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METHODS OF REDUCING POSTHARVEST LOSSES OF ROOTS, TUBERS, FRUITS, AND VEGETABLES IN DEVELOPING COUNTRY ECONOMIES

Report Prepared for
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Methods of Reducing Postharvest Losses of Roots, Tubers, Fruits, and Vegetables in Developing Country Economies

Losses of fruit, vegetables, roots and tubers in developing countries can only be reduced to a minimum when the following conditions are met:

(1) Resources (personnel, infrastructure, management, favorable governmental regulation, technical expertise and practical experience, information availability, etc.) are committed to reducing food losses to a minimum;

(2) Capital (local government, international loans and grants, and especially private capital) is generated to move the resources into place;

(3) Awareness among developing country nationals exists that most losses are avoidable;

(4) Points of loss in the postharvest food handling and marketing chain have been identified; and

(5) Intervention techniques to reduce the losses of the specific commodities are adopted as regular procedures of conservation and quality control.

This report concentrates on suggested methods of reducing losses by appropriate technologies emphasizing food processing and storage techniques. The general types of technologies available will be discussed, but more importantly the adaptation of these to the situation in developing countries is critical.

Although the role of technical assistance teams who can help design an improved processing and storage facility is significant the great importance of adequate

training at all levels must be stressed. Until developing country nationals are aware of the methods available to reduce losses to an economically feasible minimum and adequate numbers of better trained personnel are available to implement, maintain, and promulgate these improved technologies--the results of any technical assistance program will be small. Training at all levels and sharing of information on practical and technical loss information is the key method to reducing postharvest food losses in developing countries. Technical assistance support for national postharvest food conservation programs must be strengthened by complementary training at the ministerial level and the estension worker level as well.

The recent food loss study by the National Academy of Sciences has stated, "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 extention workers, as a priority need among loss reduction activities. . . . 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." (NAS, 1978)

Awareness that losses are frequently avoidable by specific technologies is thus a key method to food loss reduction. Training and education must become a major component of technical assistance efforts. During any evaluation of the requirements for improved food processing and storage facilities, the educational and training components must not be ignored, and should indeed become an integral part of most technical assistance programs.

Before specific interventions to reduce losses can be introduced it is necessary to determine what is causing the the various losses. Identification of major loss points in the postharvest system can be accomplished by loss surveys or by the application of more specific methodologies for loss assessment. IICA in Central America is developing a methodology to assess losses in fruit and vegetable commodities. This effort should help workers identify losses and compare results among countries and commodities. Future development work in fruit and vegetable as well as root and tuber loss assessment methodologies is critically needed. Efforts similar to the LIFE/AACC postharvest grain loss methodology development would provide important standardized techniques to assess losses of these more perishable commodities. Until useful methodologies for loss assessment are developed for these commodities, surveys by experienced food technologists or commodity experts must suffice. Frequently losses are so pronounced that even a cursory survey will pinpoint the major areas where losses occur. Nevertheless, it is important to survey the postharvest system when assessing losses so that the limited resources available can be brought to bear on the losses which are reducible in as cost effective a manner as possible. Often, technical experts may favor specific

remedies to a loss situation as a result of their expertise in a specific technical skill. For this reason and others, a team approach is best when examining postharvest losses. The loss situation must also be examined in a systems approach so that one stage or step in the marketing chain where losses do occur, does not receive excessive attention. In many cases, postharvest losses may result from or be aggravated by preharvest damage. It is also necessary to take into account the method of harvesting for this can greatly influence physical damage to many fruits and vegetables and particularly roots and tubers. Thus, when surveying for losses, a team approach and a systems concept must be adopted.

Possible interventions or improvements in the postharvest system can be grouped in the following categories: (1) Transportation, (2) Packaging, (3) Storage and environmental conditioning, and (4) Processing.

(1) Transportation in many developing countries is inadequate and will affect postharvest losses by influencing bruising or mechanical damage, and by influencing transportation time from area of harvest, storage, or processing to the final point of consumption. The effects of transportation can obviously be improved for example by road building and maintenance programs, however, even under existing conditions the effects of improved packaging, can mitigate the deleterious effects of transportation.

(2) Packaging Significant reduction in the amount of loss can be accomplished by improved handling and packaging at all stages of the movement of perishable produce from harvest to consumption. Delicate produce is often handled in the same way as the more durable crops. Since mechanical damage greatly increases the rate and extent of both physiological and microbiological deterioration, methods of avoiding this damage must be carefully investigated in

any postharvest food conservation program. Improvements in packaging and handling may be some of the least costly and most effective of all innovations in the postharvest system. Interventions to insure that delicate produce is handled in smaller quantities and in shallower containers can make significant reductions in the amount of damaged produce reaching the market. The substitution of wooden crates or fiberboard cartons (even plastic) for sacks or loose bulk can make dramatic improvements at little cost. Packaging and handling improvements are frequently very situation or commodity specific and thus generalizations are difficult however consideration of handling and packaging should be some of the first aspects investigated in a study of losses in the postharvest system.

For this report, the focus of suggested interventions to reduce losses of fruits, vegetables, roots and tubers in developing countries will be on physiological conditioning, storage and processing. It must be remembered that greater than 100 individual commodities are commercially important and that no single technology will reduce losses to zero. Even freezing and canning technologies have severe limitations, especially cost. The goal of appropriate food technology is to preserve, process, and store foods of acceptable quality at a price the population can afford to pay, and make a profit.

Improvements in processing and storage must also be considered in light of the systems concept. A weak transport and storage system feeding into a very efficient, modern, high capacity processing system which then feeds into a small and weak marketing system is a waste of expertise and other resources. There are many examples in developing countries where good intentioned international development groups have funded monuments to their developed countries' sophisticated food processing and technological ability. However, too frequently many modern technical assistance

projects also point out the lack of understanding for the appropriateness of such a facility. The unfortunate result may be an excellent food processing plant available but underused because the inputs before or the marketing channels after processing are weak. A common characteristic of these monuments are the beautiful cornerstones or bronze plaques which attest to the good will of the donating country. This good will frequenty ignores to stock the parts room with adequate spares and to train the personnel in maintenance of equipment, sanitation and product development to keep the plant running efficiently. One goal of food processing is certainly greater third world sufficiency in food availability and safety; however the important contribution processing, physiological conditioning and storage can make in reducing postharvest food losses must be considered in the systems concept as mentioned earlier as well as the appropriateness of any intervention within existing conditions.

In 1974 Schumacher wrote in the journal Appropriate Technology, "There are now many hundreds of thousands of people engaged in the battle against world poverty. ... The essence of their work is helping poor communities help themselves, and this means working within the constraints and limitations of poverty. These many people and their respective organizations have relatively easy access to the technologies and equipment of the affluent society but they find that much of this does not 'fit' in conditions of poverty; it presupposes the availability of ample capital resources; it depends on the existence of an elaborate infrastructure; it fits into big cities where markets are large, but not into towns and villages where markets are small because most of the people are very poor. So they are forced to look for appropriate technolgies, for the knowhow and equipment designed to help themselves." (Schumacher, 1974).

If we are to suggest new technologies to reduce food losses we must remember that the need is for processes and equipment that are small-scale, labor intensive, capital sparing and simple to operate and maintain. As Malcom Bourne states, "A typical food processing plant in a developed country takes in a large volume of well standardized raw materials and turns out a large volume of highly standardized finished goods. The developing countries are faced with the problems of small markets with low purchasing power, small volume and variable quality of the inputs that go into a food processing plant, and of course the usual shortage of capital, limited ability to maintain equipment and obtain adequate spare parts, and frequently an unreliable supply of utilities such as electric power, water, transportation and waste disposal systems. Partly offsetting these problems is the fact that the expectation of quality is usually not as high in developing countries." (Bourne, 1978)

(3) Storage and Environmental Conditioning To extend periods of availability nearly all produce is stored for various periods of time including storage during transit. Temperature, relative humidity, gas concentrations, air flow or ventilation, and absence of light affect shelf life and quality of produce greatly. The ability to manipulate these factors for optimum storability is usually dependent upon the genetic and metabolic activity of the plant tissue and on cost or technological limitations. Technologies designed to optimize perishable produce storability rely upon research which tested each commodity under varying conditions in order to determine best storage conditions. Research of this nature has been conducted on major species and even varieties of produce commonly handled in developed

areas. Unfortunately the data base for some tropical produce is incomplete and thus more work is necessary before optimum conditions for all tropical produce is known.

The following factors are commonly manipulated to optimize storage conditions: (a) physical spacing and ventilation, (b) temperature control, (c) relative humidity regulation and (d) atmospheric gas alteration.

(a) Physical spacing and ventilation can affect storability by increasing the incidence of disease from fungal attack. Physical placement of produce can either hamper or promote adequate air circulation as well as promote the spread of infection by contact.

(b) Temperature control or cooling and refrigeration is probably the greatest factor responsible for extending shelf life and reducing losses of perishables in the developed areas. However it has limitations for reducing losses of roots, tubers, fruits and vegetables in developing countries. Many of the tropical fruits and root crops sustain chilling damage at low temperatures, especially at temperatures near freezing. Cooling systems which lower ambient temperatures several degrees may be effective in reducing losses of many commodities. Simple shading of the commodities from the sun can reduce the internal fruit or vegetable temperatures significantly. Many perishable commodities are low in unit cost and therefore the cost of mechanical refrigeration and storage units may not be warranted. Cooling is still a significant method of reducing perishable losses, however, the critical maintenance of mechanical refrigeration and power supply is frequently a significant limitation on its usefulness for preventing losses. Low cost systems and mechanical deveices for cooling need to be developed and utilized. The old Serval gas refrigerator is one example of an appropriate technology that might well be put to good

use in developing areas where gas lines or bottled gas is available. These units required little electrical energy and were virtually maintenance free. Mechanical refrigeration does not necessarily mean the higher pressure freon systems but can include the lower cost ammonia systems which the developed world has largely abandoned for the sake of greater cooling efficiency with freon. In many applications ammonia refrigeration systems might be cost effective particularly when considering maintenance and capital costs.

Water or hydro cooling is another cooling technology that deserves attention for developing areas. Temperature reduction is provided when fruit is sprayed or immersed, but large quantities of high quality water are required. Filtration and chlorination may be necessary to prevent the spread of microbiological contamination. Water sanitation costs raise the energy requirements of this form of cooling and possible contamination of the food from the water source must be considered, however washing and cooling of produce, perhaps before storage or spraying during the hottest days may be helpful in extending storage life of the produce.

(c) Relative humidity regulation can affect shrivel and wilting loss of nearly all perishable produce. As a result of the inherently high water content of these vegetable materials, they tend to dry out and shrivel when humidity is low, especially at elevated temperatures. Higher humidities may reduce loss from dehydration and yet excessively high humidity levels promote microbiological growth and loss of the material. Control of humidity other than by adequate ventilation can be costly and may or may not be cost effective for a particular commodity. Evaparative air cooling may be helpful in some developing areas where a small 10-20° F

temperature drop from ambient conditions plus the high humidity created by evaporative cooling and air flow are desirable for produce storage. Desert areas where temperatures are high and relative humidities are low would find the greatest usefulness of evaporative air cooling.

(d) Atmospheric gas alteration can influence length and quality of produce storage. Controlled atmosphere (CA) storage as it is commonly called is a system for holding produce in an atmosphere that differs substantially from normal air in respect to the proportion of nitrogen (N_2), oxygen (O_2), or carbon dioxide (CO_2). While other gases, such as carbon monoxide or ethylene may be added to the storage atmosphere, historically the term CA has referred to alterations in the proportions of N_2, O_2, or CO_2. The composition of the atmosphere may be altered by restricted venting of the container, such as a storage room or individual wrapper, by scrubbing the atmosphere of CO_2 or O_2, or by adding individual gases to the container while reducing the proportion of others. For CA to be cost effective the produce must have higher quality after a given time in CA storage than it would if stored in air. CA can also store a product until availability decreases for the freshly harvested produce and prices increase at the market level to justify the expense of CA. Controlled atmosphere storage and refrigeration in developed areas have greatly expanded the season of fruit availability, especially of apples and pears. The costs may be justified as a result of greater consumer purchasing power and the economies of scale which are possible in developed country situations.

One method used to extend shelf life of bananas and plantains and thus possibly to reduce losses can be

accomplished by removal of ethylene gas which accelerates the ripening process. Ethylene is produced endogenously by the normal ripening metabolism of the fruits. By sealing the bananas in polyethylene bags which contain potassium permanganate the ethylene is absorbed and ripening is delayed.

Plastic film can act as semi-permeable membranes which inhibit CO_2 escape from sealed bags containing fruit and inhibit the entry of other gases. Packaging research with peanuts has shown that nitrogen or CO_2 flushed bags filled with peanuts then sealed can develop a partial vacuum as the peanuts metabolize trapped gases. Peanuts packaged in this manner have been successfully stored for several years at ambient conditions without loss, although the special semi-permeable plastics being used are relatively expensive at the present time. Physiological manipulations of a simple packaging method or more sophisticated controlled atmosphere storage (normally combined with refrigeration) can be designed for greater use and application under developing country conditions. Plastic bags and sheeting offer possibilities for CA storage in developing areas, but further adaptive research is necessary to design effective means for employing plastics as an inexpensive film and wrapping for gas control.

A unique storage condition for roots and tubers, especially cassava is the clamp or pit storage. This storage method hold great promise for it is merely a pile of the harvested and cured tubers piled up and covered with dirt. The dirt acts as shading and adds humidity. Sawdust impregnated with potassium permanganate is a further refinement of the method. The literature is inconclusive as to the best storage method for cassava. Considering it normal short storage life and its great magnitude of consumption, storage research with this commodity in particular would possibly expand the availability of this staple by reducing its losses.

Since most developing countries have breweries which produce CO_2 as a waste product of fermentation, research focused on the effects of increased CO_2 concentration especially on tropical produce might provide useful results.

(4) Processing of perishable produce offers perhaps the greatest impact on reducing losses. Food preservation may be grouped in the following categories: (a) drying, (b) heat processing, (c) freezing, (d) fermentation, and (e) chemical preservation. These technologies vary greatly in their cost, degree of sophistication, requirements for energy and equipment, length of potential preservation, transferability, social acceptability, and applicability to various commodities. Lettuce cannot be frozen nor heat processed and retain any of its original texture or acceptability while many vegetables or fruits can be canned or kept frozen for many months, even years and still retain most of their fresh character.

(a) Drying can involve rather simple sun drying or can require complicated and expensive air tunnels or spray drying equipment. Unfortunately few fruits and vegetables are suitable for sun drying although improvenemts in sun drying techniques would have great value to tropical countries, particularly the less humid ones. Drying is one of man's oldest methods of food preservation and is still the most widely used method of food preservation. More fruits are preserved by drying than by any other method of food preservation.

Dehydration or artificial drying under controlled conditions produces food of higher quality than sun dried counterparts and requires less land. Sun drying for fruit requires approximately one acre of drying surface f r every 20 acres of crop land. Dehydration obviously is more expensive than sun drying however

dehydrated foods have higher value as a result of their higher quality. Unfavorable weather also acts as a deterent to expansion of sun drying activities. A new innovation under development in many areas is a solar drier for foods. Solar driers can theoretically generate concentrated heat under sanitary conditions. Low maintenance, operating cost, and perhaps low capital requirements hold promise for this drying technology in developing countries.

Dried root crops have great potential for developing areas where these commodities serve as staples. Cassava chips, yam and sweetpotatoe flour can find new uses in the diet as well as traditional ones. Dried staple root crops exhibit excellent storability and present good opportunities for product development.

(b) Heat processing or canning is usually a capital intensive form of food processing, however canning as well as other forms of preservation can under some conditions reduce produce cost to the consumer. When transportation from production areas to urban consumption areas is either long or difficult, processing at the production site can eliminate losses resulting from transportation. Processed products may (other preservation techniques more than canning perhaps) be reduced in size, bulk, or weight for more convenient packaging and marketing as well as reduced costs for packaging and transportation. Once canned, produce can withstand moderately long periods of ambient storage conditions without serious deleterious effects. Canning may utilize less than market grade product for juice, puree or jam production. Also, canning as well as other processing can preserve produce during periods of abundant supply when prices are low. When harvest has passed and the quality of available fresh produce deteriorates the processed product may be less expensive and higher in quality than the unprocessed

product. Canning for local and export markets will increase in developing areas as resources become available to share the technical and administrative skills required. Small labor intensive, low capital cost systems have been developed and should receive greater attention as possible small-scale canning facilities at the village level. Ultimately the economy of scale in developing areas will foster greater heat processing of suitable perishable produce.

(c) Freezing is generally an excellent yet expensive food preservation technique. As mentioned earlier under refrigeration, ammonia systems, gas powered freezing equipment and equipment refinements may promulgate the use of freezing as a method of reducing losses and increasing availability. Freezing appears to be rather capital intensive and difficult to maintain for many developing areas at the present time, however it will grow in popularity as electricity and maintenance services are increased in the developing areas.

(d) Fermentation is one of the least costly forms of preservation. Frequently the flavor or texture of the fermented product may change drastically, yet may be preferred to the raw product. Olives, pickles, cabbage, grapes and other fermented fruit, vegetable, root and tuber crops are popular world-wide. Because of the possibility of processing without outside energy and the relatively simple nature of fermentation of perishable commodities, this method of preservation holds great promise and deserves a great deal more interest in international development programs designed to reduce losses of perishable crops.

(e) Chemical preservatives such as salt or acid or an entire host of other chemicals offer great promise for reducing postharvest food losses effectively and at low

cost. By acting directly to reduce spoilage organisms or by establishing unfavorable growing conditions for microorganisms, chemicals can prevent decay, delay sprouting, or enhance storability. Chemicals and wax coatings or dips can control disease and inhibit shriveling from moisture loss. Waxing is a simple process that deserves further work especially for use on root and tuber crops and tropical produce. There are many chemicals available presently for use in the postharvest system but great opportunity for further reduction of losses exists as chemicals and wax coatings are developed for use on produce important to developing countries.

Although this report contains many suggestions for methods of reducing postharvest losses of perishable produce, the greatest impact can be made in developing areas by the transfer of existing technologies with little or no basic research. Concern for cost effective procedures and technologies which are capital sparing and labor intensive will find greater applicability. The transfer of these existing technologies which may require slight adaptation to fit into the developing area cultural and social patterns can be accomplished through better coordinated programs of training and technical assistance. Modern processing plants must be conceptualized in terms of their appropriateness and impact on the developing economy. No single technology exists to reduce losses of all commodities and all technologies have limitations. It is only through greater sharing of technical knowhow in carefully planned programs of technical assistance that losses can be significantly reduced.

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