etc., were removed.

◦ For fish, the situation is complicated to an extraordinary degree by the unique characteristics of the "harvesting" process and the many ways in which the fish harvest can be measured. The differences between total catch live weight and landed catch on the one hand, and the weight of edible portions of individual live, gutted and deheaded, or dried fish on the other hand, are discussed in Chapter 6 on fish.

With the non-grain staples there is particular need for case studies of different crops and situations to develop the methodology for estimating losses of commodities on a standardized basis. Establishment of locality-specific standards of quality for perishables is also urgently needed.

## Chapter 3

## Notes

Note III-1.

For example, rice loss estimates for Southeast Asia are reported (De Padua, 1977) as follows:

Harvesting	1 - 3 percent
Handling	2 - 7 percent
Threshing	2 - 6 percent
Drying	1 - 5 percent
Storing	2 - 6 percent
Milling	2 - 10 percent

The possible range of weights of food lost as the grain passes through these stages is not the same as the simple sum of the percentages of loss, since the weight of a given lot of grain is reduced at each stage. Assuming that there is no removal of grain other than through loss and no dilution of the lot by addition of grain, the sum of losses in the example given above would be calculated as follows for a 100 kg lot of paddy:

<u>Stage</u>	<u>Loss Percentage</u>	<u>Grain In (kg)</u>	<u>Grain Out (kg)</u>
Harvesting	1-3	100	97-99
Handling	2-7	97-99	90.21-97.02
Threshing	2-6	90.21-97.02	84.80-95.08
Drying	1-5	84.80-95.08	80.56-94.13
Storing	2-6	80.56-94.13	75.73-92.25
Milling	2-10	75.73-92.25	68.16-90.41

Where there is withdrawal of grain at any of the stages, or dilution of the original lot with added grain at any stage, appropriate adjustments in the observations and calculations must be made.

Note III-2.

### Specific Crop Loss Assessment Considerations

The following paragraphs outline the procedures involved in the loss assessment of different cereal and legume commodities. It should be kept in mind that there is, here, a need to distinguish between crops which are gathered and cultivated and those which place a major demand on available labor, such rice, as opposed to those grown as a minor activity. The differentiation is significant to determine the relative importance of the crop in terms of postharvest loss reduction. The input labor cost is a decisive overall factor in which, in particular, the role of women on the farm is important and frequently overlooked.

On the basis of major review papers, original published material, discussions with experts, and first-hand field and laboratory experience, Harris and Lindblad (1978) conclude with regard to techniques for measuring cereal grain losses:

"All of the U.S. Food and Drug Administration-generated procedures, which are employed as standard methods of loss measurement in the USA and other countries, are too time-consuming, require a laboratory setting, require judgements that are difficult to standardize, use sample sizes that are too small, or have too variable a relationship to grain weight loss to make them suitable for use in developing countries." This results from the very different conditions under which losses occur, are estimated, and corrective measures applied to the passage of food commodities through the postharvest system in developed, as opposed to developing, countries. The same sequence of food movement, storage and marketing occurs in both kinds of country: the degree of loss at different stages differs markedly and the commodity loss profiles are different.



In the highly mechanized agricultural production typical of developed countries, losses, generally speaking, are proportionally greater during the harvesting process, smaller during processing, storage and handling, and greater again during marketing; consumer preference demands variety and high quality of products, and this, together with government standards and regulations, leads to high "shelf" losses at the market level as well as at the table.

In developing countries, on the other hand, while many components of the commodity loss profile are similar, losses tend to be low during harvest, where the crop will be mainly hand-picked, high where processing involves primitive procedures (threshing grain with animals), high during storage, and somewhat lower after marketing.

Thus, the FDA-developed tests (and by analogy other equivalent developed country procedures) are largely designed for completely different conditions, are designed for monitoring large-scale modern storage rather than for use under field conditions, and may require expensive laboratory-based apparatus and procedures which are time-consuming and difficult to standardize.

#### Losses Due to Insects

Examinations for insects on the surface of the grain, weighing insect frass and various procedures to detect visually damaged grains and count or weigh them have been given field trials in developing countries. There is a positive correlation between damage, insects, and frass with some loss quantification possible and Harris' (1972) report to the World Bank suggests their use in making rapid assessments. This information may be extremely

useful in developing a commodity loss profile and in quick comparisons to identify likely points of acute loss in the system.

Some confusion exists concerning the application of these procedures in quantifying actual losses. Their use in test situations and positive correlations to weight losses have been taken by some to indicate that they can be used with some degree of precision to determine weight losses. In fact, they cannot be used for this purpose unless the biological and physical characteristics of each estimation situation are completely understood.

All of the procedures, however, are of value in assessing a situation and coming to a personal judgment. Their precision as indicators of actual losses depends upon the expertise of the user. This is also true of the so-called gravimetric techniques in which a comparison is made of the actual weight of a sample with the weight it would have had in the absence of damage.

For reliable testing then, Harris concludes that loss in weight can only be determined by comparison weighing such as "before" and "after," equal volumes "with" and "without" treatment and other methods for various causes of loss as summarized for cereal grains by Adams and incorporated into the manual prepared by Harris and Lindblad (1978).

However, having indicated that comparison weighing is necessary to weight-loss estimates, it is more complicated than simply weighing appropriate samples at successive intervals on a balance of appropriate accuracy because the moisture content varies throughout the year. The following paragraphs will serve to illustrate the complexity of the procedure required to compensate for changes in moisture content, without repeating the excellent technical treatment which is given in the Harris-Lindblad manual.

Losses of grain prior to secondary processing are mainly due to insects and molds. The insects bore into the kernel and feed on the surfaces, removing food (sometimes selectively) permitting increased uptake of moisture by the grain from the atmosphere and encouraging the growth of microorganisms.

There are two ways in which the weight loss can be measured: by weighing a measured volume of grain--in which case the change in weight in successive samples tested over a period of time is a measure of their losses (and possibly other factors--the cause has to be determined)--or by separating damaged from sound kernels in a given volume and measuring their comparative weights calculated in terms of the whole sample.

In the first case it is necessary to express the weights of grain in terms of a constant moisture content--usually the dry weight. While it is relatively simple to measure moisture content with a moisture meter, the volume of the grain changes slightly with changes in moisture content, so it is necessary to measure, by experiment, the weight of the standard volume of grain at different levels of moisture. Then the weight of subsequent samples taken at the prevailing moisture content can be corrected to the original moisture content for weight change to be calculated independent of moisture.

Because different varieties of grain have different characteristics, graphs of weights of the standard volume of grain at different moisture levels are necessary for each variety. The procedure also is based on the assumption that the grain is homogeneous; if it is not, as in the case of lots of grain of mixed varieties, then a separate baseline graph is required for each lot.

The baseline graph is prepared by taking a bulk sample of approximately 5 kg from each store under consideration (or for each variety). The bulk sample is sieved, its moisture content measured, and it is divided into

5 sub-samples to correspond to five points on the weight/moisture content graph. Since the normal range of moisture content in stored grain is from, say, 8-18 percent, it is necessary to select five points within that range. The original 5-kg sample will have a moisture content somewhere between these two extremes; the other 4 sub-samples must be dried down or wetted up to the selected percentages to complete the required range, which in itself is a procedure requiring care and time.

Three replicate standard volumes of grain taken with a chondrometer (the test weight container) according to the instructions provided by the supplier are then weighed to the nearest 0.1 g and the mean weights of the 5 samples converted to dry weight plotted on a graph against moisture content. This graph can then be used throughout the sampling period to measure the dry weight of samples at any moisture content. The sample whose weight is to be measured is sieved (the weight of sievings being considered as losses if they are not used as food, or calculated back to the weight/volume if they are), its moisture content is measured and sub-samples are taken with the chondrometer three times. The samples are weighed, dry weight calculated from the graph, and the weight change calculated by comparison with the original sample at the beginning of the test period.

Error is introduced by factors affecting variation in packing and, hence, volume of the chondrometer-sampled grain. These factors include high levels of damage (which increases packing) and presence of insecticide dust (which reduces packing) so that treated and untreated grain should not be compared.

The comparative weights of undamaged and damaged kernels gives percentage weight loss directly on the assumption that the undamaged portion is completely undamaged. The disadvantages of this method become apparent at high and low levels of damage: hidden infestation results in underestimation of loss, because grains which have lost weight are included in the undamaged group. At high levels of damage it may be difficult to identify

and count damaged grains accurately among the debris. It also assumes that insects choose grains at random, which for maize is not the case. Nevertheless, for unshelled and mold-damaged grains particularly, it provides a useful means for estimating loss at moderate levels of infestation with a minimum of equipment.

Other methods are variations of these procedures. The chondrometer method is the preferred method as it has the highest accuracy when properly carried out. It is neither simple nor rapid, however, and requires a fairly high level of experience, if not of training, and a variety of ancillary equipment not readily assembled outside a laboratory.

#### Losses Caused by Fungi

The methods for estimating loss from insects are also applicable to fungal damage. However, because of mold, a considerable proportion of the grain rejected by the farmer is often discarded or used to feed animals, since the presence of infected grain causes a drop in quality grading. The impact of fungal infection on loss can be estimated by including the separation of mold damage from other types of damage during the analysis.

The quantification of "weight loss" when the loss is due to fungal damage will depend on local practices in the use of the damaged material. People accept or reject damaged kernels as local custom and hunger dictate. It is desirable to make measurements in one country, or region of it, that can be compared with measurements made elsewhere; in each situation acceptance-rejection limits should be defined in terms of a widely used language. Despite the difficulty, these limits, based on information from interviews, must be quantified.

It seems likely that methodology for fungal damage estimation will need to be somewhat separate from that for insect loss, but since the two are frequently interrelated and interacting, the degree of separation needed is currently unclear, and likely will be situation specific. In sampling, allowance must be made for differences in moisture content of infected and uninfected samples.

The hidden effects of moldy grain that may be consumed are more difficult to assess because of the possible presence of toxins and the tendency for repeated consumption of infected grain to cause chronic illnesses. These will lead to a reduction in output by an affected person and may be likened to the effects of nutritional loss.

Losses caused by fungal contamination can arise through:

1. The rejection of food because of visible fungal contamination or fungal damage.
2. The rejection of food (which may well not be visibly contaminated with mold) because of its mycotoxin content.

The mycotoxin contamination of food can arise from:

- a. The direct fungal contamination of the food;
- b. The consumption of mycotoxin contaminated feed by animals leading to contaminated animal products (e.g., meat, milk).

Rejected food is often used as animal feed.

3. A decrease in the yield of food:

The ingestion of contaminated feed can reduce the productivity of animals (e.g., drop in milk yield). Sufficiently high doses of mycotoxin will often result in death.

4. Acute and chronic illness caused in humans by the ingestion of contaminated food.

Because of the increasing awareness of the mycotoxin (especially aflatoxin) problem, there is a corresponding increasing likelihood of food rejection occurring. A rapid method exists for observing aflatoxin in maize (utilizing the BGY fluorescence) and groundnuts are routinely sorted using electronic color sorters. Established assay procedures also exist for the analysis of a wide range of foods and feeds for aflatoxin and other mycotoxins.

Recent examples of food rejection, after analysis, include the rejection of large quantities of corn in Zambia and of shipments of wheat in Pakistan and Bangladesh.

In some West African countries the groundnut crop contributes greatly to the GNP of the country and therefore food and feed losses can represent severe economic losses.

#### Losses Caused by Vertebrate Pests

Losses caused by vertebrates such as rodents and birds are difficult to assess directly, since they remove grains from the store. The usual method of estimation is to blame vertebrate pests for all losses that cannot be accounted for in any other way. It is difficult to obtain an accurate estimate without accurate weighing of the grain throughout the season.

Another method is based upon an estimate of the pest population, usually by trapping methods, and consumption trials conducted with captured animals to obtain a figure of daily food intake. However, allowances need to be made for situations in which the store is not the only source of food and also to account for the difference between unlimited food supply in the consumption trial and the foraging required in the field situation.

Studies carried out under warehouse and village conditions have shown that rodent populations can probably best be estimated by combining a number of techniques, including baiting, rodent sign survey, trap-release-trap, and consumption of poison baits. In captivity the roof rat (Rattus rattus) has been found to consume 8-12g of food grain/day; the house mouse (Mus musculus), 3-5g/day; and the bandicoot rat (Bandicota spp.), 25-30g/day. While consuming the food, the rats also contaminate an estimated 10 times more food with urine, feces, hair, and saliva (Urs et al., 1977).

These estimates are difficult to extrapolate with confidence because they neglect the fact that rodents often hoard amounts of food many times greater than they actually consume. Thus, predictions of losses from rodent population estimates are likely to underestimate actual food losses (Frantz, 1972).

Postharvest losses due to rodents have been summarized by Hopf et al. (1976). Estimates of damage are quite variable and range from 0.5 percent to 60 percent. Amounts are given in some cases, with India reporting approximately 11 million tonnes lost annually with a value estimated at over \$1,000 million.

Postharvest losses due to birds are likely to be of relatively minor importance compared to preharvest losses to birds and postharvest losses to other factors. Exceptions occur where grain is left in the field after harvest or spread in the open to dry for long periods, or where stores allow birds access. Other than figures of weighing before and after, including all sources of loss, there is little information on postharvest loss to birds per se. Guggenheim (1977) reports distinguishing bird damage from insect and rodent damage in millet on the cob by observation of the marks on the ear.



## Losses Due to Handling and Primary Processing

These are losses which may occur at the following stages of the grain postharvest system:

- threshing
- drying
- bagging, or placing threshed grain in other containers
- transport from field to storage
- transport to mill
- milling, which may involve several processes and stages
- transport from mill to storage or market

These losses should be determined by weighings before and after the particular step, or weighing the amount of grain or grain products in food and non-food categories. In many cases, appropriate methodology will have to be developed to meet particular local handling procedures, as grain is moved from field to store, mill and home by different methods. Links in the chain are points of potential loss to be investigated.

There is very little published information on postharvest grain losses during transportation. Yet, any transfer of grain from one stage to another implies the possibility that loss can occur.

There are three aspects of this section of the problem:

1. Handling of crops between harvest, threshing, storage, and milling.
2. Where transportation is a function allied to storage--"moving storage"--during which loss may occur due to continued deterioration of, for example, bagged grain in transit; or to spoilage of bagged grain which is exposed to rain, for example, during transportation; or spillage due to container damage, or inefficient transferrance of grain in transportation. The use of hooks to handle sacks of grain in port facilities is a frequent

glaring example, but the use of old sacks from which grain leaks, and which permits pests access, is perhaps even more important.

3. Where loss is attributable to absence or inefficiency of transportation facilities, and limited access to alternative market possibilities.

The limited information available about these aspects provides little wisdom regarding food loss. As we have earlier concluded, it is probably not productive to pursue maldistribution as a source of postharvest loss of grain, since this involves many non-technical factors affecting many things in addition to the postharvest environment. It is much more relevant to postharvest losses of perishables due to the overriding importance of moving the commodity to the market as quickly as possible after harvest.

Clearly, attention should be given to transportation problems in the interest of overall security and efficiency of delivery of food supplies.

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## Chapter 4

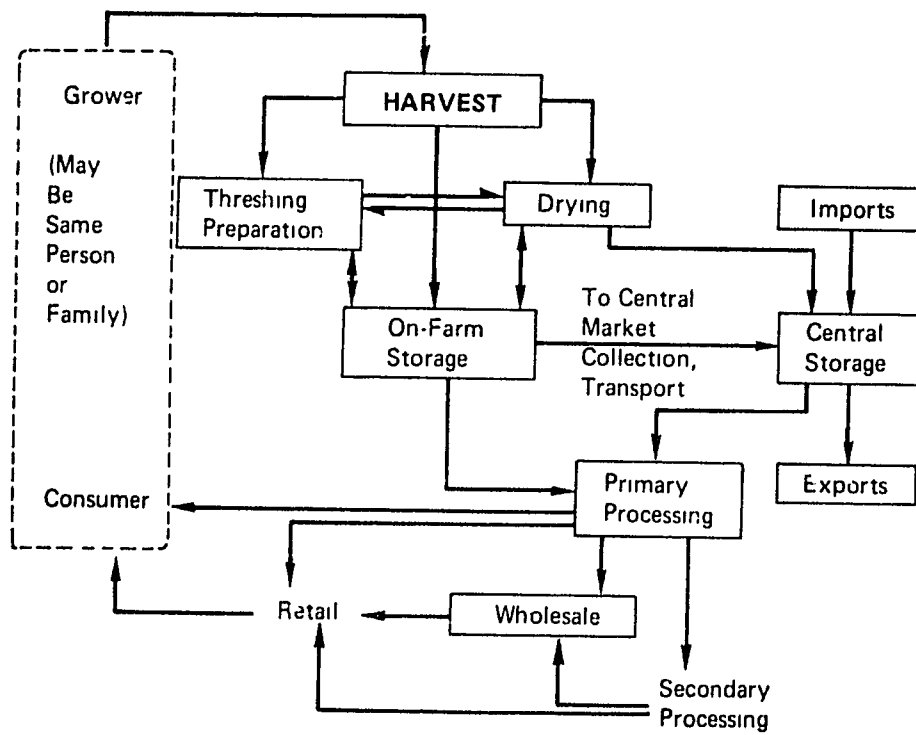
### Cereal Grains and Grain Legumes

As noted earlier, the knowledge about the nature and extent of postharvest losses is much more extensive for cereal grains and grain legumes than for other commodities.

There are a number of reasons for this. In most societies, the durable commodities are (or have been) the most important in terms of quantity produced. They are traditionally stored, and security or survival has depended on keen attention to this process. This has been less true in the case of the nongrain staples. It is easier to protect dormant dried grain from external attack by insects or rodents than it is to prevent physiological deterioration or fungal attack of perishables. Perishables are often seasonal crops that provide a relatively constant supply of (different) fruits and vegetables without storage. Many grow with minimum attention; their husbandry is therefore much less important and demanding than that of durable staples.

The bulk of harvested cereal grain and legumes passes through a fairly well-defined series of steps--the postharvest system. After harvest, the crops are threshed or shelled, dried, stored, and finally processed. Each commodity has its own variation in this process and some have additional steps that enlarge the system (rice parboiling, for example), but there are enough similarities in the flow of durables through the system to enable generalization about loss problems. The first part of this chapter





is concerned with these problems; the second part will be a discussion of loss factors specific to the individual commodities.

### General Causes of Postharvest Grain Loss

#### Preharvest Factors

The genetic characteristics of a grain variety greatly influence the postharvest losses it may incur. Traditional varieties are generally well adapted both to their usual environment and to postharvest handling. The grains which survive storage and are used in subsequent seasons have evolved characteristics that favor their survival. These may include, for instance, lower moisture content in the ripe grain, which then dries more readily, and thicker seed coat for repelling insects and rodents.

Introduction of varieties selected for high yields has resulted in greater postharvest losses where the new varieties are not as well adapted to the postharvest conditions as traditional varieties. This problem should be a consideration both in selecting high-yielding varieties and in providing for their postharvest treatment.

Damage to the growing crop may affect its postharvest characteristics, as may crop protection treatment prior to harvest. In particular, insect infestation of a maturing crop may increase its vulnerability to loss after harvest; however, residual insecticide may reduce the extent of postharvest insect damage.

## Harvesting Factors

The time of harvesting has an important effect on the subsequent storage quality of the grain. Typically, the harvest may be begun before the grains are fully ripe and may extend until mold and insect damage are prevalent and shattering has occurred. Grain not fully ripened contains a higher proportion of moisture, and will deteriorate more quickly than mature grain, because their enzyme systems are still active. If the grain remains in the field after maturity, repeated wetting from rain and dew at night, along with drying by the hot sun by day, may cause grain to crack (particularly long-grain paddy) and may increase the likelihood of insect damage (particularly in maize, paddy, and pulses).

Crops standing in the field after maturity become more liable to harvest losses. Ripened grain is more likely to be shattered onto the ground during harvesting. Maize loss may result from the loosening of the husk after it is ripe and subsequent mold infection or insect attack. The probability of insect infestation in the field is also likely to increase if the crop stands too long, as is loss to rodents, grain-eating birds, and other vertebrates.

## Threshing and Shelling

Traditional methods of threshing to separate grains from the plant, such as use of animals to trample the sheaves on the threshing floor--or the modern equivalent using tractor wheels--may result in loss of grain not separated. This method also allows impurities to become mixed with the grain, which may cause subsequent storage problems. The use of flails

to beat the grain from the stalk may also damage the grains or kernels and is not always effective.

Threshing and shelling will contribute to losses if carried out in a manner that results in cracking of grains.

On the other hand, modern devices for threshing and shelling may be used incorrectly, or for a crop for which they were not intended, with excessive breakage of grains.

### Drying

Drying is a particularly vital operation in the chain of food handling, since moisture may be the most important factor determining whether, and to what extent, grain will be liable to deterioration during storage.

Drying is used to inhibit germination of seeds and to reduce the moisture content to a level that prevents the growth of fungi and bacteria; it can also retard attacks on the grain by insects and mites.

In developing countries, the methods available to farmers for drying crops are often limited, usually to a combination of sun- and air-drying, although supplemental heat is frequently employed. In many cases, seed grain may be treated separately from food grain and with greater care. Drying is a complex process requiring considerable skill and effort on the part of the farmer; the success with which the grain is preserved over shorter or longer periods depends to a great extent on the care and attention given to the drying and subsequent storage. Drying is often complicated by the introduction of high-yield varieties that mature and must be harvested during wet seasons or by production of a second, irrigated crop ("double-

cropping") that must also be harvested during the rains. In these cases the grain requires artificial drying. The increased production of high-yield varieties and their differing characteristics may also tax the farmer's ability to handle the grain properly by traditional methods. Consequently, a new drying and storage procedure must be adopted or the crop must be sold undried. The alternative may be to forego the new variety.

Overdrying--which can easily occur in arid regions or after excessive exposure to sun or other heat--can cause breakage, damage to the seed coat, bleaching, scorching, discoloration, loss of germinative power, and nutritional changes. Too-rapid drying of crops with high moisture content also causes damage; for example, bursting (or "case-hardening"), which causes the surface of the grain to dry out rapidly, sealing moisture within the inner layers. Under-drying or slow-drying (a problem in humid regions) results in deterioration due to fungi and bacteria, and, in extreme cases, leads to total loss.

Solar technology for artificial drying is receiving attention because of its negligible costs in comparison with traditional fuels, which are becoming not only expensive but, as in the case of firewood, are adversely affecting the environment. However, the fundamental problem with solar devices is that they do not operate effectively when they are most needed--to dry grain which must be harvested during a wet spell or during the rainy season.

The Peace Corps-VITA manual, Small Farm Grain Storage (Lindblad and Druben, 1976), contains descriptions and instructions for constructing a variety of improved grain dryers--a pit oil barrel dryer, an improved maize drying and storage crib, a dimple batch-type rice dryer, and a number of simple solar dryers.

Clearly, particular methods of drying must be selected for the particular climatic, economic, and social circumstances in which they will be used. This is especially true where existing drying methods have evolved over long periods of time to meet community and family survival needs. Alternative methods should not be recommended without awareness of all possible consequences to the farmers. Problems affecting the selection of drying methods are discussed in the next section of this chapter, in the context of individual commodities.

### Storage Losses

The extent to which deterioration and loss occur in storage depends on physical and production factors, the storage environment, and biological factors. Physical factors which contribute to storage loss have been discussed in the previous section.

In addition, physical damage to the crop during harvest may also affect storage. Undamaged cowpea pods, groundnut shells, and the husks of paddy grains also afford the crop a noticeable degree of protection from infestation by most insect species, though the space occupied reduces the volume that can be stored.

### Storage Environment

Storage conditions have much to do with the rate of deterioration. High temperature and humidity encourage mold formation and provide suitable conditions for rapid growth of insect populations. Deterioration is minimal in cool, dry areas; more marked in hot, dry ones; high in cool

and damp conditions; and very high in hot, damp climates. Climatic conditions during and after harvest affect the ease with which natural drying may be carried out and may dictate the need for artificial drying. Seasonal and/or diurnal temperature differences between stored grains and the surrounding environment can result in moisture translocation or migration among quantities of bulk or bag-stored grains or in condensation of moisture on the grain. Concentration of moisture in grain can lead to conditions favorable to the development of fungi.

Some climates lessen the residual activity of certain pesticides and can reduce the effective life of storage containers and structures. Different structural materials may alter the effectiveness of different formulations of a given insecticide.

Deterioration is also related to storage method and management. For example, cob maize stored in open-sided cribs takes up moisture more rapidly during the rainy season than shelled maize in mud-walled cribs, so that conditions for rapid insect development are produced earlier in the storage season. On the other hand, properly designed open-sided cribs will allow relatively rapid drying of unhusked ears of maize and reduce losses due to mold. Traditional pest control methods often have an effect on infestation levels. For example, some farmers storing pulses and larger grains will admix a smaller seed or sand with the grains to fill the intergranular spaces. This effectively inhibits the development of bruchid beetles. Other farmers use a fire under their storage cribs to repel insects, either through the effect of the smoke or by keeping the grain dry. The admixture or overlay of ashes derived from burning various woods or dried animal dung is another method affording protection from insect attack.

## Biological Factors

The principal biological agents of deterioration during storage are insects and mites, fungi, and rodents.

Losses Due to Insects and Mites. Insect pests are a greater problem in regions where the relative humidity is high, but temperature is the overriding factor that influences insect multiplication. At temperatures of about 32°C, the rate of insect development is such that a monthly compound increase of 50 times the present number is theoretically possible. Thus, 50 insects at harvest could multiply to become more than 312 million after four months.

The nutritive requirements of insects are much the same for insects as for vertebrates. Crops with the highest nutritive values for man are also those most susceptible to damage by insects. In certain cases, farmers may keep only small amounts of a nutritious crop such as beans because they believe damage and loss to be inevitable. Furthermore, insects often select the most valuable portion of seeds. For example, four important pests of maize attack the embryo and reject the starchy endosperm, thus removing the most nutritive part of the grain as well as destroying the power of germination.

Weight loss is of economic as well as nutritive importance and, in the absence of effective control measures, insect attack on cereal grains and beans can be so severe as to reduce the commodity to empty husks and dust. Large numbers of insects can be expected to produce heavy weight losses, and the resulting contamination by dead and live insects and their excreta can be sufficient to make the commodity completely unpalatable and unacceptable in the market.



Termites in a grain store can weaken the structure, leading to its collapse. They will also readily attack the grain.

Table 4:1 below, prepared by entomologists of the Tropical Products Institute, shows the main insects and mites that attack and damage stored cereal grains and pulses.

Control measures, whether or not insecticides are available, depend first on storage hygiene. Storage containers must be carefully checked and cleaned as carefully as possible. Old stored grain should be checked and if necessary redried and cleaned to control existing infestation. New dry grain should be kept separate from old stored grain because of the risk of cross-infestation. Similarly, stores should be as remote from the field as possible to reduce the risk of infestation. In addition to store pests, it must be assumed that new grain is infested from the field and control must include a regular system of inspection and deterrence to maintain storage hygiene and take measures where infestation is observed.

Traditional pest-control systems not involving insecticides are adapted to local circumstances. Use of local herbs, mixing ash with grain, and smoking are effective and should be encouraged. As previously stressed, every effort should be made to build on traditional technology and innovations should be undertaken with understanding of the social and economic implications. This is particularly important in the case of insecticides that present severe health hazards and have other environmental, ecological, economic, and social implications (such as overoptimistic expectations that new technologies will solve all problems and remove all need for traditional efforts).

STORAGE PESTS OF GRAINS AND PULSES

Order	Family	Name	Commodities
Coleoptera	Dermestidae	* <u>Trogoderma granarium</u> Everts	Cereal grains and products
	Anobiidae	<u>Lasioderma serricorne</u> (F.)	Cereal grains and products
	Bostrichidae	* <u>Rhyzopertha dominica</u> (F.)	Cereal grains and products
	Trogossitidae	<u>Lophocateres pusillus</u> (Klug)	Cereal grains
		<u>Tenebroides mauritanicus</u> (L.)	Cereal grains and products
	Nitidulidae	<u>Carophilus dimidiatus</u> (F.)	Cereal grains
	Cucujidae	<u>Cryptolestes ferrugineus</u> (Steph.)	Cereal grains
		<u>C. pusillus</u> (Schoen.)	Cereal grains
	Silvanidae	<u>Ahasverus advena</u> (Waltl)	Cereal grains
		<u>Cathartus quadricollis</u> (Guer.)	Cereal grains
		<u>Oryzaephilus mercator</u> (Fauv.)	Cereal grains
		<u>O. surinamensis</u> (L.)	Cereal grains
	Mycetophagidae	<u>Typhaca stercorea</u> (L.)	Cereal grains
	Tenebrionidae	<u>Alphitobius diaperinus</u> (Panz.)	Cereal grains and products
		<u>A. laevigatus</u> (F.)	Cereal grains and products
		<u>Gnathocerus cornutus</u> (F.)	Cereal grains
		<u>G. maxillosum</u> (F.)	Cereal grains
		<u>Iatheticus oryzae</u> Waterh	Cereal grains and products
		<u>Palorus ratzeburgii</u> (Wisom.)	Cereal grains and pulses
		<u>P. subdepressus</u> (Woll.)	Cereal grains and pulses
		* <u>Tribolium castaneum</u> (Hbst.)	Cereal grains, grain products and pulses.
		* <u>T. confusum</u> DuR.	Cereal grains, grain products and pulses.
		Bruchidae	* <u>Acanthoscelides obtectus</u> (Say)
* <u>Callosobruchus chinensis</u> (L.)			Pulses (esp. peas and grams)
* <u>C. maculatus</u> (F.)			Pulses (esp. peas and grams)
* <u>Zabrotes subfasciatus</u> (Boh.)			Pulses (esp. beans)
Anthribidae	<u>Araecerus fasciculatus</u> (Deg.)	Cereal grains	
Curculionidae	* <u>Sitophilus granarius</u> (L.)	Cereal grains	
	* <u>S. oryzae</u> (L.)	Cereal grains	
	* <u>S. zeamais</u> Motsch.	Cereal grains	
Lepidoptera	Gelechiidae	* <u>Sitotroga cerealella</u> (Ol.)	Cereal grains
		Pyralidae	* <u>Corcyra cephalonica</u> Staint.
	* <u>Ephestia cautella</u> (Wlk.)		Cereal grains and products
	<u>E. elutella</u> (Hbn.)		Cereal grains and products
	<u>E. kuehniella</u> Zell.		Cereal products
	<u>Plodia interpunctella</u> (Hbn.)	Cereal grains and products	
Acarina	Acaridae	<u>Acarus siro</u> L.	Cereal products
		<u>Tyrophagus putrescentiae</u> (Schrank)	Cereal grains, grain products and pulses

\* Major pest species

Many insecticides are becoming widely available in developing countries as their application is encouraged by suppliers and extension services. Some are more hazardous to humans, and potentially so to the ecology, than others, but all should be used with great care. Some can be used in a strength on seed grain that would be impossible on food grain.

The grain-storage insecticides are of two main types:

- ° Contact poisons such as dusts, dispersible powders, and emulsions. Some insecticides, such as BHC, are quite stable and have long residual action; others, like malathion, usually have little residual action and are used where human consumption of the grain precludes use of longer-acting chemicals. Some compounds may be mixed with grain at the time of storage, while others are used for spraying storage containers or bagged grain. The level of application and its timing in relation to expected human consumption are major problems for extension services seeking to improve insect control in rural grain storage.

- ° Fumigants, which are gases, can penetrate bulks of grain and kill insects and their larvae living within grains. Their drawbacks are that all fumigants are safe only when used by trained personnel and that they have no residual action to protect grain from subsequent reinfestation. A first requirement is improvement of the methods of application and more careful monitoring of insecticide use to achieve maximum control of infestations. Reports of insect resistance to chemical insecticides are increasingly encountered. Awareness about the use of chemicals is also increasing and there has been renewed interest in traditional nonchemical control techniques and in developing alternative approaches to pest control.

The principal methods of coping with insect infestations involve cultural control or manipulation of the environment to make it less favorable to the insect; breeding resistant crop strains; using natural enemies of insects such as parasites, predators, and disease vectors; sterilizing insects to interfere with normal reproduction; and using attractants and repellants.

Cultural control and inbred resistance are not new techniques. Traditional methods of controlling insects in storage involve mixing sand, limestone, ash, or herbs with the grain; in addition to forming a barrier against movement of the insects through the grain, they abrade or absorb the wax coating of the insect's protective cuticle, causing a loss of body moisture. In many areas insects (and rodents) are repelled by smoke from small fires, used either within granaries to decontaminate them between harvests, or under granaries constructed of permeable materials such as woven plant fibers. The fire also assists grain drying in situ. In other areas, stored grain is inspected frequently and redried in the sun if insects are observed. Hermetic storage, with grain sealed in impervious containers, is highly effective in excluding insects. However, the system is difficult to maintain for large quantities and is usually confined to relatively small amounts of seed grain. (See Note IV-1.)

Along with investigations of newer possibilities for nonchemical biological control, traditional methods of cultural control should receive greater attention to increase understanding of their underlying biological basis. The knowledge gained about both approaches can form the basis of more effective and safer methods. Since the methods are dependent on manipulation of the ecology to the detriment of the insects, they are highly location-specific, which increases the requirement for research

and adaptation of techniques to local circumstances. This will require long-term study, making it unlikely that there will be alternatives to replace or greatly reduce insecticide use in the near future.

Losses Due to Fungi. Fungal attack in storage generally occurs when drying has been inadequate, when large numbers of insects are present, causing a temperature rise in the grain, or when the stored crop is exposed to high humidity or actual wetting. Fungal development does not normally take place when the moisture content of the commodity is below that moisture content in equilibrium with a relative humidity of 70 percent. In recent years, attention has been given to the toxic products of certain fungi, such as aflatoxin and zearalenone, which are metabolites of the fungi Aspergillus flavus and Fusarium moniliforme. Mycelia penetrate the endosperm of grains removing nutrients. In many cases the embryo is attacked first and eventually destroyed.

Fungal spoilage is more serious in those regions with a permanent high relative humidity or where a season of high humidity coincides with the time when grain is being dried or kept in store. Microorganisms may multiply and create heat that can increase in unventilated grain to the point of complete destruction. However, losses due to fungi are reduced as a result of improvements in drying and storage technology and do not need to be treated separately.

Losses Due to Rodents. Rodent damage to stored food can occur in a number of ways. The animals not only consume the food (damage to maize grains is characteristic in that the embryo is usually removed first), but also foul a large amount with their excretions (which may carry microorganisms pathogenic to man), destroy containers by gnawing holes that result in leakage and wastage of grain, and paw into and scatter grain

while they eat. This scattered grain, along with that which leaks from gnawed holes, is subject to contamination and admixture with impurities. Damage to grain stored in bulk may be much less than to grain stored on the head or in bags because rodents are unable to burrow into the bulk.

These problems have recently been reviewed by Hopf et al. (1977) in a report prepared by the U.K. Centre for Overseas Pest Research and the Tropical Products Institute. This report analyzes extensive information provided by a number of governments. It concludes that, in most countries, very little is known about the extent of the problem, although some countries with high losses, for instance India, have considerable expertise in this area and allocate large resources to rodent control.

The three main species of rodent are:

- ° Rattus norvegicus, the Norway, common, or brown rat;
- ° Rattus rattus, the roof, ship, or black rat; and
- ° Mus musculus, the house mouse.

Other species, such as the bandicoot rat (Bandicota bengalensis) are important pests in particular areas. Locally other species can assume greater importance.

Control of Rodents. Few techniques for rodent control are used and include the following broad categories:

- ° Rodent exclusion efforts in store construction;
- ° Improved sanitation; removing food and harborage from the surrounding environment or reducing it to the minimum practical;
- ° Poison baiting, including use of the anticoagulants such as chlorophacinone, warfarin, coumarin, diphacinone, and coumatetralyl, and acute poisons such as zinc phosphide, barium carbonate, red squill, and vacor;
- ° Fumigation, with phosphine or other gas;

- Trapping and hunting;
- Use of cats and dogs, and
- Rodent repellants.

Estimates of the effectiveness of these techniques are mixed, sometimes even contradictory within the same country. Results depend on the thoroughness with which the control technique is applied and the length of time it operates. Control usually is more effective when a combination of methods is used, particularly those that prevent access to food. Yet, the persistence of the situation is obvious in a report on the rodent problem in Israel, where it is fully recognized and control is vigorous and well organized, but where the estimated loss to crops in the field remains at 5 percent. The problem must be approached with the recognition that store rodents cannot be controlled unless field rodents are also controlled.

Observations from the People's Republic of China indicate that well-organized rodent exclusion, together with sanitation and field control, may have been rather successful; no published figures are available. Traditional and modern granaries are reported to be protected by detailed attention to cleanliness, by physically isolating the granary and by laying concrete on the area around and underneath the granary (which introduces aspects of behavioral control), and by providing rat barriers at points of potential access.

New rodent control technologies, even simple ones, may meet considerable resistance at the farm and village level. For instance, local acceptance of baffles fitted to traditional storage containers has been slow, at best. In this and similar cases, more research may be needed to determine

whether such unpopular solutions to problems are the most effective. There are also reports that rodents are becoming resistant to rodenticides, although there is little evidence from tropical regions and research on this aspect of control is also indicated.

Although many countries fully recognize the seriousness of food loss caused by rodents--as do India, Israel, and China, as we have seen--the editors of the report of the Centre for Overseas Pest Research conclude that "the one single fact which emerges most clearly from the survey is the widespread ignorance of the magnitude of the rodent problem, and of means to control it."

We have discussed the storage of food staples in terms of the major causes of storage losses. However, a discussion of storage would be incomplete without a summary of the actual methods now in use and the ways in which these might be improved to cut waste.

#### Reduction of Storage Losses

Having discussed the physical, environmental, and biological causes of grain loss in storage, we now turn to methods of reducing storage loss.

In developing countries, storage on the farm is an important element of the traditional farming system (the subsistence or nonmarket sector and the semisubsistence or farm-to-village market sector). It is essential both for conserving seed for the next planting and for stockpiling staples to feed the farmer, his family, and his livestock until the next harvest.

Sound storage practice has three elements:

- ° Proper preparation of the grain for storage, including drying and, where possible, separating out any infested or spoiled grain and other impurities;



- ° Sound storage structures that provide protection from moisture (rain and ground moisture) or excessive drying and a barrier against insect and rodent pests and theft; and

- ° An appropriate system of monitoring the quality of the stored grain and treating and handling it while it is in the store.

### Traditional Storage Practices

Traditional systems have evolved over long periods of time to satisfy storage requirements within the limits of the local culture. Grain for seed is frequently sealed in gourds or clay containers and kept in the house. Larger amounts of grain for human and animal consumption are stored in containers constructed of plant material, mud, or stones, often raised off the ground on platforms and protected from the weather by roofing material. The design and materials vary according to local situation and custom.

However, with the exception of sealed containers (including underground pit stores in drier areas that control insects by limiting the supply of oxygen), the traditional structures provide only limited protection against insect and rodent damage, particularly in areas where the climate is warm and humid or where grain is stored for extended periods.

These traditional grain storage systems have evolved slowly by natural selection and provide reasonable storage security for the traditional farmer. This does not mean that losses are necessarily low; it does mean that the risk of large-scale losses is minimized under traditional decentralized storage systems.

Subsistence or traditional farming systems are being improved by the introduction of high-yielding varieties of grain, which farmers are

encouraged to grow. However, as a consequence of increased production the traditional storage system is proving inadequate not only in capacity, but also in protecting grain from damage, since the new varieties may be more susceptible to insect attack.

There are three approaches to solving the traditional storage system problem:

- Improving small-scale on-farm storage;
- Centralizing grain storage with efficient collection, and drying and large-scale stores; and
- Breeding new varieties that are less susceptible to loss in storage.

Of these approaches, the last two are important long-term possibilities with political, social, and economic implications that are largely outside the scope of this report. They will require expanded research efforts, particularly on socioeconomic aspects of centralizing storage.

#### New On-Farm Storage Practices

In recent years this aspect of postharvest technology has been receiving considerable attention. In East Africa, adaptations have been made to the traditional design, for example, by fitting "rodent baffles" (Kenya and Malawi) or mud-plastering cribs for the storage of shelled grain (Zambia and Malawi).

In Guatemala, India, and Swaziland prefabricated corrugated or plain (flat) metal tanks have been in use for storage for a number of years. These tanks permit fumigation of the grain with hydrogen phosphide tablets, reduce the probability of reinfestation by insects and rodents, and reduce the rate of uptake of moisture. In Swaziland at least 40 percent of farmers were using them by 1976.

Improved grain bins have not met with the same success in Ghana and Zambia, where concrete stores proved unacceptable to farmers because of rising costs, the shortage of materials, and difficulties in construction. A more recent approach, adopted in Zambia, is to produce a cheap easy-to-construct container, using readily available materials. The container, known as the "ferrumbu," incorporates the features necessary for safe grain storage and should be affordable by emergent commercial farmers.

In Southeast Asia, metal storage containers have been introduced on a fairly wide scale. Problems have been encountered, however, with drying rice adequately before storage and providing adequate ventilation and preventing stored rice from taking up moisture from the humid atmosphere. These problems were assigned high priority in reducing losses of stored rice in Southeast Asia.

Small-scale on-farm grain storage technologies have been compiled by Lindblad and Druben (1976) in a very useful compendium that has been made widely available to developing countries through the U.S. Peace Corps and Volunteers in Technical Assistance (VITA).

The Lindblad-Druben manual includes discussion of the advantages, disadvantages, and construction of various grain-storage methods, including:

- Traditional basket storage;
- Bagged storage;
- Airtight storage--underground pits, including "Thailo" (ferrocement-lined traditional Thai grain silo), plastic sack storage, metal drums and bins, and sheet metal silos;
- Earthen structures--mud brick silos; and
- Cement/concrete--cement stone silos, including cooperative cement silos.

The selection of storage methods depends on the climate, commodity, and social and economic characteristics of the particular situation. While improved storage is a prerequisite for sustaining production increases without incurring increasing postharvest losses, the improvements must be carefully attuned to economic, social, and cultural realities.

### Losses During Processing

Losses during primary processing include:

- Losses in threshing and milling;
- Losses in parboiling; and
- Losses in further processing (baking, brewing, canning, packaging, etc.) which are important but are not central to the focus of this study.

There is a tendency for processing losses to increase as larger amounts of crop are produced and strain the capacity of the traditional processing system. Maize traditionally shelled by hand, for example, may be placed in sacks and pounded with a stick to detach the grains from the cob. Mechanical processing is generally less efficient than manual processing, both because it is incomplete and because of damage to grains due to their variation in size or poor adjustment of the machinery. The manual processing efficiency may be used as the standard against which the efficiency of machinery is measured.

Processing losses are generally specific to particular crops and will be dealt with under each commodity. There are, however, some general loss problems resulting from processing. Attitudes towards broken grains vary from society to society; acceptability of off-color grain due to poor

parboiling or drying varies. In many cases, this simply means that the poorer members of society have the broken grains and dust, or otherwise lower quality grain, and there is little loss. In Pakistan, the Council on Scientific and Industrial Research has experimented with reconstituting "whole" rice grains from broken grain and rice powder with good acceptance.

In many societies central milling facilities process grain brought in by farmers for a price determined by the initial unmilled volume or weight, and there is thus little incentive to reduce subsequent losses due to poorly adjusted equipment or leakage and spillage. Payment may also be in kind, with part of the milled product or the milling by-products going to the miller. Where the society is affluent enough that these losses are not consumed, the loss is comparatively unimportant to the central focus of this study.

#### Individual Crop Loss Problems

Among the hundreds of food crops grown around the world, some two dozen of them account for approximately 90 percent of all the food produced. Table 1:1 shows the reported production worldwide and in the developing countries of major food crops (according to FAO figures and definitions).

The cereals and legumes, the focus of this chapter, account for more than half the world's production of food crops and have received most of the attention in worldwide attempts to reduce postharvest losses. In the main, developing-country cereals are rice, maize, wheat, sorghum, millet, and barley. In this section they will be discussed in terms of the food losses connected with them as separate commodities.

## Rice

## Loss Estimates

Losses of rice in the postharvest food system (Table 4:2) are probably as well characterized as for any crop. Yet, though there are reports of much serious work, there is still uncertainty as to the magnitude of post-harvest losses of rice because of variation in situations being assessed and because of differences in methodology and definition.

On the other hand, these estimates may be approaching the level of accuracy with which it is possible to assess losses on a large, nonexperimental scale. There is also a fair level of consistency from country to country in rice loss figures from similar situations. These are summarized for Southeast Asia by De Padua (1974) and are quoted widely:

Harvesting	1- 3 percent
Handling	2- 7 percent
Threshing	2- 6 percent
Drying	1- 5 percent
Storage	2- 6 percent
Milling	2-10 percent

giving a range of loss from a minimum of 10 percent to over 30 percent.

Limited observations on rice in West Africa do not yet specify detailed loss estimates broken down by stage; however, the overall figures are consistent with those from Asia (FAO-ECA, 1976). Table 4:2 shows rice weight losses by percentages for a number of developing countries or areas.

Rice is relatively difficult to process by hand or with simple manual equipment, and processing is widely organized on a collective or centralized basis, unlike most other grains in developing countries.

TABLE 4:2

REPORTED LOSSES OF RICE WITHIN THE POSTHARVEST SYSTEM  
(Based on FAO, 1977b, Figures Unless Otherwise Indicated)

Region & Country	Total Percent Weight Loss	Reported National Production ('000 Tonnes)	Remarks
West Africa	6 - 24		Drying 1-2; on-farm storage 2-10; parboiling 1-2; milling 2-10 (van Ruiten, 1977)
Sierra Leone	10	580	
Uganda	11	15	
Rwanda	9	5	
Sudan	17	7	
Egypt	2.5	2,300	Central storage (Kamel, 1977)
Bangladesh	7	18,500	
India	6	70,500	
	3 - 5.5		Unspecified storage Improved traditional storage (Boxall and Greeley, 1978)
Indonesia	6 - 17	22,950	Drying 2; storage 2-5
Malaysia	17 - 25 c.13	1,900	Central store 6; threshing 5-13; Drying 2; on-farm store 5; handling 6 (Yunus, 1977)
Nepal	4 - 22	2,404	
Pakistan	7	3,942	On-farm 3-4; on-farm store 15; central store 1-3
	2 - 6		Unspecified storage 5
	5 - 10		Unspecified storage 2 (Qayyum, 1977)
Philippines	9 - 34	6,439	Unspecified storage 5-10 (Greaves, 1977)
	up to 30		Drying 1-5; unspecified store 2-6; threshing 2-6
	3 - 10		Malaysia workshop (FAO, 1977c)
Sri Lanka	13 - 40	1,253	Handling (Toquero et al., 1977)
	6 - 18		Drying 1-5; central store 6.5; threshing 2-6
Thailand	8 - 14	14,400	Drying 1-3; on-farm store 2-6; milling 2-6; parboiling 1-3 (Ramalingam, 1977)
	12 - 25		On-farm store 1.5-3.5; central store 1.5-3.5
			On-farm store 2-15; handling 10 (Dhamcheree, 1977)
Belize	20 - 30	2	On-farm storage (Cal, 1977)
Bolivia	16	113	
			On-farm 2; drying 5; unspecified store 7
Brazil	1 - 30	9,560	Unspecified store 1-30
Dominican Republic	6.5		On-farm store 3; central store 0.3

De Padua indicates that because of the complexity of the system reduction of losses will require a combination of increased efficiency at each step in the postharvest system and improved drying, threshing, and milling technology.

Rice postharvest technology is described in detail in the publication of that title (Araullo et al., 1976) published by the International Development Research Centre (IDRC) and widely available. Details of the stages of processing are described in so far as they relate directly to postharvest losses and loss reduction.

### Harvesting

The bulk of rice produced in Asia and Africa is still grown on small farms and harvested by hand. Combine harvesters of the type used in Europe and the United States are unsuited to small farms, and even the smaller Japanese models have not gained wide acceptance due to high cost, exacting field requirements, and high field losses which they cause.

Some major losses are connected with the time that rice is harvested; that is, with the maturity of the crop and the effects of a season on harvesting decisions: for instance, postponement of the harvest under certain dry or wet conditions.

Delay in harvesting a mature rice crop leads to lower yields because of lodging and shattering and the exposure of the ripe grain in the field to rodents and birds. It also leads to postharvest losses by lowering milling yields and recovery of head grains. Introduction of new quick-maturing varieties, in major part due to the breeding and management research carried out at the International Rice Research Institute in the Philippines, has enabled double-cropping (two crops per year).



The summer or dry-season rice crop does not have to be dried quickly; if it is left in windrows after reaping in good weather, there is little damage to the grain. However, if semi-dried grain is remoistened by rainfall or a heavy dew, it may crack and high milling losses will result.

The rainy-season crop creates much more difficulty. To avoid significant loss, the wet harvest must be threshed, cleaned, and dried within 24 hours unless predrying facilities are available. It cannot be left in windrows or stacked in the field since this results in mold, fermentation, and even germination. De Padua reports some farmers in the Philippines are becoming reluctant to plant wet-season crops because of the threshing and drying problems (TPI, 1978).

### Threshing

Traditional threshing techniques are a frequent cause of loss. They include:

- ° Beating the straws against slats through which the grain falls into tubs or buckets; and

- ° Threshing by trampling with feet--human or animal--and occasionally by using tractor wheels, or (in Thailand) with a tractor-drawn roller.

The Japanese down thresher--an adaptation of the paddle wire loop thresher--is widely used and has been the first step toward mechanization in India, Bangladesh, and Burma.

The dry-season crop is frequently dried in the field in windrows or stacks (such as the large rice stack, the "mandola," used in the Philippines) and can readily be mechanically threshed when relatively dry. A variety of mechanical threshers and cleaners is found in developing countries, frequently

based on adaptations of United States or Japanese model combines, especially in Asia.

The wet-season crop chokes many conventional mechanical threshers. Further, the wet conditions make it difficult to bring threshing machines to the field. Development of satisfactory mechanical wet-season crop threshing equipment is a priority IRRI research activity, and a number of double-drum threshers have been shown to work satisfactorily and are being introduced commercially. In many areas the capital cost of these threshers, and the training and organization their use entails, limits their widespread use, although Samson and Duff (1973) demonstrated the cost effectiveness of mechanical threshing, drying, and milling over traditional methods in the Philippines. Rice losses due to delayed threshing are likely to be reduced as mobile mechanical threshers become more widely available.

#### Drying

Rice grain at time of harvest varies in moisture content from low levels to over 30 percent, depending on the season. This must be reduced to 13-14 percent if the rice is to be stored for any length of time. Inability to do this quickly leads to rotting of the grain and reduction in milling quality from high breakage. It also causes discoloration and loss in quality due to fermentation and heat damage. Mold attack, including possible aflatoxin production, may also lead to loss in quantity and quality.

Traditional sun-drying of spread-out grain is an effective means of reducing moisture in the dry season. Wet-season crops require forced air drying with heated or ambient air. The commercial driers are designed either to dry grain in batches, in deep or shallow beds in which the grain may be stationary or mechanically circulated, or continuously in stages as

the grain flows through the drier. The physical design and operating characteristics, including such factors as air volume to grain volume ratio and air temperature, influence the rate of drying and quality of the dried grain. These mechanical characteristics differ for different kinds of grain, and great care must be exercised in using a drier for a grain other than the one for which it was designed.

This is particularly important in the case of rice, which is much more sensitive to thermal stress than other grains and is eaten as whole kernels. High temperature and low air-volume movement, while rapidly removing moisture, result in fissuring and a high proportion of broken grains when milled. The same rate of drying may be achieved at lower temperatures with greater air flow--the important characteristic being the vapor pressure differential between the drying air and the grain--at less risk of damage to the grain.

Other characteristics of drying equipment to be considered include time required to dry grain from high moisture content and peak volumes that must be handled during the harvest season. The strength of the construction material is important, as paddy rice is highly abrasive and rapidly wears through sheet metal. Some parts of rice-conveying systems in the People's Republic of China are frequently constructed of glass, which both counters the wear and permits visual inspection of the rice flow.

In spite of the evident need, driers have not received wide acceptance in Asia and Africa. Factors mitigating against them include:

- The high capital cost of both imported and locally constructed driers because the limited market has not led to the large-scale manufacture that would reduce unit cost;

- Unsatisfactory performance of some models and lack of experienced operators, which has resulted in poor milling of dried grain;
- Unmatched drying capacity with threshing, milling, and transportation capacities (with large-capacity central driers this also involves difficulty in catering for many different varieties and grades received); and
- Delays in harvesting, threshing and transportation that reduce the benefit of mechanical driers, since drying spoiled grain does not pay for the investment.

For these reasons, it is agreed that the most immediate equipment need is for low-cost batch-type farm driers locally fabricated from locally available materials. This simple operation, properly carried out, gives dried grain of good milling quality with a minimum of delay, particularly where the drier can be moved from the storage or milling plant to the farm to reduce the delay between harvest and drying.

In certain situations, these small batch driers can be used to complement large central drying plants, particularly at the peak of the harvest season when the grain has very high levels of moisture. They can be used to dry the grain partially to around 18 percent, at which level the grain can be kept for several days without significant bio-deterioration before being centrally dried to the 13-14 moisture percent required for storage and milling. An alternative possibility is to use a preservative, such as propionic acid, which can retard spoilage of wet paddy for several days before central drying.

The level of sophistication of the farm-level batch driers can vary according to need, capital resources, and construction and operating experience available. Very simple driers can be built that are also designed to burn rice husks, thereby reducing operating expenses. Natural ventilation

drying methods similar to those used for maize should also be investigated.

The necessary credit for the farmers to purchase the driers must be available and the infrastructure to support their use and maintenance. This may include pricing policies which encourage production of better quality grain; the profit incentive will stimulate adoption of the improved technology.

Larger driers can be purchased commercially or designed and constructed with expert advice from engineers of national agencies or international organizations such as FAO, IRRI, or the West African Rice Development Association (WARDA).

#### Milling

Because rice is mainly consumed as intact grains, rice milling, in contrast to processing of other cereals, is a complicated process; a large number of operations are required to produce white polished rice grain from harvest paddy. (Rice is widely called "paddy" prior to milling, and "rice" after milling, a convention followed here to distinguish between the two forms.) These operations are parboiling, precleaning, hulling, husk separation, paddy separation, and whitening and polishing.

At each stage, losses are incurred due to the inherent efficiency limits of the process and, of course, due also to inefficient operation. Because these losses--and the processes themselves--are reported to be priority areas for attention and improvement, they are described in Note IV-2.

## Storage

Much of the traditional rice-growing area of the world lies in the humid tropics, with a climate characterized by high average temperatures (around 30°C) and relative humidity (around 85 percent).

Under these conditions grain (whether stored as paddy or as milled rice) at equilibrium tends to absorb moisture from the atmosphere at the more humid times of day. Unless the storage is adequately ventilated, spoilage may result from increased respiration of molds in the grain, accompanied by local heating and possibly fermentation.

In closed structures, there can be a problem with condensation of moisture, which may be given up by moist grain at the hottest part of the day and condense on the walls during the night, causing local wetting of the grain. Aeration (forced ventilation) permits equalization of moisture content throughout the stored grain, and also reduces the temperature of the grain by evaporation. The drop in temperature also cools the grain and tends to reduce respiration and spoilage.

Paddy is commonly stored either in the form of bundles of panicles, in sacks or plastic bags, or in bulk storage. The sacks or bags provide a means of separating varieties for specific milling requirements. However, they deteriorate with use and allow access to insects and rodents, particularly if not properly stacked and handled with hooks and if the store hygiene is not adequate. Bulk storage, if properly organized, is efficient and relatively inexpensive. However, its efficient operation requires considerable capital investment and trained manpower, both of which may not be available.

Storing rice as paddy has advantages over storing milled grain, particularly where storage facilities are less than completely adequate. The protection afforded the kernel by the husk against insect, fungal, and even rodent attack as well as the problems of storing poorly milled rice accounts for the bulk of harvested dried paddy being stored in this form before milling, although this depends to some extent on the local economic situation and supply and demand for paddy and milled rice at different times in the season.

#### Washing Losses of Rice

Rice is commonly washed prior to cooking, and in Korea, Cheigh et al. (1977) estimate weight losses due to washing local varieties of polished rice at over 2 percent. While it can be argued that this is not, strictly speaking, a postharvest loss as such losses are defined in this report, since the food is in the hands of the final consumer and loss takes place immediately prior to consumption, it has postharvest loss implications. The loss of nutrients accompanying the total solids loss is similarly not a postharvest weight loss, but is clearly important. The authors suggest that improved postharvest handling that delivers sanitary rice to the household and makes washing unnecessary could minimize these substantial losses.

#### Economics of Improved Rice Processing

Studies have been made at IRRI on the magnitude and nature of field grain losses in paddy production. Samson and Duff (1973) indicate different levels of loss between varieties, wet and dry seasons, and moisture content at time of harvest. A related series of trials investigated losses

ascribable to handling, bundling, stacking, and field drying. Total paddy losses are given as approximately 1-3 percent for the harvest operation and 2-7 percent for the intermediate handling steps.

A comprehensive survey of rice milling and field level operations was undertaken in three regions of the Philippines, including 180 rice mills and approximately 600 farmers. Based on the results, a series of pilot trials was undertaken to assess the impact of different systems of technology at the farm and rice mill level.

These trials compared the traditional methods commonly employed by farmers (threshing manually and sun-drying prior to storage and milling) with various systems of improved technology: mechanical threshing, batch-drying, and combinations of each with manual threshing and sun-drying.

Losses from manual threshing were found to be three times greater than losses from mechanical threshing. Increases in yield of about 12 percent were observed using either the drier or thresher in combination with traditional methods, and using both in sequence gave the greatest increase in output. A large part of this increase is ascribed to the reduction in time between harvest and threshing.

The improved technology also increased the quality of the grain, largely reduction in broken, fermented, discolored, and immature grains due to the improved drying, and the reduction in time between harvest and drying. Total expenditure per tonne was estimated to be twice as high for traditional as for the improved methods evidently much favored by farmers.



## Maize

### Loss Estimates

The FAO-published figures (1977b) report average maize losses from 9.6 percent to 20.2 percent, mainly in storage (either unspecified or on-farm as opposed to central storage) and due mainly to insect damage, followed by fungus and rodent damage. However, the data is markedly inadequate, and as the FAO report concludes, "the estimates of losses of durable commodities and the methods by which they are derived were inadequately refined." Much painstaking work on farm-level maize storage is of limited use in determining weight losses because of the difficulty of measuring and interpreting losses due to "insect damage" reported as a percentage of damaged grains. Adams (1977) notes the lack of information from Central and South America in contrast to the considerable attention paid to cereal losses generally in most regions of Africa.

Maize presents particular problems of loss estimation because it can be stored either on the cob or shelled, affecting the subjective evaluation of what is edible. Storage on the cob enables a process of selection at the time of shelling; individually damaged grains may be separated as the grain is shelled, or the cob may be considered so heavily damaged that it is rejected, good kernels and all. The correlation between visible insect damage and weight loss varies according to the type and length of infestation. Accurate estimates of losses are impossible unless clear definition of these factors accompanies the numerical data.

The preferred methodology for determining maize losses involves weighing standard volumes of shelled grain. Losses would be measured on a dry-weight basis and reported on a typical moisture content that is

acceptable in the market place. This moisture content should ideally become a "standard" that would be widely adopted.

Table 4:3 gives an indicative compilation of reported estimates in different countries.

### Harvesting Factors

Postharvest losses are influenced by harvesting practice and field infestation by pests.

In many areas, standard practice includes turning down the ripe ears on the stalk, where they are left to dry further before collection, in traditional varieties, the corn husk completely encloses the grain and protects it from insect attack. The husk also protects the ear from exposure to moisture after it is turned down.

Resistance to field infestation by insects is low in many high-yielding varieties. Increased grain production on the cob generally results in both more and larger grains that may be incompletely covered by the corn husk and are more susceptible to field attack by insects and birds. The effects of these attacks may be carried over to the storage phase.

### Shelling

Damage in shelling is proportional to the moisture content of the grain. Maize shelling is traditionally accomplished by hand and this method, though hard, tedious, labor-intensive work, is efficient in stripping the cobs and in minimizing damage to the grains; it also permits hand separation of damaged or infested from sound grain. Increased production increases the amounts of grain to be shelled and this can strain the

TABLE 4:3

REPORTED LOSSES OF MAIZE WITHIN THE POSTHARVEST SYSTEM  
(Based on FAO, 1977b, Figures Unless Otherwise Indicated)

Region & Country	Total Percent Weight Loss	Reported National Production ( '000 Tonnes)	Remarks
Benin	8 - 9	221	Traditional on-farm storage; 6 months improved silo storage (Harris & Lindblad, 1978)
Botswana		62	Insect damage
Ghana	7 - 14	395	(Rawnsley, 1969)
	15		8 months storage (Hall, 1970)
Ivory Coast	5 - 10	120	12 months stored on cob (Hall, 1970) (Van de Venne, 1978)
Kenya	10 - 23	1,360	4-6 months central storage
	12		Hybrid maize, hotter regions, 6 months (De Lima, 1973)
Malawi	6 - 14	1,200	Drying 6; on-farm store 8 (TPI, 1977); (Schulten, 1975)
	min. 10		Hybrid
Nigeria	1 - 5	1,050	On-farm storage
	5.5 - 70		6 months on-farm storage (FAO:ECA, 1977)
Rwanda	10 - 20	60	On-farm storage
Tanzania	20 - 100	1,619	Unspecified storage
	9, 14, 67		3, 6, & 9 months (Mushi, 1978)
Togo	5 - 10	135	6 months central storage (Tyagil et al., 1975)
Uganda	4 - 17	623	
Zambia	9 - 21	750	On-farm storage (Adams & Harman, 1977)
India	6.5 - 7.5	6,500	Central storage, 7.5 (Agrawal, 1977)
Indonesia	4	2,532	
Pakistan	2 - 7	70	
Belize	20 - 30	20	Traditional on-farm storage (Cal, 1977)
Brazil	15 - 40	17,929	Farm storage
Dominican Republic	19	49	Farm storage, 15; processing, 1
Honduras	20 - 50	289	Traditional storage, poor facilities (Balint, 1977)
Mexico	10 - 25	8,945	
Nicaragua	15 - 30	201	
Paraguay	25	290	(Martino, 1977)
Venezuela	10 - 25	532	

capacity to shell the dried cobs by hand. Methods of shelling quantities of cobs include beating bagged cobs with a stick, which results in increased loss due to incomplete stripping of the cobs and damage to the grain. Mechanical shelling losses are relatively low when the equipment is adjusted and operated competently and grain moisture levels are low. Wooden hand-held maize shellers developed by the Tropical Products Institute (Pinson, 1977) offer an efficient intermediate-level technology to increase manual shelling capacity. The sheller is shown in use in Figure 2. The dry maize cob is held in one hand and the sheller in the other. As the cob is pushed into the sheller, the ridges pull out the grain.

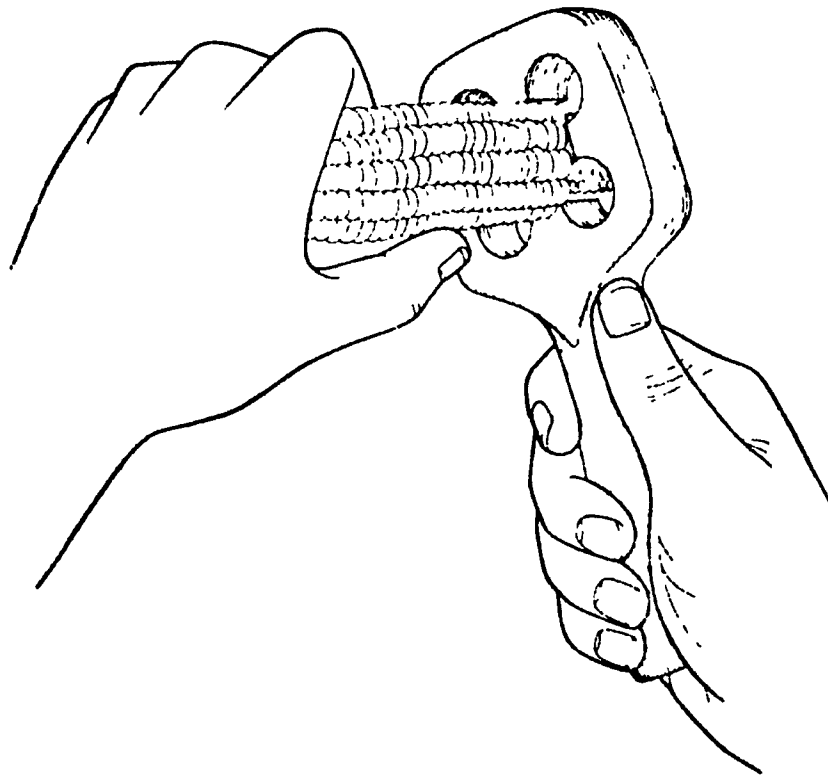


Figure 2.

### Drying and Storage

Harvested ears of corn are normally stored and dried at the same time and these two functions should be considered together.

In developing countries there are a number of on-farm traditional methods for drying and storage of maize.

In Ghana, for instance, these include the Ewe barn, a raised circular platform on which ears are built up to form a cylinder and roofed with thatch, and the Ashanti crib, a raised rectangular structure of wood or bamboo that is also thatched. Losses are estimated at 7-14 percent over 3-6 months (Rawnsley, 1969).

In a number of places in West Africa and elsewhere, ears are hung to dry from horizontal poles protected from the rain or from branches of trees.

In Kenya and Tanzania, stores for shelled grain are constructed from woven branches and the basket structure supported by a strong platform raised on poles or stones. In humid areas the maize is stored in a special loft or crib over the cooking fire, which deters insects and reduces humidity.

In a number of countries storage baskets may be plastered with mud. Sometimes they are completely sealed to exclude infestation, in which case it is usual to open the store periodically and redry the grain in the sun.

The use of hessian sacks for storing shelled grain is widely reported. A limitation is that the sacks are vulnerable to insect, mold, and rodent damage when left on the ground in the corner of a hut for extended periods, although this may be prevented by frequent inspection.

Other containers commonly used to store small quantities include gourds, pots, tins, and small baskets.

In general, the traditional methods of storage work well as long as they are in balance with the rest of the farming system. The inherent quality of local maize varieties, such as the hardness of the endosperm and low moisture content, and storage on the cob with husk intact, all help to protect the grain from insect attack. A long process of natural selection has led to the survival of varieties that provide a reasonable return to farmers for their farming and storing efforts. This can be seriously disrupted by introduced changes; in addition to new crop varieties with their different grain properties, the amount of grain to be stored generally increases and may place a strain on the traditional storage facilities or on the time available to the farmer and his family for processing it.

**Improvements to Traditional Drying.** Drying is often a problem, particularly when, as in West Africa, the crop matures during a period of high humidity and the effectiveness of natural drying of large quantities of maize is uncertain.

The African Rural Storage Center at Ibadan, Nigeria, recommends the construction from locally available materials of improved drying cribs designed to make best use of free ventilation drying effects. About four months of crib drying of dehusked maize, to which insecticides are applied externally, is the technique recommended over field drying or the storage of shelled grain immediately after harvest. Crib drying reduces losses due to both fungi and insects to about 2 percent after 4 months' storage. There

no evidence to show that small-scale mechanical driers are a good answer to drying needs, and the fuel supply from firewood or fossil fuels makes this method environmentally and economically less attractive than free ventilation methods for farm and village-level drying.

(Photo of drying crib)

Nyanteng (1972) notes the problems of organizing cooperatives to carry out drying and storage and the difficulties of introducing "improvements" through grain marketing cooperatives in Ghana. The problems stem partly from inappropriate technology and partly from poor management.

Reduction in losses due to insects has been reported when properly dried maize is stored shelled. This controls Sitotroga by restricting its movement through the bulk of the grain and its opportunity to deposit eggs. In the shelled grain, damage is confined to the exposed surfaces. Sitophilus is readily controlled by insecticides suitable for direct application to grain, such as malathion. Crib drying with insect control, followed by storing shelled grain in impervious containers, has been reported as a successful combination for reducing losses in humid regions of West Africa and Zambia.

## Wheat

The production of wheat continues to increase in the main producing countries--India, Mexico, Pakistan--and the problems of harvesting, threshing, transport, marketing, storage, and processing have increased proportionally. However, these have been accompanied by extensive efforts to improve the postharvest system in these countries, and research, training, and infrastructure are relatively sophisticated compared to other commodities in other countries.

### Loss Estimates

Of loss problems suffered among all grains, relatively few of these are specific to wheat.

Loss reports for wheat average 10 percent, with the major causes being insects, rodents, and mold during storage, particularly where overproduction has strained storage facilities to their limits. Rodents are a major problem in India (as noted earlier in this chapter).

Milling losses are not reported to be a serious problem. As with rice, they result from inefficient operation or maintenance of machinery, often due to inexperienced operators or difficulty in obtaining spare parts. The roller milling of wheat grains is a highly complex technical process that must be carefully adjusted to achieve efficient milling of wheat grain to flour of various qualities, plus germ and bran. It differs from rice milling in that the product is ground flour rather than intact kernels and grain breakage is not a major issue. Unlike rice processing, wheat processing is not reported to be an area where substantial postharvest loss occurs or that requires priority research and development in developing countries.



With wheat, the primary need is careful precleaning prior to milling to remove all damaged, spoiled, or infested grains and dirt and debris. This ensures high-quality flour and protects the machinery from damage.

### Threshing

Threshing and winnowing are still done in open yards rather than in combines. The grain is exposed for an extended period; considerable losses due to birds, rodents, and spillage occur, and losses due to high moisture, molding, and fermentation may result if it rains. Inefficient operation of mechanical threshers breaks the grain and makes it more susceptible to insect attack or threshes it incompletely.

### Storage Problems

In addition to storage problems common to all harvested grains, wheat may be rendered unfit for malting or bread making because of spoilage during storage, particularly due to mold. Indian government reports on storage losses of wheat (Krishnamurthy, 1972) give figures of approximately 2.5 percent loss due to rodents and a slightly higher percentage due to insects. Small-scale farm storage losses vary, but are typically around 10 percent.

### Processing Losses

Use of wheat and wheat products is increasing in developing countries in response to the demand for bread. However, wheat flour is put to other uses besides bread. In a number of countries, unleavened bread ("hubus," "chapattis," "puris," etc.) is made from a variety of grades of flour.

TABLE 4:4

REPORTED LOSSES OF WHEAT AND BARLEY, MILLETS, AND SORGHUM  
 WITHIN THE POSTHARVEST SYSTEM  
 (Based on FAO, 1977b, Figures Unless Otherwise Indicated)

Commodity & Country	Total Percent Weight Loss	Reported National Production ('000 Tonnes)	Remarks
<b>WHEAT</b>			
Pakistan	5-10	8,500	On-farm storage 5-10; milling 2; central store 5 (Qayyum, 1977; Greaves, 1977; Chughtai, 1977)
	12		Unspecified storage
India	8-25 2-52	24,000	(Amla, 1977; Agrawal, 1977) Farm storage to 45; threshing 1; central storage 8
Rhodesia	10	2,571	On-farm storage (Howden, 1977)
Sudan	6-19	880	
Bolivia	16	833	Store 7; drying 3
Brazil	15-20	906	Storage 1-4
<b>BARLEY</b>			
Pakistan	9	130	Unspecified storage 7; processing 2
Bolivia	14	80	Drying 2; unspecified store 6; transport & distribution 4
Sudan	17	?	Central store
<b>MILLETS</b>			
Mali	2-15	804	On-farm store 2-4; central store 10-14 (Guggenheim, 1977)
Nigeria	.1-.2	3,200	On-farm storage
Rhodesia	10-15	564	On-farm storage (Howden, 1977)
Sudan	14	450	Central store
Zambia	10	30	On-farm storage
India	7-10	9,600	Drying 2-5; farm storage 5 (Chaturvedi, 1977; Agrawal, 1977)
Pakistan	7.5	503	Storage 5; processing 2.5

TABLE 4:4 (continued)

Commodity & Country	Total Percent Weight Loss	Reported National Production ( '000 Tonnes)	Remarks
SORGHUM			
Nigeria	0-37	3,680	On-farm over 26 months (Hall, 1970)
Rhodesia	25	716	On-farm store (Howden, 1977)
Sudan	6-20	1,800	Central storage
Zambia	0-10	46	Local varieties, negligible; high-yielding varieties 10 (TPI, 1977)
India	7.5	544	Unspecified storage
Indonesia	4.0	?	
Pakistan	7.0	621	Storage 5; processing 2

While white flour technically comprises about 63-80 percent of the whole wheat grain, practical milling considerations in current mills require an extraction rate of about 75 percent to produce a white flour suitable for western bread making. More widespread use of higher extraction brown flour (such as the 95 percent "atta" in India) would reduce milling losses.

### Barley

Barley is produced in cool upland areas and is a major crop in Korea, China, India, Iran, Syria, Turkey, and Ethiopia. Its processing is similar to rice. An important use of barley is for sprouting (malting) and fermentation to produce beer and other alcoholic beverages, and considerable quantities are imported to developing countries for this purpose.

Drying of the grain prior to malting must be done carefully to ensure germination, and malting is not affected.

There are few reports in the literature of losses of barley in developing countries, and it appears that there is no special problem peculiar to barley. This may reflect, in part, the fact that it is mainly produced in the cooler countries, the care with which the brewing industry handles the crop, and the relatively few stages of processing it requires.

### Millet and Sorghums

Millet and sorghums are grown in semiarid areas, and although their annual reported production (approximately 20 million and 30 million tonnes respectively, FAO, 1977a) represents only 6 percent of total cereal production,

they are the main staple in drier regions of Africa, the Middle East, India and Pakistan, and China.

In developing countries, most production is still at the farm and village level, and postharvest technology is unimproved compared with that for the major cereals.

#### Loss Estimates

Postharvest losses of millets and sorghums have received relatively little attention. Reported losses have often cited damage rather than weight loss. Loss estimates have indicated relatively moderate levels occurring during storage, 1-5 percent (Spencer et al., 1975). Other losses occur during harvest and as the grain dries in the field.

#### Harvesting

Because harvesting is carried out under dry conditions, the crop is commonly left standing in the field to dry for a period. Sorghum stalks may be tied together at the top in threes or fours to prevent the dry stalks from lodging.

This field-drying period may extend for a considerable time, during which the grain is exposed to bird and rodent and insect attack, including termites. Although these may in many cases be considered as preharvest problems, depending on local variations in handling, the result affects postharvest deterioration of stored grain.

#### Threshing

Millet and sorghum grain is frequently stored on the head and threshed as required, except for seed grain, which may be threshed and

sealed in small containers to be kept in the house for special security. In other cases, however, seed grain is kept unthreshed hung from the roof.

### Millet Storage

Guggenheim (1977) and Spencer et al. (1975), describe traditional and central warehouse storage of millets in Mali and Senegal and report losses averaging 2-15 percent. Losses in traditional stores were lower than in the central warehouses.

The difference between estimates of loss under traditional and central storage results from a number of factors. In Mali, farmers may be assigned a quota of grain which they must sell to the government; they are prepaid for their quota and provided with empty sacks in which to deliver the shelled grain, but are not paid for the transportation, and there is thus no incentive to speed the delivery of the bagged grain to the collection centers. The collection centers themselves have insufficient, often ill-designed space, even specially designed stores may be poorly constructed. The bagged grain may be left uncovered on open ground or kept in old store-rooms or school buildings, or in the extension agent's residence together with his animals. And since the grain that farmers sell to the government is commonly the oldest available, or of a quality they do not wish to store themselves, it may not be very durable at the outset. As a result, comparatively high losses of 10-15 percent are encountered in the government system.

Dogon traditional granaries are built of rock, wood, and banco (clay mixed with millet chaff) about 2.5-3.33 m high, depending on the terrain, excluding their conical grass thatch roofs. Figure \_\_\_\_\_. They have wooden foundations which lift the mud structure 30 cm from the ground to protect it from moisture.

Good management of granaries is fundamental to keeping postharvest losses low. Millet heads are roughly classified during harvest: very poor and aborted grain is not cut, poor grain is cut but kept apart, good grain is prepared for storage. The grain to be stored is spread on the flat terraces of the houses for drying. The very best is reserved as seed, usually kept under the kitchen roof, protected by smoke against insect attack. The remainder is moved to the granary 6 weeks to 3 months following harvest, in December or January, by which time it is very dry--typically below 10 percent moisture.

Rodent damage in the field and in storage is difficult to differentiate, as is bird damage in the field and while the grain is drying on terraces of houses. Quelea quelea (the grain-eating weaver bird) is responsible for heavy losses of early maturing varieties of millet, and wild pigeons cause major damage to grain during drying.

Fungal damage appears to be negligible when millet is stored on the head for up to 4 years; in bulk with the addition of ash, the grain is reported to keep up to 5-7 years. However, this grain is thought to lose its flavor, perhaps as a result of biochemical deterioration.

Traditional methods of fumigation, such as smoking with burning millet chaff mixed with pepper, appear to be effective. Leaves of plants such as Andropogon (grasses) and Combretum (vines), whose odor is thought to repel both insects and rodents, are placed with the grain. More important is the use of ash of Boscia senegalensis and millet stalks, a mixture scattered on the floor and rubbed into the walls of the granary. It is also mixed with the threshed grain.

### Sorghum Storage

Annual production of sorghums in developing countries was estimated to be 31 million tonnes in 1978 (FAO, 1977a). Little investigation of losses has been reported, and generalization from the few reports is obviously risky.

Storage is similar to millet. Reports by Giles (1964) of storage in northern Nigeria, Nyanteng (1972) for northern Ghana, and Spencer et al. (1975) in Senegal indicate the existence of methods and problems similar to those of millet in Mali.

Losses are reported to be relatively low in storage of traditional varieties of sorghum. Insect damage, from Sitotroga, Sitophilus, and Rhyzopertha dominica occurs particularly in newer high-yielding varieties in central stores. Estimates of 1-20 percent losses are reported.

Dusting the stored grain on the head with BHC is reported to have been effective in controlling insect infestation in mud granaries for up to 18 months (TPI, 1977).

### Grain Legumes

The grain legumes or pulses occupy an important place in global food and nutrition with a current annual production of about 50 million tonnes (FAO, 1977a). Half of this is produced in developing countries, where they are disproportionately important dietary constituents of many people, supplementing cereal diets with essential amino acids and improving nutrition where animal protein is scarce.



Substantial amounts of grain legumes are consumed, particularly in Africa and Asia, after milling to dehusk and split live grains or some other type of processing. Many commercial technologies are either obsolete or inadequate for this purpose as they cause heavy losses due to breakage and powdering; research and development in a number of countries, particularly India, has been devoted to developing improved technologies.

Grain legumes are more difficult to store than cereals and suffer greater damage due to insects and microorganisms. Damaged grain also suffers higher milling loss.

Yields of grain legumes are low compared with cereal grains, averaging from 200 to 1,500 kg/ha, and total production has remained roughly constant over the past 10 years. This was the subject of discussion at a special seminar organized by the Protein Advisory Group of the United Nations in 1972 (FAO, 1973), which emphasized the importance of developing new varieties of grain legumes to resist pests, diseases, and drought, and of developing improved technologies for processing and conserving them.

#### Nomenclature

There are some 36 major species of grain legume grown and consumed as food. All have common or local names, some of which are given to more than one species.

Table 4:5 lists both common and botanical names alphabetically.

TABLE 4.5

## NOMENCLATURE OF THE GRAIN LEGUMES

<u>Common Name</u>	<u>Botanical Name</u>	<u>Botanical Name</u>	<u>Common Name</u>
Arhar	<u>Cajanus cajan</u>	<u>Arachis hypogaea</u>	Groundnut, peanut
Bambara groundnut	<u>Voandzeia subterranea</u>	<u>Cajanus cajan</u>	Pigeon pea, Arhar, Redagram
Beans, dry	<u>Phaseolus subterranea</u>	<u>Cajanus indicus</u>	Pigeon pea, Congo pea, Yellow dhal
Bengal gram	<u>Cicer spp.</u>	<u>Cicer arietinum</u> , <u>C. motinum</u>	Chickpeas, Bengal gram; Garbanzos
Black gram	<u>Phaseolus mungo</u>	<u>Dolichos biflorus</u>	Horse gram
Black-eyed cowpea	<u>Vigna unguiculata</u>	<u>Ervum vulgare</u>	Lentils, masur dhal
Broad beans	<u>Vicia faba</u>	<u>Faba vulgaris</u>	Windsor bean
Chick peas	<u>Cicer spp.</u>	<u>Glycine max</u> ; <u>G. hispida</u> ; <u>G. soja</u>	Soybeans, Soja
Congo pea	<u>Cajanus indica</u>	<u>Lathyrus sativus</u>	
Cowpeas, dry	<u>Vigna unguiculata</u> , <u>V. sinensis</u>	<u>Lens esculenta</u> ; <u>L. culinaris</u>	Lentils, masur dhal
Feijao	<u>Phaseolus spp.</u>	<u>Lupinus spp.</u>	Lupins
Garbanzos	<u>Cicer spp.</u>	<u>Mucuna pruriens</u>	Velvet bean
Golden gram	<u>Vigna radiata</u> ; <u>V. aureus</u>	<u>Phaseolus angularis</u>	Dry bean
Green gram	<u>Phaseolus aureus</u>	" <u>aureus</u>	Mung bean, Green gram, Golden gram
Groundnut	<u>Arachis hypogaea</u>	" <u>lunatus</u>	Lima bean
Haricot bean	<u>Phaseolus vulgaris</u>	" <u>mungo</u>	Mung bean, Mungo bean
Horse gram	<u>Dolichos biflorus</u>	" <u>radiatus</u>	Mung bean, Green gram, Golden gram
Kidney bean	<u>Phaseolus vulgaris</u>	" <u>vulgaris</u>	Haricot, Kidney, Navy, Pinto or Snap bean, Feijao
Lentils	<u>Ervum lens</u> , <u>Lens spp.</u>	<u>Pisum angularis</u> , <u>P. arvense</u> , <u>P. sativum</u>	Dry peas
Lima beans	<u>Phaseolus lunatus</u>	<u>Psophocarpus tetragonolobus</u>	Winged bean (humid tropics)
Lupins	<u>Lupinus spp.</u>	<u>Sphenostylis stenocarpa</u>	Yam beans
Masur dhal	<u>Lens spp.</u> ; <u>Ervum lens</u>	<u>Stizolobium spp.</u>	Velvet beans
Mung beans	<u>Vigna radiata</u> ; <u>V. aureus</u> ; <u>Phaseolus aureus</u> ; <u>P. radiatus</u>	<u>Tetragonolobus purpureus</u>	Winged bean (Europe)
Mungo bean	<u>Phaseolus mungo</u>	<u>Trigonella foenum graecum</u>	
Peanut	<u>Arachis hypogaea</u>	<u>Vicia faba</u>	Broad beans
Peas, dry	<u>Pisum spp.</u>	<u>Vicia sativa</u>	Vetch
Pigeon peas	<u>Cajanus spp.</u>	<u>Vigna aureus</u> , <u>V. radiata</u>	Mung beans
Pinto bean	<u>Phaseolus vulgaris</u>	<u>Vigna sinensis</u>	Dry cowpeas
Redagram	<u>Cajanus cajan</u>	<u>Vigna unguiculata</u>	Black-eyed cowpeas
Snap bean	<u>Phaseolus vulgaris</u>	<u>Voandzeia subterranea</u>	Bambara groundnut
Soybeans, soja	<u>Glycine spp.</u>		
Urd	<u>Phaseolus mungo</u>		
Velvet bean	<u>Mucuna pruriens</u> ; <u>Stizolobium spp.</u>		
Vetch	<u>Vicia sativa</u>		
Windsor bean	<u>Faba vulgaris</u>		
Winged bean	<u>Psophocarpus tetragonolobus</u> (humid tropics); <u>Tetragonolobus purpureus</u> (European)		
Yam beans	<u>Sphenostylis stenocarpa</u>		
Yellow dhal	<u>Cajanus indicus</u>		

## Loss Assessment

Most grain legumes are harvested after a preharvest period of field drying. During this drying period, the pods and grains are exposed to attack by birds, rodents, and insects, and preharvest losses result not only from the food they consume but also because they cause shattering of the seeds.

The harvested legumes may carry a field infestation, mainly by bruchid beetle species, which lay their eggs on the maturing pods (Prevett, 1961). Although the infestation at harvest may be as low as 2 percent (Booker, 1967), this may provide a nucleus sufficiently dangerous to cause serious losses after several months of storage.

Taylor (1977) reports that in Nigeria field infestation often causes farmers to dispose of a crop as soon as possible after harvest. Although this passes the storage problem to middlemen, it also imposes on the farmer the necessity of buying back needed legumes later in the season when the price has increased and the quality decreased. Grains may change hands many times before consumption, making loss assessment and control more difficult.

Studies have been directed mainly to assessing losses in storage and processing. The loss assessment problems of cereal grains also apply to legume losses and are compounded by the large variety of legume species and their traditional production as supplements to, or in rotation with, cereal grains. The fact that they are produced and stored in comparatively small quantities has increased the difficulty of loss estimation. High variability is shown by the reported figures, attributed to the variety of storage systems and containers and the progressive consumption during

the season, leading to high proportion of damage and loss in the residue at the end of the season. Losses are reported from 2 to 3 percent to as much as 50 percent; many of the reports give damage assessments rather than weight losses. Representative figures are given in Table 4:6, but the degree of variability makes it impossible to arrive at an average figure. Experienced observers agree that losses are normally somewhat greater than for cereal grains.

#### Preharvest Loss Control

The extent of field infestation by insects has led to preharvest prophylaxis in legumes to reduce storage loss. In food for human consumption, prevention is clearly preferable to postharvest control measures. Effective preharvest control involves making the grain inhospitable to the insects. This may be achieved, to some extent, by breeding resistant varieties and by treating the crops with insecticides before harvest.

#### Harvesting

Harvesting problems arise where the crop does not mature evenly or where harvesting must be done when rain prevents satisfactory drying of the crop on the mature plant. Uneven maturing is less of a problem on small farms, where mature dry legumes can be picked over a prolonged period. Larger plantings that have to be harvested at a particular time may contain pods with more than 13-14 percent moisture and will need to be dried before or during storage to prevent molding and discourage insect attack.

TABLE 4:6

REPORTED LOSSES OF LEGUMES WITHIN THE POSTHARVEST SYSTEM\*  
 (Based on FAO, 1977b, Figures Unless Otherwise Indicated)

Country	Total Percent Weight Loss	Reported National Production ( '000 Tonnes)	Remarks
Ghana	7-45	11	Shelled beans, 1-5 months; unshelled beans, 22 (Rawnsley, 1969)
Nigeria	5.4	932	Cowpeas (Caswell, 1968)
	1- 2		Cowpeas stored 3 months in shell (Boshoff, 1975)
	4.5	350	Groundnuts (Howe, 1977)
Kenya	30	280	On-farm storage ( Lima, 1973)
Rhodesia	5	706	On-farm storage (Howden, 1977) groundnuts
Sudan	4-27	980	Groundnuts, central store
Swaziland	5	?	Groundnuts, insects and mold
Uganda	9-18.5	220	Groundnuts, mainly insects and mold
Zambia	40	600	Cowpeas (TPI, 1977)
India	8.5	12,956	Pulses, central storage
Indonesia	5	900	Unspecified storage (Sumartono, 1977)
Pakistan	5-10	785	Pulses (Chughtai, 1977)
Thailand	10-30	1,008	Soybeans, drying 15-17; farm store 12-15; handling 10 (Dhamcharee, 1977)
	.25-68		Soybeans, central storage
	.25-16	1,347	Groundnuts, central storage
Belize	20-50	1	Kidney beans, on-farm storage (Cal, 1977)
Brazil	15-25	1,923	Drybeans
Costa Rica	24		Drybeans (GIDA, 1977)
Honduras	20-50	48	Drybeans, on-farm storage (Balint, 1977)
Nicaragua	10-35	54	
Paraguay	15	8	Soybeans (Martino, 1977)

Losses can be minimized by good hygiene of stored legumes, by storing only whole pods and shelling the rest for sale or immediate use, by attention to drying the crop properly, and by carefully excluding insects and rodents in the transition between field and store.

### Storage

Major losses of grain legumes occur during storage.

The bruchids breed rapidly in stored legumes, preferring relatively high temperatures and humidity. Most have preference for particular legumes and will not necessarily thrive on any variety of pulse.

Dehusked and split stored pulses may be infested by insects from other stored product. as Rhizopertha, Trogoderma, and Tribolium spp. In addition to physical damage, contamination by insect excreta and fragments are extensive--guanine and uric acid are the most abundant substances. They are found in greater abundance in legumes than in cereals.

### Treatment of Harvested Grain Legumes

Because legumes are so prone to insect damage, special measures are often taken to protect them after they are harvested.

### Physical Treatment

Farmers in many areas spread grains in the sun to disinfect crops, possibly the only economical treatment currently available to farmers in developing countries, although experimental uses of cold, heat, and radiation have been tried.

Blockage of intragranular spaces using smaller grain such as millet (Eleusine coracana) or other inert material restricts movement of bruchids through stored grain and limits ovipositing. Steaming and parboiling, which cause hardening and gelatinization of the grain starch, have also been tried. As in the case of cereal grains, the use of inert materials to abrade and absorb cuticle wax and dehydrate insects is reported to be very effective.

Lemon oil has been shown to be effective in controlling cowpea weevils in black-eyed peas (Su et al., 1972), and a number of other oils and terpenes have insecticidal properties. Recently, work at IITA (1976) showed that groundnut oil added to cowpeas at 0.5-1.0 percent prevented insect attack for over 6 months. Castor, mustard, coconut, and sesame oils also are reported to be effective (CFTRI, 1977).

### Biological Control

Various predators and parasites have been recorded attacking and killing storage insect pests. A predacious mite (Pyemotes [Pediculoides] spp.) has been observed to attack and kill eggs, pupae, and adults of Acanthoscelides obtectus and Callosobruchus maculatus. Adults and larvae of the hymenopteran Pteromalus schwenkii feed on the larvae of C. chinensis, the bean weevil that attacks the mung bean. Dinarmus laticeps is a very common parasite of bruchids. However, though predators may locally reduce populations of pests, they cannot be considered an effective method of control.

Juvenile hormone analogs have been reported to block embryonic development of the cowpea weevil C. maculatus (El-Tantawi et al., 1976). A new pheromone which can act as an inhibitor of oviposition is reported by Yamamoto (1973). These methods are still only experimental.

#### Chemical Control

Malathion is a contact insecticide commonly applied to pulses that appear to give satisfactory control of store pests for extended periods.

Because of the infestation of storage facilities by infested crops brought from the field, fumigation of harvested crops has been widely employed. Fumigants have included carbon disulfide, ethylene di-bromide (EDB), methyl bromide, and aluminum phosphide. Aluminum phosphide proved better than EDB because of better penetration; however, excellent control of bruchids was accomplished with EDB-absorbed in chalk tablets used to fumigate small quantities of pulses in air-tight containers. Some eggs and larvae are tolerant to phosphine and require increased concentration of fumigant or fumigation time (Muthu, 1973).

From reports it appears that the pulses are more difficult to store at the farm level than cereal grains and that the structures and treatments for legumes are better at trading and government warehouses than on farms. Several factors may enter into this, including greater field, and hence farm, infestation; greater difficulty in controlling infestation in the larger grains without chemical insecticides or fumigants; and the fact that legumes may receive more attention in commercial or government storage because of their higher unit value.



## Processing

Dried food legumes go through a variety of primary processing steps before the final consumer can prepare food from them. These procedures include dehusking, puffing, grinding, splitting, and sprouting.

They are practiced at different levels of sophistication in different countries and regions, from hand-operated farm and home methods to small-scale cottage industry to major industrial processing similar to that of the rice and wheat industries in India and Southeast Asia.

**Dehusking.** Dehusking or hulling is the removal of the fibrous seed coat of the legume, the husk. This improves the quality of the grain by improving its appearance, texture, palatability, and cooking properties as well as digestion and absorption of nutrients after it is eaten. The simplest methods involve grinding the heated or sun-dried grain in a mortar and winnowing off the husks. The husk may also be loosened by soaking the grain, then removed by wet-grinding stones. In large-scale operations, husks may be removed by either wet or dry methods or a combination of them. In the wet method, the grain is soaked and sun dried, or mixed with small amounts of water to the appropriate amount. In the dry method, the grain is sun dried after application of small amounts of oil, moisture, or both. In some cases, simple sun drying may be sufficient.

In removing the husk care must be taken to remove as little of the edible kernel as possible. Several factors must be considered: variety of legume, which influences thickness of husk; thickness of the gum layer binding the seed-coat to the kernel; shape, size, and uniformity of the grains; hardness of the grains; texture and waxiness of the seed-coat; and age of the grain. Because of the variation in hulling characteristics

dependent on these factors, there is no standard procedure for hulling a given variety, and different combinations of methods are empirically employed.

Removal of the husk is commonly done in small machines, including both hand- and power-operated under-run disc-shellers, or blunt-plate mills. In many cases, hulling is accompanied by splitting the cotyledon; the husks are removed by aspiration while unhulled grains are easily separated from the split cotyledons by sieving. Roller mills are also used, but cause loss of kernel by scouring of the surface of the dehusked grain, which also leads to loss of surface proteins. These losses are particularly high if the grains are not well graded by size.

Moisture affects hulling and splitting of the grains: lower moisture helps the dehusking process, while higher moisture assists in splitting. Losses are reduced if these operations are done separately.

Splitting also causes loss of the embryo (amounting to 2-5 percent of grain weight) and breakage of the edges of the cotyledons. No widely used method satisfactorily permits dehusking without splitting and loss of the embryo; this is an area where opportunity exists for technology to improve the processing yield of edible grain, and to make an important contribution to nutrition. Improved milling technologies are being developed at the Central Food Technological Research Institute, Mysore, India. Separate methods are used to loosen the husk by heated air followed by tempering and husk removal by abrasion in a pearling machine, with each method adjusted for the particular legume. These combinations are reported to give impressive experimental yields of over 95 percent dehusked grain in a single operation. They are being introduced for commercial operation, and three automatic plants of between 0.5 and 2 tonnes per hour capacity are in

production. Other existing mills are being converted to the new technology. The process has been standardized for pigeonpeas, chickpeas, mung beans, black gram, lentils, cowpeas, soybean, horse gram, and kidney beans (Kurien, 1977).

These methods are suitable only for improving large-scale commercial milling. Nevertheless, they offer possibilities of conserving considerable amounts of legume yield, and thus of high-quality protein. Kurien estimates that possible additional yields of at least 8 percent could be achieved by adopting improved technology, which would amount to 800,000 tonnes additional milled pulses per annum, containing approximately 240,000 tonnes crude protein (flour from the peripheral layers of seeds contains about 30 percent crude protein) and costing approximately US\$290 million. He indicates that further improvements are needed, including:

- Increased milling efficiency of the dehuskers;
- Adjustment of machines to the needs of individual legume varieties;
- Better separation of husks from unhusked grain;
- More detailed knowledge about the nature of gums and mucilages and their influence on grain milling;
- Improved efficiency in splitting pearled grains under all conditions with minimum losses; and
- Improved recovery of edible portions of byproducts.

Larger varieties of legume are easier to mill, give higher yields, and are preferred by millers, while the smaller varieties, like pigeonpeas, black gram, and mung beans require repeated and severe premilling treatments that are associated with high scouring and splitting losses. In wet milling methods, water-soluble nutrients are lost. The development of milling

technologies that reduce these losses can therefore make possible additional yields of protein.

**Puffing.** Legumes may be puffed by subjecting them to high temperatures for a short duration. At the farm and home level, this may be done by gentle heating to around 80°C, followed by moistening with 2 percent water, which is absorbed overnight. The following day the grain is toasted with hot sand at 250°-300°C, at which point the cotyledons puff and split the husk, which is removed by gentle abrasion. At the cottage industry level, puffing is accomplished with husk-fired furnaces and large toasting pans operated by a number of people. More recently, fully automated continuous oil-fired or electric toasting or parching machines have been introduced. Chickpeas are the most common puffed legume, although puffed peas and cowpeas are also found in many countries. Puffing expansion is low--1.5 compared to the 8-10 times expansion of puffed cereals. Losses are not mentioned in the literature, and presumably are relatively low, in view of the simple processing technique.

**Grinding.** In a number of countries, whole legumes or dehulled splits are ground dry or wet into flour or batter; this is used for a number of sweet or savory preparations, either alone or in combination with cereal grains or oilseeds. The quality of these products depends on the composition of the flour, fineness of grinding, relative proportion of ground particles of different mesh grades, and method of preparation. Chickpeas, peas, black gram, and cowpeas are the most commonly ground pulses. The grinding may be done in mortar or stone grinders, with or without sifting, or in plate or hammer mills. Although the dry flour is easier to handle, in some countries wet-ground preparations are preferred to dry-ground flour mixed with water. Mechanized mortars are available for this purpose where larger quantities are handled.

Cooking. Legume seeds, either whole or split, are commonly cooked in the traditional way: for extended periods of 1-4 hours following overnight soaking. This is necessary to produce a tender, edible product and to extract (if soak water is discarded) or inactivate antinutritional factors such as antitrypsin and hemagglutinins. As in the case of rice, the precooking washing and soaking, as well as the prolonged boiling, lead to losses of total solids and other nutrients. While these are not defined as postharvest losses in the strict sense, only postharvest technology prior to cooking that reduced the need for these severe treatments would constitute, in effect, a loss reduction.

A variety of these processes has been developed. Precooked, quick-preparation legumes have been developed, using flaked splits, pressure-cooked and dehydrated beans, and beans that have been soaked in solutions of inorganic salts and subjected to vacuum infiltration (the "Hydravac" process, Rockland et al., 1977). These techniques require careful quality control to retain the appropriate flavor and texture of the end product. While these technologies are somewhat remote from the main focus of post-harvest loss reduction in this study, they have the potential for increasingly important savings of food as more centralized storage and processing becomes feasible for a greater proportion of the harvested crop. Research and development in this area is encouraged.

The loss of cooking properties of legumes after storage is an important problem; some legumes become tough and do not become tender regardless of the amount of cooking, a result of as yet unknown changes occurring during storage.

Note IV-1. Considerable research is in progress on the use of controlled atmosphere (inert gas) storage, but its application to date has been limited to a few installations in developed countries.

Note IV-2. The following pages describe the various stages of parboiling and processing paddy to produce white milled rice grains.

Parboiling. Rice milling involves the removal from paddy of the hull germ and bran (a mixture of pericarp, seedcoat and part of the aleurone layer of the grain), with the intention of leaving as much of the kernel as possible in its original shape. Some varieties of rice do not yield much head rice (defined as a "grain" of rice, with at least 75 percent of the length of the original unbroken kernel). Even under optimum processing circumstances, certain varieties of paddy produce a low head rice yield because of poor milling characteristics inherent in the genetic composition. To counteract this problem, premilling treatments have been developed in a number of countries.

Since early times, particularly in India, paddy has been soaked for varying lengths of time in hot or cold water and dried before being milled. This may have originated as a method of cleaning the threshed grain, but its effect on the hardness of the grain and improved milling qualities must have become apparent, and it is now widely practiced.

The changes occurring with parboiling result from its effect on the structure of the paddy grain kernel, in which the endosperm is composed

of loosely packed polygonal starch granules and intergranular spaces filled with air or moisture. The spaces, together with any cracks or fissures that may have resulted from handling, are the source of weakness from which broken grains result during milling. By soaking the paddy in water, the starch granules swell and absorb moisture, particularly if heat is applied. In this case, some of the granule structure may be weakened, permitting more moisture to penetrate, and irreversible swelling, known as gelatinization, to take place. At the end of this process, the paddy may have 45-50 percent moisture and must be dried before further processing. Gelatinization takes place at or above a critical temperature specific for each variety of rice. It may be achieved either by soaking in hot water at or above the gelatinization temperature or by soaking in water below the gelatinization temperature and then heating to expand and fuse the starch granules irreversibly. The most convenient heat source for this purpose, since it must be moist head, is steam.

Another reason for parboiling rice is to avoid loss of nutrients which, other than carbohydrate, are mainly found in the outer layers of the rice kernel. These are lost during milling, but water-soluble nutrients may be absorbed to some extent into the kernel during the parboiling process.

Parboiling generally conveys the following advantages to the paddy:

- Hulling of paddy is easier because the husk is split during parboiling;
- The gelatinization of the starch helps to reduce grain breakage during milling;
- A higher proportion of amino-acids, vitamins, and minerals is retained than in the same variety of raw milled rice;

- Because the grain is harder, it is more resistant to insect attack during storage;

- On cooking, there is less loss of solids to the cooking water, and overcooked rice suffers less damage than the same variety of raw rice;

- The parboiled rice bran contains up to 10 percent more oil than raw rice bran, and the quality is higher because the heat treatment destroys the rice lipase which hydrolyses the oil.

Parboiling also has certain disadvantages:

- Parboiled rice does not store as well. Heat treatment destroys natural antioxidants, and parboiled rice develops rancidity more rapidly in storage than white rice;

- Parboiled rice may have taste, texture, flavor, color, or odor which does not satisfy local preferences;

- Under the moist conditions molds may develop and produce harmful mycotoxins;

- Parboiled rice must be dried from a moisture content of 45-50 percent, as opposed to 25-28 percent of paddy, which adds to fuel costs;

- Parboiled rice is more difficult to polish because it is harder, which reduces milling capacity and increases cost;

- The higher oil content of parboiled rice bran may cause it to clog the polisher screen; and

- Parboiling requires additional capital expenditure.

In spite of these disadvantages, when parboiling is properly carried out, the higher efficiency of milling and 1-2 percent greater yield of total rice and head rice increases the total value of product to a point where it is reported to be possible to produce parboiled rice cheaper than white rice (Kisan Krishi Yantra Udyog, 1972).



Drying parboiled rice differs from drying paddy. If it is dried slowly to remove the large amount of moisture, microorganisms grow and may spoil the rice to some extent. If it is dried quickly, on the other hand, cracks may develop and the milling quality will be low. The rate of drying is the main factor controlling the breakage. Research (Bhattacharya and Indudharaswamy, 1967) indicated that breakage does not occur equally throughout the drying process: drying can take place quickly down to 18 percent, but the moisture content must be reduced slowly from above 18 percent to below 18 percent to avoid breakage. As the grain is dried, a moisture gradient develops between the center and surface of the kernel, which stresses the kernel and at a certain stage causes cracking. The cracks appear two hours after the drying is completed.

Sun-drying and hot-air-drying are the two most common drying methods. In India, the parboiled paddy is dried in the sun for 4-5 hours, with continual stirring and turning. This reduces the moisture content to 18-20 percent, after which the rice is heaped and covered with mats or straw and tempered for 2-3 hours, to allow moisture in the kernels to migrate. It is then spread and dried for a further 1-2 hours to complete the drying to 14-16 percent moisture. Average milling yields of sun-dried paddy are 72.5 percent. Average losses due to birds, insects, and rodents during the drying process are estimated to be 0.2 percent in calculating the drying cost (Bal et al., 1974).

Simplified machine-drying technology using a Louisiana State University (LSU) continuous-flow drier fueled by rice husks has been successfully used to generate steam both for the parboiling and the heat-exchanger hot-air generation. The drying is carried out in two passes

with a tempering period of 8-10 hours, which seems to produce good milling yields. Drying may also be carried out in the paddy heating vessel by applied vacuum, stirring, and indirect heat (Gariboldi, 1974).

Traditional parboiling methods give rise to a variety of problems. Most of these result from fermentation due to prolonged soaking or delayed drying, with concurrent development of fungus and mycotoxins and discoloration to the grains, which acquire an unpleasant odor and flavor. Handling and drying conditions are often unhygienic, and losses to birds, rodents, and insects may be high. Some research has been carried out on improving the traditional methods by such steps as adding sodium chromate to the soak water to retard fermentation.

The International Rice Research Institute has recently conducted successful research on a "dry" parboiling process in which the threshed paddy is dried at high temperature by being mixed with sand at 200°C. This process evidently causes gelatinization of the kernel starch with the moisture in the kernel as it is being dried, without the need for prior soaking or steaming and without excessive breakage. If such parboiling proves economic, it may offer an attractive alternative method of handling wet paddy.

**Precleaning.** Prior to the actual milling, it is necessary to clean the paddy received from the farmer of large and small impurities so as to protect the milling equipment and improve the quality of the milled grain. Cleaning is normally done in large mills by sieving to remove impurities of different size from paddy grains. Dust is usually removed by aspiration.

**Hulling.** The hulling process removes the outer husk from the grain, and the objective of the hulling process is to do this with minimum damage to the bran layer and without breaking the brown rice grain. The process requires that a certain amount of friction be applied to the grain surface

to remove the husk, and a certain amount of damage and broken grain is unavoidable. As we have already seen, this is particularly high when the drying grain has been exposed to moisture and has cracked. The amount of damage also depends on the design and construction of the huller, the skill with which it is adjusted, operated, and maintained, and the uniformity of the grain being milled. For example, one of the most common types of huller, the under-runner disc huller, consists of two horizontal cast-iron discs, partially coated with an abrasive layer. The grain is fed centrally down a sleeve through the top disc, which is fixed between it and the rotating lower disc, and the clearance between them determines the efficiency with which the grain is hulled and not broken. The quality of the abrasive coating, and the accuracy with which the discs are "dressed" or kept flat and level, is also important. As hulling continues, the discs become worn and periodic redressing is required. Because there is no flexibility in the discs and the gap between them is fixed, the machine is sensitive to the size of the grain. Proper operation should include provision for pre-grading to minimize both breakage of the outer layers and the proportion of small, unhulled grains.

Another type of huller is the rubber roll huller, in which two rubber-covered rollers, mounted horizontally and parallel with clearance between them smaller than the thickness of paddy grains, rotate in opposite directions at slightly different speeds. The grains, fed onto the rollers from above, are caught between the rollers, and because of the difference in speed, the husk is stripped off. Wear on the roller is considerable, reducing its diameter and thereby the speed of the surfaces, which in turn reduces the efficiency of hulling. Although the dehusking performance of roller hullers is superior to disc hullers, the efficiency of the rubber rolls in

tropical countries is not good for a number of reasons: the rollers wear quickly because of the high temperature and humidity; they are expensive to replace; and the design of the machinery (usually Japanese) is for short-grain varieties of rice, whereas in tropical countries the grain is often long or medium and wear is greater.

Husk Separation. The output from the huller is a mixture of brown hulled rice, paddy, husks, bran, dust, broken grain, and immature grain. It is necessary to separate the husks from this mixture before it passes to the paddy separator. The dust and bran can either be carried off with the husks or separately aspirated. There are many designs of separator; some operate from hullers, others incorporate into the huller. All of them operate by aspiration of the mixture, and their efficiency depends upon the experience of the operator and adjustment and maintenance of the equipment. When a machine is not operating correctly, it is possible that some broken and immature grains will be lost with the husks. Such grains are a potentially avoidable loss.

Paddy Separation. Following separation of hulls, broken and immature grains, bran, and dust from the hulled brown rice and unhulled paddy, the rice and paddy can be separated. The amount of paddy varies according to the efficiency of the huller, normally between 80 and 95 percent. If the efficiency of the huller is 80 percent, 20 percent of paddy will remain unhulled, and 80 percent will be hulled, yielding 64 percent brown rice and 16 percent hulls. The output of the huller (without the hulls) requiring separation will therefore be a paddy/hulled rice mixture containing 24 percent paddy. With typical minimum efficiency hulling, therefore, separators must be capable of separating a maximum of 25 percent of paddy from the input feed.

This paddy is then returned to the huller or a special "returns huller." This final separation is accomplished by taking advantage of the different physical characteristics of the paddy and brown rice kernels. The weight of a given volume of paddy on average is less than that of the same volume of brown rice; paddy grains are more bouyant, longer, wider, and thicker than brown rice. Separation is carried out on oscillating trays with indentations the size of brown rice which retard their passage, while permitting the paddy to flow across.

Problems are encountered with this type of separation when the grain is not of the length for which the trays were designed or when wet or dirty grains are processed.

Whitening and Polishing. The whitening process removes the silver skin and bran layers and, in most cases, the germ, while the polishing process imparts a slight polish to the whitened rice grain.

There are three kinds of whitening machine. The vertical whitening cone is a cast-iron, cone-shaped cylinder with an abrasive coating that rotates inside a wire mesh screen. The mesh of the screen and the distance between the cone and screen are selected according to the size of the rice. The screen is divided at intervals into segments by adjustable rubber brakes. The brown rice is fed into the center of the machine and distributed over the surface of the cone; the rubber brakes impede its flow and press the grains against the abrasive coating and the wire screen, and the friction removes the bran coating, which then passes through the screen. The partly whitened rice falls out at the bottom of the cone and passes onto the next processing stage.

Adjustment of the distance between cone and screen, usually at around 10 mm, and periodic replacement of the rubber brakes and worn sections of screen are necessary to ensure good operation and avoid excessive grain breakage. Regular maintenance of the equipment is also necessary to ensure that it runs without vibration, which also causes breakage. The effectiveness of the whitening process depends on the friction between the grains themselves, the cone, and screen. If too much heat is generated during this process, there will be excessive broken grains. For this reason grain whitening is increasingly accomplished by passing it through several times, a process known as "multipass whitening" in which the bran is removed more gently, the grain spends less time in the machine, and the clearance between cone and screen is increased, so that less heat is generated.

This does not require much additional investment, because the capacity of a single-pass whitening cone is much lower than a multipass system. The multipass system can be composed of several smaller cones with equivalent capacity to one large single-pass cone.

The Japanese horizontal abrasive whitener consists of a cylindrical abrasive roll that rotates at high speed in a cylindrical whitening chamber perforated with slots. Rice is fed in between the roller and slotted cylinder and held by an adjustable valve in the outlet so that slight pressure is built up and the grains forced against the abrasive drum. As it circulates, adjustable steel brakes along the length of the cylinder wall control the orientation of the rice grains and the efficiency of the whitening process. The adjustment of these brakes depends on the variety of rice being whitened, and breakage losses depend on the experience of the operator. The rolls wear out and have to be replaced, which creates a supply problem. Another disadvantage is that the clearance cannot be adjusted.

The horizontal friction whitening machine, which is often used for the final separation of bran from grain, consists of a horizontal, partly hollow, perforated shaft on which a cast steel rotor with friction ridges is clamped. Perforated screens surround the rotor and rice is fed into the gap between the rotor and the screen, while a strong, adjustable stream of air is blown through the shaft and the rotor and then into the rice. The air cools the grains, separates the loosened bran from the rice, and blows it out of the machine. The friction in the gap imparts a slight polish to the grain, and the air keeps the grain cool. The machine is designed mainly for short grain varieties; with medium and long varieties, there is considerable breakage of grains and wear on the screens and cylinder, which are expensive to replace.

The vertical polishing cone is similar in construction to the vertical whitening cone, however, the cone itself is made of wood on which leather strips are nailed and there are no rubber brakes. As the rice is fed into the machine, it is gripped by the leather strips and rolled against other grains and the screen. The remaining bran particles are removed, and the rice becomes more shiny and translucent. The horizontal polisher or refiner works on the same principle. Both of these simple machines need little adjustment, operate without significant breakage, and the leather strips can be readily made locally and replaced as required.

## Chapter 4

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## Chapter 5

### Perishables

The main perishable staples are cassava, yam, sweet potato, white potato, taro, banana and plantain, and breadfruit. In the developing countries these staples and the major vegetables and fruits comprise over 39 percent of food crops consumed (see Table 2:1). However, their importance in the diets of many peoples is disproportionately greater than this because they are the major source of carbohydrate and energy or supplement otherwise monotonous cereal-based diets with vitamins and minerals.

For the perspective of postharvest losses, the perishable staples present a very different set of problems from the durable commodities, the cereal grains and grain legumes. They have relatively high moisture content--from 50 percent upwards--and are difficult and expensive to dry and hence to store as dry products. Furthermore, the dried product is very different from the fresh and is often less acceptable. Lacking the hard texture of cereal grains, the perishables bruise easily. Although they are storage and reproductive parts of plants, even those that are organs of dormancy (such as yams) are metabolically much more active than the seeds of durable staples and seldom have prolonged dormant periods. Roots and tubers continue to respire and metabolize, albeit at a low level compared with the growing plant but at a much faster rate than in cereals, as they

maintain the life of the plant through the non-growing season. This fact limits their extended storage possibilities.

The edible parts of most fruits and vegetables are not the seeds, which are often discarded, but fleshy tissues whose natural function is to support the germination and growth of the seed where it falls or to attract birds or other agents by which the seeds could be spread. The edible tissue is meant to perform these functions when it is ripe, not to serve as a food store in the dry condition, and its storage life may be only days.

The high moisture content seriously affects loss estimation, since it is difficult to express weight loss on a constant moisture basis, and loss of moisture over short periods may be taken to be loss of nutrients. As noted earlier, reports of loss assessment must be meticulous as to the age and state of the commodity.

#### Estimates of Loss

There are few accurate figures available for losses of perishables measured by a described methodology. Even those loss figures that have been obtained by direct measurements are of limited value because they cover the loss for one specific commodity, in one location and for one specific set of conditions, and the extent of loss in perishable products can vary greatly within a short time.

Table 5:1 (from FAO and other sources) lists figures for losses in horticultural produce. The very wide range of loss cited and, in a few cases, the improbably precise narrow range of loss given in this table reveal the inadequacy of data on losses of perishable products. Nevertheless, the opinions of a group of professionals (NAS, 1978) with long exper-

ience with some of the commodities in developing countries produced the following figures as being typical of the normal ranges of loss experienced under usual marketing conditions:

White potatoes in Chile, Peru and Venezuela	25 to 30 percent
Cassava in Venezuela, Colombia, Ecuador, Dominican Republic, and Central America	15 to 25 percent
Tomatoes for fresh market in most developing countries	50 percent
Yam in Nigeria and Ghana	10 to 20 percent

Although specific examples of loss can be found that lie above or below the ranges cited above, the experienced professionals who provided these figures believe that they represent a fair overall assessment of current losses in the commodities named and are sufficiently realistic to be used as a basis for future planning. They nevertheless consider it worth further effort to obtain more and better figures in order to identify the specific areas where loss reduction activities would be most effective. There is unanimous opinion that these levels of loss warrant substantial intervention.

#### Preservation, Storage, and Conservation

Preservation and conservation of nongrain staples is very different from drying and storage of the durables. In many developing countries there has been no need (because of abundant cheap supply) or no policy (because of predominant interest in export, commercial crops, or grain or legumes) for trying to reduce these losses.

The commodities cover a wide range of roots, tubers, fruits, and vegetables, with possibly more differences than similarities between them. Their storage life may be as little as a day or two or as long as several

TABLE 5:1

## NONGRAIN STAPLES, VEGETABLES AND FRUITS

Losses Reported by Region and Country

(From FAO, 1977b Unless Otherwise Indicated)

Region/Country	Roots/Tubers Percent Loss	Fruits/Veg. Percent Loss	Remarks
AFRICA			
Ghana	10 - 20	30 - 35	
Nigeria	15 - 60 10 - 50	10 - 50	Yams, Olorunda (1977)
Rwanda	5 - 40	5 - 40	
Sudan		50	Lack of transport to market
ASIA/FAR EAST			
Sri Lanka		20 - 40	
Thailand		23 - 28	
Indonesia	10	25; 15 - 25	cassava
Philippines		10 - 50	
Malaysia		20	
India		20 - 30	
Jordan		2 - 3; 5 - 10	Lack of cold storage
Iran	5 - 100	14 - 28	Frost in potatoes, Steppe (1976) Subtropical fruits
LATIN AMERICA			
Dominican Republic	24 - 26 17	25	Except plantain--10; tomatoes--13; green beans--12 cassava, Tejada (1977)
Chile	30	30	potatoes
Brazil	5 - 30	8 - 10	Cassava--10; potatoes-- 5 - 30; pineapple--8; banana, tomatoes, orange-- 10
Bolivia	24	17 - 30	potatoes citrus--27; tomatoes--30; pineapple-- 17
Peru	20 - 50		Potatoes, Werge (1977)

TABLE 5:2

NONGRAIN STAPLES, VEGETABLES AND FRUITS  
Postharvest Food Losses by Commodity

Commodity	Production in LDCs (FAO, 1977) .000 tonnes	Estimated Loss Percent	Remarks
<b>ROOTS/TUBERS</b>			
Carrot	557	44	Thompson, in Coursey (1971)
Potatoes	26,909	5 - 40	8% in cold store; 20 - 40% on farm: FAO (1977)
Sweet Potatoes	17,630	35 - 95	Thompson, in Coursey (1971) Hall (1970)
Yams	c.20,000	10 - 60	FAO (1977); Olorunda (1977)
Cassava	103,486	10 15 - 25	Indonesia, Brazil, FAO (1977) (see text)
<b>VEGETABLES</b>			
Onion	6,474	16 - 35	Thompson (1971); Steppe (1976)
Tomatoes	12,755	20 - 50 5 - 16	Thompson (1971); Steppe (1976); Olorunda (1977) In transport only, Rawnsley (1969)
Plantain	18,301	35 - 100	Olorunda (1977)
Cabbage	3,036	37	Thompson (1971)
Cauliflower	916	49	Thompson (1971)
Lettuce		62	Thompson (1971)
<b>FRUITS</b>			
Banana	36,898	20 - 80	Olorunda (1977)
Papaya	931	40 - 100	Olorunda (1977)
Mango	12,556	16	Singh (1960)
Avocado	1,020	43	Thompson (1971)
Peaches, apricots, nectarines	1,831	28	Steppe (1976)
Citrus	22,040	23 - 33 20 - 95	Steppe, Iran (1976) Olorunda, Nigeria (1977)
Grapes	12,720	27	Steppe (1976)
Raisins	475	20 - 95	Steppe (1976)
Apples	3,677	14	Steppe (1976)

months. There are a number of common storage problems that will be outlined briefly before individual categories of perishables are discussed.

### Storage Problems

Storage deterioration is brought about by endogenous physiological processes or by attack of pathogens (fungi and bacteria) both of which may be aggravated by physical damage to the crop.

Insect damage is usually a relatively minor problem of perishables stored fresh. It most frequently occurs while the root is still in the ground or the fruit or vegetable still attached to the plant, and is relevant mainly in that it aggravates fungal problems by providing additional points of entry to the crop. Fungal damage is also influenced by the lack of rigidity of perishable crops, as, compared with grains, and the ease with which they are damaged during harvest or handling. A third major source of storage loss in roots and tubers is sprouting at the end of the natural period of dormancy.

In general, losses due to physical, physiological, and pathological damage are minimized by care in harvesting and appropriate storage treatments and conditions. In many cases, however, harvest lesions caused by separation of the organ from the plant are unavoidable. Roots and tubers can be "cured" to reduce the effects of minor harvesting damage by being kept at high ambient temperature (35-40°C) and relative humidity (85 percent) for a few days. Under these conditions suberization occurs, a healing process in which a callus is formed over the damaged areas, minimizing the risk of fungal infection. Lowered temperature generally prolongs storage life, although it is characteristic of many typical crops to suffer low-temperature or "chilling" damage when subjected to temperatures below about 10°C.

Apart from the curing situation, high storage temperatures are detrimental and measures to prevent the produce from being exposed to heat are of considerable importance.

With fruits and vegetables, low temperature and modified-atmosphere storage will often provide adequate conservation for those commodities of sufficient value to justify capital and running costs; however, in many situations these technologies are not yet economic, particularly in those which are the principal focus of this study. Simple, inexpensive alternatives are available to make minor storage improvements, but extensive improvements will depend as much on administrative and managerial factors as on technology. These factors include: improved packaging, marketing, and transport arrangements to move the fruits and vegetables rapidly and without damage between production and consumption, (which can be as simple as protection from the sun, or as complicated as refrigeration); improved extension systems to provide better information and inputs (seed, fungicides, etc.) to farmers; and improved processing facilities and quality control for local canning, drying, bottling and pickling, where there is sufficient market for these products. Choice of planting variety for good postharvest quality and storage life, or breeding programs aimed at developing these qualities, are also important. But it is low-cost cooling systems that offer the greatest possibility for extending the life of perishables and radically changing traditional handling limitations. Even relatively low reductions in temperature could have an enormous impact, making this a priority area for research.



## Individual Perishable Crops

The remainder of this chapter deals with the major nongrain staples.

### Roots and Tubers

Roots and tubers provide the staple food for an estimated 400-500 million people in the tropical world, and of the estimated 1976 world production of 558 million metric tonnes, 177 million were produced in tropical and semitropical regions (FAO, 1977a). Table 5:3 shows estimated production of the main species by region in 1975 (the last year FAO production estimates were so reported). Cassava production in developing countries (105 million tonnes in 1976) made it the second most important crop after rice (Table 2:1, Chapter 2).

Coursey and Booth (1972, 1975) estimate that 23 percent of the total production of root crops is lost due to an inadequate understanding of storage needs. Most storage problems are related to the physical characteristics of the stored root crop. Roots and tubers are living, actively metabolizing organs that continue to respire and transpire at much higher rates than the dry, dormant grains of durable crop products after harvest. Unlike the food grains, they are high in moisture content and are essentially perishable commodities susceptible to mechanical damage, physiological breakdown, and attack by fungi and bacteria.

This fact has long been recognized in developing countries, where cassava is usually left in the ground until needed; once harvested, the roots

TABLE 5:3

Production of Root Crops in the Developing World (million metric tons) after FAO (1975<sup>a</sup>)

	Cassava	Potato	Yam	Sweet Potato	Taro	Miscellaneous Root Crops*	Total
Africa	42.844	2.039	19.279	5.539	3.569	1.446	74.716
Latin America	32.201	8.951	0.291	3.379	-	0.811	45.633
Near East	1.128	4.706	0.260	0.094	0.059	-	5.747
Far East	27.643	8.445	0.030	8.764	0.090	1.674	46.645
Other	0.221	0.006	0.700	0.560	0.262	0.390	1.639
Developing World Total	104.037	23.647	20.060	18.336	3.980	4.321	174.381

\*Includes Xanthosoma, arrowroot, arracacha, yam beans, oca and olluco

are either used immediately or processed into dried products with longer storage life. Occasionally, yams are also left in the ground until needed, but usually they are stored hanging on supports, stacked on racks, or kept in boxes that allow the air circulation necessary to the metabolism of the detached tuber.

The traditional system allows cassava to be harvested over a long period, but Ingram and Humphries (1972) estimate that the practice of leaving cassava in the ground until required unnecessarily occupies 750,000 ha of agricultural land. In addition, losses due to pathogens can increase when the roots remain too long in the ground. Further, although the roots may continue to grow with the plant they become more fibrous and woody, with a decrease in both nutritional value and extractable starch content.

Investigations at the Centro Internacional de Agricultura Tropical (CIAT) (1973, 1974; Booth, 1973, 1976, 1977) identify two types of post-harvest deterioration, termed primary and secondary.

- Primary deterioration usually makes the roots unacceptable for consumption and is initially manifested by blue-black streaks in the vascular tissue.

- It is generally associated with mechanical damage, especially a harvest lesion where the roots are separated from the plant. The possible role of microorganisms at this stage has not yet been clarified. The discoloration spreads and causes a more general, brown discoloration of the root tissue.

- Secondary deterioration involves a widespread invasion of the tissues by any of a number of destructive fungi, which are not, however, primary pathogens.

Factors responsible for storage losses in root crops have been reviewed by Coursey and Booth (1972) and Booth (1974). Five principal factors operate to bring about the deterioration:

1. Physical processes. Purely mechanical damage to the produce, such as lesions produced at harvesting, crushing or breakage, and spillage or loss from faulty containers is common. Such damage causes further storage problems by enabling penetration by pathogens and stimulating physiological changes.
2. Autolytic processes. Chemical or biochemical changes in the produce may arise as a result of reactions in the produce that are purely internal or that occur between it and its environment.
3. Insect attack. Durable produce in store often become infested with insects or other arthropods, causing both actual loss of the produce and partial or complete spoilage of what remains. With most root crops, these are usually of only minor importance, except with roots stored in dried form, which then behave like durable crops.
4. Microbiological attack. Many species of fungi and bacteria, whose initial invasion may occur either pre- or postharvest, have a deleterious effect on stored root crops, and in some cases--especially in tropical climates-- can cause serious losses.
5. Rodent attack. The damage done to stored crops by rodents and occasionally by other vertebrates is well known. Conventional control measures, as developed for grain storage situations, can be applied.

Cassava (*Manihot Esculenta*)

The role that cassava can play in industrial development has been inhibited by storage problems; substantial deterioration can occur even during the few days that buffer stocks of fresh roots are being held at the factory to await processing. Where the crop is marketed as a fresh vegetable, considerable losses occur at all stages in the marketing chain, especially where the market is some distance from the farm. Booth and Coursey (1975) speculate that cassava may differ from other root crops such as yams, potatoes, and sweet potatoes as a result of its evolution, and suggest that "the swollen edible roots developed as an artifact of domestication by man in the comparatively recent past rather than as a response to any climatic stimulus." The cassava root thus appears not to be an organ of dormancy, which may explain its inherently poor storage qualities.

The rate at which deterioration occurs appears to differ considerably between cultivars (Montaldo, 1973; Booth, 1976), beginning from 0-7 days after harvest. This rate may also be related to the differences that exist between cultivars in ease of harvesting, with resultant differences in amounts of mechanical damage. Selection of cultivars for good storage and handling properties is being undertaken at a number of centers, particularly CIAT and IITA. Recent studies have suggested that plant growth regulator systems are involved, and that deterioration may be inherently associated with detachment of the root from the plant.

**Curing.** Curing has been widely used for enhancing the storage life of a number of root crops such as potatoes, yams, and sweet potatoes but

not so far for cassava. At relatively high temperatures and humidities, wounds are healed and subsequent deterioration delayed or limited. Booth (1973, 1976) reports that at a relative humidity of 80-85 percent and temperatures between 25-40°C suberization occurs in cassava in 1-4 days and a new cork layer forms around wounds 3-5 days later. At 40°C and above, primary deterioration usually takes place before the wound can heal. Curing delays the onset of primary deterioration and reduces both secondary deterioration and moisture loss. Curing arrests only previously acquired damage, and if the produce is handled again recuring is required to inhibit further deterioration; thus, the number of times roots are handled should be minimized.

**Storage Techniques.** Traditional techniques exist for storing small amounts of fresh roots that are successful for several days or even weeks using either reburial, coating with mud, placing under water, or piling in heaps and giving a thorough daily watering. Ingram and Humphries (1972) cite several cases of successful storage of larger quantities of fresh cassava roots for longer periods using various simple techniques such as burying, with success considered due to curing of the roots. Successful trials of curing followed by storage achieved in simple field clamps or in boxes packed with moist material have been carried out at CIAT (Booth 1973; Booth and Cousey, 1974; Booth, 1977). The experience indicated that successful clamp storage of quantities up to 500 kg/clamp can be achieved for periods up to 3 months under relatively cool, moist conditions, whereas during hot, dry conditions, almost complete loss of roots occurred after one month. This may result from rapid deterioration inside the clamp where the temperature has exceeded 40°C, and appropriate ventilation should be included

where this is likely to occur. Although excess moisture should also be avoided to prevent rotting, small amounts of moisture help to keep the clamp cool. Clamp design therefore tends to be highly location specific.

Packing freshly harvested cassava roots in moist sawdust in boxes is also reported to be very effective in storing them for 1-2 months. Moisture content and temperature appear to be critical; if conditions are too dry, curing does not occur and primary deterioration results; if too wet, secondary root development and rotting occur. Local ambient temperature under shade (around 26°C) appeared most satisfactory. This method, which also provides a simple and relatively inexpensive means of transporting and marketing the roots without further handling, appears particularly suited for farmers producing for commercial markets some distance from the farm.

Waxing cassava is reported (IIT, 1973) to extend life of cassava to 30 days by reducing the rate of gas transfer between tissues and the atmosphere; this approach should be pursued further.

These techniques appear to be a major contribution toward solving the problem of longer-term storage of fresh cassava, offering simplicity for both curing and storage in a single operation, and an acceptable weight of usable produce after storage periods of weeks or even months. However, the factors involved are not fully understood, and storage is not always successful. Further location-specific, adaptative research appears to be needed.

Storage of Dried Cassava Products. A variety of dried cassava products is prepared in Africa, Asia, and Latin America according to local needs, traditions, and tastes. There has been comparatively little research into the storage of these products, perhaps because they are of relatively low commercial value and improved storage technology may be considered uneconomic.

The problems of dried cassava storage are similar to those of grains. Drying below a critical moisture content of 12-13 percent is the first essential for successful storage, and insect attack, rather than endogenous or pathological processes, is a major cause of storage loss. The principal losses in storage resulting from the activities of insect pests are tabulated by Ingram and Humphries (1972).

The main products of dried cassava are chips, flour (ground from the chips), and several kinds of granular meal.

### Cassava Chips

To make chips, roots are washed, peeled, and chipped or sliced into suitable sizes, then dried. Sundrying, usually the only process that is economic, takes 3-10 days depending on the weather. When the moisture content is reduced to 12-13 percent, the chips have good storage qualities, but if stored too long they are subject to insect attack, atmospheric moisture absorption leading to mold and souring. If properly dried, chips will usually keep from 3 to 6 months before becoming excessively infested; if necessary, they can be redried in wet weather. Chips made from bitter cultivars are said to store best. Delayed drying after harvest affects storage qualities of the chips adversely.

When properly prepared the chips are crisp and white and break easily without crumbling. They have a comparatively low density, which means they require relatively large storage facilities.

Parboiled chips, commonly made in India, are reported to have a longer storage life than ordinary chips; however, this may reflect



greater care in storage rather than inherent properties. Bags lined with polythene reduce moisture uptake and insect infestation. Chips are readily attacked by insects, and losses in exports from Tanzania some years ago were reported to amount to 10-12 percent. Conventional insect control using a variety of chemical sprays and fumigants, combined with careful disinfection of warehouses before storage, is generally effective.

Any fungal infection of chips usually begins during the drying period, particularly if this is extended on account of wet weather. It can be controlled to some extent by steeping the chips in sulfurous acid (Ingram and Humphries, 1972).

#### Cassava Flour

Grinding or pounding the chips produces cassava flour or meal. This presents a different set of storage problems, and it is recognized to be more difficult to store in bulk. Fortunately, some insects that attack chips do not thrive in flour, suitable bags can provide a barrier to those that do. Flour also takes up moisture and becomes sour more readily than chips.

#### Cassava Granules: Gari and Farinha de Mandioca

Two important dried cassava products are the West African gari and the similar Brazilian farinha da mandioca. Well-prepared gari will keep for several months, but it is subject to fungal attack if not properly dried: moisture levels of 12-13 percent are the maximum for safe storage. Gari is normally consumed soon after production and is not stored for long, as it takes up atmospheric moisture rapidly and molds easily.

Yams (Dioscorea spp.)

Yams, like most staple food crops, are not all consumed immediately after harvesting; they are a highly seasonal crop and the tubers must be stored at least for several months, from the end of one harvest to the beginning of the next. This is possible because the tubers have inherently longer storage life, being organs of dormancy, than most perishable foods.

Storage Practice. Being largely crops of farmers with small holdings, yams are generally stored in limited quantities, rarely more than a few tons and often less. Storage in markets is usually of short duration as stocks are turned over rapidly, with reserves of yams being held by the farmers and sold off gradually throughout the year. A substantial proportion of the yam crop is used for subsistence and never even appears in local trade.

Yams are sometimes simply left in the ground until they are required for food or sale, especially in some of the remoter parts of West Africa, but better storage methods are used in most districts. After lifting, they may be simply piled into small heaps of only a few dozen tubers, sheltered from sun or flooding in such places as crevices in outcrops of rock or between the buttresses of large trees. Alternatively, yams may be stored without any special arrangements or precautions in ordinary storerooms or in sheds or huts, either not in use or specially constructed for this purpose. Small thatched mud-block or wattle-and-daub huts are sometimes built for yams, or the space under houses or piles or stilts can be utilized. The importance of good ventilation in such stores, even under the subtropical conditions of the

southern United States, has been emphasized by Young (1923), and the need for shade has been emphasized by Coursey and Nwanko (1968).

Throughout most of West Africa, the world's largest yam-growing area, the usual type of store is the "yam barn" (Plate       ). Yam barns vary considerably in design and construction between regions, but all consist, in principle, of an approximately vertical wooden framework 2 meters or more high to which the yam tubers are individually tied. The length of the frames depends on the amount of material to be stored. The vertical poles of the frame are frequently of timbers which will take root and sprout when set in the ground, e.g., Dracaena, Gliricidia, Ximena, or Gmelina. This reduces the danger of termite attack or decay and, after the poles have sprouted, they provide some of the shade necessary for successful storage. The cross-members of the frame may be of lighter timber, bamboo, or palm leaf midribs. A palm thatch roof may be provided, and two or more frames are often erected alongside each other and the whole barn surrounded by a fence or hedge for security.

In practice, these structures are highly effective. The tubers receive adequate ventilation and are protected from termite attack and danger of flooding. The construction materials cost little, or are often cut as required from the forest for nothing.

Rather similar structures ("huttes-greniers") are used in parts of Oceania, consisting of platforms of light poles supported above ground level on vertical poles that also carry a roof of straw or thatch. The

yams are stacked vertically on this platform, and further horizontal poles fixed around the platform to prevent them from falling off (Figure \_\_\_\_\_).

Experiments in Nigeria on storing yams in "clamps" like those used for potatoes in Europe (Waitt, 1961) gave somewhat variable results, some cultivars storing better in clamps than in barns, while for others the reverse was true. Clamp storage has not been adopted in practice although further investigation would be of interest.

Experiments on the storage of yams in underground pits have also been undertaken but have not proved very successful, since the fundamental requirement of yam storage--ready availability of air--was not satisfied. Similarly, storage in hermetically sealed containers or silos, which has proven very satisfactory for grain and legume crops, has not worked well with yams.

Storage Loss Estimates. The opinion has become widespread among agriculturalists that "yams store well, " probably arising from the fact that storage deterioration of yams usually manifests no immediately obvious defects. There is no doubt that compared with most nongrain staples yams have an inherently long storage life. There are great variations of storage suitability between species and cultivars, or even within cultivars, influenced by such factors as conditions of growth, time of harvest, and fertilizer treatment. Gooding (1960) quotes loss after 4 months' storage as between 7 and 23 percent in different Dioscorae alata cultivars. Farmers are usually well acquainted with variations in storage quality between forms grown in their area.

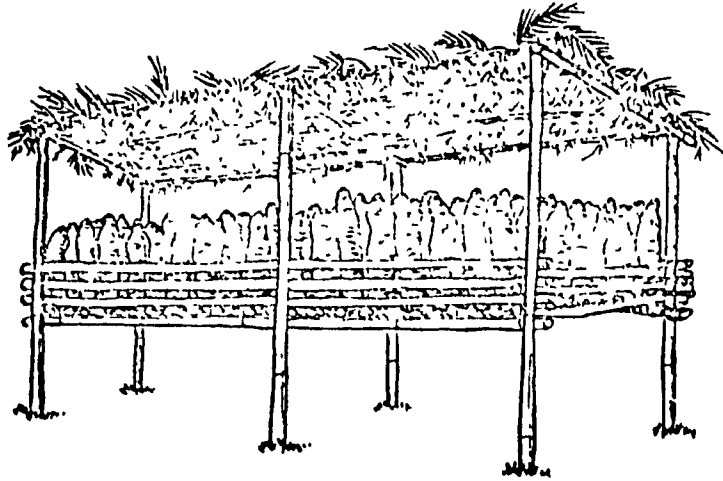


Figure \_\_. "Huttet-greniers" used for storing yams in Oceania (after Barrau).

Yam tubers are sometimes suspended individually on strings from horizontal poles, themselves supported above ground level on forked sticks set in the ground. This has the advantage of affording protection against rodent attack, as well as providing ample ventilation and security from flooding (Figure \_\_).

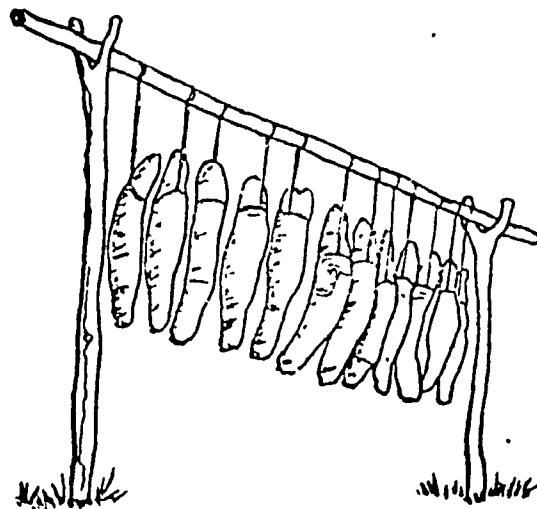


Figure \_\_\_\_. Another storage method

Yams, nevertheless, suffer serious losses in weight during normal storage, as is indicated in the results of the experiments summarized in Table 5:4. These observations suggest that weight losses of 10-15 percent are normal during the first 2 months' storage, while after 6 months the losses may be as much as 30, or even 50, percent. Allowing for the proportion of the crop that is stored and that which is consumed shortly after harvest, it has been estimated that in West Africa alone about a million tons of edible yams is lost annually in storage (Coursey, 1965). These weight losses are not from desiccation, but are, at least in part, losses of food material arising from the metabolism of dry matter to carbon dioxide and water. Many varieties of yam may nevertheless be stored for long periods without significant reduction in quality. Although the quantity of food has been diminished in storage, what remains (unless pathogenic invasion has occurred) is nutritionally and physically comparable with fresh material.

Factors Responsible for Storage Losses. In stored yams, all five types of loss--mechanical, metabolic, insect, microbiological, and rodent damage--occur to some extent. The most important of the above are metabolic or autolytic processes and attack by fungi or bacteria. A sixth source of damage, chilling, is also discussed below.

Table 5:4

## Summary of Information on Weight Losses in Stored Yams

(from Coursey, 1968)

Country of origin	Species	Percentage weight lo. during storage							
		1 month	2 months	3 months	4 months	5 months	6 months	8 months	
Puerto Rico	'Guinea yams', presumably <i>D. cayenensis</i>	1	3	8	(sound tubers)				
Trinidad	Not stated	2	6	11	(tubers slightly infected by rot)				
Trinidad	<i>D. alata</i>	—	—	14.5	—	—	—	—	
Nigeria	<i>D. rotundata</i>	—	—	—	—	—	—	*30-40	
		—	—	—	—	—	—	50 (at Abak)	
		—	—	—	—	—	—	67 (at Umuahia)	
Trinidad	<i>D. alata</i> (various cultivars)	—	—	—	—	—	—	33 (at Abakaliki)	
Nigeria	<i>D. rotundata</i>	5	7	12	7-23	—	—	—	
		4	6	10	20	29	—	(at Bori)	
		3	6	14	14	21	—	(at Abakaliki)	
Nigeria	<i>D. cayenensis</i>	6	17	29	23	30	—	(at Umuahia)	
Ghana	<i>D. rotundata</i>	1	5-7	15-17	26-27	34-40	—	—	

\* Treated with methyl alpha-naphthyl acetate to inhibit germination.

1. Mechanical damage. Yam tubers are readily injured during harvesting, especially with the large-tubered forms; tubers are easily cut or bruised and are awkward to handle. To reduce the risk of damage, wooden spades or digging sticks are often used in yam harvesting in preference to normal iron tools. A strong positive correlation exists between tuber size and extent of harvest damage. The incidence of severe damage ranged from less than 5 percent in the smaller tubers examined to over 50 percent in the largest. Bruising and abrasion of the tubers also occurs during transportation, especially when they are moved by vehicle over the rough roads of many tropical countries.

2. Metabolic damage. Yam tubers are still living, if dormant, systems in which the basic metabolic processes of the plant continue, although more slowly than in the active growing phase. The most important metabolic process is respiration, resulting in the conversion of the carbohydrates of the tubers into carbon dioxide and water, which are lost by evaporation. Respiration has been more thoroughly investigated in temperate crops such as the potato, but little direct respirometric evidence is available in the case of the yam. Passam and Noon (1977) have shown variation in respiration patterns during storage, and Passem et al. (1976a) illustrate the physiological factors associated with wound repair in yams and demonstrate the correlation of respiratory changes with carbohydrate loss.

3. Insect Damage. Insect attack is generally of little importance in the storage of improcessed yams for sale (ware yams). Scale



insects do infest them occasionally, but cause comparatively little ware yam loss, although they may affect the viability of stored seed tubers.

The yam beetles Heteroligus and Prionoryctes spp. are preharvest pests, but the damage they cause before harvesting may render the crop more liable to invasion by rotting organisms during subsequent storage. Paleolopus is an occasional postharvest pest of yams in the Caribbean.

Yams in store are occasionally attacked by termites, especially if they are stacked on the ground. In barns, termite attack can easily be avoided by simple attention to hygiene, with any tunnels built by termites on the supports of the barn being regularly destroyed.

Nematodes can cause postharvest loss of yams. Thompson et al. (1973) showed that nematode populations increased during storage. Fumigation was not successful, and although hot water treatment reduced the numbers, damage still occurred to the tubers. Nematode infections also increased susceptibility of tubers to storage rots; Ekundayo and Naqvi (1972) show their association with dry rot disease.

4. Microbial Damage. Apart from metabolic processes, storage rots are the main factors responsible for the deterioration of stored yams. Several fungal species have been identified (Table 5:5) as associated with tuber rots, including hard brown dry rots and wet, slimy rots. (Ogundana et al., 1970, 1971, 1972).

Various bacterial infections have also been observed in yams. Pathogenic invasion of the tubers is greatly facilitated by mechanical damage by accidental cutting or bruising or by preharvest nematode attack. In some producer countries it is a common practice to treat cut or bruised

Table 5:5. Some Rotting Organisms Associated with Stored Yams

<i>Organism</i>	<i>Country where Isolated</i>	<i>Reference</i>
<i>Botryodiplodia theobromae</i> Pat.	Ivory Coast	Miège, 1957
<i>Botryodiplodia theobromae</i> Pat.	Ghana	Dade and Wright, 1931
<i>Botryodiplodia theobromae</i> Pat.	Nigeria	Anon, 1962; Okafor, 1966
<i>Lastodiplodia</i> sp.	Ivory Coast	Miège, 1957
<i>Rhizopus nodosus</i> Namyslowski	Ivory Coast	Baudin, 1956
<i>Sphaerostilbe repens</i> B. et Br.	Ivory Coast	Baudin, 1956
<i>Fusarium oxysporum</i> Schlecht ex Fr.	Ivory Coast	Baudin, 1956
<i>F. bulbigenum</i> Cooke et Masee	Ivory Coast	Baudin, 1956
<i>F. solani</i> (Mart.) Sacc.	Ivory Coast	Baudin, 1956
<i>Rosellinia bunodes</i> (B. et Br.) Sacc.	Jamaica	Smith, 1929
<i>Rosellinia bunodes</i> (B. et Br.) Sacc.	Jamaica	Larter and Martyn, 1943
<i>Hendersoniella toruloides</i> Natrass	Nigeria	Okafor, 1966
<i>Macrophomina phaseoli</i> (Maubl.) Ashby	Nigeria	Okafor, 1966
<i>Penicillium</i> sp.	Nigeria	Okafor, 1966
<i>Serratia</i> sp.	Nigeria	Okafor, 1966
<i>Aspergillus</i> , etc.		Ogundana, 1971

portions with an alkaline material, such as limewash or wood ash, to reduce the probability of infection. Coursey (1961) has shown that limewashing and other fungicidal treatments reduce weight loss during the first 2-3 months of storage, but may be ineffective over longer period. Losses due to causes such as wound pathogens, weight loss, and respiratory loss, are reduced by "curing" and/or storage at low temperature (Gonzalez and Collazo de Rivera, 1972; Rivera et al., 1974; Martin, 1974; Passam et al., 1976b). Thompson et al. (1977) have reviewed the use of fungicides in the storage of yams.

Quite beyond the loss of acceptability that occurs when yams decay, infection leads to greatly enhanced weight loss. Even sound tubers that later become rotten lose weight faster than those which remain sound, suggesting that pathogens actively contribute to weight loss even before symptoms of decay are visible. This agrees with the observation by Coursey

et al. (1966) that the respiration rate of apparently sound yam tissue is reduced by antibiotics.

5. Rodent damage. Yams are occasionally attacked in store by rodents. Although the quantities actually consumed are generally small, the damage done to the tubers predisposes them to decay. In West Africa, most damage is probably done by the large cane-rat or "cutting-grass," Thryonomys swinderianus (Peters) and the giant rat Cricetomys gambianus (Thomas and Wrongton). Conventional control measures can be applied with good effects.

6. Chilling Damage. Yams, like most crops cultivated in tropical countries, suffer physiological damage at temperatures well above freezing. Young (1923), discussing yams as crops for the southern United States, points out that freezing temperatures must be avoided in storage and suggests that 12-16°C is the optimum range of storage temperature.

It appears that cold storage is unsuitable for yams, but the possibility exists of using cooled storage, probably around 15°C, at which no chilling damage will occur, but at which the rate of metabolic processes, and hence the storage losses, will be very substantially reduced. Extensive research will be needed if this principle is to be applied to practical storage on a commercial scale, as each species, and probably many different cultivars, doubtless have differing optimum storage temperatures.

Effects of Inhibitory Treatments. The storage behavior of potatoes and other temperate root and tuber crops can be improved considerably by the use of sprouting and respiratory inhibitors, and some have gained widespread commercial acceptance. Similar techniques have not as yet

been applied to yams on a practical, farming scale. Experiments to date with chemical sprout inhibitors are inconclusive and more research is needed.

### Yam Flour

This staple is manufactured in quantity in parts of West Africa, and to some extent elsewhere; it is virtually the only processed food product made from yams. Yam tubers are sliced, usually parboiled, and the slices peeled and dried in the sun to a moisture content of only a few percent. After drying, the yam pieces are ground in mortars or milled in corn mills to yield a coarse flour. The flour is reconstituted by stirring into boiling water to form a pasty dough.

Yam flour is usually manufactured from yam tubers that are of inferior quality or peculiar shape; that have been badly damaged in harvesting or heavily attacked by yam beetles, or that are partially rotten and would not store well.

The storage of yam flour or dried pieces of yam presents entirely different problems for storage of fresh yams. Insect attack is a serious threat; several stored-products insects infest yam flour (Cornes, 1964), of which *Araecerus fasciculatus* De G. (Coleoptera, Anthribidae) and *Sitophilus zeamays* Mots. (Coleoptera, Curculionidae) are by far the commonest. Pieces of dried yam arriving at mills are often riddled with holes caused by the first species, and stores where yam flour is kept in normal sacks are usually heavily infested with one or both types. However, insect attack can be fairly easily controlled, first by milling

the dried yam pieces shortly after preparation in insect-resistant containers such as polythene bags or polythene-lined sacks. Infested material could be fumigated by normal methods, for example, with methyl bromide.

Rodent attack may also be severe, but can be prevented by good storage hygiene and conventional control measures.

#### Potatoes (*Solanum tuberosum*)

In 1976, the annual production of potatoes in developing countries approached 27 million tonnes (Table I.1, FAO, 1977a), contributing over 3 percent of major food crop production. The potato is the major crop of many poor farmers in the tropical highlands of Latin America and is increasingly important in the highlands of East and North Africa, Bangladesh, India, Korea, and the People's Republic of China.

Losses. Like other tubers, the potato is subject to postharvest weight loss due to its continuing metabolism, to damage during harvest and handling, to rotting, drying and shriveling, and to sprouting. As with all nongrain staples, losses may be considerable after extended periods of storage, although very few loss estimates have been made in developing countries. In the Dominican Republic losses have been estimated (Mansfield, 1977) at 7.5 percent weight loss due to dehydration and infection over 24- to 48-hour period; 31 percent total loss in less than 15 days (not including harvesting losses) and greater losses over longer periods. Coursey and Booth (1972) give a global figure of 25 percent.

Present modern storage technology in the United States, employing intermittent ventilation with 9°C air containing 95 percent relative humidity, reduced weight loss to 6.3 percent and total potato loss to 12.7 percent after 11 months (Sparks, 1973). This represents probably the lowest loss attainable with good conservation practice.

**Preharvest Causes of Loss.** The planting variety is an important element in potato loss. Those varieties with thicker skins are less likely to suffer mechanical damage during harvest. Those with long dormancy will suffer less from sprouting during storage. During growth in the field, potatoes are subject to infection by light blight, pink rot, and brown rot, and the presence or absence of disease (influenced by varietal selection, chemical spraying and, cultural practices) will affect postharvest storage properties. The Centro Internacional de Papa (CIP) is beginning research on resistance to soft rot caused by Erwinia carotovora and is selecting resistant varieties.

**Harvesting Losses.** Physical damage during harvest is a major cause of subsequent storage losses since it facilitates fungal infections and stimulates physiological deterioration and loss of moisture. Mechanical harvesting permits rapid, relatively gentle digging and movement of potatoes to storage and marketing and significantly reduces harvesting loss. However, since mechanical harvesting is unlikely to be widely employed in the poorer countries for some time, attention should be focused on reducing losses by harvesting when the crop is mature and the outer skin thick; by careful digging and handling of the dug potatoes; by protecting newly harvested potatoes from exposure to wind and sun; and by prompt curing and storage.

Storage Practices and Losses. Storage of seed potatoes and those for food or sale in Peru has been the subject of detailed investigation by Werge (1977), who classifies storage into three main types--house, outbuilding, and field. House storage is convenient and secure, and appears related to food preferences. Potatoes traditionally boiled with the skin on are normally stored in the attic where the dryness and air circulation cause them to shrivel rapidly. They are considered preferable to fresh tubers because of their sweetness (Papa dulce). On the other hand, modern varieties, peeled before preparation, are often kept with the seed potatoes on the ground where moisture helps to keep them firm and makes them easier to peel.

Seed potatoes are often stored on the ground on a thin bed of straw or eucalyptus leaves, in piles against the walls of the house up to one or one-and-a-half meters high, or in outbuildings stores. Sometimes small bins (trojas) are also constructed to adobe bricks to give the piles more stability and keep the potatoes more level.

Where animals are found in the house, the potatoes may be stored on low shelves; ware potatoes may also be stored on a platform of eucalyptus branches (Chaclanka) in the rafters of the house and covered with a thin straw layer.

Field storage is more common at higher elevations. Selected potatoes are placed in a straw-lined hole or clamp, covered with straw and sealed with soil. The cool, moist conditions reduce dehydration; however, there is the risk of rotting if the clamp is flooded.

Storage losses are primarily due to disease, dry rots, gangrene and bacterial soft rots, dehydration, and sprouting. Losses can be greatly reduced by selecting only good-quality potatoes to be stored, to prevent spread of infection in the stored crop.

Clamp- or pile-stored potatoes often display preferential sprouting of the lower layers where light does not reach to inhibit the process. Refrigerated storage inhibits sprouting, but may be difficult and expensive to arrange in some locations. Chemical sprout inhibitors are available and used commercially; however, they generally inhibit suberization, so that loss reduction due to prevention of sprouting may be offset by losses due to inhibited curing. Further, the problem of chemical residues in the tubers may arise from tetrachloronitrobenzene ("tecnazene," "Fusarex") reported not to inhibit curing and to have fungicidal properties, although its sprout-inhibiting properties are less than some other chemicals.

Research during 1975 at CIP into small, above-ground earth storage systems at Huancayo (3,200 m) showed that where natural air was conducted under the pile of tubers they stored acceptably, but where no air was provided all the tubers were lost. In Ecuador, partial underground storage constructed with local materials with air ducts under the tubers to utilize night temperature cooling, produced less than 10 percent loss of potatoes stored for 5 months.

Improved storage with provision for high humidity/low temperature ventilation is the most likely means of reducing storage losses. The value of the harvested crop and current market prices will determine the degree to which providing these conditions will be economically justifiable. Booth and Harmsworth (1977) provide an analysis of the factors affecting choices between traditional, improved, and refrigerated storage costs and losses.



Curing. As we have seen in the discussion of yam storage, curing is the woundhealing process through suberization of the cells adjacent to damaged surfaces, followed by formation of wound periderm, cork, and skin. The general thickening and hardening of the skin provides greater protection against infection.

Curing should be undertaken as soon as the potatoes have been placed in storage before wound pathogens have an opportunity to become established. Successful curing may be achieved over a wide range of temperatures between 8°C and 20°C and with high relative humidity, at least 85 percent, without causing condensation on the tubers. These conditions can be readily provided; the high respiration rate of the freshly harvested potatoes causes a rapid increase in temperature as soon as ventilation is restricted, and water evaporation from the fresh wounds and adhering soil increases the humidity. Little research has been carried out on the effect of temperatures above 20°C on the curing process. Below 20°C it is completed in 10-14 days, although different varieties and types of wound heal at different rates (Booth and Harmsworth, 1977).

Freeze-drying. Chuño, a naturally freeze-dried potato product has been a staple food for Andean altiplano inhabitants since pre-Columbian times. The potatoes are spread out on rock ledges to freeze at night and thaw under the high radiation of the sun during the day. The water released by freezing is trampled out to evaporate, producing a dry product, called black chuño, which is reported to store almost indefinitely.

A more sophisticated product is made by soaking the tubers, after the freezing and thawing, in cold running water for two to three weeks. The skins sloughs off, and the dried product is white chuño.

Cooked potatoes sundried by this technique give an even better product.

#### Sweet Potatoes (*Ipomoea batatas*)

Sweet potato production in developing countries totaled 17 million tonnes in 1976, approximately 2 percent of total developing country food crop production, mainly in Southeast Asia, Brazil, and Central and East Africa (FAO, 1977a).

The postharvest loss situation appears similar to that of Irish potatoes, except for the sensitivity of sweet potatoes to cold temperatures, with damage occurring when the temperature falls below about 12°C. There is little quantitative information on postharvest losses in developing countries, but it is generally believed that under tropical conditions they are very high (Coursey, 1971).

Most studies on sweet potato storage have been made under the sophisticated conditions of the southern United States and Japan, where sweet potatoes are grown as a summer crop, and storage is through a cool or cold winter. Under these conditions, roots should be cured at 35°C and a relative humidity of 85-90 percent relative humidity give the best results (Kushman and Wright, 1969).

#### Taro (*Colocasia esculenta*) and Tannia (*Xanthosoma sigattifolium*)

Taro is an ancient vegetable grown throughout the tropics for its edible corms. It is a major subsistence crop of a number of Melanesian

and Polynesian Islands, but the bulk of it is from Africa, where the name "cocoyam" is applied to both taro and tannia. Production figures are no longer reported separately by FAO; in 1974, the last year of separate reporting, taro production in developing countries was approximately 4 million tonnes. Production of both crops together was reported as 4.3 million tonnes during the same period.

There is very little published information about taro storage. Gollifer and Booth (1973) report storage rots of taro corms in the Solomon Islands, which prevented storage for longer than 1-2 weeks. The rots are reported as being of three types: dry rot caused by Fusarium solani; spongy back rot caused by Botryodiplodia theobromae; and a Sclerotium rot due to S. rolfsii. Under humid conditions all three fungi could penetrate and rot undamaged corms, although most natural infection is thought to occur through wounds. No rot occurred at low humidity. In the Cameroons, Praquin and Miche (1971) recorded weight losses of between 12 and 15 percent in sound corms after 4-6 months' storage. However, when sprouting occurs, soon after harvest, over 50 percent loss was observed after 2 months, and 95 percent after 5 months. Fusarium rots are also found in Xanthosoma cocoyam in Nigeria.

In view of the role of mechanical damage in permitting access to fungal infection, great care should be taken to minimize damage during handling. Curing may reduce infection, and with suitable environmental conditions it is possible that storage life may be considerably extended. Pit or clamp storage, in which high humidity is maintained, is traditionally used in some parts of the world.

### Other Nongrain Staples

Banana (Musa AAA cvs.), plantains (Musa AAB and ABB cvs.), ensete (Musa ensete), coconut (Cocos nucifera), breadfruit (Artocarpus altilis), and dates (Phoenix dactylifera) are the main nongrain staple food crops other than root crops.

The cooking bananas and plantains are by far the most important of these crops. They grow readily throughout the tropics and are a familiar feature of rural villages where there is sufficient moisture and good rich soil to support their growth. In West Africa, the Caribbean, and northern parts of South America they are very widely used. Under suitable conditions they grow continuously and are typically available throughout the year in the humid tropics. In drier regions they show some seasonal tendency, and at higher elevations they are very susceptible to damage from frost (Burden and Coursey, 1977). Postharvest food losses of these crops as staples in the rural diet are less important where there is ample supply, and difficult to assess where there is scarcity. The available published figures of between 20 and 80 percent loss apply to the movement of bananas and plantains from the rural area to the urban markets. Inadequate transport and marketing arrangements are the chief problem. A major investigation of the postharvest problems of plantains has recently been initiated by the Tropical Products Institute.

Ensete (the Abyssinian banana) does not have edible fruit; the starchy pulp of the stalk of the plant is either used directly for cooking or is fermented in a pit for several days. The plant is locally important as a staple in parts of Uganda and southwestern Ethiopia, but is not used elsewhere.

Coconut production is mainly for the oil in the dried flesh of the nut, and comparatively little is eaten, except as a confection, in most parts of the world. Creams prepared from the flesh are important as additives to various dishes.

Breadfruit is a staple of local importance in some places. Losses in the crop have never been quantified, but are certainly very high. The fruit is only fit for human consumption for a very short period: it cannot be eaten until mature, and becomes inedible again once the ripening process commences.

Dates are a staple for a large number of people particularly in the Near East region, 2.4 million tonnes being consumed in 1976. There is no information on postharvest losses.

### Vegetables and Fruits

Vegetables and fruits play an important role in the diet of many peoples in the tropics, providing essential minerals and vitamins and adding flavor, color, and variety to what would otherwise be a monotonous diet. They also contribute protein and calories. Developing-country production of fruit and vegetables in 1976 represented nearly 20 percent of total food crop production (FAO, 1977a).

In this section, as in the case of the cereal grains, we are considering only the perishables used indigenously as food and are not concerned with the considerable losses associated with food processing (such as canning), either for the urban supermarket or for export.

Comparatively little information is available on postharvest losses in fruits and vegetables. This may result from a number of causes, which

illustrate the complexity associated with both estimation and reduction of losses of perishable produce:

- Even with good handling and costly storage facilities, deterioration and loss occurs more rapidly than with the durables, and some storage methods (refrigeration for example) have costs in direct proportion to time of storage.
- The relative unit value, compared with necessary handling and storing costs, is normally low.
- Perishables are comparatively large and vary in shape and size, compared with cereal grains; it is also difficult to express weight loss on a constant-moisture basis.
- The relative food value and importance of perishables to the diet (or to survival) is less than that of the durables.
- Production, commonly spread throughout the year, can often be organized to provide a relatively continuous supply of different fruits and vegetables without storage.

The major perishables (as defined in part by the magnitude of their production) are shown in Table 5:2, along with reported production estimates and loss estimates in developing countries. General information on the postharvest physiology, handling, and utilization of tropical and subtropical fruits and vegetables is provided by Pantastico et al. (1975), Ryall and Lipton (1972), Ryall and Pentzer (1974), and Lutz and Hartenburg (1968).

### Loss Estimates

As we have discussed, then, reports of loss estimates are few, and even where there are published results, the methodology is often not specified. The figures presumably indicate total weight loss and do not normally distinguish between loss of food per se, and loss of moisture during storage, or loss of weight due to metabolic processes that continue after harvest.

The length of time from harvest to observation is much more critical to percentage loss estimation in perishables than in durables; losses frequently increase rapidly, often becoming total within weeks or even days. In future critical work, the time must be indicated.

From the few figures available, losses are clearly excessive, save in a few cases where the unit food value is relatively high and efficient handling and distribution systems operate. The average minimum losses reported for roots and tubers and fruit and vegetables were 16 percent and 21 percent respectively; many more "qualitative" references not included here indicate estimates of 40-50 percent and above. The figures are hard to interpret. One can only conclude that losses are severe, that more critical work is required to obtain better estimates, and that as living standards slowly rise in developing countries, both government and private organizations will endeavor to improve the marketing process and the supply of higher quality perishables to the consumer.

### Causes of Loss

**Mechanical Injury.** Perishables are much more susceptible to injury than durables because of their shape and structure, the relatively soft texture associated with their high moisture content, and the need for more frequent specialized handling. Injury can occur at almost any point in the postharvest system beginning at harvest, and results from poor handling, packaging, transportation and storage conditions, or from damage in the marketplace.

**Physiological Losses.** Physiological losses consist of natural losses due to endogenous respiration, losses of moisture from wilting or transpiration, and abnormal losses that may arise from exposure to heat, cold, or otherwise unsuitable environmental conditions.

**Losses Due to Disease.** Possibly the greatest single cause of postharvest loss in perishable produce is decay caused by microorganisms. This usually occurs from initial infection by one or more specific pathogens, which may then be followed by secondary infection by a broad spectrum of biodeteriogens saprophytic on the dead or moribund tissue remaining from the primary attack (Coursey, 1971.).

Attack by rodents or stored-product insects are usually of relatively minor importance in comparison to decay from microorganisms, although these factors may be important in particular instances.



## Cooling and Refrigeration

Refrigeration is undoubtedly an important means of prolonging the storage of high-quality fresh tropical produce, but it has a number of limitations for reducing food losses in developing countries:

- Many tropical horticultural products are liable to low temperature injury--physiological deterioration at temperatures near, but above, freezing.
- Many of the commodities are too low in unit cost to bear the cost of mechanically refrigerated storage.
- The capital cost--and the not-inconsiderable cost and organization of efficient and continuous maintenance of significant amounts of mechanically refrigerated storage--is likely to continue to be a major limitation for the foreseeable future.

In the long run, economies of scale will undoubtedly increase the importance of large-scale cooled storage. Other simpler and less costly approaches are necessary in the short run. The provision of simple shade can make a great difference to the storage life of perishables; exposure to the tropical sun can raise the internal temperature to 45°C when ambient temperature is only 30°C. Low-cost simple cooling systems, as distinct from mechanical refrigeration, could make possible a great improvement in holding and marketing perishables; reducing the temperature even a few degrees might make a difference. This area requires priority research, with respect to both technology and to the physiology of deterioration.

## Handling and Packaging

Major reduction in the amount of loss can undoubtedly be accomplished by improved handling and packaging at all stages of the movement of perishables from harvest to consumption. Delicate produce is often handled in the same way as the durable crops, and the mechanical damage greatly increases the rate and extent of both physiological and microbiological deterioration. Improvements in packaging and handling also may often be accomplished at little cost. They may require nothing more than ensuring that the produce is handled in smaller quantities and in shallower containers, for instance, in rigid wooden crates or cardboard cartons rather than sacks or in loose bulk. These improvements are normally so situation specific that a detailed discussion is beyond the scope of this report. Proper packaging and handling is so important, however, that it should be among the first aspects of food loss to be investigated.

Improvement in transportation and marketing systems, to reduce the time between harvesting and consumption, can greatly reduce loss.

## Physiological Conditioning

One aspect of developing country food loss reduction that has so far received little attention is manipulation of the physiological condition of the produce. Some types of physiological change can be effected, resulting in reduced storage losses.

Delayed ripening of fruit by removal of endogenously produced ethylene has been used to enable bananas and plantains to be transported

at ambient temperatures instead of under refrigeration. The fruit is sealed in polyethylene bags containing potassium permanganate-impregnated absorbent, which eliminates the ethylene as it is produced.

#### Drying, Pickling, and Fermentation

A number of fruits and vegetables--particularly pimentos, peppers, and the subtropical fruits (such as grapes, apricots, and plums) are amenable to drying, traditionally by the sun. In many countries, large quantities of red bell peppers are processed in this way as a condiment. And in the Far East, large quantities of cabbage are dried. These undoubtedly add nutrients to the diet of the consumer, although the contribution is probably minor. There is little information on the magnitude of production or associated losses.

In drier regions, large amounts of grapes, apricots, apples, and plums are preserved by drying. There is little information on the losses of these commodities in developing countries.

In a number of developing countries, particularly China, Thailand, and Korea, a variety of vegetables are pickled. Great quantities of cabbage are preserved for use during the winter as sauerkraut or kimchi, and lesser quantities of cucumbers and carrots, more for use as condiments than as vegetables. In Africa, okra, mushrooms and cucurbits are commonly dried. In the Indian subcontinent many fruits and vegetables are preserved as chutney. There is no information on losses associated with this process. The application of pickling and fermentation methods to preservation of tropical vegetables is a potentially important area for research.

## Diseases

The control of postharvest diseases of fruit and vegetables has improved dramatically in the last 10 or 15 years with the introduction of new chemicals, a development which has been compared to the impact of antibiotics in medicine. These chemicals, including thiabendazol, benomyl, 2-aminobutane and a few others, are capable of dramatically reducing fungal infection in plant material. They may be applied in very low concentration, as aqueous solutions or suspensions of only a few parts per million by spraying or dipping methods. Little or no toxicity to higher life forms is reported, although resistance problems have arisen. Much research needs to be done, and clearly the utmost caution should be exercised in introducing chemicals, even for experimental purposes, into developing countries for use in connection with foods. Nevertheless, the possibility now exists of making a further contribution to reducing losses of perishables under certain circumstances, in settings where other organizational and handling improvements have been made and where the economics of storage and marketing warrant it.

Much research has been conducted on the use of radiation to extend the life of horticultural produce. To date, however, this technology has not been licensed by the U.S. Food and Drug Administration for produce sold for human consumption. At present it is also more expensive and not as effective as refrigeration (Meric et. al, 1971).

## Chapter 5

Note V-1.

## Notes

There are local variations on the method of preparation, but basically the method is to wash and peel the roots, which are then grated and the mash allowed to ferment spontaneously (Brazilian farinha is not fermented, or only for a very brief period; West African gari, for 2-5 days). The water is squeezed from the residual mass and the granular product prepared by drying and partial gelatinizing, usually in a metal pan or plate over an open fire.

## CHAPTER 5

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## Chapter 6

### Postharvest Losses of Fish

Postharvest loss in the production of fish\* is unique among the staples examined in this study. For no other class of food is there both so much evidence of serious loss at every stage from harvest to consumption and so little precise knowledge of the overall proportion of losses to the potential harvest or to the fish finally consumed.

In this discussion of postharvest fish losses, attention is focused particularly on artisanal fisheries which are small scale, poor, dispersed, and unorganized.

The following aspects of fishing and fish consumption are not considered:

- Commercial fisheries carried out by large vessels on the high seas;
- Fish meal and fish oil industries; and
- Fish caught but not consumed as a result of religious or ethnic preferences or taboos.

These excluded areas, although of great importance in terms of losses, are not central to the focus of this study. Previously, we have said that nonutilization or underutilization of commodities not recognized as acceptable food is not loss. However, for fish we need an expanded definition of postharvest food loss that includes, among other things, non-use of edible species.

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\*In this study "fish" is used for all aquatic animal produce.

Specifically, postharvest losses of fish should include fish discarded at sea as by-catch in the harvest of other species, such as shrimp; this seems justified not only because the by-catch frequently represents a multiple in weight of the principal--and economically more valuable--harvest, but also because the discarded harvest often contains a large proportion of locally acceptable food fish, because the loss could be identified, and because research and development could be applied to reduce this loss.

By extension, the loss definition should include food fish that is locally unutilized or underutilized for any reason except for religious or ritual grounds, again not only because this potential food is quantitatively identifiable, but also because an effort should be made to determine by research special handling and preservation requirements that might exist for these species.

Because fish harvesting differs in many ways from the land harvests of the other food commodities in this study, an overview of fishing and fish consumption will be helpful as a prelude to further discussion of postharvest fish losses.

### General Aspects of Fish Harvest and Consumption

#### Fisheries

Fisheries (as opposed to fish farming) involve the greater proportion of worldwide fishing activities, and those on the high seas represent probably the most dangerous and demanding of food-providing occupations.

Although there are significant regional differences, preference on shore and in the market place in most developing countries is for whole fish. Under the usually prevailing primitive conditions of preservation and distribution, only small harvests can be rapidly disposed of. As a result, most ocean fishing in developing countries is carried out by fleets of many small fishing boats

skipped by individualistic, competitive captains, each acting according to his own lights and laws, trying to make the best living he can.

The fishing trade is doubly hazardous: once because of the dangers inherent in harvesting, and then, because of the perishability of a commodity whose consumers demand that it be fresh. It requires a great deal of perseverance and capital to weather the vicissitudes of fish supply and demand. The fishermen who sell their catch to tradespeople--who in turn operate on the open market--have since time immemorial had to use all the tricks of the trade to avoid being left with large amounts of unsold and inedible catch. The special vulnerability that has forced many fishermen and fish-traders to resort to sharp practice in selling their goods has led fishtrading to be placed, in many countries, at the very bottom of the hierarchy of desirable professions.

#### Consumption

Of the 20-25,000 species of fish known to exist in salt and fresh waters, only a few dozen species are utilized at present on any large scale, though more are probably used on a small scale in specific locations.

Experience with toxic species or those traditionally believed to be poisonous has compelled consumers, especially in warm climates, to demand that fish remain whole to permit identification of species and inspection for freshness. It has also generated local traditions that only particular fish species are acceptable for human consumption; species that are desirable in one place may for a number of reasons be quite unacceptable in others.

In 1976, of the worldwide catch of about 70 million tons of fish--in the general sense of food of aquatic origin--about 35 percent was used for the manufacture of feed material for animals (almost all used in developed countries); about 40 percent was consumed "in the round" fresh or frozen, 10-15 percent was

dried and cured, although in some developing countries consumption of cured fish is disproportionately higher; and 8-10 percent was canned, with the rest being used in miscellaneous ways. Here again, regional variations in the forms in which the fish is consumed cannot be overemphasized. Fermented fish products, such as those in Southeast Asia, for instance, are locally consumed in very large quantities and should be studied much more intensively to determine their nutritional contribution to consumers' diets. If unutilized or underutilized species such as capelin, krill, squid, and other major groups of aquatic animals could economically be harvested, processed, distributed, and marketed, the total aquatic food resources would be increased by as much as tenfold.

James (1977) summarizes the information regarding the costs of expanding existing fisheries to meet the demand, particularly in developing countries. He points out that the investment in equipment, manpower, and technical development required simply to double production from the present level would be of the order of \$30 billion, or about \$500 per additional tonne.

#### Importance as Food

All available evidence indicates that fish has been used as human food since long before recorded history. At present fish provides about 17 percent of the world's animal protein intake (Table 6:1).

Fish is unique insofar as it is the only universal staple that inhabits a medium potentially hostile and dangerous to man. This seems to have endowed it with attributes and powers more varied, colorful, and deeply engrained than those associated with perhaps any other food. The need to select nontoxic species from the harvest and to devise methods to avoid spoilage has provoked strict preference and avoidance patterns, with the development of severe criteria for safety and precise eating habits and taboos.



About 60 percent of the world's edible fish catch goes directly to consumers in the round, reflecting their desire to inspect the raw fish carefully for freshness. In countries where Japanese and other Far Eastern fish sausages and sauces are unknown, the only fish products in which the original identity is not preserved are products similar to fish sticks and gefilte fish, but these represent only a very small proportion of fish consumed.

TABLE 6:1

ESTIMATED WORLD VEGETABLE AND ANIMAL PROTEIN PRODUCTION, 1975<sup>1</sup>

Protein Source	Amount of Protein (Million Tonnes Per Year)		
	Available to Man	Fed to Livestock	Total
Cereals	57	38	95
Legumes	24	6	30
Other Vegetables	5	1	6
Livestock	30	3	33
Fish <sup>2</sup>	6	3	9

<sup>1</sup>From Pimentel et al. (1975).

<sup>2</sup>Fish includes all seafoods harvested from the ocean and for 1975 is estimated at 66 million tonnes (based on FAO figures) that contain an estimated 14 percent protein. A reduction from 17.5 to 14 percent in total fish protein is included for cleaning the fish consumed by man. An estimated 33 percent of the fish harvest is fed to livestock.

Fish thus represent close to 17 percent of man's direct animal protein intake; in certain regions they make up the bulk of a nation's animal protein fare.

It is noteworthy that in spite of the wide availability of fish resources, the recognized nutritional value of fish, and the important economic contributions that fisheries have made everywhere, fish is still largely consumed as in was ancient times and with the exception of canning and mechanical refrigerated freezing no basic technological advances have been made in its preservation. These observations are significant in that they do not apply to the consumption or preservation of any other staple food and reflect the general, long-term, stubbornness of the consumer intent on dealing with fish in a special way. This pervasive attitude continues to influence the nature of the fishing, fish processing, and fish marketing industries. It also affects the possibility of estimating postharvest losses in developing countries since fish spoil rapidly and are mainly preserved by drying (with or without salting and smoking.)

As fishery resources available to the subsistence fisherman are very limited because of these attitudes, and in many cases they are exploited at or above their maximum potential, it is therefore essential to make better use of what is landed and to preserve its economic value.

#### Postharvest Losses

FAO estimates for fisheries in some countries place fish losses among the highest for all commodities. There are very few documented studies to support this; one carried out on Lake Chad indicates that fish losses there may be as high as 50 percent.

James (1977) roughly estimated losses of dried fish due to insect infestation at 3 million tonnes per year (25 percent of 12 million tonnes produced); discarded edible by-catch from shrimping alone at 5 million tonnes (5 times the total shrimp catch); and due to spoilage at 2 million tonnes (i.e. 10 percent estimated spoilage loss of the 46 million tonnes used for direct human consumption, of which 20 million tonnes is estimated to be consumed fresh).

These rough conservative approximations give a loss figure of 10 million tonnes a year--20 percent of the total catch now going to direct human consumption.

These figures are highly speculative, since there are no reliable data for any developing country on either postharvest losses or the unregistered harvests caught by unchartered and uncontrolled individual fishermen. In general, however, it seems clear and can easily be documented that:

- ° Serious postharvest food losses begin immediately after harvest on board ship because of the lack of means to preserve the catch until landed;

- ° Important losses are caused by enzymatic spoilage and insect infestation as the catch is landed, is processed on the beach, and awaits transportation to market; and

- ° Further heavy losses are caused by primitive methods of handling, preservation, transportation, and exposure at market.

Moreover, the entire marine fisheries industry in developing countries is so fractionated by local customs and cultures, and is controlled by so many individual entrepreneurs from harvest to the consumer, that losses occur simply as a consequence of frequent handling and transfer of the variously processed food from one middleman to another. It seems, therefore, fair to say that no reliable figures for overall postharvest losses are available at present for any one region.

The committee recommends that, in view of the present situation and since loss assessment must be an integral part of loss reduction intervention, efforts should be concentrated on a) initiating a number of specific projects, particularly in Southeast Asia to assess losses in relation to local socioeconomic conditions; b) to understand the technological and social organization of artisanal fisheries in different regions; and c) to improve the handling and processing techniques in those stages where the most important losses occur and

where the greatest loss reductions can be achieved--preservation on board boat, drying, transportation, and marketing.

Despite the difficulty in establishing global or even regional loss figures, there is probably merit in developing methods for loss measurement, or at least informed estimates in specific fisheries or geographic areas. Some concrete figures, even if used only as examples, would help persuade governments to commit funds for prevention. Selected studies in Southeast Asia and Africa may well strengthen the case for intervention.

Food losses in the artisanal fisheries industry are related to the various steps of the postharvest system as it leads from the initial catch to the consumer's table.

#### Fresh Fish

The extent of postharvest losses on board the fishing vessel is unknown, but is likely to be considerable because of spoilage due to lack of refrigeration; actual losses are camouflaged, however, because even stale or spoiling raw fish is processed. This results in economic loss, since the price for the fresh and poor-quality dried product is often the same per unit weight, while the fresh fish is five times the weight of its dried equivalent.

#### Traditionally Processed Fish

Major losses occur with traditionally processed products, particularly with smoke-dried and dried or salted-and-dried fish. Although these are very different products that are often specific to a region, it is possible to refer to them as dried products.

## Drying

The simplest, and most widely used, technique for preserving fish is sun drying, in which the landed fish are spread on the beach or on a mat and allowed to dry in the sun.

The wet fish are subject to attack by blowflies, mainly Chrysomyia spp., whose larvae burrow into the fish and cause damage and spoilage. Apart from physical damage to the fish and the enhanced spoilage, the blowflies are a dangerous carrier of pathogenic organisms particularly since the beaches they infest are widely contaminated with human feces as a result of limited public sanitation facilities.

Dried fish is also subject to attack by Dermestes beetles. If this infestation is allowed to proceed, the beetles consume the fish.

A wide range of other insect pests and mites attack drying and dried fish.

## Salting

Preliminary salting is often used to enhance the quality and acceptability of naturally dried fish. Salting either by stacking the split fish with dry salt between the layers or, preferably, by immersing the fish in brine, speeds up the removal of water from the flesh and reduces the time necessary for air or sun drying. In the case of oily fish such as sardines, prolonged drying leads to discoloration and rancidity; a 15-minute immersion in saturated brine may reduce drying time by half. Waterman (1976) reports that presalted dried fish kept in fair condition for 6 months, while unsalted controls were rotten or moldy.

Salting is also a chemical method of bacterial and insect control. Flies will not attack fish that has been brined before drying, and the rate of attack by beetles is inversely proportional to salt concentration (James, 1977). One of the most difficult problems with salted dried fish is to control reabsorption of moisture from humid atmospheres after processing. For this purpose, proper packaging is required.

#### Smoking and Smoke Drying

Smoke drying is widely used in Africa for a variety of foodstuffs, many of which spend some time suspended over cooking fires as a means of deterring insect infestation. In the Lake Chad area, fish may be partially dried in the sun and then covered with grass or papyrus, which is set on fire and the fish scorched and charred to form a hard, protective outer surface. Some fish may be smoked over a grid or fire, or simple kilns may be employed.

These methods, however, offer little protection against insects and may result in additional loss from charring and burning. The insect pests lay their eggs in the flesh before and during drying. During smoking of thick-bodied fish, they are deterred by the heat and smoke, but the larvae already present penetrate the deeper parts of the fish where the heat and smoke cannot reach. Products attacked by insects range from those with high water content and a storage life of 1-2 days to hard-dried products with shelf lives of several months.

A certain amount of spoilage results from storage of improperly processed products, which causes direct losses. Improved quality-control procedures and market incentives will alleviate these losses. Traditional processing may be responsible for a loss of nutritional value as high as 15 percent (Hoffman et al, 1977).

## Storage and Distribution

After losses to insects, the most important physical and economic losses result from crumbling during storage and distribution. Poorly dried fish is a fragile product that, if roughly handled or vibrated on overloaded trucks on poor roads, will crumble to a powder. Prior insect attack weakens the structure and can result in a mixture of pieces and a powder of fish and insect frass. With poor packaging, there can be direct physical losses and, although fish powder also has a market, there are always economic losses. Inadequate protection is recognized as an area in need of study

## Strategies for Loss Reduction

With an industry as fractionated, little-organized, independent, and subsistence-oriented as capture fisheries in a developing country, the obstacles that must be overcome to bring about change are enormous. To effect social change, there are basic requirements of cultural and economic appropriateness, political compatibility, and sound promise of economic or other benefits that must be met. Cooperation with members of the food-fishing industry--the men and women who harvest, process, sell, buy, preserve, store, package, transport, and purchase fish in the marketplace--involves the same basic considerations as cooperation with those who deal with and consume the farm commodities discussed in this study. Requirements for successful intervention in a traditional postharvest system, adapted here to the fishing industry, include:

- ° A communication link between the fishing people and the rest of the community;
- ° Incentives for loss-reduction efforts;
- ° Government support;

- ° Knowledge of locality-specific social and cultural patterns; and
- ° Knowledge of locality-specific preference for, and avoidance of, certain fish species.

In the case of fish, locality-specific patterns and preferences are especially important. All suggested postharvest conservation strategies must be appropriate-- that is, must fit into the system technologically, culturally, and socially. For example, the idea of comminuting fresh fish with cereals or tubers in simple meat-grinding machines to manufacture inexpensive "intermediate moisture products" (which are stable because of the low moisture content of the product) should only be proposed if such fish-cereal mixtures are known and accepted by the community in question.

There are also, of course, unique characteristics of the fishing industry that must be considered in planning for reduction of postharvest loss. For example, in an industry that consists typically of one-man operations with very small boats, it is essential that appropriate scale not be overlooked in the design of conservation technology. Other problems which must be considered include the small space available on a fishing boat, the large number of boats, and the small batch sizes of fish that must be processed and protected after they are landed at dispersed coastal locations.

The rest of this chapter deals with specific characteristics of the fishing industry as they relate to postharvest food losses: the locations at which intervention may be most effective in reducing loss; new technologies; and training and organization.

As in grain and perishable losses, the initial step in planning loss reduction is to pinpoint stages at which intervention appears to be needed and promises to yield substantial benefits.



### Aboard Ship

The most effective intervention at the immediate postharvest stage is improvement of storage conditions to reduce deterioration of fish prior to landing. However, each situation must be looked at separately for cost effectiveness, and many potential improvements may be beyond the resources of the artisanal fisherman. There is need for research and development in this area. Low-cost cooling devices would be particularly helpful and, though ice would be better, even seawater cooled by several degrees can greatly retard spoilage of certain species.

### On Shore

Insect infestation of wet fish with Chrysomya (blowflies) followed on dried fish by Dermestes (beetles) cause losses that are measurable (though with difficulty), but these vary so much from one area to another or from season to season that accurate measurement is difficult and expensive. As an example, in the rainy season in Malawi losses due to blowfly larvae varied from 2 percent to 40 percent (Meynell, 1978). These losses can be significantly reduced by dipping boxes of small fish in an inexpensive insect-repellent solution.

A variety of technologies, old and new, have been developed to improve on simple sun drying to reduce blowfly and beetle infestation. These methods are discussed in an FAO publication "The Production of Dried Fish" (Waterman, 1976), see Note VI-1.

It should be stressed that the following techniques should be considered in the context of local circumstances and that introduction of these technologies to new or different areas are likely to require adaptive research and development. Waterman's treatment of the principles of drying

is highly recommended to anyone interested in acquiring a detailed basic knowledge of the subject.

### Preparation of the Fish

In preparing simple, naturally dried fish products, with or without supplementary salting or smoking, the basic preparation and hygiene of the conditions with which the fish is handled are crucial to the quality of the final dried product.

Although drying is often seen as an alternative for unsold fresh fish, and although the characteristic flavor of dried fish may to some degree mask the flavor of stale raw fish, poor quality fresh fish makes poor quality dried fish. To the extent that the fish can be cleaned thoroughly and, if possible, chilled before drying, the better the product and the less likely the occurrence of losses.

### Drying, Salting, and Smoking

Once drying has been decided upon, the first step is to keep insects away from the fish and reduce the drying time by raising the fish off the ground. Simple racks constructed from local materials work very well. It is also desirable to be prepared to cover the drying fish in case of rain (as an alternative to moving them under cover from the racks), and plastic sheet is cheap, effective, and generally available. In Zambia and in West Africa, this kind of drying fresh-water sardines is combined with a period of drying in a smoking oven. Salting is also used to speed up the drying and preserving process. The availability at reasonable cost of plentiful, good quality salt is an important aspect both of technology and of government policy directly related to conservation.

New designs of smoking oven have been developed by a number of workers and are slowly being introduced (see, for example, Clucas, 1977).

The strong-tasting smoke-dried product is popular and in demand and will probably continue to be competitive with fresh and frozen fish products. A disadvantage in many countries is the increasing scarcity and cost of wood and charcoal, although the new oven designs are much more efficient than the traditional ones.

### Solar Heating

Heat treatment of fish to kill insects and their larvae and eggs is well established. In Bangladesh, Doe (1977) using a simple solar dryer constructed in the form of a tent from polyethylene plastic sheet and sticks killed all stages of blowfly in 20 hours at 45°C. The temperature was achieved with clear plastic facing the sun, black plastic behind; vents were provided at top and bottom.

### Chemical Control of Tropical Insect Infestations

The literature contains a number of suggested chemical treatments for both short- and long-term infestation. However, it stresses at the same time the inherent limitations of the technology imposed by the potential hazard to the consumer. There is as yet no chemical means of control of insects that may be recommended and applied on a commercial scale without this health hazard. Cautious use of chemical control is vital in developing countries where different insecticides are produced, transported, distributed, and used by many people who have little knowledge of their hazards. Moreover, there is a lack of coordination between scientists working on experimental control and health authorities, so that work to improve the safety of certain compounds may be academic because of a ban on their use.

The use of contact insecticides should be considered only as a last resort, where:

- ° No other means of coping with the pest infestation is as practical or economic;
- ° The techniques employed are simple and foolproof; and
- ° The treatment uses insecticides of low mammalian toxicity at dosage rates that leave residues within FAO/WHO tolerance limits.

Some examples are given in Note VI-2.

Systems that include insecticides generally call for a combination of physical methods (drying racks, etc.) with chemical, using insecticides to control insects by treating fish containers or places where fish is handled rather than the fish itself. These techniques, used in a way that minimizes potential contact of the fish with residues, should be used with physical methods wherever possible before resorting to direct contact methods.

More research is needed and new products of low toxicity must be developed before direct treatment with insecticides can play a more important role in insect control in fish. The focus should be on the extension of effective and safe methods to the producers. Dried fish production is generally carried out by small, widely scattered, and conservative groups who would be reluctant to adopt new methods even if trained extension agents were available to convey them. Aggregation of production through centralized collection and processing by large-scale mechanical dryers requires high capital investment, and the standardized product may not have market appeal.

#### Refrigeration and Ice

Because of the expressed preference for whole, fresh fish, there is major interest in using refrigeration and ice to extend storage life. With ice, tropical species (i.e., those actually living in warmer water,

rather than those living in cold water in tropical regions) generally keep longer, on average, than cold water species. Shelf lives up to 45 days have been recorded for some species, and 20-30 days is common. This probably results from the effect of the greater temperature difference between ice and warm-water fish on spoilage microorganisms and tissue enzymes.

There appears to be little if any advantage in deheading and gutting tropical species for cold or chill handling. The further handling creates additional hazard, and the intact fish is commonly preferred in the local market.

With a number of exceptions, apart from a small percentage of urban markets the use of refrigeration is still limited, although it is expected to increase (James and Krone, 1976). Where refrigeration does exist, postharvest losses associated with refrigerated storage and transportation are likely to be so minor compared with other postharvest losses that they can be overlooked here. An excellent account of the use of refrigeration technology for fish preservation can be found in the FAO report Ice in Fisheries (1974).

Solar- and wind-powered cooling and ice-making equipment is still relatively young. Research in this, as in other aspects of renewable energy source utilization, should be encouraged. Application of renewable energy to the particular needs of developing countries should also be encouraged, perhaps through cooperative research and development projects at a regional level between universities and governmental organizations in developed and developing countries.

#### New Technologies

Recent developments for preserving fish as fish silage, fish cheese, and low-salt fermented fish (using added cereal "ragi" in Southeast Asia)

are discussed in the proceedings of a conference organized by the Tropical Products Institute in London in 1976 (Tropical Products Institute, 1977).

Traditionally, fermented fish has been widely used in Southeast Asia as nuoc-mam, but its high salt content has limited its use, particularly by young children, as a source of protein in the diet. The development of low-salt fermented fish offers the possibility of extending the protein supply wherever this variety of marine product--one in which the source species is unidentified--is acceptable.

#### New Methods of Drying

Drying racks, improved smoke-drying ovens, and design and introduction of better solar driers can contribute to loss prevention.

#### Training and Organization

Extension links are weak throughout the third world, although extension services exist on paper in many countries. It is vital to demonstrate to young, developing-country men and women that technical extension can be a rewarding career. Many of the solutions to postharvest loss can come from extension work, particularly that resulting from socially oriented research projects with women. In some areas, particularly in Africa, women are the economic power in the fish business and extension work is unlikely to succeed unless this is recognized and women extension officers trained. Osuji (1976) makes the following points about the need for extension in the dried-fish industry, for instance:

Extension services are necessary in order to increase the awareness on the part of fishmongers as well as consumers of the considerable economic and nutritional losses incurred through insect damage. Such campaigns would attempt to destroy the traditional belief in most places that the beetles are part and parcel of the dried fish, or that "dried fish must have beetles." Attention should be drawn to the fact that beetle infestation is not spontaneously generated within the fish. Infestation can, on the contrary, be prevented or reduced to a minimum by the application of simple measures including better sanitation and the inexpensive modification of existing techniques.

The principle loss of value to the fisherman for his fresh fish results from inability to hold fish in the expectation of better markets. Containerized chill stores, supplied with ice from central locations, can be established reasonably cheaply. These can be used to test the economic feasibility and acceptance by the fishermen before permanent (e.g., ferrocement) stores are built. Community storage can also be organized for dried fish--making adequate disinfection and protection possible.

#### Marketing and Infrastructure

Fishermen, because of the nature of their trade, are particularly vulnerable to pressures exerted by middlemen who often exploit the situation. However, experience has shown that it is dangerous for external assistance to be directed to supplanting the middleman or woman. The general improvement of social and economic conditions of the community as

a whole is important to create larger and more prosperous markets for fish and fish products.

The adoption of new technologies through extension programs is bound to be unsatisfactory unless there is also provision for improvement of the infrastructure. Economically feasible projects successfully implemented on a small or local scale need to be multiplied by substantial investments. These investments are also required to improve the general quality of rural village life. They include provision of port and landing facilities, fish marketing and storage, water supply with improved sanitation and sewage disposal. Upgrading road or water transport can also substantially reduce postharvest losses.

Each of these areas--technology, extension, and infrastructure--contains a critical manpower component to which both governments and technical assistance agencies should be particularly sensitive as this is generally the weakest part of improved technology applied to economic development.



## Chapter 6

## Notes

## Note VI-1.

As Waterman points out:

There are hundreds of different dried fish products in the world, and a great number of ways of making them. Some of the products are highly prized, some are tolerably pleasant, while others are barely acceptable except as an alternative to starvation. The intention here is not to persuade producers of dried fish to make standard products; the raw material, the climatic conditions and the markets are all so different in different regions that uniformity is neither possible nor desirable.

Furthermore:

Of the many accounts of regional methods on record, it is unfortunate that all too often the essential details are missing that make all the difference between haphazard procedure dependent largely on luck, and a controlled reproducible method. This is rarely the fault of the recorder; in all probability the process times and temperature, brine strength, water content and other factors have never been measured, let alone set down on paper.

Note VI-2.

For wet fish, short immersion in pyrethrum solution (0.125 percent w/v) with 1.25 percent w/v piperonyl butoxide has been recommended for short-term fly control prior to drying (McLellan, 1963). This was not effective against dermestids, which requires a further immersion of the dried fish in a water emulsion containing 0.018 percent w/v pyrethrins and 0.036 percent w/v piperonyl butoxide. Provided the fish was properly dried before and drained after treatment, it did not become too moist for storage nor unacceptable to consumers (Proctor, 1972 and 1977). This method of control is reported to be effective for 8-12 weeks. Recent work in Malawi (Meynell, 1978) has shown that dipping or spraying boxes of fish with a solution of pyrethrum (0.02 percent) synergized by piperonyl butoxide (0.04 percent) reduced losses from blowfly by 10 percent at a cost of 0.1¢ per pound.

## Chapter 6

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## Chapter 6

## Recommended Reading

It is difficult to suggest background reading material solely related to postharvest fish conservation. The interested reader is advised to peruse publications in the wider field of handling, processing, and distribution of fish. From these it is possible to identify problem areas where losses are apparent and, in many cases, where means of prevention are defined. A recent FAO bibliography extracts the major monographs and journal articles in the postharvest area.

A number of the FAO technical papers and reports listed below are readily available and should be consulted

However, the most concise and recent materials are the Proceedings of the Conference on Handling, Processing, and Marketing of Tropical Fish (Tropical Products Institute, 1977), and the forthcoming Proceedings of the Symposium on Fish Utilization, Technology, and Marketing in the IPFC Region, Manila, Philippines, 8-11 March 1978.

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## Chapter 7

### Education, Training, and Extension

Postharvest food loss, for all its importance, involves problems and issues still little known or understood in either industrialized or developing countries. The members of the study committee are convinced, as a result of their practical experience with food loss problems in many countries, that better education and training about food loss and its alleviation are essential if significant worldwide improvement is to occur. This conviction has been reinforced by the results of a request for contributions distributed by the committee widely throughout the developing countries; the returns clearly identified education and training, particularly of extension workers, as a priority need among loss reduction activities.

In assessing the need for education, training, and extension with regard to postharvest food losses, the committee has had neither the resources nor the special competence to make a scholarly investigation. These topics demand attention, however, and this chapter illustrates certain important aspects.

#### Education and Training

Comprehensive instruction on ways to minimize postharvest food loss is needed at every level, from public officials who make policy to

administrators, technicians, extension generalists, extension specialists, and the producer at the farm or fish-catch level. Education and training programs must be locally designed and conducted and, most important, be adapted to local needs.

There are many elements to be considered in the development of national systems of education and training in conjunction with postharvest food loss reduction. They include:

- Extension services, with training of extension specialists;
- Graduate-level training and research;
- Training of students from developing countries in developed-country institutions;
- Nonformal training for rural communities; and
- Preparation of teaching materials at basic and advanced levels.

The balance between these needs and available resources should be determined by the national postharvest food conservation policy body. However, the national policy body will require an implementing agency with trained professional staff. One model of such an agency has been developed on the basis of extensive experience by the British Tropical Products Institute, and is described in an extract from a recent paper (Prevett, 1977) which relates the kind of training required to the type of implementing agency. (See Note VII-1.)

The model represents only one of many possible approaches to the planning and implementation of postharvest food loss activities; smaller and less-extensive structures could be used, and different institutional linkages established. It illustrates the variety of special skills that bear on postharvest loss problems, the need for relevant specialists to



be trained about postharvest losses, and the importance of extension agents in carrying out effective loss reduction. But it should be noted that the model leaves a number of important issues for governments and technical assistance agencies to resolve. For example, what kind of structures can facilitate improved consultation between national policy bodies and leaders at the village level? In the process from assessment to decision making, how can planning best be informed by a sound understanding of the socio-cultural conditions that underlie food losses and affect preventive measures? How can local initiative be encouraged?

#### Extension Services

Although extension services constitute one of the basic mechanisms for education and training at the producer and consumer level, extension as currently practiced has a number of weaknesses. Usually, extension service workers are not trained in recognizing and dealing with the broad range of postharvest food loss problems. There are also mismatches between trainers and those people being trained. In some countries this is particularly evident where women who are producers and marketers of basic foods as well as the family members responsible for food preparation are by-passed by male extension workers. For that matter, the women may regard many of these activities on which men can have no useful knowledge. Unless women extension agents can be trained, employed, and given full backing (including the same career possibilities as their fellows) many of these producers and marketers will not be reached. Equally important, in the government there is often no practical awareness of the fact that food losses exist and that simple interventions could reduce them significantly.

In most countries, the key person to give farm-level training should be the extension agent. Rarely does this agent now have training in techniques for food-loss prevention. This situation should be remedied so that the agent can become the person who helps the food producer recognize the economic consequences of postharvest losses, motivate him to reduce losses, and train him in practical techniques. At the same time, the general extension agent must be supplemented by specialists who have more comprehensive experience in reducing losses in grains, fruits, vegetables, meats, and fish.

The initial selection of extension agents is crucial because they must be sensitive to the culture of the people whom they serve. They must recognize that the people with whom they work are intelligent, and be prepared to take their guidance about local conditions and practices. However, studies of extension work have clearly shown that merely intensifying extension programs can be a wasted effort unless a number of other developments take place simultaneously. These include giving farmers incentives to adopt new approaches; removing local constraints that may inhibit acceptance of new methods; giving extension workers enough incentives to do their work properly, including decent working environments and mechanisms for promotion and professional advancement; and getting support of the local community for various demonstration activities.

In addition to classic extension services, there are several techniques and a variety of media for reaching food producers through training and education programs. Nonformal education techniques are especially effective. Radio, TV, and visual materials produced for the local area are of particular importance. Natural leaders within the community who practice good food

conservation techniques can be used as a resource for extending education begun by the extension agents.

An understanding of postharvest food conservation should also be fostered at the primary and secondary school levels. It is here that techniques of sanitation, hygiene, and prevention of insect infestation can be taught at an early age as a part of the basic curriculum.

The committee strongly recommends a basic multilevel program of training and education to reduce postharvest food losses as follows:

1. Farm and agriculture training. Training programs in postharvest technology should be directed toward extension services, agricultural colleges, and farmers' training institutes. There is also a need for ongoing, in-service training and career development for workers at all levels in the food storage, processing, distribution, and marketing system.
2. Managerial training. Managers of both government and private marketing, storage, and processing organizations should be given enough technical knowledge to increase their awareness of the problems involved in the decisions they make.
3. Support staff training. The training need requiring the greatest input, both in national commitment and expert assistance, is in-country training aimed at the lower staff levels of government and quasi-government marketing agencies, produce-inspection and pest-control services, extension services, etc.
4. Food handlers' and producers' training. Courses should be designed to meet the special needs of personnel responsible for procurement, quality control, pest control, warehouse management, drying, handling, and processing of foods. Graduate-level training in these technical areas is necessary to establish a professional staff cadre.

5. Aid programs for local training of graduate and senior staff in technical institutions have largely concentrated on men. Women may control, or be involved at important stages of the marketing and processing of certain commodities. It is essential that proposed changes not lead to their replacement by trained men, rather that they be recruited for retraining for the new occupations the changes will create, in procurement, quality control, pest control, warehouse management, etc. Otherwise, they will be excluded from their present occupation with no alternatives, to the detriment of their own status and economic position.

6. Development of learning models. Effective learning models for village people--who are often illiterate--should be determined, including the kinds of teaching aids needed and the people who can best prepare teaching materials for the various levels of learning. These broader questions must be tackled by authorities or bodies at the national level.

7. Manpower development. Cooperation between aid agencies and recipient governments is urgently needed for enlarging the manpower required to initiate postharvest food loss reduction programs.

At the 1975 meeting of the FAO Committee on Agriculture, FAO was requested to carry out in its regular program a survey of available technical expertise for agricultural development, both in developed and developing countries, and to establish and periodically update this inventory. As the second part of such a study, an evaluation should be made, at both the national and international level, of long-term requirements for skilled manpower. Training capacities of both developed and developing countries should be adapted to meet these demands.

8. Constructive use of local customs. Knowledge about local customs and institutions needs to be integrated into educational activities. It

may be advisable to pool past experience and to encourage the development of models for this purpose.

Note VII-1.

Components of a National Program and Its Personnel Requirements

The objective is to initiate, develop and sustain national postharvest food loss reduction programs, encompassing the whole postharvest system.

All postharvest planning and activity within the framework of a national program should be closely integrated and coordinated, and authority for this should be invested in the appropriate Ministry (normally, the Ministry of Agriculture). In our view, the most effective way to achieve the necessary action, in the long term, is through the establishment of a national "Postharvest Research, Training and Advisory Unit" with the following objectives:

1. To ensure efficient postharvest operations through the application of known technology and continuous evaluation and follow-up.
2. To establish programs of adaptive research to determine the extent to which available technology may be applied to local conditions and, where appropriate, to undertake research and investigations on local problems for which solutions are not evident.
3. To assist in the establishment of continuous in-service training for staff of storage, marketing and processing organizations and others active in the postharvest field.
4. To assist in the development and maintenance of an effective extension service to farmers, farmers' cooperatives, traders and local marketing agencies.

5. To assist and liaise with government departments and organizations concerned with the planning of agricultural policies and programs, and coordinate activities with external technical assistance agencies.

In order to establish a Unit of this type with responsibility for grains, professional staff experienced in the following fields will be required:

Head	-- Senior technologist with wide experience in food grain technology and storage
Biologist	-- Experienced storage entomologist/biologist
Processing Engineer	-- Cereal technologist with milling experience
Storage Engineer	-- Agricultural engineer experienced in grain drying, handling and storage and storage structure design
Training Officer	-- Agricultural educator trained in storage technology
Extension Officer	-- Agricultural extension worker trained in storage technology

In many cases the first step will be to conduct an initial survey to identify the component parts of the system (i.e., harvesting, threshing, drying, handling, storage, marketing and processing), to determine their inter-relationships and relative importance, to identify areas in which immediate remedial action is justified and those in which loss assessment or other studies are needed in order to determine the appropriate course of action. For such a survey a team of three specialists will be required: a grain marketing economist, a grain storage specialist with broad experience in analyzing causes of grain losses and controlling

them, and a grain storage and processing engineer. Projects involving loss assessment need to be serviced by personnel having suitable technical expertise in relation to the part of the system under study, coupled with experience of loss assessment methodology. They will need to be supported by suitably trained survey teams in order to ensure the proper collection of data. Extension of these activities to include non-grain staples will require additional personnel with experience appropriate to the crops under consideration.

The availability of finance is clearly of the utmost importance to the successful implementation of such a program, but the availability of adequately trained and experienced manpower will be one of the major constraints. The problem is two-fold. The long-term objective, through training, must be to upgrade the capability of local staff involved at all levels of operation from the subsistence farmer through to the consumer, in all sectors of the postharvest system. However, technical assistance agencies that are planning activities designed to meet this objective are already aware of the global shortage of expertise in tropical postharvest technology and there is an urgent need for action to increase the availability of this "expert" manpower.

For an effective program of postharvest loss reduction, implemented by a technical training and advisory unit operating under a national policy body, two main types of trained personnel are required-- extension agents and



subject matter specialists--"expert" personnel, in the FAO terminology, both supplied by technical assistance agencies and trained through national programs.

## Chapter 7

## References

- FAO. 1977. 1976 FAO Production Yearbook. Food and Agriculture Organization of the United Nations, Rome.
- IFPRI. 1977. Recent and Prospective Developments in Food Consumption: Some Policy Issues. Research Report No. 2. International Food Policy Research Institute, Washington, D.C.
- James, D. 1977. Postharvest losses of marine foods--Problems and responses. Paper presented to the Institute of Food Technologists Annual Meeting, Philadelphia.
- NAS. 1976. Energy for Rural Development: Renewable Resources and Alternative Technologies for Developing Countries. Report of an ad hoc panel of the Advisory Committee on Technology Innovation, Board on Science and Technology for International Development, National Academy of Sciences, Washington, D.C. p. 73.
- NAS. 1977. World Food and Nutrition Study: The Potential Contributions of Research. National Academy of Sciences, Washington, D.C. p. 1.

## Chapter 7

## Recommended Reading

There is very little published information specifically directed at extension and training aspects of postharvest loss reduction. In addition to the three publications in this list, the general literature on extension in agricultural production and rural development should be consulted.

Abdel-Hamid, F., and Abdel-Aziz. 1975. Storage of Food Grains: A Guide for Extension Workers. Food and Agriculture Organization of the United Nations. 33 pp.

Community Development Trust Fund of Tanzania. 1977. Appropriate Technology for Grain Storage. Report of a Pilot Project, in cooperation with the Institute of Adult Education Economic Development Bureau. Economic Development Bureau, 234 Colony Road, New Haven, Connecticut, USA 06511.

Lindblad, C., and L. Druben. 1976. Small Farm Grain Storage. United States Action/Peace Corps Program and Training Journal, Manual No. 2. VITA Publications, Manual Series No. 35E. Volunteers in Technical Assistance, Washington, D.C.

## Chapter 8

### Conclusions and Recommendations

The committee's basic conclusions about postharvest food losses and their reduction are summarized below. The chapter begins with a general discussion of these conclusions and ends with a more specific section on recommendations.

#### General Conclusions

##### Loss Estimation Problems

From published information of actual measurements of food loss and estimates by experienced observers, it is clear that postharvest losses of food in developing countries are enormous. When the consequences of such losses are measured in terms of human suffering and economic cost, they represent an international challenge that richly merits priority attention.

The variability of these losses--from season to season, among different crops, from location to location, and under different kinds of postharvest treatment--makes accurate measurement of their extent extremely difficult, and hence expensive. In certain cases, it may never be possible or economically feasible to estimate losses, whether of weight, quality, or nutritive value, with any statistically significant degree of accuracy.

Until recently, loss estimation methodology has been given little critical attention (with a few notable exceptions), and the value of

published information has been reduced by the absence of standard methods of definitions. Fortunately, this has been rectified for the cereal grains with the preparation of the manual of Postharvest Grain Loss Assessment Methods (Harris and Lindblad, 1978). No comparable methodologies exist for perishables, which constitute an area requiring priority attention.

### Current and Projected Losses

Although the methods of loss estimation are frequently suspect and the substantiating data rough, there are, as we have noted, sufficient data to show that substantial amounts of food are being lost annually in the postharvest system. Since estimates of both loss and production in developing countries are subject to differing interpretations and degrees of accuracy, projections of the amounts of food that might become available through loss reduction are doubly difficult. With these limitations, however, it is necessary to make rough approximations to illustrate for decision makers the possible magnitude of the losses involved.

Conservative expert opinion resists generalizations of loss estimates because they cannot be substantiated by statistically sound data. For planning purposes experts cite minimum overall losses of 10 percent for durable crops and 20 percent for nongrain staples, perishables, and fish. Table 8:1 gives an extrapolation in monetary terms of these minimum loss estimates for 1976.

The figures in Table 8:1 indicate that in the developing countries a conservatively estimated minimum of 42 million tonnes of cereal grains and legumes were lost in 1976; this amount is equivalent to 60 percent of the annual total cereal production of Africa, 95 percent of Canada's annual cereal grain output, and slightly more than the production of Indonesia and Thailand combined. At 250 kg per year, this tonnage would provide more than the annual minimum calorie requirements of 168 million people--twice the population of Pakistan, or a quarter of the population of India.

Table 8:2 presents analogous calculations based on projections of food crop production in 1985 and continued losses and prices at present levels.

TABLE 8:1  
1976 Estimates of Minimum Postharvest Food Losses  
in Developing Countries<sup>1</sup>

	<u>Durables</u>	<u>Perishables</u>	<u>Fish</u>
1976 Food Production (million tonnes)	420 <sup>2</sup>	275 <sup>2</sup>	
Estimated Minimum Loss Percentage	10	20	
Estimated Minimum Loss (million tonnes)	42	51	10 <sup>3</sup>
Estimated Price/Tonne (US \$) <sup>4</sup>	165	25	225
Estimated Loss Value (US \$ billions)	6.9	1.3	2.3

<sup>1</sup>"Developing Market Economies" according to FAO (1977) definition.

<sup>2</sup>Production estimates from FAO (1977) assuming 79 percent of durables and 75 percent of perishables are actually used for food. (based on NAS, 1977).

<sup>3</sup>James (1977).

<sup>4</sup>Figures used by the International Food Policy Research Institute (IFPRI, 1977).

TABLE 8:2

1985 Projections of Minimum Postharvest Food Losses  
in Developing Countries

	<u>Durables</u>	<u>Perishables</u>	<u>Fish</u>
Projected 1985 Food Production * (million tonnes)	472	302	
Estimated Minimum Overall Loss Percentage	10	20	
Projected Minimum Losses (million tonnes)	47	60	10
Estimated Price/Tonne (1976 US \$)	165	25	225
Estimated Loss Value (US \$ billions)	7.8	1.5	2.3

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\* Based on approximately 2 percent annual increase from 1976 FAO production reports and figures in the World Food and Nutrition Study (NAS, 1977, Appendix A, Table 1) of approximately 75 percent of total durable crop production used for food in 1985. Also assumes the proportion of durables to perishables produced in 1976 (61:39) will hold for 1985, and that there are no improvements in food conservation.

In total, these figures represent a conservative minimum estimate of 107 million tonnes of postharvest food losses, which, together with 10 million tonnes of fish losses, is valued at approximately US\$11.5 billion. Successful implementation of the United Nations General Assembly VIIth Special Session Resolution calling for a 50-percent reduction in postharvest food losses by 1985 would, therefore, save an estimated US\$5.75 billion worth of food annually.

A 2-percent annual increase in production of food crops over 1976 figures would result in a production of durables very close to the projected demand figures for grain in 1985--474.5 million tonnes (NAS, 1977). If this level of production were achieved, however, a shortfall of food grain would result from the projected postharvest loss--a minimum of approximately 47 million tonnes. Production sufficient to meet both the projected demand and the estimated 10-percent postharvest loss would require an increase of 2.85 percent annually. If the UN Resolution's 50-percent loss-reduction target were to be achieved over this period, the annual production increase could be reduced to 2.32 percent.

It must be stressed again that these figures and computations are only illustrative and that they are included to show the magnitude of the problem and the potential benefits of its alleviation. Moreover, we do not yet know what proportion of the postharvest losses it is technically or economically feasible to reduce. Nor will we be in a position to assess this until systematic, coordinated efforts to estimate and reduce losses are implemented at national, regional, and local levels over a wide area. For this reason, it is important for loss estimation and loss reduction efforts --both technical and socioeconomic aspects--to be integrated within the



framework of a national policy. This will enable identification of targets where food loss reduction will have particular social benefit, a priority need.

#### Food Conservation Programs

Implementation of the United Nations Resolution will require substantial resources, particularly trained men and women. The committee believes that available information justifies considerable worldwide expansion of current efforts, directed particularly toward helping developing countries to establish their own postharvest loss reduction policies and programs.

The current level of international effort expended for estimating and reducing losses is hard to quantify, since few organizations and programs are limited to, or clearly identified by a concern for, postharvest loss activities. It is also difficult to disaggregate expenditures on storage, for example, from national agriculture budgets or large agricultural development loans.

Furthermore, few developing countries have research and extension activities specifically directed to postharvest losses. There is general agreement among knowledgeable observers that, with a few notable exceptions, the overall level of effort directed to postharvest losses is inadequate compared with both agricultural production activities and the potential savings of food.

There are many reasons for this inadequate attention to the postharvest system differing in detail and degree from country to country.

Among the more important reasons is the lack of professional identity and opportunity for career employment, which in turn reflects the limited attention and money allocated to the problem. In part, this is because the high costs and environmental consequences of continued expansion of production have only recently made postharvest conservation of food an obvious alternative. Even so, the cost effectiveness of postharvest loss reduction on a broad scale has not been demonstrated. Nevertheless, loss reduction through "sound conservation practice", involving actions that use relatively small investments of time and money, is a reasonable way to protect the investments of labor, capital, and other inputs already made to produce the food.

#### Food Conservation Practices and Technologies

Sound conservation practices range from a variety of common-sense measures (better hygiene, simple technologies for storage or drying like those described in the Lindblad-Druben manual, or shade and ventilation for marketed perishables) to the use of small, sophisticated equipment (such as moisture meters). Each situation will present a different range of possibilities to be identified and evaluated, and governments can assist this process by providing incentives to conserve food and helping farmers assess their own conservation possibilities.

Among new technologies for conserving food, solar-powered devices have received particular attention because of their presumed low running costs. The most needed devices are those for drying crops or for cooling, particularly to extend the market life of perishables. There is no

significant commercial manufacture of solar crop dryers, although a number have been designed. Their basic limitation is that they do not operate when they are needed most--in wet, humid weather. According to a recent National Academy of Sciences report, solar cooling and refrigeration require considerable research and development "because of the lack of a practical solar refrigerator at any price and of any understanding of the cost of systems that could be developed. An objective and critical analysis of the need for, and the prospect of, practical solar refrigeration should be the first step in any development effort" (NAS, 1976). Low-cost cooling, solar powered or not, is of such potential importance in developing countries that it may justify, at least in part, the need for this research and development.

#### Technical Assistance Agencies

A number of national and international agencies are engaged in postharvest food loss reduction in developing countries, and an FAO-prepared list is included at the end of this chapter. Many of these agencies work closely together, with coordination of effort at many points. Information about efforts to conserve cereal grains and grain legumes is coordinated by the Group for Assistance on Systems relating to Grain Afterharvest (GASGA). GASGA includes in its membership the Tropical Products Institute (TPI), supported by the British Overseas Development Ministry; Kansas State University, supported by the U.S. Agency for International Development; the Canadian International Development Research Centre (IDRC); the Institut de Recherche Agronomique Tropical et Cultures Vivrieres (IRAT) of France; the

Australian Commonwealth Scientific and Industrial Research Organization (CSIRO); and the Food and Agriculture Organization of the United Nations (FAO). The secretariat functions are provided by TPI and IRAT. No central organization yet exists for the perishables, nor is there machinery for coordinating the general postharvest interest of the donor agencies (like that for production in the Consultative Group for International Agricultural Research).

### Personnel and Training

The loss reduction activities described above and other national projects and programs not specifically identified do much useful work in postharvest technology. However, all are affected by a common problem: the critical shortage of trained technical personnel.

Personnel training concerns must be complemented by organizations that facilitate the integration of activities at the village level, that improve communication between farmers and representatives of governments, educational agencies, and planning organizations, and that help disseminate information and learning materials.

### Socioeconomic Considerations

Particular attention must be paid to conditions that provide incentives at various levels of food conservation activity:

- ° for farm men and women to change established practices,
- ° for young people to assume careers in postharvest food conservation, and

° for the general process of development at the farm and village level. Governments need information that will enable a careful weighing of alternatives for food conservation and that will place cost-benefit analyses in a comprehensive socio-economic context.

The traditional, nonmarket, largely subsistence level of food production, where only small amounts of food enter the market economy and where the bulk of agricultural production remains, offers particularly important opportunities for food conservation. Efforts to reduce loss at this level will affect large numbers of needy people. The analysis of social cost-benefits in Chapter II indicate that attention to the traditional sector can alleviate problems for families while also creating secondary benefits for other sectors of society. Some of these benefits may be quite direct, such as, generating cash to create demand for new services on the village level, or creating incentives for entering the market economy. Others may be less tangible; for example, greater security and more opportunities for individual choice by farm men and women.

The effects of food conservation may also benefit the urban poor, whose numbers are increasing rapidly and who often have fewer means to adapt to shortages of food.

#### Publications and Information

There is a very large body of published material dealing with many aspects of postharvest food technology, and the bibliography compiled for this study has proved to be much more extensive than anticipated. Although much remains to be done to improve the quality and update this

compilation, and to make the information more widely available, it represents progress in collecting the material in a comprehensive way.

A number of problems complicate this effort, however, an important one is access to the information. It is difficult to identify entries relevant to postharvest losses from the titles of papers and other publications because of the lack of recognition, until recently, that postharvest food loss involves a discrete set of problems. As a result, the information is widely scattered throughout the technical literature on agriculture, applied biology, food technology, or engineering, much of it is relatively obscure journals with limited circulation. Far greater use could be made of this knowledge if it were easier to identify and obtain.

Moreover, information directly and obviously related to losses in developing countries is predominantly on grain storage, with very little on losses of perishables and fish, or on the economic and sociocultural aspects of food loss.

FAO has now created a separate postharvest section in the AGRIS bibliography, where relevant publications will be clearly identified. There is the further need, however, for a mechanism to select and update this bibliography on a continuing basis; to refine the present bibliographic entries in the system, since there are relevant publications not listed (both current and back to, say, 1945); and to establish a retrieval system for the information in the bibliography in reprint, microfiche, or photocopy form, available particularly to workers in developing countries. Currently, FAO has a service in all member countries that enables anyone to obtain copies of FAO publication from local booksellers or publications offices in local currency. However, this does not include publications of

other organizations for copies of technical papers, although these may be listed in the AGRIS bibliography. There are plans for a technical information retrieval service in FAO that would make available selected non-FAO publications listed in AGRIS, but this is several years hence; at the moment there are no plans to include postharvest technology as a category in the system, and funds are not yet available for this purpose.

One of the most active sources of information about postharvest storage losses in developing countries is that provided by the TPI Storage Department, through the bimonthly periodical, Tropical Storage Abstracts, free copies of which are sent to some 3,000 organizations and specialists.

Thus, in response to growing awareness, there already exists an abstracting service, operating from a specialist organization that has built up an important network of contracts, backed up with document supply services. The potential for closer collaboration between TPI and the Commonwealth Agricultural Bureau (CAB) is being explored with special reference to gaps that may exist in their combined coverage of the literature on tropical food storage and postharvest losses and the possible basis for joint publishing of abstracts in this field. Account will be taken, of course, of the work of FAO/AGRIS and other organizations in this subject area.

A third problem, in addition to the inadequacy and inaccessibility of postharvest food loss information, is the quality of the published information. In many cases, reports describe and quantify food losses but the information is not sufficiently specific about what is meant by "loss"; there is often no distinction between damage and loss, or, in quantification, between percent unit loss or weight loss percent. There is usually no attempt to clarify the relationship between what the observer is measuring and the definition or perception of loss by the consumer; social and

economic data that would greatly increase the validity and usefulness of reports are seldom included. The weakness of the published data results not only from the absence of standard methodology, but also from the fact that food loss observations are often secondary to the objective of the study.

### Recommendations

The conclusions above lead to the committee's specific recommendations for implementing food conservation programs throughout developing countries.

#### Program Implementation

There are three basic components to postharvest food conservation programs in developing countries: institutional arrangements, policies, and mechanisms; training and education at all levels; and basic and applied research.

#### Institutional Arrangements, Policies, and Mechanisms

The Committee recommends that the following essential institutional arrangements and mechanisms be established in developing countries to deal with postharvest food losses:

- A national policy body;
- A national implementing agency or postharvest food conservation unit; and



- A mechanism to facilitate communication among planning agencies, decision makers, and villagers.

We further recommend that technical assistance agencies direct their efforts toward helping governments strengthen the capabilities of these postharvest food conservation bodies where they exist and to support their creation where they do not.

The national policy body will provide an overview of the postharvest food loss situation; determine priorities and allocate resources in the context of national development objectives and in harmony with social, cultural, and economic realities; coordinate activities among the various ministries and agencies involved, and initiate requests for technical assistance.

To be effective, this body should have high-level representation from the agencies and ministries, since it must influence policies and regulations. It might typically report to the office of the prime minister or president, be chaired by the minister of agriculture.

The postharvest food conservation unit, or implementing agency, composed of senior technical professional men and women, will administer the national food conservation program. Ideally, it should be a multidisciplinary group of experienced food technologists, storage-structure engineers, agricultural economists, entomologists, chemists, and social anthropologists, among others, according to the nature of the specific problems in the country. Part of the unit's responsibility will be to strengthen local capabilities to identify points of serious loss in the postharvest system, aided by mechanisms to facilitate communication between villagers and officials.

Collectively, the policy and operating bodies would be responsible for assessing the national food loss situation and developing a national

plan of action; undertaking rapid assessment of potential points of severe loss; examining national policies with respect to pricing and the role of marketing boards and other financial agencies; provide effective quality control in government commodity purchasing; supporting priority research in both technical and socioeconomic areas; and, ultimately, recommending policy options on food conservation to the decision makers.

The committee recognizes that in some countries these bodies already exist and that technical assistance agencies have successfully supported them. But many other countries lack such structures, and the committee is convinced that their role is crucial to the success of national commitment to loss reduction. Without these bodies of able people at the appropriate level of influence and expertise, directing the initial steps toward public information extension programs, research, and development of incentive--in short, assuring the legitimacy and status of postharvest food conservation and of those who work in it--there is little likelihood that significant reductions in loss can be achieved. Postharvest technology should become an integral part of the research and extension program of all agriculture and fisheries organizations in developing countries.

Creation or support of such bodies does not necessarily imply large capital investment. The implementing agency can be relatively small, and much of its work can be directed to assisting other agencies, such as the national agricultural extension service, in their efforts to bring food conservation improvements to farming and fishing families, and rural villages.

## Postharvest Loss Estimation

The committee recommends more systematic approaches to loss estimation in developing countries by:

- Adoption of standard loss estimation methodology;
- Development of guidelines for loss estimation of perishables;
- Consideration of socioeconomic aspects of food loss; and
- Integration of loss estimation conservation activities.

### Adoption of standard methodology

Agreement is needed on both the kinds of methodology appropriate for given situations and the ways in which estimated losses are reported. These are discussed in detail in the Harris-Lindblad manual, which should be used as the basis of a standard grain loss estimation procedure. Rapid assessment methods should be clearly distinguished from scientific measurement of weight loss, and methods and results should be explicitly reported to avoid ambiguity. It would be particularly helpful if losses of major durable crops in a particular country or region could be reported at a standard moisture content equal to that at which most of the crop is normally stored.

### Development of guidelines for loss estimation of perishables.

In the case of perishable crops and fish, time from harvest and precision about temperature and humidity are of the utmost importance in describing the loss situation. The condition of the food--whether the

fish is whole or gutted, the vegetable whole or peeled, etc--must be explicitly reported.

Information on socioeconomic aspects of food loss.

Knowledge about the cultural perception of loss in a particular society is vital, both with respect to the definition of loss (what is or is not regarded as loss) and to an understanding of the local importance of loss and, hence, the incentive for loss reduction. Similarly, information about the cost effectiveness of loss reduction measures is woefully inadequate, and increased understanding of economic and social benefits is central to gaining support of the sustained efforts needed to reduce loss on a meaningful scale. Multidisciplinary assessment of loss should also be stressed.

Integration of loss estimation and loss reduction.

Given the formidable difficulties for estimating losses of many foods--fish, for example--it may only be possible to measure losses by the relative effects of conservation activities. Moreover, since it is also desirable to institute loss reduction measures as quickly and extensively as possible, it is hard to justify using the limited supply of trained observers for estimation alone.

### International Cooperation Mechanisms

An organization should be created to give international focus to the neglected area of loss in perishable staples.

The Committee, which includes several members of organizations that belong to GASGA, believes that this organization has made an excellent beginning in international cooperation and coordination of efforts to reduce postharvest grain losses. Similar efforts are necessary in areas not covered by GASGA, particularly for the perishable staples. An organization created to deal with problems of perishable staples should receive support additional to that currently provided to GASGA and grain loss reduction generally, and staples should not be part of an expanded GASGA.

The establishment of such a group will be a step towards strengthening mechanisms for international cooperation, which in turn will help to legitimize and professionalize the postharvest area on a worldwide basis. Strengthening the multilateral FAO assistance programs for regional collaboration in fish technology research should also be encouraged.

These programs, which have been started in Asia, Africa, and Latin America, attempt to link institutes within the region to work on common problems and to seek assistance from institutes in developed countries. The National Marine Fisheries Service (NMFS) and university departments in the United States could well be included in the further development of these activities; exchange visits and supplemental equipment are the main costs involved.

### Information on Postharvest Food Losses

In view of the importance of improving the quality and availability of published information on postharvest food losses, the international technical assistance agencies should cooperate to strengthen and expand postharvest food loss documentation services.

Specifically, the following steps should be taken:

- FAO should be supported with funds to ensure that the AGRIS bibliographic reference service section on postharvest technology is adequately strengthened and continually updated. This will entail provision of technical expertise to identify appropriate postharvest technology publications for entry to the system on a regular basis.
- Support should be provided for a microfiche service of the AGRIS publications (through FAO or other agency) to national or regional institutions engaged in postharvest food conservation research, education, or extension. This will make reprints of the information generally available from a source either within a developing country or from a regional institution in a neighboring country.
- Developed-country institutions should be supported in cooperating with FAO to provide assistance in selecting postharvest entries for the reference service (GASGA members, their equivalents for the perishable staples, and national agricultural library systems).

Authors, editors, and reviewers, should make every effort to ensure that publications dealing with postharvest food losses are clearly identifiable by title, and that loss estimation or measurement methodology is adequately described and, where possible, conforms to generally agreed standards.

The bibliography prepared in connection with this study should be sent to one or two institutions actively engaged in postharvest loss research in each developing country, and to institutions elsewhere working on developing country food losses. Compilation of national bibliographies of research findings would be very useful.

### Education, Training, and Extension

Priority attention should be given to training programs to remedy acute personnel shortages at all levels of the postharvest food system.

Specifically, training efforts are recommended at the following levels:

- Training programs in postharvest technology for agricultural colleges and similar institutions for extension workers, farm men and women, and others working in agriculture and fisheries. This, the single most important training need, should be accomplished within the framework of a system of career development and professional opportunity.
- Courses and in-country training programs for other personnel in the postharvest food system, including:
  1. lower cadres of marketing agencies involved in procurement, quality control and pest control, warehouse management, and drying, handling, and processing of foods;
  2. Managers of both government and quasi-government marketing, storage, and processing organizations who should be given sufficient technical knowledge to increase their awareness of the problems involved in their decisions; and

3. Country representatives of technical assistance agencies who should be familiar with postharvest loss problems.

- Teaching skills and materials developed at universities, colleges and research institutions for instructing fishermen and farmers. There is also need for graduate-level training in technical areas to increase the professional staff for teaching and research programs; technical assistance agencies and governments should assist this training both in-country and by providing scholarships to overseas institutions.

We recommend, as an educational priority co-equal with manpower training, the establishment of programs to deliver postharvest conservation information to rural people.

Two major channels exist for disseminating this information:

- Formal schools, literacy programs, and adult education at the rural level should be used to spread postharvest conservation information. This information should also be integrated with other village improvement services, including health and sanitation and community-development activities of all kinds.

- Nonformal education mechanisms such as radio, television, and newspapers should be used to maximum advantage for emphasizing the importance of postharvest loss reduction, as should agencies outside the formal educational system--for instance, religious and youth organizations and commercial enterprises.



## Research and Development

The committee recommends, as basic to formulation of national-level food loss reduction policies, intensive research and socioeconomic factors, general postharvest technologies, and crop-specific technologies. The bulk of this research should be developed by the national postharvest universities, the research institutes of ministries, and the private sector.

These research needs, which should be concentrated at the rural level, are discussed below.

### Socioeconomic Research.

Substantial refinement of knowledge about economic cost-benefit factors in postharvest food loss reduction is needed. Plans for food conservation should be supported, meanwhile, by knowledge of the effects of social and cultural factors on the introduction of technological change.

### General Research and Development Needs.

- Development of low-cost cooling systems for food preservation in developing countries.

For preserving durable crops, current drying and processing technologies and storage structures are at least adequate under most

conditions in developing countries, for considerable lengths of time and at reasonable cost. This is not yet true for perishables; the two modern developments that enable large quantities of perishables to be stored and transported over long distances--canning and cooling--are not yet economic in many developing countries. The development of cooling technology with low capital and running costs could extend the life of perishables in rural areas and have a dramatic impact on the health, income, and welfare of rural people.

- Research on insecticides, fungicides, and rodenticides, with particular reference to their safety for use in foodstuffs, their environmental consequences, and their use in integrated systems of pest management.

With present chemicals, there are increasing concerns about cost, safety, and effectiveness (as a result of development of resistance to them by pests), and the development of alternatives should be a matter of high priority.

- Fundamental research on tropical food crop deterioration and its relationship to environmental conditions.

Comparatively little work has been carried out on the biochemical and physiological aspects of postharvest deterioration of perishables in the tropics, including the precise effects of various conditions of temperature and humidity, and pathogenic organisms. This research is closely linked with, and complementary to, research on low-cost cooling systems.

- Research on storage characteristics, or other qualities of crops that affect their postharvest fate, as one aspect of breeding and selection programs.

Too often the increased production characteristics of an "improved" variety are utterly negated by increased postharvest losses. Resistance to storage loss in crops should be part of this research.

- Socioeconomic studies of the problems of introducing centralized storage in rural areas, with implications for technology design, costs, responsibility and management essential to facilitate this process.

Since wider introduction of centralized storage is probably inevitable, one consideration of the studies should be ways of reducing the number of hands through which commodities pass as a means of reducing losses.

- Adaptive research on small-scale storage technologies, including development of cheap rodent- and insect-resistant containers that are properly ventilated or sealed as well as resistant to moisture and rainfall.

- Rodent surveys and greater emphasis on rodent control in both agricultural and health extension services.

#### Commodity-Specific Research Priorities

The following research areas illustrate the kind of work that needs to be done with individual commodities and do not comprise a full list of priorities.

##### Rice

- Economic drying of wet-season rice, including particularly natural ventilation methods, and use of preservatives for short-term preservation.

- Improved design of threshing, parboiling and milling equipment.

### Maize

- Improved low-cost drying and storage cribs
- Improved village-level processing equipment

### Millet and Sorghums

- Improved traditional storage and fumigation methods
- Improved village-level processing equipment

### Legumes

- Improved milling equipment
- Ways to avoid loss of cooking quality during storage

### Roots and Tubers

- Determination of optimum storage temperature, humidity, and ventilation for different varieties
- Better box and clamp design
- Storage of cassava chips, flour, and pellets
- Use of sprouting and rot inhibitors

### Fruits and Vegetables

- Low-cost controlled-environment storage, including waxing, storage under plastic sheeting, gas absorbents, rot retardants, etc.
- Better low-cost packaging
- Damage control during storage and movement, and in the

market

### Fish

- Better drying, smoking, and salting methods
- Improved on-board storage and use of by-catch

Some Institutes Endeavoring to Reduce  
Postharvest Food Losses in  
Developing Countries\*

Commonwealth Scientific and Industrial Research Organization, Division of  
Entomology, Canberra, Australia

Commonwealth Scientific and Industrial Research Organization, Mechanical  
Engineering Division, Melbourne, Australia

Bangladesh Rice Research Institute, Joydebpur, Bangladesh

Food Research Institute, Campinas, Sao Paulo, Brazil

Stored Products Research Centre, Agriculture Canada, Winnipeg, Canada

International Development Research Centre, Ottawa, Canada

International Centre of Tropical Agriculture (CIAT), Cali, Colombia

Laboratory on Durum Wheat and Rice Technology, National Research Institute  
for Agronomy (INRA), Montpellier, France

Research Institute for Tropical Agronomy (IRAT), Paris, France

Central Food Technology Research Institute, Mysore, India

Central Plant Protection Training Institute, Hyderabad, India

Indian Grain Storage Institute, Hapur, UP, India

Rice Process Engineering Centre, Indian Institute of Technology, Kharagpur,  
India

BULOG Rice Processing Centre, Tambun, Indonesia

Stored Products Division, Institute for Technology and Storage of Agricultural  
Products, Tel Aviv, Israel

National Agricultural Laboratories, Nairobi, Kenya

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\*Food and Agricultural Organization of the United Nations (1975), Reduc-  
ing Postharvest Food Losses in Developing Countries. (AGPP: MISC/21). FAO, Rome.  
15 pp. and annexes.

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 Royal Tropical Institute, Amsterdam-0., The Netherlands  
 International Institute for Tropical Agriculture, Ibadan, Nigeria  
 Nigerian Stored Products Research Institute, Lagos, Nigeria  
 Department of Entomology, University of Agriculture, Lyallpur, Pakistan  
 Vertebrate Pest Control Centre, Karachi, Pakistan  
 International Rice Research Institute, Los Banos, Philippines  
 Rodent Research Centre, Los Banos, Philippines  
 Department of Agricultural Engineering, University of the Philippines at Los  
 Banos, Los Banos, Philippines  
 Food Research Institute, Dakar, Senegal  
 National Research Centre for Agronomy (CNRA), Bambey, Senegal  
 Institute of Food Technology, Valencia, Spain  
 Rice Processing Development Centre, Anuradhapura, Sri Lanka  
 Food Research Centre, Khartoum, Sudan  
 Faculty of Agriculture and Forestry, University of Dar-es-Salaam, Morogoro,  
 Tanzania  
 Marketing Development Bureau, Cooperative College, Moshi, Tanzania  
 Rice Processing Department, Department of Agricultural Engineering, Bangkok,  
 Thailand  
 Rice Protection Research Centre, Bangkok, Thailand  
 Centre for Overseas Pest Research, London, United Kingdom  
 Pest Infestation Control Laboratory, Tolworth and Slough, United Kingdom  
 Tropical Products Institute, London, United Kingdom  
 Tropical Stored Products Centre, Slough, Berks, United Kingdom  
 Environmental Studies Center, Bowling Green State University, Bowling Green,  
 Ohio, United States

Denver Wildlife Research Centre, Fish and Wildlife Service, Denver, Colorado,  
United States

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