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9. ABSTRACT

Examines the technical aspects of postharvest food loss reduction activities and presents the most promising avenues that A.I.D. should follow to obtain maximum benefit from its expanding involvement in this area. In the past, the bulk of A.I.D. funds for the development of food supply in LDCs has been devoted to increasing food production. Now that improved systems exist for food production, increased attention should be given to caring for food so that it is not lost after production. Heavy pressures have been placed on the postharvest food chain, exposing its weaknesses and deficiencies. The total demand for food is constant on a day to day basis (ignoring long-term changes in population), but the supply of food is very uneven from day to day over the course of a year. The problems of food preservation have been largely solved in the developed countries. Little effort is now spent in trying to reduce further an already low level of post-harvest loss. In contrast, LDCs have high rates of loss and spoilage and lack the knowledge and equipment to reduce it. This difference should be reflected in the food technology programs that are being developed in LDCs. In terms of allocation of resources, 60% should be apportioned to grains and cereal legumes; 20% to roots and tubers and 20% to perishable foods. Activities should include education (55%), adaptive research (25%), basic research (15%), and literature research (5%). Other recommendations of this report include: a comprehensive educational program starting with top level government officials and reaching down to school children; a study trip to China to learn how the Chinese are implementing postharvest food handling; adaptive research activities in the drying and storage of perishable foods in the humid tropics; greater use of chemical preservatives; and a literature search on tubers he paper advises against major support of commercial canning, freezing, and irradiation.

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Promising Avenues for Increased Efforts in Reducing Post Harvest Food Losses in Developing Countries

A Report to the Technical Assistance Bureau,

Agency for International Development

by

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to the Office of Agriculture, Office of Nutrition
and Office of Science and Technology

June 1976

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Summary

This report examines the technical aspects of post harvest food loss reduction activities and points out the most promising avenues that A.I.D. should follow in order to obtain maximum benefit from its expanding activities in this area.

In terms of commodities it recommends that the effort be apportioned approximately 60 percent to grains and cereal legumes; 20 percent to roots and tubers and 20 percent to perishable foods. In terms of activities it recommends approximately 55 percent to education; 25 percent to adaptive research; 15 percent to basic research and 5 percent to literature research.

A comprehensive educational program in DCs that starts with top level government officials and reaches down to school children is recommended. A.I.D. should initiate a program to establish a course in post harvest food technology in selected U.S. colleges, and later have this course taught in colleges in DCs.

The report recommends that A.I.D. sponsor a tour of China by a group of experts to learn how the Chinese are implementing post harvest food loss reduction activities.

Recommended adaptive research activities include the development of drying and storage practices for cereals that are tailored to the conditions of each local area, and that the Agricultural Extension Service in DCs provide a grain fumigation service to farmers by training extension Agents and good farmers to be fumigators.

storage of tubers, long term high temperature storage of [illegible] development of low cost refrigeration, and a search for a package of practices using simple technology that will permit the drying and storage of perishable foods in the humid tropics.

A literature search on tubers and a selected few perishable foods is recommended. Also a search of old USDA and Experiment Station publications to find what simple methods of food preservation were recommended in the old days when U.S. farmers had to produce most of their own food, with a view to extending the best of these practices to DCs.

Greater use of chemical preservatives is recommended. A.I.D. should immediately contract for a study of the feasibility of using propionic acid to allow storage of wet paddy for a period of 5 to 10 weeks. The use of sprout and rot inhibitors to extend the keeping qualities of tropical roots and tubers should be explored.

The report advises against any major support of commercial canning, freezing, freeze drying, and irradiation as a means of reducing food losses among the poor.

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I. Introduction

A.I.D., in common with most other organizations that have an interest in international development, has identified the food supply in developing countries as one of the critical areas that need attention and over the years has devoted considerable funds to this end. The bulk of these funds have been devoted to increasing food production while the preservation and protection of the food after harvest has received much less attention.

There were good reasons for this decision to concentrate initially on production because this has an open-end potential and increases of 50 percent, 100 percent, and 200 percent are possible. In contrast, food preservation technology has a closed-end potential. For example, if post harvest losses are 20 percent the maximum increase that could be obtained by the application of post harvest food technology is 20 percent. The decision to begin with increasing production of food was the correct one.

The new technologies and investments in production that have been applied in the developing countries (DCs) are now paying off; greatly increased quantities of food have been produced in recent years keeping up with the population increase and in some cases moving ahead to give a higher per capita food production. Now that the procedures for developing and supporting increased food production in DCs have developed into improved systems it is time to give increased attention to caring for the food so that it is not lost after production.

The increased production of food has placed heavy pressures on the post harvest food chain exposing the weaknesses and deficiencies in that chain with painful clarity. Much of the recent hard won increased food production in the DCs will be lost unless it is given better post harvest care than is presently available. Food losses represent an economic and nutritional loss to the country, and the economic loss increases as the food moves down the chain from producer to consumer. Another reason for concern with post harvest food losses (PHFL) is the feedback mechanism to the producer; the farmer has no incentive to increase production if that increase cannot be satisfactorily stored and marketed.

The benefits that accrue to a DC that invests in post harvest technology can be greater than might appear at first sight of the definite ceiling in the amount of extra food that can be put on the table as a result of post harvest technology. DCs produce 90 percent to 95 percent of their food supply even in a bad crop year. The 5 percent to 10 percent short fall that must be imported can represent large tonnages of food because of the large populations that must be fed and this imposes logistical problems and severe strains on the balance of payments for the country. If post harvest losses can be reduced by half or more from their present levels of 10 percent to 20 percent (most frequent estimates of range of losses), they can reduce or eliminate the economic havoc that results from importation of large quantities of food.

The need for more funding and investment in post harvest food technology has become increasingly visible in recent years, culminating in Secretary of State Kissinger's speech to the UN General Assembly on September 1, 1975, calling for the world community to work together towards the goal of cutting in half post harvest food losses by 1985 and to develop a comprehensive program to this end. His call was adopted as a UN resolution on September 21, 1975.

This report is designed to contribute to the development of the comprehensive program to reduce PHFL. It will concentrate on the technical aspects of the problem because this is the area of expertise of the consultant. Other important dimensions to the problem such as major investments in storage and handling facilities and political and economic aspects will not be addressed in this report except insofar as they interact with technology.

It should be recognized that reducing PHFL by 50 percent worldwide is a major task that has never before been attempted. There will have to be a total mobilization of all resources in post harvest systems and technology in both develop and developing countries if the goal called for by the UN resolution is to be met.

A proposed definition of the meaning of the term "post harvest food loss" has already been prepared and circulated and will not be discussed here.

II Nature of the Problem

The total demand for food is constant on a day to day basis (ignoring long-term changes in population) but the supply of food is very uneven from day to day over the course of a year. Post harvest food preservation and storage is the mechanism by which mankind tries to match up the uneven day-to-day supply of food with the even day-to-day demand for food.

The ideal situation in balancing daily food needs and supplies occurred when the Children of Israel made their historic 40 year trek from Egypt to the Promised Land across great desert. Their food was provided in the form of manna that fell every night in a quantity sufficient to feed the migrating nation for one day. This is probably the only time in the world's history that there has been a perfect match between the daily supply and the daily need for food. It is just as well that the manna rained down from heaven each night because it had poor keeping qualities. After 24 hours storage, it "bred worms and stank" (Exodus, Chapter 16). Although the Children of Israel were in an ideal situation in terms of their daily food supply they complained bitterly that there was insufficient variety in the diet (Numbers Chapter 11, verses 4-6).

The preservation of food to prevent spoilage falls within the field of food technolo The disciplines of chemistry, biochemistry, microbiology and engineering form the base on which food technology is built and are known as food science. There are many colleges, in the U.S., especially Land Grant Colleges that have a departmen of food science and technology, while others have activities in this area without

recognizing it as a formal department. There are some departments of food science and technology in DCs but not nearly enough in number or in strength to cope with the task of reducing PHFL by 50 percent within 10 years.

The Institute of Food Technologists is the major professional society that serves the needs of all food scientists, food technologists, and food engineers in the U.S. It has a membership close to 14,000. In addition, there are a number of other professional societies that serve a segment of the total food spectrum by specializing in one commodity area, e.g., the American Association of Cereal Chemists. Other professional organizations cover both production and post production aspects of a commodity area, e.g, the American Association for Dairy Science and the American Society for Horticultural Science. Still other organizations that are based on a scientific discipline have a section devoted to foods e.g., the Food and Agriculture Division of the American Chemical Society. There are also a number of trade associations that serve every aspect of the U.S. food industry. DCs do not have this extensive network of professional societies and trade associations to keep professionals and para professionals up to-date on developments in their field.

Food technology operations may be divided roughly into three classes.

a. Preparation is the preliminary separation of edible from non-edible agricultural production e.g., dehulling grain and slaughter and dressing of animals.

   Preservation is the prevention of loss and spoilage of food e.g.,

   fish. This class is where A.I.D. must direct most of its activities in order to reduce PHFL in DCs.

   Processing is the conversion of edible food into another form that is more acceptable to the consumer, e.g., the making of bread from wheat; brewing beer from barley and making instant coffee from coffee beans.

The problems of preservation of food have been largely solved in the developed countries. Consequently the food industry in these countries expends its greatest effort in the food processing area. Greater profits can be made by developing some new convenience factor or new flavor to titillate the taste buds of the well fed than by trying to reduce further an already low level of post harvest loss. This attitude is reflected in the teaching programs of most departments of food science and technology in developed countries where food processing and quality factors generally receive greater emphasis than food preservation.

In contrast, the DCs have high rates of loss and spoilage in their food supply chain and lack the knowledge and equipment to reduce it to a low level. Food preservation technology is the great need in these countries. Their populations

cannot afford to buy any great quantity of processed foods and food processing occupies a smaller proportion of the total food industry activities than in developed countries. This difference should be reflected in the food technology programs that are being developed in DCs.

Post harvest food losses may be divided into two classes:

a. Disappearance losses caused by spillage, by consumption by non-human agents such as rodents, insects and birds or by excessive polishing, peeling or trimming in the preliminary preparation of food.

b. Losses in quality to the point where people refuse to eat the food. They can be caused by chemical, biochemical, physical, physiological or microbiological action or by combinations of these factors.

All stored foods undergo deteriorative changes in time resulting in loss of flavor, color, texture or nutritional value. There is no known method for stopping these losses. This is a fundamental fact in all food preservation activities. Food preservation technology can slow down the rate of deterioration but it cannot stop the deterioration. Every food, no matter how well preserved, will eventually become unfit for human consumption if stored for a sufficient length of time. However, from a practical viewpoint, we know that cereals and most other dried foods, together with some other processed foods, can be stored and maintained in good condition for periods of several years provided they have been correctly preserved and are subject to good storage conditions and good management practice.

The most important factors that affect the rate of deterioration of stored food are temperature and humidity. The rate of deteriorative changes in stored foods increases with increasing temperature and with increasing humidity. The prevailing high ambient temperatures of tropical countries makes the problem of preserving the quality of stored food more difficult than in the temperate zones. The year-round high temperatures of tropical countries allows pests such as rodents and insects to feed and multiply throughout the year whereas the cold winters of the temperate climates stops reproduction and reduces feeding activities of these pests, and in very cold climates can even kill off many of the insects. The high humidity of the humid tropics makes food preservation even more difficult because foods that have been properly dried will absorb moisture from the air to the point where molds can grow unless the food is well protected from the high humidity surroundings.

Even if the tropical countries had the same per capita income as the developed countries they would still have a more difficult set of problems with the preservation of their food supply than the temperate zones. The shortage of funds to provide adequate technology and equipment in DCs makes a bad situation even worse.

The developed countries have a large cadre of well trained, experienced personnel at all levels of responsibility in the food supply chain who know how to care for food properly and minimize losses. No such extensive cadre of trained people is present in DCs.

To sum up, developing countries have four strokes against them in the battle to reduce post harvest food losses.

a. insufficient knowledgeable personnel who know how to preserve and protect food;

b. insufficient capital to provide the necessary handling and storage equipment;

c. insufficient purchasing power to pay for the cost of proper protection (although some food loss reduction activities should pay for themselves because of food saved);

d. climatic conditions that favor the growth of insects, rodents, and molds, and that accelerate the normal deteriorative changes that occur in stored foods.

III. Distribution of Effort

A. Commodity Breakdown

Most organizations that work in the area of post harvest food loss reduction devote their efforts wholly, or almost wholly to losses in grains and dry legumes. This approach is based upon the fact that the greater part of the calories and protein intake of populations in LDCs derives from cereal-based foods. But there are large areas where roots and tubers such as Irish potato, yam, sweet potato, and cassava provide a large proportion of the calorie intake. Some attention should be given to these commodities. The International Potato Center (CIP) has already been established in Peru to study problems of production and preservation of Irish potatoes; therefore this commodity will not be discussed further because it is already covered by CIP.

Perishable foods are usually given little attention although they provide many of the important vitamins, minerals and high grade protein. These commodities should be given some consideration in food loss reduction activities. In general, nutritional deficiencies of the minor nutrients (vitamins and minerals) take a longer period of time to produce obvious clinical symptoms than do deficiencies in calories and protein, but deficiencies in minor nutrients can sap the vigor and increase the morbidity and mortality rate in a population just as surely as caloric and protein deficiencies.

Extensive nutrition surveys conducted in the Philippines have shown that the average Filipino comes close to a sufficiency in cereal intake but falls far short of recommended intake in some of the perishable foods. This is shown in Table 1.

TABLE 1

Mean Per Capita Food Supply in the Philippines

Food Group	Recommended Intake g/head/day	Available Intake	
		g/head/day	% of recommend
Cereals	317	314	99.0
Roots and Tubers	67	89	132.8
Sugars and Syrups	33	52	157.6
Pulses and Nuts	19	33	173.7
Fruits and Vegetables	249	133	53.4
Meats and Fish	108	90	83.3
Eggs	15	7	46.7
Milk	173	42	24.3
Fats and Oils	29	8	27.6

(From Philippine Journal of Nutrition 22(2) April-June 1969, page 77.)

This same survey showed that in terms of nutrients the average Filipino gets 76.5 percent of the recommended calorie intake and 86.2 percent of the recommended protein intake. Increased consumption of cereals would help overcome the caloric deficiency and make up part of the protein deficiency. The survey also showed that the average intake of calcium is 33.7 percent of the recommended level, and of Vitamin A, 49.8% of the recommended level. The deficiencies in nutrients that are provided mainly by perishable foods are much worse than the deficiencies in calories and protein.

Many other DCs show a food intake pattern similar to that of the Philippines with the gravest deficiencies in those nutrients that are supplied by the perishable foods . There are pressing nutritional considerations for alloting a part of the overall PHFL reduction activities to preservation of perishable foods especially in view of the fact that most other donor agencies expend no funds in this area. A.I.D. should break new ground by allotting a portion of PHFL funds to perishable foods.

The number of perishable food items is so great that it would be impossible to cover them all. A.I.D. should seek the advice of a group of experts consisting of country representatives, nutritionists and food technologists in selecting a limited number of perishable foods (perhaps 10 in number) for PHFL reduction activities and restrict its interests to this list. Some obvious candidates for inclusion in this list would be fish, papaya, mango, plantain and citrus fruits.

Cereals should continue to have the major part of PHFL reduction funding because

supply of cereals emerging from the consumer end of the food supply pipeline to keep up with the increasing population.

With these considerations in mind, I propose that A.I.D. apportion its PHFL funding in approximately the following ratios:

Cereals and dry legumes	60%
Roots & Tubers	20%
Selected perishables	20%

These proportions will need to be changed somewhat from country to country, depending on local circumstances. For example, tubers might range from 40 percent of the effort in a country in which they provide a large proportion of the calories down to zero in a country in which tubers are barely used.

B. Activity Breakdown

There is an obvious need for construction of many food storage and handling facilities in the DCs. An analysis of this area requires expertise in construction engineering and economics. Since these are fields outside the special competence of this consultant, they will not be discussed further in this report apart from noting the need for major activities in this area. This report will concentrate on the technological aspects of post harvest food loss reduction activities.

The actual amount of food lost in the post harvest chain is not known exactly, but for cereal grains the average overall loss is probably in the range of 10 percent to 20 percent of production. It is anticipated that the study about to be undertaken by NAS will establish what reliable figures for loss are on record, and that the in-country survey teams proposed in the Milner Report will fill in the knowledge gaps that will be exposed by the NAS study. It will be 1 to 3 years hence before these figures become available, so for the time being we will have to accept the broad consensus of opinion among experts that PHFL are excessively high in DCs and that they can be substantially reduced at an economic cost.

In the meantime we should press vigorously ahead with those activities that will clearly reduce losses in DCs. One third or more of the ten-year time frame of the UN resolution will be lost if we wait for the desired firm figures from the NAS and other studies before initiating major actions.

An elegant example of excellent control of PHFL in wheat can be found in Australia where wheat is harvested in the hot summer months and there is little problem with high moisture grain. Seven percent (7%) of wheat produced in Australia is retained on the farm and the other 93 percent can be sold only to a Government Agency called the Australian Wheat Board. This Board keeps careful records of all stocks and movements of wheat. Its records show that the average loss from all non-insurable causes for the years 1962-1972 is 0.249 percent with a range of 0.138 percent to 0.675 percent per year during this period. They note that.

The average cost of reducing losses to this low level is 15.6 cents per tonne (this cost excludes capital costs of storage and handling structures). These figures show that it is possible to reduce losses to a very low level and they serve as an established reference figure for an achievable goal.

It is impressive to note that methods for controlling post harvest food losses are well known and widely used in developed countries but not in DCs. There is a widespread lack of knowledge in DCs of how to reduce losses. A widespread educational program is therefore needed across all levels of society in DCs to alert the population to the need for protecting the food supply, and how to go about accomplishing it.

There are cases where there is no incentive to apply the available knowledge. Whe the lack of incentive is because of economic, political, social, or other factors it should be noted that providing the know-how will not reduce the losses. In these cases non-technological interventions are required.

There are instances where the technology to adapt the basic knowledge to local conditions is lacking. A detailed, complete, practical technology that is tailore to specific localized problems needs to be made available to each distinctive region. This requires a considerable amount of adaptive research.

There is a need for more basic research to extend the knowledge of the underlying causes of post harvest food losses and to develop better means of attacking these causes. Continued basic research should occupy a limited proportion of the total budget.

More literature research is needed. Organizations such as the Tropical Products Institute have maintained thorough reference lists on losses in cereals, and some references have been kept on losses in tubers, but there has been little literature research on PHFL in perishable foods. Some effort should be devoted to literature searches in perishable foods.

Taking these factors in consideration leads to the recommended breakdown of A.I.D. funding of the technological aspects of PHFL reduction activities shown in Table 2. Each of these activities will now be discussed in more detail.

TABLE

uggested Distribution of A.I.D. Funds for Technological Aspects of PHFL Activities

Activity	Cere.	Roots and Tubers	Perishables	Total
Education	40%	10%	5%	55%
Adaptive Research	15%	5%	5%	25%
Basic Research	5%	5%	5%	15%
Literature Search	-	-	5%	5%
Totals	60%	20%	20%	100%

One assumption in this report is that the major losses in DCs occur early in the chain that links the farm to the table. Consequently, the emphasis in this report is placed on the early part of the food supply chain. I doubt whether losses in the home are a source of great loss for two reasons, 1) the cost of food makes up so much of the family budget that food must be in a very poor conditic to be thrown out; and 2) the homemaker in DCs usually makes frequent trips to the food stores and she does not hold any quantity of food in the house. This places the risk of loss on the storekeeper. It may be worth a study to find out how much food is lost in the home, and if it is higher than expected to engage home economists to develop a program to reduce food losses in the home. "In-home" losses are not meant to include the "on-farm" losses of stored grains of the subsistence farm family.

1. Educational Activities

There should be a major educational effort across the whole spectrum of society in DCs. The entire population should be made aware of the fact that large losses are not inevitable, that there are known causes for the losses, and that there are known cures for each cause of loss. In some areas it will be necessary to overcome superstitious and erroneous beliefs such as the one that insects are spontaneously generated in stored foods. Those persons handling food should be taught how to care for it properly. Some specific actions that A.I.D. could take in this area are as follows:

a. Top Level Government Officials such as Ministers of Agriculture from DCs and their immediate staff should be given a short course or workshop of 2-5 days duration to put across the message that stored food is a living system that must be continously watched; that stored food is not inert like a stockpile of metal or lumber that can be stored and forgotten. Stored food must be cared for by knowledgeable people. Large storages require trained people for proper operation Funds must be provided to hire and hold these people and to provide them with essential inputs such as electric power, fumigants, etc.

In these proposed workshops, stored products specialists should explain the need for correct storage practice and show the damage and loss that occurs when these practices are not followed. This part of the course should be general in content. Economists should then cover the
including the costs of maintaining proper care of stored food. It will be diffic for the political process of a developing country to provide the funds for adequa storage and maintenance unless top government officials have a clear understandin of the general principles of storage and the costs that are incurred in implement good storage practices.

b. College Level Training. There are many foreign students receiving an education in U.S. Universities and Colleges who should be given some training in food preservation and protection practices. A.I.D. should encourage and assist colleges to introduce a course in tropical food preservation. Foreign students in food science, agronomy, and other departments in colleges of agriculture should be placed under heavy pressure to take this course when it is offered. Other students who should be encouraged to take this course are: (i) all foreign student no matter what their major; (ii) American students who have any thought of serving overseas, and (iii) potential Peace Corps Volunteers.

To the best of my knowledge no college in the U.S. teaches a comprehensive course in preservation and protection of foods with particular reference to the constraints that apply in DCs. A.I.D. can step into this gap by arranging for a workshop to be attended by selected faculty from U.S. Colleges. The workshop would be conducted by the best experts in food technology, entomology, grain and storage engineering, and stored products economics who would go through the principle of tropical food preservation with the intention of having the faculty teach an interdisciplinary course along these lines in their own college. The proceedings of this workshop should be published as a textbook under competent

editorship for use by students who take the course, and by other interested parties. The course in cereal storage that is offered by Kansas State University each summer would be a good core around which to build a multidisciplinary, multi-commodity course in post harvest food technology.

Once this has been successfully accomplished in the U.S. the workshop should be offered to a selected faculty in those colleges in DCs that undertake to offer the course on a regular basis. This activity should be given high priority by A.I.D. because it is an essential first step to increase the number of people in DCs who are knowledgeable in the area of post harvest food technology. This phase would be a logical activity for the United Nations University if it develops the competence it is hoping to achieve in the post harvest food area.

c. High School and Primary School Education. All children in school in rural areas in DCs should be given some instruction in the technology of food protection. A.I.D. should encourage Education Departments in DCs to include in the curriculum some of the simpler concepts of food protection and practical ways to preserve food. This effort could reach all the way down to children in the 10-12 year old age group. It is just as important that these children learn how to preserve their precarious food supply as it is to learn how to read and write. A.I.D. can help by arranging workshops for teachers, and for courses in teachers' colleges to impart the knowledge to teachers and teachers-to-be. A.I.D. could also support the development of teaching materials in this area suitable for the target age group. The teaching materials should be prepared by experts in education and checked for accuracy by specialists in post harvest food technology. The specialists should not prepare the materials because most scientists do a poor job of communicating with lay people. This activity should be done in close consultation with the Regional Bureaus and with A.I.D. personnel who are involved in education and human resources.

d. Extension Service. A.I.D. should help develop education programs for the personnel in the Extension Service in DCs. There is a considerable amount of appropriate technology already available that should be brought to the farmers. A.I.D. could also help by funding the development and supply of educational material such as posters, leaflets, and movies to be used by Extension Service personnel in their work with farmers. These materials should be developed by extension personnel and communications experts and checked for accuracy by scientists.

A.I.D. should also assist in training Extension Service personnel in the procedures of simple fumigation and spraying techniques for control of insect infestation in small on-farm grain storage. Extension personnel should be authorized to perform this service for farmers and be provided with some equipment such as sprayers, etc., that is needed to do the job properly.

The simplest, cheapest and safest fumigation technique is the proprietary formula of the Degesch Corp. which is sold under the registered name Phostoxin.

The U.S. distributors of Phostoxin inform me that all users of Phostoxin in the U.S. must be trained before the first purchase of Phostoxin is authorized. The Distributor maintains field staff around the country to give the training, which is done on the premises and requires only an hour or two for the average American farmer. The U.S. Distributor says that the cost of Phostoxin tablets is higher in the U.S. than in most other countries because the cost of maintaining the field staff throughout the country has to be included in the selling price. Even so, the Phostoxin cost of fumigating grain ranges from $4 to $24 per thousand bushells depending on how much Phostoxin is purchased, the gas tightness of the storage, temperature of grain, and other factors.

A.I.D. can help by making this low cost simple technique widely available in DCs. Perhaps the best way to begin is for A.I.D. to arrange with local government to train, and if necessary, register Extension Personnel to fumigate farmers' grain storages. Once the technology has become established and understood it should be possible to train conscientious farmers to fumigate their own and their neighbor's grain supplies thus relieving much of the pressure on the Extension Service.

e. Food For Peace Seminars. The Office of Food For Peace has conducted training sessions in Latin America, Southeast Asia, and Africa for those personnel in DCs who receive and distribute FFP commodities. This is a worthwhile program that should be continued because it can reduce losses in FFP shipments. These regional seminars should be held regularly in order to keep up with the turnover of personnel who handle FFP commodities in DCs. The seminars should continue

should continue to emphasize the care and protection of FFP commodities. It would be unwise to attempt to use this program as the vehicle to carry out the major educational effort across the whole spectrum of society as outlined in the sections above.

f. Reverse Education. The People's Republic of China has gained a reputation for effectively adapting simple technology to the rural level and having it widely implemented as a means of improving the food supply and nutritional status of its immense population. There is a good probability that they have been successful in developing simple low-cost technology for protection of stored food. The National Academy of Sciences arranges for visits to China by about five U.S. professional groups each year. Several groups with some interest in agriculture have toured China but there has not yet been a group of experts in the post harvest field. A.I.D. should try to arrange for a team of experts to tour China to see what activities they have in this area and to determine whether some of their practices might be copied or adapted for use in other DCs. This tour should be arranged as soon as possible while A.I.D.'s expanding program is still in its formative stages.

2. Adaptive Research

A.I.D. should support efforts that seek to convert the basic knowledge of food preservation into low cost simple technology packages that will fit right

into the farmers' existing practices and customs. Most of this work will need to be country specific, taking into account local customs, local building materials, and whether or not there are incentives for the farmer to adapt the new package. Every aspect of the total package must be worked out in detail and checked out in practice before it is taught on a wide scale. It is wasting everybody's time and money to rush in with a new recommended practice that has not been thoroughly tested under the conditions of that particular locality. In those cases, where the cost of the new package is beyond the farmers' means, A.I.D. should consider what grants or loans can be raised to pay for the needed capital investments.

Drying and storage of grains should be given major emphasis in adaptive research. Activities such as aeration of the grain when atmospheric conditions are right, mixing fine inorganic dusts in grain as a means of killing insects, use of large plastic bags for small-scale fumigations, waterproofing and rodent proofing of storages should be given much attention. A number of other avenues for consideratic for adaptive research are given in the section "Methods for Preserving Food".

There is a good probability that the study of Chinese practices will provide a number of examples of well worked out packages of improved post harvest technologies that can be used in DCs.

It is worth reviewing here how the State Experiment Stations introduce new practices to American farmers. The usual procedure is to first develop the new practice on the Experiment Station farm performing whatever backup laboratory

the state in collaboration with some of the best farmers. Modifications are made in the proposed new practice as a result of the joint experience of the farmers and researchers. The new practice is not extended to all farmers in the state until it has been thoroughly tested, adapted to local conditions and proven to the satisfaction of the test farmers to be a superior practice. The next step is to extend the new technique by means of demonstrations, meetings, and publications.

This procedure can require several years from the first on-farm trial to the point of state-wide extension but the Experiment Stations know from long experienc that this is the best route to follow. With this successful model at home to serve as an example, A.I.D. should be prepared to fund adaptive research activities in each location for a sufficient number of years to ensure that recommended new practice are fully compatible with and acceptable to local conditions and customs and that there are real incentives to farmers to adapt them.

3. Basic Research

A.I.D. should consider funding basic research in a few areas where more informati is needed to provide the foundation on which new successful technologies can be developed. This kind of funding needs long term commitments of the order of five to twenty years given to a single center of excellence in each area of interest. Areas that are recommended because of their relevance to PHFL-reduction potential are:

a. Drying Technology for Cereals. This should include use of solar energy and use of local fuels such as hulls, straw, and other inedible plant materials like shrubs, bamboos, and trees that have no other economic use. It should also include studies on the technical-economic feasibility of "ultra drying" of cereal Present practice dries grain to a moisture level that stops the growth of molds (usually about 14 percent). The growth of insects can also be stopped by drying grain to even lower moisture contents (usually about 10 percent).

b. High Temperature Storage of Cereals for Extended Periods of Time. The proposed programs to establish large world food reserves are predicated upon the assumption that grains can be stored and maintained in good condition for period of many years. We know this can be done in temperate climates but there is no assurance that it can be done in tropical climates. A.I.D. should consider it a matter of urgency to initiate a long term study of grain storage practice and changes that occur in grain stored for a period of five years or longer under tropical conditions.

c. Drying Technology for Certain Perishables.

d. Low Cost Refrigeration and Cooling Systems That Do Not Use Electricity as the Power Source.

e. Post Harvest Physiology of Tropical Roots and Tubers.

Economic Analysis of the Comparative Costs of the Various Methods Available

Some of these items will be discussed more fully in the section "Methods for Preserving Food".

4. Literature Research

The Tropical Products Institute maintains a complete file of published articles concerning storage of cereals and export tropical crops and there is no need for A.I.D. to duplicate this work.

The University of Georgia compiled a comprehensive bibliography on cassava under an A.I.D. contract. A.I.D. should support the compilation of an extensive bibliography on all other tropical tubers of importance, and make provisions to keep the compilations up-to-date on a continuing basis.

Other donor agencies have had almost no activities in assembling a bibliography on losses and causes of losses in perishable foods, with the possible exception of fish. There is a real gap here. A.I.D. should select a limited number of perishable foods for attention and establish and maintain a bibliography on these commodities.

In the early days of the U.S. Department of Agriculture and State Experiment Stations, much attention was given to food spoilage on the farms, and simple practical ways that farm families could reduce their losses were developed. The advent of modern transportation, marketing, and supermarkets have relieved today's American farm family of the task of raising and preserving almost all their own food. There should be good, practical information buried in the older publications of these agencie that should be applicable to DCs. A.I.D. should sponsor a search through this old literature to retrieve it, bring it up-to-date in the light of advances in knowledge in food science and apply it to problems in DCs.

IV. Methods for Preserving Food and Reducing Losses

This section is a brief review of methods available for preserving food and reducing losses. It is intended to indicate to A.I.D. those areas that should have a high priority in food loss reduction activities and those that deserve a low priority.

One important consideration is the cost of the various methods of preservation. A.I.D. should engage an economist to assemble and analyze typical figures for the total cost of the different methods of preservation in the U.S. and use these figures as a base to project probable costs in DCs. This will help select the lowest cost methods of preservation and eliminate from further consideration the more costly methods.

This has been the major method for preserving and storing mankind's food supply throughout recorded history. The technologies of canning, refrigeration, pasteurization, and freezing that have been developed over the last 150 years have relegated drying to a smaller role for perishable foods. But drying is still the preferred method for preserving grains and hence it is still the Number 1 food preservation technique based on tonnage. Since drying is one of the lowest cost methods of food preservation it should still be looked upon as a major method for preservation of perishable foods in DCs. A.I.D. should continue to support research on drying of cereals. Special attention should be given to using solar energy, and energy from locally available fuels. The KSU concept of mixing a desiccant with moist grain to dry it, and later separating the desiccant and regenerating it warrants continued study.

Drying and dehydration should also be one of the major preservation techniques for perishable foods in DCs. The fact that this is a labor intensive, time consuming, low capital cost technique that yields a product that requires several hours to prepare for consumption has made it unpopular in developed countries but these are just the attributes that are desirable for DCs.

A good sun drying technology is available in the arctic regions where drying occurs under low temperature conditions, and in the arid temperate regions where high summer temperatures and low relative humidity causes rapid drying. But no technology has been developed for sun drying in the humid tropics where temperature and relative humidity are high but the intensity of the sun's rays is also high. A.I.D. should support a research center in a long term program to develop a package of technology for drying and storing perishable foods under the conditions of the humid tropics.

Since all dried foods, cereals, legumes, and perishables depend on their low moisture content to prevent growth of molds, it is essential that they be kept dry by protecti them from water and high humidity surroundings. There is also a need to be protecte from higher forms of life such as insects and rodents. Adequate protective packaging of dried foods is therefore an essential corollary of the total preservation-by-drying process. Effective packaging should be a major area of support by A.I.D., including retail packages, small storages on farms and stores, and large storages at elevators and terminals. There is a need here for basic research, adaptive research, education, and construction of major storage facilities. The provision of additional food store capacity in DCs should be the major avenue for construction and investment funds in the worldwide PHTL reduction program.

B. Refrigeration and Cooling

It is a well established fact that reduced temperatures prolong the storage life of foods. There are three activities that A.I.D. should support in this area.

cooling is not as good as complete refrigeration but it is better than no cooling at all. Methods that should be extended include keeping foods out of direct sunlight, use of evaporative type water coolers in regions that have low relative humidity, and insulated storages for those regions that have cold nights and hot days.

Tropical roots and tubers have an optimum storage life at temperatures in th range of 50-55 degrees F. These temperatures are easier to achieve and maintain than the usual refrigeration temperatures of 32-40 degrees F. These simple and partially effective methods for reducing temperatures should be of particular use for the storage of roots and tubers.

2. Development of small, low cost cooling systems. A.I.D. had a contract with General Electric Co., in 1962 (Contract No. REPAS-1) part of which included a survey of methods of refrigeration-cooling systems for rural communities in developing countries. There appears to have been no A.I.D. activity in this area since 1962. Even though refrigeration may not be within reach of the subsistence farmer it might be possible to develop some kind of a locker system operated by a storekeeper or cooperative that would make cold storage space available to a community. This project calls for persistence because some kind of cooling system is badly needed, especially for the perishable foods.

The use of solar energy and biogas should be considered as possibilities for the energy source for refrigeration systems in DCs.

Process Products Inc., of Gardena, California make an "icy ball" refrigeration system that uses an intermittent fire to operate. The unit they manufacture is too expensive for DCs but the principle of operation might be adaptable. It is claimed that icy ball type refrigerators were widely used in rural areas of the U.S. before the farms were connected to the electricity supply.

3. Storage of cereals in tropical climates under reduced temperatures should be studied because there is no assurance at this time that cereals can be successfully stored for long periods of time under hot conditions. Some preliminary experiments along these lines have been performed at the Tropical Products Institute but the technique should be studied further with reference to long term storage of cereals in tropical climates.

Another possibility for long term storage of grain in the tropics is to construct the storage centers at high altitudes where the prevailing temperatures are lower. Below about 60°F insects practically stop multiplying, mold growth and biochemical reactions in the grain are slowed and the whole storage problem becomes much easier to manage. This would need to be a technical-economic study because the cost of transporting the grain to a high altitude would have to be offset against quality deterioration and possible loss of the grain in storage near sea level where temperatures are higher.

C. Chemical Preservatives

These come close to the ideal method for preservation of foods in the tropics. They are cheap, effective, easy to apply and usually require a minimum of equipment. The food additives that are permitted by the U.S. Food and Drug Administration can be divided into two main groups. (i) Preservatives that retard spoilage of food. This is the group in which A.I.D. should have an interest. (ii) Functional additives that are used to improve the color, flavor, texture, or nutritional properties of the food. This group is of minor interest to A.I.D. Actions that A.I.D. should take in this area are listed below.

1. Fumigants, insecticides, and rodenticides already have a well established place in grain storage systems. These practices should be extended more widely in DCs, especially the use of Phostoxin.

2. The production of a second crop of rice has begun to be adopted in some areas but it raises the serious problem of how to dry the rice harvested during the wet season. Chemical preservatives are available, notably propionic acid, that can inhibit mold growth in moist grain for a year. This practice is used extensively in U.K. and Europe on grain intended for cattle feed and has been the subject of experimentation in the U.S. Propionic acid is not used on grain intended for human consumption because of its unpleasant flavor but the sodium and calcium salts of propionic acid are permitted to be added to bread without limitation in the U.S. as a mold inhibitor.

It is quite possible that a lower dose of propionic acid applied to moist paddy rice would prevent mold growth for a month or two and that most of the acid would be removed when the rice was dehulled thus eliminating the flavor problem. The potential additional weeks that the moist paddy could be safely stored would ease the problem of overloading the capacity of rice dryers during the harvest season and might even hold the moist paddy until the end of the wet season thus allowing it to be dried in the sun. The cost of the propionic acid would be in the range of $1 to $5 per ton of treated rice, based on the U.S. price.

I have made extensive inquiries and can locate no attempt to use propionic acid as a short term mold inhibitor for wet paddy that is destined for human consumption. The potential advantages of chemical control of mold in wet paddy are so great that A.I.D. should consider this a high priority research project and should contract for this line of research to be started as soon as possible.

A.I.D. should make a contract with a qualified organization to study the effectiveness of propionic acid or mixtures of propionic with other preservative chemicals in inhibiting mold growth on high moisture paddy. The study should be restricted to rice intended for human consumption. It should not be extended to include other grains. The ideal organization to perform this contract would have the following characteristics: (1) free access to known varieties of rice harvested at known moisture contents; (2) agricultural engineering capability to apply the acid uniformly to the paddy; (3) either a tropical climate for storage or a controlled temperature facility that can duplicate the conditions of the humid tropics; (4) dehulling and milling equipment that can give close control of these operations; (5) analytical laboratory to measure acid levels; and (6) a food technology department with capability in the area of sensory testing methodology to determine whether the flavor of the propionic acid can be eliminated before the cooked rice reaches the table.

3. Stored roots and tubers are prone to sprouting and decay. Chemical treatments are available that stop the sprouting of potatoes and onions (maleic hydrazide and chlorprofam) and that inhibit rotting in stored potatoes and fruits (thiobendazole and benomyl). These treatments are permitted and are well established practices in the U.S. Their use should be explored for extending the storage life and reducing spoilage of tubers in tropical climates. This would require a combination of basic research to work out the procedures to be used on a particular commodity such as yam followed by adaptive research to make the procedure fit regional conditions.

4. A number of chemical preservatives such as benzoic acid, sulfur dioxide, sorbic acid, benlate, and fat antioxidants are used as permitted food preservatives in the U.S. Their use on specific products to reduce spoilage should be explored and the successful applications extended to DCs. This requires teaching the use of preservatives in courses in food preservation and supporting adaptive research to fit them into local conditions.

5. One of the best and safest chemical preservatives is salt. It is used in many tropical areas in an attempt to preserve fish and it can be used to preserve some vegetables. Unfortunately the salt is usually very impure and the impurities cause almost as many problems as the addition of the salt solves. The technology for producing pure salt from sea water is well known and effectively used in developed countries. A.I.D. should bring in salt experts to teach the DCs how to upgrade the purity of their supply. The salt industry often has political overtones in DCs but its importance as a food preservative is so great that some effort should be made to upgrade its quality.

6. There are some interesting possibilities in combining chemical preservatives with drying procedures for perishable foods. The use of preservatives as an adjunct in drying should be a feature of the effort to develop a package of practices for effective sun drying of tropical fruits.

D. Fermentations

Some fermentations, notably the alcohol and lactic acid fermentations develop a natural preservative as a product of the fermentation. The alcohol fermentation is widely used as a means of helping to preserve certain beverages and requires no further comment. The lactic acid fermentation is effective in preserving certain vegetables and in helping to preserve some processed meat products. Although not a high priority matter, the adaptation of the lactic acid fermentation to local conditions should be encouraged whenever possible.

E. Canning

The thermal sterilization of food in cans or bottles is one of the best means of preserving perishable foods but it is an expensive process and there is a low probability of the cost being reduced substantially. A new development in this area is the use of heat sealable plastic pouches to replace the cans but this technology is even more expensive than cans at the present time. Commercial canning is not recommended for subsistence populations because of the high cost but it has an expanding role in those city populations whose standard of living is increasing.

There is one area of exception to this recommendation against action in canning. Some years ago, A.I.D. contracted with the Ball Corporation to develop a home canning center for DCs. The concept here was to have a community canning center where small scale facilities would be available to all members of the community to preserve any excess of perishable food over immediate needs. The glass jars that

come with the canning kit are reusable which reduces the container cost. This concept has potential and should be encouraged for those villages that have a strong community spirit and the funds to provide the initial capital cost of the canning center, or the ability to persuade some donor to provide the equipment and the jars.

F. Freezing and freeze drying are excellent but expensive means of preserving high quality in food. Their cost puts them out of the reach of low income populations.

G. Sterile filtration and pasteurization require sophisticated equipment and on these grounds are unsuited for low income populations.

H. Irradiation

At one time irradiation promised a convenient low-cost method of preserving food. However 25 years of intensive research has clearly demonstrated that, under present conditions, irradiation is inferior to other means of preservation with respect to cost and convenience. (There are still a few partisans who loudly proclaim its potential!)

The disinfestation of insects from grain can be successfully accomplished by means of irradiation but an analysis of the total costs involved show that fumigation techniques cost less and are more convenient. The extension of the storage life of fruits and vegetables can be accomplished better and cheaper by [illegible] than by irradiation. The sterilization of foods by canning is done more conveniently, at lower cost and yields a better quality product than sterilization by irradiation. There is a possibility that irradiation will find a niche in the food preservation industry, but if it happens it will probably be for a very special set of circumstances that apply only to a minor food item.

A.I.D. should not support irradiation studies as a means of PHFL reduction at this time. However, irradiation should not be dismissed and forgotten. There is always the possibility that a new development in irradiation technology will occur that will make it attractive as a food preservation technique. In the unlikely event that the Food and Drug Administration bans the use of all grain fumigants, irradiation would probably be used to disinfect grain despite its higher cost and inconvenience because it would be better than no treatment against insects. In the meantime, the burden of proof of the efficiency of irradiation as a low cost preservation technique should remain with its proponents, not with A.I.D.

I. Single Cell Protein and Food From Waste

These two topics are presently receiving much research attention, and publicity. There have been some attempts to link these projects with PHFL reduction activities. They belong in the field of food production not in the post harvest phase and hence have no valid claim to be a post harvest activity. If these processes ever become successful, they will almost certainly be large, sophisticated, capital intensive operations. It is unlikely that these operations will make a significant contribution to the food supply of low-income populations and A.I.D. should not support these activities as a possible means of improving the food supply of DCs.

J. Dehulling and Milling

Dehulling and milling of cereals is not a preservation activity but it can be a source of considerable loss of food, especially rice. A.I.D. should help improve the efficiency of the dehulling and milling operations whenever possible. Some activities that A.I.D. could support are: (1) programs that teach operators of this type of equipment how to run it with maximum efficiency; (2) research into improved methods of threshing, dehulling and milling grain for small operations in DCs; (3) the aquisition of new equipment.

K. Small-scale Extraction Processes

Small processsing plants in DCs that extract sugar from sugar cane and oil from oilseeds, coconut and peanuts are usually inefficient, extracting only 50 percent to 75 percent of the wanted food material. The sugar remaining in the pressed cane is lost food. The oil left in the oilseed presscake is not a loss if the cake is used for human consumption but more often it is lost because the cake is used for cattle feed or fertilizer. A.I.D. should help to improve the efficiency of these simple extraction processes whenever the opportunity is presented by supporting research in this area and providing new or improved presses for extraction. This problem of low extraction does not apply to large, modern extraction plants such as sugar centrals that usually have the equipment to give high efficiency of extraction and minimum loss of food in the residues.

L. Transportation

Although outside the area of expertise of the consultant, it should be noted that a transportation system that is adequate in quantity and quality is an important component of the total post harvest food system.