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FRUIT, VEGETABLES, ROOTS AND TUBERS IN THE DEVELOPING ECONOMIES: AN ESTIMATION OF LOSSES

Report Prepared for
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by

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LOSSES OF FRUIT, VEGETABLES, ROOTS AND TUBERS

Fruit, vegetables, roots and tubers are so liable to spoil and deteriorate that they are referred to as perishables. (This report restricts the use of perishable to plant tissue only.) Losses manifest in loss of quality and quantity result from physiological, pathological, or physical damage. Weight loss causes not only a direct quantitative monetary loss because produce is often sold by the pound, but also causes a qualitative loss in appearance and thus salability. Weight loss is accompanied by a flavor loss and more inportantly a nutritional loss. Weight loss is reported to particularly reduce vitamin C and carotene levels as well as other important vitamins in fruit and vegetables which are frequently the major source of these vitamins in the diet. Nutritional loss of vitamins in perishables after harvest is of major importance and deserves greater attention, however the focus of this report is the absolute or total loss of these commodities in developing areas.

Postharvest losses of perishables present a very different set of problems as compared to the "durable" crops of cereal grains and grain legumes. Perishable crops are more varied and numerous than are the grains. The compositional, production practice, and loss differences between cassava and tomatoes are much greater than these same differences between wheat and corn. Also the perishables are more numerous. United States' wholesale produce markets frequently handle approximately 150 different kinds of fruit and vegetables during the year. When tropical species commonly consumed in the world are also included, the number of fruits, vegetables, roots, and tubers greatly exceeds 1,000 species. The numerous species of horticultural produce commonly consumed in the world is contrasted sharply to the dependence of less than 15 grain species for world cereal supplies. This diversity of perishable commodities makes loss estimation difficult for each commodity exhibits different loss patterns.

A second problem in loss estimation in perishable commodities is the difficulty of expressing weight on a defined moisture basis. This is important for comparability of any loss estimates, and particularly so in perishables where water contents are frequently in the range of 50-75% and occasionally up to 95%. Further, the separation of pre- and postharvest losses in perishables is more difficult than in the durable commodities. It would be easier if damaged and spoiled fruit would be discarded at the point of harvest so that any subsequent loss is attributable only to postharvest factors. This practice is likely to be unrealistic, particularly where no uniform commercial market standards exist and especially in developing areas where food may be scarce. Reported postharvest loss values may thus tend to be overestimated as a result of including preharvest damage in the estimation of losses.

The time from harvest to observation is much more critical to percentage loss estimation in perishables where losses increase rapidly over days. Time from harvest must be included for critical work in loss estimation of perishables. Although loss estimation is made difficult with perishable commodities for the above mentioned reasons, losses which occur can be grouped in the following three categories: physiological, pathological and physical factors.

Losses from Physiological Factors

Perishable commodities are frequently reproductive parts of plants. Sometimes as in celery, spinach or other leafy vegetables the edible part may be nearly the entire plant. Plant tissues continue to respire after harvest and must be considered a living entity. Roots and tubers also continue to respire at a lower level than the growing plant, but are still not suited for prolonged storage. The edible parts of most fruits and vegetables are not the seeds which are often discarded, but the fleshy food which is designed to support

the germination and growth of the seed or to attract animals and birds which then act as seed dispersal agents. Perishable commodities remain living organs after harvest and as such have relatively high rates of metabolic activity. Although grain in storage is usually still living, it is dormant and its respiratory activity, although measurable, is exceedingly low compared to fruits, vegetables or root crops. This difference in respiration is one factor that is responsible for faster spoilage of perishables as compared to grains and thus one can expect greater losses of perishables.

The metabolic processes in respiration convert starches present into carbon dioxide and water vapor which is lost to the atmosphere by transpiration. Of the perishable vegetable commodities some roots and tubers respire slowly and lose 2-5% of their weight per month depending upon storage conditions. For other tubers such as yams, values up to 20% per month have been reported (Coursey 1967). Perishables other than root crops are more active metabolically and may show even greater weight loss from transpiration. Hruschka showed that snap beans may lose up to 83% of their weight in only 5 days (Hruschka 1977). Although the rate of respiration varies from commodity to commodity, it approximately doubles for every ten degrees centigrade rise in temperature. This temperature relationship is particularly important in the tropics where storage temperatures frequently are 30° C and yet on hot afternoons it is reported that the tissues of stored tubers exposed to the sun have reached 50° C (Coursey 1968). The appreciable amount of weight loss associated with these physiological processes is thus inherent in their storage metabolism, but can be greatly affected by the temperature of the plant tissue. Further, for metabolism to continue, adequate supplies of oxygen are

necessary for the maintenance of respiration and therefore life. Hermetic storage techniques which are often successful for grains, cannot be adopted for perishables as they would shortly produce anaerobic conditions which would result in the death of the material and subsequent decay.

Other metabolic processes involved in ripening and senescence give fruits and other perishables and inherently short life or exacerbate losses from other factors. Enzymatic and other biochemical factors lead to a softening of tissue which makes the commodity more susceptible to mechanical damage.

Although root and tuber crops may exhibit periods of dormancy and thus greater storability, the storage period will eventually be terminated by sprouting. Even when sprouting can be delayed by the use of sprout inhibitors, endogenous changes may often commence at sprouting time and may become deleterious in terms of quality. Susceptability to pathogenic attack may be greater during such artifically extended periods of dormancy. Appropriate physiological or biochemical manipulation can sometimes delay the ripening process itself. Although progress has been made in controlled atmosphere storage and chemical sprout inhibition, some of the techniques require costly equipment or refrigerated containers.

Other physiologically related losses that can occur result from freezing, chilling, heat injury, sun burn, immaturity, over-maturity and various conditions such as blossom end rot and internal browning of tomatoes, scald of apples, and tipburn, russet spotting and rib discoloration of lettuce. These injuries appear to predominate in developed area markets but may be found in developing areas as well. Unless the products are consumed shortly after harvest, losses from physiological factors quickly become unavoidable unless the products are preserved by some form of processing such as canning, fermentation, or drying.

Losses from Pathological Factors

Micro-organisms

Attack by micro-organisms (fungi, bacteria and to a lesser extent viruses) is probably the most serious cause of postharvest loss in fruit, vegetable, and root crops. Physical and physiological damage frequently predispose vegetable material to pathogenic attack. The pattern of this attack is usually an intitial infection through a wound by one of a few specific pathogens. This is followed by a massive infection by a broad spectrum of weakly pathogenic or saprophytic organisms which grow on the dead and dying tissue resulting from the initial infection. These second invaders exaggerate the damage started by the primary pathogens. Losses caused by the parasitic organisms are accounted for principally by bacterial soft rot, blue mold rot, gray mold rot, fusarium rot, watery soft rot, rhizopus rot, alternaria rot, cladosporium rot and anthracnose rot. Other decay producing organisms attack only certain groups of fruits and vegetables, yet may cause serious losses. Brown rot of stone fruits, stem-end rot of citrus, mycosphaerella rot of watermelons and cucumbers, black rot of pineapples and bananas, late blight of potatoes and tomatoes are among this group. Other organisms are even more selective, such as those causing fruit rot of eggplant, black rot and bull's eye rot of apples (Friedman 1960).

The occurrence and magnitude of losses due to pathogenic micro-organisms are variable and dependent on several factors. Perhaps the major factor governing the incidence and magnitude of such losses is the physical condition of the produce, however, water left on produce tends to promote infection.

Losses from Physical Factors

Mechanical Damage

As compared with the "durable" grain and grain legumes, fruits and vegetables have relatively low mechanical strengths

and bruise or damage easily. This is at least partially associated with the high water content of these products. Other horticultural commodities such as soft fruit and leafy vegetables are conspicuously susceptible to mechanical injury. With some crops (cassava is a particularly important example) the harvesting process itself necessarily produces a major lesion. Food handling techniques are generally poorly developed in the tropics and fresh produce is too frequently treated as an inert object. While more emphasis is being placed on crop mechanisation to reduce crop production costs, consideration should also be given to the increased losses which usually occur following mechanical harvesting, particularly of root crops. Transportation damage over bumpy roads in field situations and over developing area highways greatly increases physical injury. Lack of adequate packaging also is a major cause of loss. Even when packaging and transportation are good, produce is frequently over-filled in the containers and this may result in crushing when the containers are stacked. Even under British conditions, it has been estimated that one-third of the potato crop suffers serious damage between harvest and reaching the consumer (Coursey and Booth, 1972).

Insect Damage

Insect injuries of fruits and vegetables do not represent as great a loss as the factors mentioned above. Insect damage is occasionally seen in the form of worm injury of various vegetables and scale insects sometimes damage citrus and nectarines. The bronzing of citrus fruit usually results from the russeting caused by rust mites. Nematodes may cause much damage in the field, however in postharvest operations potatoes may infrequently be affected by the root knot nematode. Scale insects occasionally infect stored yams but cause comparatively little damage. The yam beetles

Heteroligus and *Prionoryctes* spp. are essentially preharvest pests, but the damage they inflict on the tubers before harvesting may render them more liable to invasion by rotting organisms during subsequent storage. Yams are occasionally attacked by termites, especially if they are stacked on the ground. The slight importance of insects in the loss of perishable horticultural produce is in great contrast to that which applies to most other food crops, especially in the tropics where great destruction is wrought by a wide range of insect pests.

Animal Damage

Rodents do not appear to cause great losses of perishable produce. Some damage to yams may occur, especially when they are stored in heaps in contact with the ground. In West Africa, most damage is probably done by the large cane rat *Thryonomys swinderianus* (Peters) and the giant rat *Cricetomys gambianus* Thomas and Wrongton, as well as the familiar *Rattus rattus* L., *R. norvegicus* Berkenhout and *Mus musculus* (L.). In general, however, loss from rodent attack is not severe. In some areas of Africa and elsewhere, pilferage by monkeys does occur but is of a local and minor concern. Reported animal damage from birds is likely for certain fruit and orchard crops, however the literature on losses from birds is rarely reported for grain crops and nearly absent in perishable produce.

Problems Associated with Loss Data

The reliability of loss data of perishable produce is frequently questionable. There are few accurate figures available for losses measured by a described methodology. When data are obtained from on-site measurements they are of limited use because they cover the loss for one commodity in one location for one specific set of conditions. The extent of loss in a horticultural produce varies widly

within an exceedingly short period of time after harvest. The wide range of loss estimates cited in the literature demonstrates that an inadequate data base presently exists for losses of horticultural products.

Lower levels of education and technology in the developing countries imply that handling techniques are less satisfactory; fewer sophisticated facilities are available; and losses may be substantially higher. A parallet may exist between losses and the state of technological advancement. However, information relating to losses in the tropics is extremely scarce. Perhaps the absence of enforced grade standards may tend to foster a lower level of acceptability for slightly damaged produce thus increasing the consumption of produce that might be considered below grade or unfit for use in developed areas. On the other hand the lack of adequate storage facilities which allows longer availability may tend to produce local surpluses, especially when transportation is lacking. During periods of glut, markets may become saturated with the fruits in season and prices may drop as certain produce becomes monotonous. Losses under these conditions may thus tend to increase with local availability after initial demand is satisfied.

Estimates of loss are frequently misinterpreted. Coursey and Booth (1971, p. 674) report the following, "Estimates of material loss in fruit and vegetables in the U.S.A. were 11% for the period 1942-1951 and 8% for 1957-1960 (Friedman, 1960)-indicating the benefits obtained from a decade of intensive research and application." Unfortunately these respected authors have made the following errors with this one statement: (1) Upon checking the reference cited, no mention is made of an 11% loss for the period 1942-1951 nor an 8% loss for the period 1957-1960. In fact no general loss figures are quoted for fruits and vegetables in the U.S.

whatsoever. (2) Loss values in the paper by Friedman were quoted only for transit losses in 1958, processing losses in 1954, retail losses in 1956, and kitchen losses during 1933-1935. No other loss estimates were given. (3) The nine year period '42-'51 nor the three year period '57-'60 represents a decade and the two unequal periods should not be compared. (4) Furthermore the conclusion that the difference between the misquoted losses should reflect "benefits obtained from a decade of intensive research and application" is totally illogical and misleading. This detailed description of the problems associated with loss estimation and the possible misinterpretation of data from "reliable sources" points out the need for scientifically designed methodologies for loss assessment. The exceedingly complex marketing chain from producer to consumer and the great diversity of fruit, vegetable, root and tuber crops will prevent accurate loss measurements except for specific conditions, certain commodities, and only during a specified period.

Man's over zealous desire to produce a value or a number and call it research is demonstrated in the following loss data taken from Araullo, de Padua, and Graham, 1976, p. 85.

> Ruiz (1965) concluded that the average grain losses at different harvesting times were: 1 week before maturity 0.77%; at maturity 3.35%; 1 week after maturity 5.63%; 2 weeks after maturity 8.64%; 3 weeks after maturity 40.70%; and 4 weeks after maturity 60.46%.

In this example losses are directly dependent on the author's definition of maturity. Furthermore, the value of <u>average</u> grain losses is highly questionable. As a last note, the use of two decimal places to describe losses is particularly unnecessary and not scientific although the intent is to make the loss values look scientifically accurate. There is no meaning of any loss data beyond whole integers.

Any "scientist" who believes a loss value of 40.70% is any better than 41% is kidding himself and leading his readers astray.

Another example of how loss values are commonly misused comes from a paper presented by Dante B. de Padua at the Institute of Food Technology Annual Meeting, Philadelphia, Pennsylvania, 5-8 June, 1977. He presents estimates of rice losses in a system as follows:

Harvesting	1 to 3%
Handling	2 to 7%
Threshing	2 to 6%
Drying	1 to 5%
Storage	2 to 6%
Milling	2 to 10%
Total Range of Losses	10 to 37%

I congratulate the author for using a range of estimates, however the addition of estimates at each stage is totally in error. Correct range estimation through a system is accomplished as follows:

Stage	Loss	% Remaining	Loss	% Remaining
Harvesting	1	99	3	97
Handling	2	97	7	90
Threshing	2	95	6	85
Drying	1	94	5	80
Storage	2	92	6	76
Milling	2	90	10	68
	100-90		100-68	
	10% Loss		32% Loss	

Thus it can be noted that at low levels of loss this error is minimal, but at moderate levels of loss the error is greater. The error is also greater when more stages in the system are reported.

Do these misinterpretations and others which occur in the literature invalidate reported loss value? Obviously the answer is yes. Until better data is assembled from scientifically designed assessments the best estimates or guesstimates of specialists in the field must suffice.

It is obvious that loss estimates are questionable because of insufficient data. Furthermore, different sources cite estimates whose validity has not been established. Nevertheless, there is general agreement that losses are enormous, not only in terms of food but in terms of human toil and other costly inputs.

There is no valid generalization for losses of perishable commodities. An example of the variety of estimates available is found in the following (Coursey and Booth, 1971):

> Fruit crops experience very high losses on account of their susceptibility to mechanical damage and inherently low storage life. In selected, top quality, tomatoes in Ghana, Rawnsley (1969) reported handling losses of 16%; over the crop as a whole, this figure could probably be doubled. In India, Singh (1960) estimates that 40 per cent of the mango crop is lost by bad handling between harvest and consumption. With bananas it has been estimated (Ben-Gera and Kramer, 1969) that a third of the crop enters international trade, a third is used locally and a third is wasted. Even higher losses have been estimated for fruit and vegetables in some tropical situations: Lowings (1969) suggests that losses of 50 per cent are not uncommon: F.A.O. (n.d.) quotes wastages of 40 per cent of vegetables and 50 per cent of fruit in Chile: in Colombia, the extraordinary figure of 80 per cent wastage in perishable produce has been given (Hall, 1970). However, taking only the levels of loss actually reported for specific crops, and assuming that they are typical for the tropical world, a total loss of around 30 million tons/ annum, or 25% of production (excluding cassava, which is rather a special case) may be estimated. This must, however, be regarded as a highly conservative estimate (Coursey, 1971).

If one assumes that nearly one third of all perishable produce in developing countries is lost this would equal al total crop failure every three years. If one further accepts the conservative estimate of dollar value of only

11-22 billion dollars then losses would be at least 4-8 billion dollars in developing areas alone. The dollar value developed in the first report of this series was based on only 38 selected perishable commodities from the hundred commonly consumed. Even this conservative estimate is enormous and deserves concerted international action to reduce and prevent these losses. As population increases and resource constraints become more sever, the need to reduce these losses and the need to develop a better data base regarding perishable losses will be even greater. All evidence indicates that losses of fruit, vegetables, roots and tubers are high and yet may be partially preventable by the application and transfer of known technologies.

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