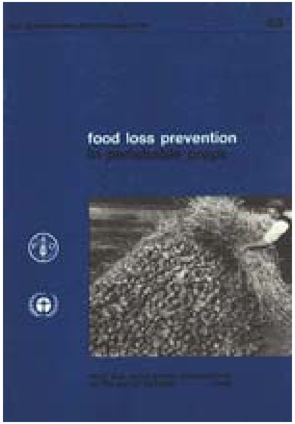

Food loss prevention in perishable crops

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based on an expert consultation jointly organized by the food and agriculture organization of the united nations and the united nations environment programme

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Foreword

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This study deals with the Post-harvest losses occurring in perishable crops and how they can be reduced or prevented. It is the combined result of study tours, literature search, and discussions during an Expert Consultation jointly organized by the Food and Agriculture Organization and the United Nations Environment Programme in May 1980. More than 30 specialists from the different disciplines of the post-harvest system and representing a wide geographical area were at one stage or another involved in this study.

This publication is primarily intended for policy-makers, planners, development corporations and potential investors in the developing countries, although it could conveniently be used as background material for training courses in post-harvest technology. With its mixture of technical background information and recommendations for curative action it is hoped that the document will create sufficient awareness for initiating steps to recover a food availability which is now lost.

The publication is divided into two main parts, preceded by a Summary in which the Recommendations for post-harvest loss prevention measures in perishable crops are incorporated.

In Part I the concept of post-harvest loss prevention and its increasing importance to provide more food is introduced followed by the Conclusions reached by the Expert Consultation. Part II describes the technical aspects of post-harvest losses and the factors that influence their magnitude and opportunities for their reduction.

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Summary

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Forecasts as to the extent to which the increasing demand for food in the world can be fulfilled over the next decades range from very cautious to optimistic. More concrete is the expectation that the necessary food supplies will have to be derived increasingly from the intensification of agricultural production rather than from additional land use. This will require a more judicious use of limited production inputs and may have repercussions on costs.

The reduction of post-harvest food losses is a complementary means for increasing food production. This draws its importance not only from a moral obligation to avoid waste, but also because the cost of preventing food losses in general is less than producing a similar additional amount of food of the same quality. Therefore, the concept of food loss prevention, to which attention was drawn by the World Food Conference in 1974, will afford mankind increasingly significant opportunities to meet its food requirements. The programmes that have been initiated so far at the international level, amongst which is FAO's Food Loss Prevention Programme, have focused mainly an the durable food grains because of their prominence in the daily diet. The perishable crops, because of their high moisture content, are inherently more liable to deteriorate, especially under tropical conditions. Fruits and vegetables provide basic food and nutritionally essential vitamins and trace elements and, moreover, have an important role in improving food flavour and acceptability.

This study, therefore, is concentrated on the perishables of plant origin and endeavours have been made to review the magnitude of losses, the places where they occur and the measures that can be taken to reduce them in the developing countries.

The findings and course of action to improve the situation are reflected in the Recommendations proposed by the Expert Consultation on Food loss Prevention in Perishable Crops, held at FAO, Rome, in May 1980, and are listed below:

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Recommendations

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1. An international action programme of post-harvest food loss prevention in perishables of plant origin should be initiated. A proper balance should be

maintained between postharvest scientists and economists, engineers and food technologists in project formulation and implementation.

2. All projects designed to increase food production or improve food marketing should give consideration to the post-harvest implications of the project including both project development and project monitoring phases,.
3. All post-harvest food loss reduction activities should consider the environmental impact of that activity. Environmental and health issues should be part of the documentation of project proposals and the planning process.
4. Each country should attempt to identify the principal problem areas affecting losses in perishables of plant origin occurring in its own postharvest system with a view to establishing appropriate priority areas for action. Since the value of the product may be doubled in the post-harvest period, these value changes need to be assessed for specific crops. The scale of priorities should be compiled on the basis of the magnitude of the losses, their economic and nutritional importance and the feasibility of applying effective remedial action that is operationally and economically reasonable. A systems approach should be used in this process taking into account biological, physical, economic and social factors with reference to the various economic groups including the rural poor. There should be full participation of the expected beneficiaries in the planning of food loss reduction activities. Traditional technologies should not be ignored.

5. The use of proper temperature management procedures should be promoted This includes simple cooling systems such as shading from direct sunlight and use of evaporative cooling. Where appropriate, more cool stores and better utilization of existing cool stores should be promoted. The International Institute of Refrigeration should co-operate with national and international organizations to organize training in refrigeration management, design, operation and maintenance suitable for conditions experienced in developing countries.
6. The search for low cost cooling systems should be intensified. This should include the application of solar energy and other renewable sources of energy to power cooling systems. Practical research programmes should be drawn up by national and international agencies and institutes to adapt refrigeration techniques to the needs of developing countries.
7. There should be development and promotion of gentle handling of horticultural produce at all steps in the harvesting and marketing system when it is technically feasible and economically viable. This includes the development and use of improved market and field containers that are used to harvest, transport and store horticultural produce. All training manuals should emphasize that mechanical damage is the major factor in providing pathways for infection of produce by microorganisms. The avoidance of mechanical injury should be an essential criterion in the design of harvesting and handling machinery. The

importance of efficient marketing systems as a factor in the prevention of post-harvest losses particularly the less durable fruits and vegetables has also to be recognized' and such systems adapted to suit the requirements of efficient perishables' marketing.

8. There should be active encouragement of rigid sanitation and public health procedures of all produce handling and operation areas, sanitary operation of equipment, containers and stores, and sorting out and proper disposal of diseased and damaged units from the produce.
9. The relevant International Agricultural Research centres of the Consultative Group for International Agricultural Research in collaboration with national and other international institutes should be encouraged to initiate or expand a co-ordinated programme of research to resolve outstanding problems related to post-harvest factors and storage behaviour of horticultural crops, e.g., root crops. Plant breeders in these institutions should consider long inherent storage life as an important criterion of selection in the breeding of fruits, vegetables, roots and tubers.
10. Research to develop small scale drying technology or other suitable appropriate technologies for transforming horticultural crops should be promoted. The use of these technologies should be promoted where their benefits have been clearly demonstrated.

11. Every country should be cautioned against the use of hazardous protective agricultural chemicals until the following actions have been accomplished:

    a. analytical laboratories and inspection services have been established to monitor the proper use of pre- and post-harvest agricultural chemicals;
    b. guidelines have been developed and are being applied to educate farmers and food handlers in the proper and safe use of hazardous compounds and safe disposal of empty containers;

    Information should be available in each country as to which national and regional laboratories have the facilities to identify decay organisms.

12. A variety of types of training programmes in prevention of losses in horticultural crops should be initiated. These should be designed to suit the differing needs of the people in different parts of the harvesting and marketing chain. While most training should be provided within their own country exchanges with other countries may be beneficial in some cases. The transfer of existing good storage technology from national and international institutes to potential users should-receive priority in the programmes of these institutions.
13. The following publications should be prepared:

a. technical loss prevention manuals for commodities or groups of commodities;
b. a world-wide directory of institutions and training programmes involved with prevention of losses in perishable crops;
c. guidelines for loss assessment.

14. An international information network on food losses in horticultural crops should be established making as much use as possible of existing national and international programmes to facilitate technical go-operation between similarly oriented institutions. The information to be collated in a World Directory (13 b) should form the basis for establishing International and Regional co-operation in improvement of training at all levels.

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I. Rationale and directions for reducing food losses in perishable crops

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Securing an adequate food supply has been the fundamental concern of mankind over the millenia, and even in today's mode m world of great scientific and technological achievements, diets are inadequate for about five hundred million people. In the community of nations concern is increasingly focused on fulfilling the basic needs of all people, and the need for food is a dominant one. Without ensuring satisfactory diets, people cannot lead healthy and productive lives.

Agriculture, including fisheries, is the main if not the sole provider of food and the crucial question can be raised if and how far agriculture can respond to the rising demand for food in the gaming decennia.

A recent study (FAO) referring to 90 developing countries representing 98% of the population in the developing world (excluding China) reveals that the most striking share of increases in food demand will be caused by expanding world population. By the year 2000 fifty per cent more food will have to be available to meet present intake levels; yet additional food supplies will be needed by the end of the century to conquer famine and malnutrition. With respect to the material production inputs, which include land, water, minerals, organic substances, and energy, to meet these production targets, the availability of land will be the most limiting factor.

Consequently, between 1980 and 2000 only twenty-eight per cent of the required additional crop production will be derived from area expansion and seventy-two will have to come from yield increases and more intensive cropping. This, in turn, will put more than proportional demands on water, fertilizer, pesticides, energy and managerial skills.

These figures and trends may illustrate that the case to reduce postharvest losses, or preserving what has been produced with increasing efforts and costs, has became much stranger and will became more so in the future.

Attention to the concept of post-harvest food loss reduction as a significant means to increase food availability was drawn by the World Food Conference held in Rome in 1974. The 7th Special Session of the U.N. General Assembly in 1975 passed a Resolution calling for a 50 per cent reduction of post-harvest losses by 1985. This recognition of the potential value of post-harvest loss reduction has found practical expression in the continuing debate among a number of International Organizations and Institutions. As a result several initiatives at the international level have been taken with the special aim of making a concerted effort to reduce unnecessary losses at all the post-harvest stages of the food production process. In FAO, after consultation with its Governing bodies, food foes prevention became a priority area and an Action Programme became operational in early 1978. The United Nations

Environment Programme supports and promotes ecologically sound and sustainable development. Food loss reduction is an important activity in which UNEP has an interest, because this will increase the resource base as well as enhance the environment.

The FAO Action Programme so far has focused only on staple foods with particular emphasis on food grains, in order to make the greatest possible impact with limited resources. This should, however, not detract from other important foods where losses are known to exist in the post-harvest system. It was felt that a stage had been reached where a second large group of commodities, the perishable crops, which for reasons of their importance to human nutrition, their magnitude of production and their vulnerability to oilage have common characteristics and problems, should be investigated further.

To this end the United Nations Environment Programme and FAO organized an Expert Consultation on the subject. Preceding this meeting three Consultants with different background and geographical expertise visited major Centres of activities in this field and prepared three working documents.

For the Consultation itself another 15 Specialists from the various post-harvest disciplines and with a broad geographical coverage were invited. me 4-day meeting took place in May 1980 at FAO Headquarters in Rome. m e complete list of people attending, or having assisted in the preparation of this Consultation, is given on Pages xvii-xix. m e major task of the

Meeting was to discuss and complement the information prepared by the Consultants on the present status of the post-harvest food losses occurring in perishable crops and the opportunities and means to reduce these losses.

The conclusions reached by the meeting were:

1. Post-harvest loss in perishable crops constitutes an important issue that needs increased and continuing attention at national, regional and international levels by FAO, Governments and other concerned organizations because it requires fewer resources and applies less pressure to the environment in maintaining the quantity and quality of food than through increased production to offset post-harvest losses.
2. Traditional effective methods for preventing and reducing Postharvest losses need to be identified and exploited; this includes maintenance of continuous supply, storage for restricted periods, and transformation to durable products.
   Some valuable traditional technologies for food Preservation are in danger of becoming lost because they are being superseded by more sophisticated methods

of doubtful long-term value. Modern and technology-intensive methods should be applied appropriately according to prevailing conditions including cultural factors. Efficient and proper management of such technologies is as important as the types of equipment and facilities selected.

3. The entire food production and supply system needs to be addressed as a whole, because of the interrelationship between and amongst the different components of the system. A substantial amount of post-harvest losses have their origin in the pre-harvest stage, for example, genetic factors, infections, pest infestations, environmental factors and cultural practices during the production stage.
4. Most post-harvest losses in horticultural produce result from infection by fungi and bacteria (pre- or post-harvest), and from inherent physiological activity although insects, rodents, nematodes, and occasionally birds may cause significant losses under certain conditions Insects can disseminate some plant pathogens and also provide wounds as points of entry for microorganisms. In general, pre-harvest application of fungicides is more important in the control of post-harvest problems of fruit and vegetable crops than in root crops. Infections established prior to harvest are extremely difficult to control after harvest. Sanitation in all post-harvest operations is a key factor in eliminating sources of infection and reducing levels of contamination.
5. A distinction needs to be made between post-harvest losses incurred as a result

of inadequate production planning (surpluses), speculation or excessive quality grading (mostly occurring in developed countries) and losses incurred due to lack of know-how, technology, or infrastructure (mostly occurring in developing countries) because the reduction of the different types of losses requires different approaches.

6. All food losses occur a particular socio-cultural and economic environment. Techniques to reduce food losses require cultural and economic adaptations. While physical aspects are clearly mast important, the subject must be considered within the wider framework of an approach whereby human as well as physical factors are taken into account.
7. Since losses are commodity and location specific, there is a need for specific activities, e.g., workshops, pilot projects, training courses, marketing studies, etc., in each country or region to address the priority problems of that area. Particular attention needs to be given to locally important commodities in each area. International assistance to developing countries in the field of post-harvest loss prevention needs to be geared to improve capability of the developing country to handle these programmes.
8. There is a need for an international information network to promote exchange of information on prevention of losses in perishable crops. Links between existing national and international institutions need to be strengthened. There is a need

for a periodically annotated bibliography covering studies on post-harvest food losses in perishable commodities and for a world-wide directory of post-harvest technology centres and personnel.

9. There is a need to establish exchange programmes (technical co-operation between developing countries) between countries of similar needs and interests but which have an apparent difference in advancement in post-harvest handling systems.
10. Proper management of temperature and humidity of root crops and certain other perishables in the initial post-harvest period is essential to good curing which improves wound healing and minimizes infection by microorganisms.
11. Refrigeration is an important tool in the temperature management of perishables. It is desirable to remove field heat as soon as possible after harvest and to store at that temperature which will give the longest shelf-life. However, refrigeration technology should not be adopted as a panacea for all problems connected with deterioration associated with high temperature. Its introduction needs careful study, due consideration of its appropriateness and of the supporting infrastructure available within the post-harvest system, as well as the relation of refrigerated storage capacity to the collection, pre-cooling, transportation, marketing and distribution system. Special care may be needed when a complete "cold chain" cannot be maintained within this system, and where refrigerated

storage would form an additional operation in post-harvest handling.

12. A key factor influencing the magnitude of post-harvest losses is the severity of mechanical damage to the crop during harvest and subsequent handling because it provides pathways for invasion by fungi and bacteria.
13. Intervention activities need to be particularly directed to those individuals involved in handling the commodity throughout the post-harvest system and consideration needs to be given to their level of understanding.

    Any innovation to reduce post-harvest losses introduced to the private sector should be accompanied by a clear financial incentive.

    In exploring new technologies, due attention needs to be paid to ensuring their acceptance by producers and market operatives, particularly if the adoption of a new technology would mean the displacement of labour or a particular class of labour (e.g., women).
14. In view of the very short post-harvest storage life of cassava, research work on fresh cassava should continue but priority should be placed on research related to its transformation into stable products. Gari and cassava flour are examples of such transformed products.

    In the case of yam, parallel work is necessary on the fresh product as well as on the transformed forms but with major emphasis on storage of the fresh product.

    Processing or transformation of perishable crops could form a rural agro-industrial operation and assist in retaining the added value of processing in rural areas.

15. Additional research effort is needed in some areas where basic knowledge is inadequate, for example, chilling damage to tropical fruits and vegetables, the causes of deterioration of cassava, dormancy of yams, post-harvest physiology and pathology of roots and tubers, genetic improvement techniques, biological nest control, the effect on storability of chemicals and cultural practices used during the growing period. This will require the training and employment of specialized post-harvest technologists concerned with perishable crops.
16. Based on presently available information, the use of post-harvest chemicals has not shown toxicological problems. But when they are used there is need to ensure that the dosages and residues conform with internationally recommended maximum levels, e.g., of the FAO/WHO Codex Alimentarius Commission.
17. The preparation of outlines on when, where and why losses occur in selected perishable food crops is desirable but it is recognized that preparing a full methodology for loss assessment on perishables of plant origin is a complicated and time-consuming task. Diagnostic studies using an interdisciplinary approach are needed to properly identify the area where losses occur within the post-harvest system of perishable food crops.
18. There are some important issues that lie outside the immediate scope of this

Expert Consultation that warrant further attention, for example, preventing the possible carryover of excessive field pesticides into the postharvest system, agricultural chemicals that have been banned in the country of origin but nevertheless still exported, grades and quality standards for horticultural products, reduction of losses in household food preparation, and increased consideration of environmental aspects in post-harvest intervention activities related to cereals and other foods.

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FAO Headquarters, Rome

6-9 May 1980

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II. Post-harvest losses in perishable crops

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1. Introduction

1.1 The problem

"There is a war going on that began millions of years ago. Although the many generations of soldiers have not changed a great deal in appearance during this time, the tactics and weapons have grown more sophisticated. Each army has won a share of the battles, but the consummate victory has eluded both. Neither side can afford to give up' for nothing less than the sustenance of life is at stake. The war I refer to is, of course, the war between humankind and certain species of insects, weeds, pathogens, nematodes, rodents, and other peats that daily compete for our crops, gnaw at our dwellings, infest our domestic animals, or destroy our health" (Kuhr, 1979).

The above statement vividly describes the problem mankind has always had to preserve 0a food supply after he has produced it. The loss of foods in the post-harvest system is not new; it has always boon a problem for mankind. In these days of rapidly enlarging populations in the poorest countries whore food is already short, there is an increasing urgency to do a better job of conserving mankind 'e food supply in order to alleviate hunger and malnutrition. Some far-sighted individuals have been drawing attention to the problem of post-harvest losses for many years.

The United Nations General Assembly resolution of September 1975 focused world-wide attention on the problem of post-harvest food losses and called for concerted action to reduce these losses in the following words: "The further reduction of post-harvest food losses in developing countries should be undertaken as a matter of priority' with a view to reaching at least a 50% reduction by 1985. All countries and competent international organizations should co-operate financially and technically in the effort to achieve this objective".

As a result of this resolution a number of national and international donor agencies expanded existing programmes and initiated new programmes that were directed to the problem of reducing post-harvest losses. Most of those activities have been directed toward reducing losses in cereal grains, oilseeds and grain legumes.

A report prepared by the United States National Academy of Science in 1978 on the problem of post-harvest food loaves in developing countries pointed out the need for giving consideration to losses in food products other then the cereals, particularly roots and tubers, fruits and vegetables. Largely as a result of this report, the donor organizations are beginning to consider intervention programmes that can reduce losses in horticultural crops.

Post-harvest losses of fruit a and vegetables are more serious in devoloping oountries then those in well developed oountries. An additional constraint to improving this situation is that in moat developing countries the number of scientists concerned with post-harvest food losses is significantly lower than those involved in production research. In the early days of horticulture in wolf developed countries, heavy losses occurred in much the same manner as they do today in developing countries. Increasing industrialization in technologically advanced nations gradually brought about improvements in crop handling. Elaborate harvesting equipment replaced the crude harvesting tools. Collection centres were strategically established in major producing areas. Containers were remodelled to add more protection to the produce. Commercial storage plants were installed and grade standards adopted. Engineers and economists became more and more aware of raw material behaviour. Concomitant advances in Refrigeration Technology in the developed countries have made possible establishment of cold chains for the entire post-harvest and handling operations. At the institutional level post-harvest research was initiated. Pilot packing houses were installed, coupled with the development of intensive training programmes. the improvement of product quality and reduction in post-harvest losses became the main concern of producers, middlemen, marketing specialists and consumers. Today, enormous volumes of quality horticultural crops produced in technologically advanced countries are made available to millions of people through improved post-harvest handling. Thus, historically and by necessity, post-harvest technology is part of the normal development processes in agriculture.

These handling procedures are not fully recognized in less developed countries. Here agriculture may be characterized as disjointed. Production is not linked with marketing. With perishable crops like fruits and vegetables, storage, packaging, transport and handling technologies are practically non-oxiatant, Hence, considerable amount a of, produce are loaf. Thus, as more fresh fruits and vegatables are needed to supply the growing population in less developed countries, as more produce is transported to non-producing areas, and as more commodities are stored longer to obtain a year-round supply, post-harvest lose prevention technology measures become paramount. It is distressing to note that so much time is being devoted to the culture of the plant, so much money spent on irrigation, fertilization and crop protection measures only to be wasted about a week after harvest. It is, therefore, important that post-harvest procedures be given as much attention as production practices the stages from planting until the product a roach the consuming public must be a mutual undertaking between the growers and those who will handle the products after harvest.

Fruit a and vegetables, root a and tubers (horticultural crops) are quite different in nature from cereal grains and oilseeds the differences are summarized in Table 1. The causes of spoilage, the rate at which spoilage occurs, the degree of spoilage, and the actions needed to reduce spoilage are substantially different than for the cereals. Because of these differences it is necessary to design a different set of intervention programmes to reduce post-harvest losses in horticultural products,

Table 1 Comparison of Horiticultural Crops

Cereals and Oilseeds	**Horticultural Crops**
Low moisture content, typically 10% to 20%	High moisture contort, typically 70% to 95%
Small unit size, typically less than 1 gram	Large unit size, typically 5 e to 5 kg
Very low respiration rate with very small generation of heat. Heat production is typically 0.05 megajoule/ton/day for dry grain	High to very high respiration rate. Heat production is typically 0.5 to 10 megajoule/ton/day at 0C to 5 to 70 megajoule/ton/day at 20C
Hard texture	Soft texture, easily bruised
Stable, natural shelf life is one to several years	Periahable, natural shelf life is a few days to several months

Losses usually caused by molds, insects and rodents sprouting, and bruising	Losses usually caused by rotting (bacteria, fungi), senescence
Losses in LDCs usually 10% to 20%	Losses in LDCs usually 15% to 50%

In the warm humid tropics, fresh fruit a and vegetables have an extremely, low level of natural protection against the climate peat a and bio-chemical and physiological deterioration. It is also in the warm humid tropics that human diseases are moat numerous and widespread and consequently where the need for the nutritional value of fresh fruits and vegetables la moat essential. On the other hand, dried grains and legumes, and to a certain extent, root crops (yams), have a fair degree of natural protection against the various deteriorative elements, even though considerable post-harvest losses do occur.

1.2 Importance of perishable crops

Production data for the root crops are given in Table 2 (Appendix 1 - Page 1). In terms of importance as assessed by volume of production within the tropics these are cassava, potatoes, yams, sweet potatoes, taro and others. It is estimated that some 174 million tone of roots and tubers are produced annually of which cassava constitutes about 60%. Cassava is almost entirely produced and consumed in

developing countries although in recent years there has developed a substantial trade in dehydrated cassava chips which are exported from developing countries to European countries as a low-goat animal feed ingredient, The European Economic Community imported 2.3 million tons of dried cassava chips in 1975. Next in volume of production are potatoes, yams and sweet potatoes. These make contributions respectively about 14, 11 and 10%. At the end of the scale taro contributes a lowly 2.2% while miscellaneous tubers account for 2.5%.

Table 3 (Appendix 1 - Page 2) lists the major vegetables and Table 4 (Appendix 1 - Page 3) lists the major fruits that were produced in developed countries, developing countries, and centrally planned economies in 1973. The total world production of roots tubers, vegetables and fruits is enormous and approaches that of the total production of the staple cereal grains as can be seen from the following figure e

Commodity	**Production 1978 (million tone)**		**% of Cereal Production**	
	World	**Developing Countries**	**World**	**Developing Countries**
Cereals	1,580.8	730.6	100%	100%
Roots & Tubers	522.9	290.1	33.1	39.7

Vegetables & Melons	327.2	189.2	20.7	25.9
Fruits	261.9	141.6	16.6	19.4
Total horticultural production	1,112.0	620.9	70.4	85.0

(Data from FAO Production Yearbook 1978)

The total annual production of horticultural crops in developing countries is 620 million tone which is 85% of the cereal production in these countries. This surpasses the relative world average whore horticultural crop production is only 70% of the cereal production. These high production figures indicate the important role that horticultural crops play in the economy of developing countries although it must be remembered that these crops are far higher in water content than are the cereals.

The ten leading horticultural crops in developing countries in forma of total production are the following

Commodity	**1978 Production (million tons)**

Cassava	110.5
Banana	35.1
Potato	29. 5
Citrus fruits	23 9
Plantain	20.4
Yam	20
Sweet potato	16.9
Tomato	14.5
Mango	13 5
Grapes	11.3

Horticultural crops are essential for a nutritionally balanced diet. Fruits and vegetables are the major source of vitamins A and C, a good source of calcium and iron, and they supply part of the requirements for a number of other minor nutrients. Roots, tubers, bananas and plantains are important sources of calories and also supply a number of minor nutrients, and some protein.

In addition, horticultural crops add variety, enjoyment and a sence of satisfaction with

the diet because of their appealing colours, flavours and textures. For example, it has been said that although onions and garlic are not rich in nutrients, they make a vegetarian diet acceptable because of the savoury flavour they impart to the monotonous starchy diet in a developing country. It is no accident that onions rank third, and garlic ranks tenth in volume of vegetable production in developing countries. (Table 3)

On all of these counts- economics, nutrition, acceptability- horticultural crops play a major role in developing countries, amply justifying the contortion that something should be done to reduce the high losses that presently occur in these commodities.

1.3 Definition of terms

Since the ramifications of food and the food supply spread right through society it is necessary to define exactly what is moans by the term "post-harvest food loss" if we are going to have a manageable problem with known boundaries. The working definition given below is based on that developed by Bourne (1977) and modified by the U.S. National Academy of Sciences (1978) and Harris and Lindblad (1978). For the sake of convenience the definition is divided into three parts.

"POST-HARVEST" bogies at the moment of separation of the edible commodity from

the plant that produced it by a deliberate human act with the intention of starting it on its way to the table. The post-harvest period ends when the food comes into the possession of the final consumer.

"FOOD" moans weight of whole some edible material that would normally be consumed by humans, measured on a moisture-free bests. Inedible portions such as skins, stalks, leaves, and seeds are not food. Potential foods (e.g., leaf protein) are not foods; they do not become food until they are accepted and consumed by large populations. Feed (intended for consumption by animals) is not food.

The method of measuring the quantity of food in the post-harvest chain should be on the basis of weight expressed on a moisture-free basis. There will be times when information on losses in nutritional unite and economic losses will also be needed but these should not be the prime means of measuring post-harvest food losses.

"LOSS" means any change in the availability, edibility, wholesomeness or quality of the food that prevents it from being consumed by people.

1.4 Causes of losses

There are so many causes for losses in the post-harvest food chain that it helps to

classify them into 2 groups and a numb or of sub-groups

A. PRIMARY CAUSES OF LOSS are those causes that directly affect the food. They may be classified into the following groups

a. **Biological. Consumption of food by rodents, birds, monkeys and other large animals causes direct disappearance of food. Sometimes the level of contamination of food by the excreta, hair and feathers of animals and birds is so high that the food is condemned for human consumption. Insects cause both weight losses through consumption of the food and quality losses because of their frass, webbing, excreta, heating, and unpleasant odours that they can impart to food.**
b. **Microbiological. Damage to stored foods by fungi and bacteria. Micro-organisms usually directly consume small amount e of the food but they damage the food to the point that it becomes unaceptable because of rotting or other defects. Toxic substances elaborated by molds (known as mycotoxins), cause some food to be condemned and hence lost. The beat known of the mycotoxins is aflatoxin (a liver carcinogen), which is produced by the mold Aspergillus flavus. Another mycotoxin which is found in some processed apple and pear products is patulin, which is formed in the apple by rotting organisms such as Penicillium expansum which infect fresh apples before they are processed.**

c. **Chemical. Many of the chemical constituents naturally present in stored foods spontaneously react causing lose of colour, flavour, texture and nutritional value. An example is the Maillard relation' that causes browning and dicolouration in dried fruits and other product a There can also be accidental or deliberate contamination of food with harmful chemicals such as pesticides or obnoxious chemicals ouch as lubricating oil**
d. **Biochemical reactions. A number of enzyme-activated reactions can occur in foods in storage giving rise to oft-flavours, discolouration and softening. One example of this problem is the unpleasant flavours that develop in frozen vegetables that have not been blanched to inactivate these enzymes before freezing.**
e. **Mechanical. Bruising, cutting' excessive pooling or trimming of horticultural products are causes of loss.**
f. **Physical. Excessive or insufficient heat or cold can spoil foods. Improper atmosphere in closely confined storage at times causes losses.**
g. **Physiological. Natural respiratory losses which occur in all living organisms account for a significant level of weight lose and' moreover, the process generates heat. Changes which occur during ripening, senescence, including wilting, and termination of dormancy (e.g., sprouting) may increase the susceptibility of the commodity to mechanical damage or infection by pathogens. A reduction in nutritional level and consumer acceptance may also arise with these changes.**

Production of ethylene results in premature ripening of certain crops.

h. **Psychological. Human aversion, such as "I don't fancy eating that today". In some cases food will not be eaten because of religious taboos.**

Microbiological, mechanical and physiological factors cause moat of the losses in perishable crops.

B. SECONDARY CAUSES OF LOSS are those that load to conditions that encourage a primary cause of loss. They are usually the result of inadequate or non-assistant capital expenditures, technology and quality control. Some examples are:

a. **Inadequate harvesting, packaging and handling skills.**
b. **Lack of adequate containers for the transport and handling of perishables.**
c. **Storage facilities inadequate to protect the food.**
d. **Transportation inadequate to move the food to market before it spoils.**
e. **Inadequate refrigerated storage.**
f. **Inadequate drying equipment or poor drying season.**
g. **traditional processing and marketing systems can be responsible for high losses.**
h. **Legal standards can affect the retention or rejection of food for human use by being too lax or unduly strict.**
i. **Conscientious, knowledgeable management is essential for maintaining tool in**

good condition during marketing and storage.

j. Bumper crops can overload the post-harvest handling system or exceed the consumption need and cause excessive wastage.

1.5 Sites of losses

Losses may occur anywhere from the point where the food has been harvested or gathered up to the point of consumption. For the sake of convenience the losses can be broken down into the following sub-headings:

a. Harvest. The separation of the commodity from the plant that produced it. In the case of roots, tubers and bulbs the commodity is lifted out of the soil.
b. Preparation. The preliminary separation or extraction of the edible from the non-edible portion, e.g., the peeling of fruits and vegetables.
c. Preservation is the prevention of lose and spoilage of foods. For example, the sun-drying of fruit, the use of refrigeration and the use of funficides to inhibit mold growth in fruits.
d. Processing is the conversion of edible food into another form more acceptable or more convenient to the consumer, for example, the manufacture of fruit juice and the canning of fruits and vegetables.
e. Storage is the holding of foods until consumption. Most storage is common

storage (ambient temperature) but there are extensive storage capacities that can hold food under refrigerated or controlled atmosphere conditions.

f. Transportation. All forms of transportation are used to convey foods from the point of production to the ultimate point of consumption.

Post-harvest losses in fresh root/tuber crops have their origin in mechanical damage, physiological processes, infection by decay organisms and, occasionally, pest infestation. The losses caused by these processes may occur during all stages of the food supply system from crop maturity, through harvesting, transportation and storage. The degree of lose associated with these factors is determined by the plant material involved, the prevailing environmental conditions and management of the food supply system. The major causes of lose in roots and tubers and the sites where they occur are summarized below:

1.6 Magnitude of losses

Reliable statistics on losses are few. It is possible to find individual cases with losses ranging from 0% to 100%. The extent of losses is highly variable depending on a number of conditions. Stable foods such as cereal grains can be stored in good condition for several years, whereas perishable foods such as fruit a and vegetables, spoil quickly unless given special treatment such as canning and freezing. The longer

the time the food is stored the more opportunity there is for losses of all kinds to occur. Perishable crops generally suffer from higher losses than the cereals.

A number of figures for the extent of loss is quoted in scientific literature and by the communications media, but much of this information is unreliable because the amount of loss has been estimated and has not been obtained by actual measurements. There is often the temptation to cite "worst case" figures to dramatize the problem.

Another problem is that even some of the figures that have been obtained by careful measurements are manipulated for various reasons. In some cases there is the temptation to exaggerate the figures of loss, particularly if there is a prospect that high figures of loss will prompt aid from donors. In other cases there is a temptation to minimize loss figures in order to prevent the embarrassment of acknowledging the magnitude of losses, or for political, financial or trading reasons.

Another precaution that needs to be taken in assessing overall losses is to ensure that the arithmetic of calculating loss figures is correct. The extent of losses can be unwittingly exaggerated unless the arithmetical calculations are correctly performed. Some examples of misleading arithmetical calculations are discussed by Bourne (1977).

The pattern of losses varies widely from country to country. There is a marked contrast between the site of major losses in developed countries and developing countries. In a typical developed country losses may be fairly high during harvesting because the agricultural machinery that is used to harvest the crops leaves some of the commodity in the field and mechanically damages some of it. Considerable quantities of foods a may be discarded at the point of harvest because they are of the wrong size, shape or colour. These are planned losses. In developing countries harvest losses are usually lower because most of the crop is hand picked. The amount of material rejected in developing countries is less because the expectation of quality and uniformity is generally lower than for developed countries.

In developed countries losses are generally small during processing, storage and handling because of the efficiency of the equipment, good quality storage facilities, and close control of critical variables by a highly knowledgeable cadre of managers. In contrast, in developing countries losses in processing, storage and handling tend to be rather high because of poor facilities and frequently inadequate knowledge of methods to care for the food properly.

Table 5 (Appendix 1, Page 4) lists some estimates of losses of selected commodities in developing countries. The tragedy of these enormous losses in developing countries is not only that this is a severe economic loss in regions that are struggling to escape

from poverty but also a major loss of important nutrients to populations who are malnourished.

Pantastico (1977) pointed out that post-harvest losses in developing countries often exceed production losses and cites as an example the following figures for losses is the Philippines:

Crop	**Production (m. tons)**	**Production Value ($)**	**Percentage Loss**	**Loss Value ($)**
Fruits	2,763,443	403,909,220	28.1	113,498,490
Vegetables	1, 640, 541	248, 564, 310	42. 2	104,894,130
Total	4,403,984	652,473,530	_	218,392,620

1.7 Loss assessment

There appears to be no established generally accepted methodology for determining post-production lose in root/tuber crops. The National Academy of Sciences (USA) publication (1978) on post-harvest losses makes the following differentiation between assessment, measurement and estimation of losses:

<u>Assessment</u> is a rough quantitative approximation of food loss or the characterization of the relative points of lose in a particular food supply system. This approach implies a measure of subjectivity resulting from a lack of sufficient information.

<u>Measurement</u> on the other hand is a more precise quantitative observation with less subjectivity. With measurements there is a high expectation of reproducibility without observer bias.

<u>Estimation</u> is the interpretation of a number of scientific measurements. Here the process of interpretation depends on the experience and judgement of the observer.

At whatever level of precision post-harvest lose is determined the value will be specific in time and for location. This is due to the fact that lose is a function of the condition of the material, the prevailing environment, the nature and intensity of bio-degenerating organisms and the crop material management. None of these are constant. They are all dynamic factors liable to continuous change. As a consequence, crop loss, however determined will always be variable. This is illustrated by yam storage. Some cultivars of the <u>rotundata/cayenensis/discorea</u> species remain dormant for about 3 months, during which period storage loss is low. When placed in the traditional yam barn the keeping characteristics of these yams are good. It is generally believed that little improvement can be achieved without radical change in storage

technology. However where the tubers are infected by nematodes the storage potential is much reduced and high losses occur.

It would be useful to have a standard method for assessing losses for each type of commodity but this is a difficult task due to crop diversity, inherent perishability and the complexity of the marketing and distribution channels.

1.8 Effects of the environment on food losses

The environmental conditions under which foods are stored and processed can have a major effect on the keeping quality of the foods and the amount that is lost. The major environmental influences on the keeping quality of foods are the following:

Temperature. In general, the higher the temperature the shorter the storage life of horticultural products and the greater the amount of lose within a given time, as most factors that destroy the produce or lower its quality occur at a faster rate as the temperature increases. This statement applies to the rate of growth of spoilage microorganisms, the rate of indigenous physiological change and physical processes such as water loss and wilting, Figure 1 show. changes in the quality of lettuce and asparagus during storage at different temperatures, Lettuce stored at 25 C becomes unsaleable within 7 days, while lettuce stored at 10 C will reach the unsaleable

condition in approximately 18 days and lettuce stored at 0C requires 35 days to reach the point of being unsaleable. For asparagus the loss of quality occurs at a more rapid rate than lettuce, reaching the point of being unsaleable in 3 days when stored at 25C. Figure 1 is a clear demonstration of the rationale for the extensive cold storage facilities that are used for storing horticultural produce.

Humidity. There is movement of water vapour between a food and its surrounding atmosphere in the direction towards equilibrium water activity in the food and the atmosphere, A moist food will give up moisture to the air while a dry food will Absorb moisture from the air. Fresh horticultural products have a high moisture content and need to be stored under conditions of high relative humidity in order to prevent moisture loss and wilting, exceptions to this being onions and garlic. Dried or dehydrated products need to be stored under conditions of low relative humidity in order to avoid absorbing moisture to the point where mold growth occurs.

Figure 1 Loss of quality in fresh lettuce and asparagus stored at various temperatures (from Lutz and Hardenburg 1968)

Solar Radiation. The solar radiation that falls upon foods held in direct sunlight increases the temperature above the ambient temperature. The amount of increase in temperature depends on the intensity of the radiation, the size and shape of the food'

and the duration of exposure to the direct rays of the sun. The intensity of solar radiation depends upon latitude, altitude, season of the year, time of day, and degree of cloud cover. Under clear skies it is most intense when the sun is most directly overhead. Hence the intensity of radiation is greater in tropical zones than in temperate zones. As discussed above, a high temperature is deleterious to food quality and increases wastage. It is ironic to note that, in the temperate climates where the intensity of solar radiation is moderate, almost all food is kept inside under cover whereas in tropical climates, where solar radiation is much higher, considerable quantities of food can often be found in the direct rays of the sun deteriorating in quality at a rapid rate.

<u>Altitude</u>. Within a given latitude the prevailing temperature is dependent upon the elevation when other factors are equal. There is on the average a drop in temperature of 6.5C for each Km increase in elevation above sea level. Storing food at high altitudes will therefore tend to increase the storage life and decrease the losses in food provided it is kept out of the direct rays of the sun.

<u>Atmosphere</u>. The normal atmosphere contains by volume, approximately 78% nitrogen, 21% oxygen, 1% argon, 0.03% carbon dioxide' various amounts of water vapour and traces of inert gases. Modifying the atmosphere can improve the shelf life and reduce wastage of certain foods.

One type of controlled atmosphere storage (CA) is refrigerated storage in which the level of oxygen is reduced to about 3% with the carbon dioxide content being raised to 1 to 5%, depending on the commodity. This CA storage may double the storage life over that of regular cold storage for certain varieties of apples and pears by slowing down the natural rate of respiration.

Many fruits, the "climacteric fruits", generate ethylene gas during ripening and the presence of this gas Accelerates the rate of ripening. If the ethylene is removed from the atmosphere surrounding these fruits as it is generated, their storage life may be extended. Experiments have shown that placing such fruits in a fairly gas-tight container with potassium permanganate, which absorbs ethylene gas, can substantially extend the storage life even at ambient temperature.

"Modified atmosphere storage" is another type of controlled atmosphere storage. This term denotes storage of horticultural products in a beneficial atmosphere other than air that is not under as close regulation as in CA storage. Modified atmosphere storage can be obtained in boxes of pears, apples, and cherries that are lined with polyethylene film which acts as a barrier to the escape of carbon dioxide and the ingress of oxygen. Another method of obtaining a modified atmosphere storage is by the addition of dry ice which increases the carbon dioxide in the atmosphere to some extent,

<u>Time</u>. The longer the time the food is stored the greater is the deterioration in quality an' the greater is the chance of damage and loss. Hence storage time is a critical factor in lose of foods, especially those that have a short natural shelf life. The time involved from harvest to consumption of perishable commodities is much shorter than that from planting to harvest. While production time could take about several years for fruit trees, and generally about three to four months for vegetables, the duration of post-harvest handling could be as abort as one day to a few weeks. Any improvement in post-harvest handling treatments would therefore involve less risk and would be more economical than improvements in production.

<u>Biological pressures</u>. Bacteria and fungi are always present in the atmosphere to contaminate food and cause spoilage should conditions favour their growth. However, it should be emphasized that the contamination or inoculation process with bacteria and fungi occurs to an equal extent during the harvesting process. Soil organisms as well as foliage pathogens can be introduced. Bacteria that cause disease in plants are not usually introduced from the air par so except in aerosols. Micro-organisms can multiply very rapidly whenever conditions are favourable for growth. The only foods that are free from micro-organisms are those that have been thermally processed, such as canned goods.

A similar situation occurs with insects. Insects are in the field and can accompany

foods as they are brought from the field into storage. Most of the stored products' insects can increase is number by a factor of 10 to 50 times par month under favourable conditions. Stored food insects are ubiquitous, hiding in storage facilities and moving with stored foods when they are moved. Consequently we can assume that foods can become infested with insect pests at any time unless special precautions are taken.

Rodents and sometimes birds can exert biological pressures similar to those of insects and micro-organisms. The great capacity of living organisms for multiplication by geometric increase generates heavy biological pressures upon stored foods.

1.9 Environmental considerations

A number of people who have accepted the idea, of the need for better conservation of food wonder why the United Nations Environment Programme (UNEP) is interested in food losses and control of food losses. There are substantial reasons for UNEP's interest in this area and these will now be discussed.

UNEP is interested in promoting the health and well-being of both people ea. the environment, as well as sustainable development. Reducing food losses should improve nutritional status and human health' especially in those countries here a

large proportion of the population is inadequately fed. Decreasing food losses offers an opportunity to reduce the pressure on the land and still deliver the some quantity of food to the table, thus reducing to some extent environmental damage caused by agricultural practices. Hence, UNEP encourages the conservation of food because of its positive environmental effects.

UNEP is interested in efficient and non-wasteful utilization of resources. Although it is difficult to obtain firm figures, it is generally conceded that considerably less energy and other inputs are required to conserve food than to produce an equal quantity of food. For example, it has been estimated that the total energy cost of good grain storage practice is about one percent of the energy cost of producing that grain. Hence' UNEP encourages good conservation practice because of its more efficient use of energy and other inputs.

UNEP's activities include reviewing proposed new initiatives to determine the environmental impact of these initiatives before they are put into effect and to help select from among competing initiatives those that are most desirable from the environment standpoint' to encourage their use, and to do this in the early planning stages of the project. Hence, UNEP is interested in what methods are proposed to be used to reduce post-harvest food losses

The next section of this report lists thirteen methods that are used to reduce losses in horticultural products. The first twelve methods have little adverse effect on health' safety or the environment and are recommended for use on environmental grounds. Of course, it is recognized that additional criteria will be used to make the final selection of methods to be actively promoted.

The thirteenth method of control is by use of post-harvest chemicals which is of great interest to UNEP because of the justifiable concern about the consequences of man-made chemicals that are used and discharged into the environment. The question of post-harvest chemicals is reviewed and the conclusion drawn that they probably cause little harm to human health and little damage to the environment when they are correctly used, but shore may be grave risks to both if they are misused. This leads to the conclusion that postharvest chemicals should only be used in those locations whore shore is adequate training in their proper use backed up by adequate machinery to enforce proper use. The environmental approach in this case is not to oppose the use of chemicals but to point out the need for using them properly and carefully.

The finding that most of the thirteen methods for reducing losses do not aggravate the environment or harm human health is encouraging. It means that intervention programmes can be planned with the knowledge that they cause much positive good

and little harm. It is worth the effort of this exercise to establish this finding.

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2. Factors related to the post-harvest system

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2.1 Technologies

The major technologies for reducing losses in horticultural products are listed below followed by a statement of probable environmental effects from the named procedure.

2.1.1 Gentle handling

Because of their soft texture All horticultural products should be handled gently to minimize bruising and breaking of the skin. Bruising renders the product unsaleable to most people although it usually has minor effect upon the nutritional value. The skin of horticultural products is an effective barrier to most of the opportunistic bacteria and fungi that cause rotting of the tissues. Breaking of the skin also stimulates physiological deterioration and dehydration. Careful digging and movement of roots and tubers significantly reduces postharvest losses. Careful handling of fruits and vegetables to minimize bruising and breaking of the skin likewise is a well-known method of reducing postharvest losses as is the provision of adequate shipping containers to protect the produce from bruising' and puncturing of the skin. Reducing the number of times the commodity is handled reduces the extent of mechanical damage.

Environmental effects. There are no adverse environmental effects to this technology. Thus careful digging, harvesting and handling, and appropriate packaging end transportation are environmentally count methods for reducing losses. Also, since damaged skin is the major entry point for fungal infections, some of which produce mycotoxins, gentle handling can improve the safety of the produce.

2.1.2 Temperature control

It is well known that cooling horticultural produce extends storage life by reducing the rate of physiological change and retarding the growth of spoilage fungi and bacteria. Cooling is the foundation of quality protection (see Figure 1 Page 12). There are several ways of reducing the storage temperature of horticultural crops:

Cooling technique	Environmental effect
a) Keep out of direct rays of sun.	This is an easy low-cost method with minimal effect on the environment. Almost all societies can provide shade at low economic or environmental cost.
b) Use natural cooling, e.g., harvest during the cool early morning hours, open stores for ventilation during the cool of the night, utilize the cool temperature of high altitude or a natural source of cold water when available.	Minimal environmental costs.
c) Evaporative cooling obtained by	Minimal environmental and economic costs.

drawing dry air over a moist surface.	Restricted to areas of low humidity and low-cost water.
d) Mechanical refrigeration.	Energy coats and economic costs are relatively high but give most positive control of temperature. Generated heat is dumped into the environment.
e) Cool promptly after harvest.	High energy coat.

Since every degree reduction from ambient temperature increases storage life' every form of cooling is beneficial even if it is not optimum cooling, i.e.' simple low-cost cooling or refreshing the product is better than no cooling at all.

The optimum storage temperature for most temperate horticultural crops is close to 0C. If they are cooled slightly below this temperature they freeze and suffer from "freezing injury" and spoil quickly. Most tropical horticulture crops however can be injured oven at temperatures above freezing point. This is called "chilling injury" and causes rapid deterioration in quality. The optimum storage temperature for most tropical horticulture crops is between 7 to 10C; for yams and bananas it is about 15C.

Although refrigerated storage is not often appropriate for some commodities such as

yams, it should be considered an important element in the temperature management of a wide range of perishable crops because it gives the most positive and direct control of temperature. The popularity of refrigerated storage in some countries has suffered setbacks duo to occasional poor design of units and bad management. This has sometimes resulted in the impression that refrigerated storage is costly and unsuited for use in developing countries which is not necessary the case. Good cosign and proper management are essential ingredients in considering the introduction of refrigeration techniques as are the supporting infrastructures available within the post-harvest system. When studied on a case-by-case basis it seems likely that refrigerated storage will continue to find many successful applications to the needs of developing countries.

There are tour basic principles which must be correctly applied for successful refrigeration of perishable crops:

i. **Select only healthy products. Refrigeration does not destroy pathogens responsible for product deterioration but only slows their activity; it does not improve product quality but only maintains it. A damaged product will deteriorate more quickly than a healthy one even in refrigerated storage, hence it is pointless to submit poor quality produce to refrigeration. In addition storage under refrigeration increases the coat to the product. The storage therefore of**

low grade diseased produce frequently cannot achieve an adequate economic return.

ii. **Timely cooling: Since refrigeration slows the development of micro-organisms and physiological changes responsible for deterioration of perishable crops, it is obvious that cooling should be applied as soon as possible after harvest. The technique of pre-cooling was developed to fill this need by cooling produce soon after harvesting down to a temperature appropriate to that product.**

iii. **Adhere closely to optimal conditions for temperature and relative humidity. It is well known that refrigeration provides maximum storage life it these two parameters are correctly adhered to. This fact is especially important for tropical fruits and vegetables because their optimum storage temperatures vary considerably between varieties and even between producing areas. One of the main roles of research centres in tropical countries should be to define optimum storage conditions for commodities grown under tropical conditions. There is a need to evaluate the limitations of storage of these commodities under a range of temperature conditions and to consider the implications and problems of product compatibility under conditions of mixed commodity storage.**

iv. **Uninterrupted cooling: Refrigeration should be applied from the point of harvest through to the point of consumption where maximum post-harvest life with high product quality is justified. This is the well known concept of the "cold chain".**

2.1.3 High humidity

High humidity retards wilting and maintains the product in better condition. Most horticultural products store best in an atmosphere that has a relative humidity of 90% (Lutz and Hardenburg, 1968). Providing humidity has little environmental cost.

2.1.4 Waxing of the surface

Waxing the surface of horticultural products is a treatment used on a number of commodities including citrus fruits, apples, rutabagas and cucumbers. It retards the rate of moisture loss, and maintains turgor and plumpness and may modify the internal atmosphere of the commodity, and is performed primarily for its cosmetic effect; the wax imparts a gloss to the skin and gives the produce a more shiny appearance than the unwaxed commodity. Sometimes antiwaxing is a techniques that could probably be used more widely in developing countries with advantage. In some countries indigenous waxes may be suitable for this purpose. For example, experiments in Colombia have shown that waxing of cassava can extend the storage

life from 2 to 3 days up to about 30 days by preventing discolouration in the vascular tissue. (Buckle et al 1973) Work in India has also demonstrated the efficacy of indigenously produced wax emulsion formulations in extending the storage life of different fruits and vegetables. (Dalal et al 1970)

Environmental effects. The waxes and wax formulations that are used in the U.S. are approved by the Food and Drug Administration and are kept under continuous review. Most of the ingredients in the wax mixtures are classified "Generally Recognized As Safe" (GRAS). In most cases the skin is removed and discarded before consumption in which case the wax is not ingested and should cause no special problems. However, problems might arise if unregistered formulations are used, or if the skin is eaten by humans or fed to animals.

2.1.5 Controlled atmosphere storage

Controlled atmosphere storage consists of placing a commodity is a gas-tight refrigerated chamber and allowing the natural respiration of the fruit to decrease the oxygen and increase the carbon dioxide content of the atmosphere in the chamber. Typically, for storage of apples the oxygen content is lowered to about 3% and carbon

dioxide is allowed to increase to 1 to 5%. This atmosphere can extend the storage life of apples by several months and allows fresh apples to be marketed every month of the year. This technology requires expensive storage chambers and close supervision of the composition of the atmosphere and is unsuited for widespread use in less developed countries.

Some roots and tubers are stored in pits in the ground, known as "clamp storage". Well designed clamps tend to change the atmosphere to some extent by reducing oxygen and increasing the carbon dioxide content. Modified atmosphere storage would probably be effective for a limited number of commodities in developing countries especially if coupled with low temperature storage. Wills and Wimalasiri (Hort. Science, 14 528 1979) have recently shown that short pre-storage exposure to high carbon dioxide and low oxygen atmosphere of vegetables can extend the storage life of commodities even at ambient temperature.

Environmental effects. Since this technology only manipulates the proportions of asses that are naturally present in the air there should be no adverse environmental effect.

The now technology of hypobaric storage is emerging which maintains reduced pressure in the refrigerated storage chamber by means of vacuum pumps. In this system the commodity is placed in a flowing stream of highly humidified air which is

maintained at a reduced pressure and controlled temperature. Under these conditions, Bases released by the commodity that limits its storage life, are flushed away. Reports indicate that the storage life of certain fruits and vegetables is extended substantially by this procedure. The economic feasibility of this type of controlled atmosphere storage is presently being tested. This is an energy-intensive and capital-intensive technology and is perhaps unsuited for less developed countries. The major environmental effect is the high energy coat.

2.1.6 Field factors

Maturity at time of harvest is an important factor in the keeping quality of horticultural products. Commodities that are harvested in an immature state not only have poor eating quality but may tend to shrivel in storage and be more susceptible to storage disorders. When picked too mature the commodity is soft or fibrous, the flesh breaks down more quickly and it has a shorter storage life. There is an optimum time of harvest to give maximum storage life for fruits, vegetables and tubers.

The rootstocks used for establishing fruit orchards may affect [oases. For example, McDonald and Wutscher (1974) reported decay in grapefruit ranging from 3.3% to

27.7% depending on the rootstock. It is reported that the storage life of fresh cassava can be greatly extended by leaving part of the stalk attached to the tubers at harvest time. There are a number of other field factors that affect losses and these should be utilized as much as possible.

Environmental effects. Generally there are no adverse environmental effects in these operations.

2.1.7 Suberization and curing

Potatoes, sweet potatoes, yams and several other roots and vegetables have the ability to heal skin wound e when held at moderately warm conditions end high humidity for several days after harvest. The self-healing of wounds, cute and bruises is known as curing. There are two steps in the curing process. First is suberization - the production of suberin and its deposition in cell walls. The second is the formation of a cork cambium and production of cork tissue in the bruised area. The new cork tissue seals the cut or bruised areas and helps prevent the entrance of decay organisms. The healing of injuries received in harvesting and handling prolongs the storage time and reduces the incidence and spread of decay in storage.

The storage life of onions and garlic is extend-d by exposure to warm dry conditions for several days to dry the outside akin and prevent the ingress of spoilage organisms. This process if also known as curing although physiologically it is rather different and causes about 5% weight loss. Curing is carried out in the field when weather conditions are suitable; otherwise the product is subjected to forced circulation of warm dry air when first put into storage.

This is sound environmental practice. There is little effect on the environment from curing.

2.1.8 Genetic control of shelf life

Each variety of a horticultural crop has a limited storage life even under optimum storage conditions. The potential storage life is partly under genetic control and can be manipulated by breeding. Table 6 (Appendix 1 - Page 5) shows the normal storage life of some North American varieties of potatoes and onions under Rood storage conditions. This very wide range of storage life is typical of horticultural products; each variety has its own particular life span.

Plant breeders should be encouraged to include potential storage life as one criterion in their programme for breeding improved varieties of roots, tubers, fruits and vegetables. This is particularly needed with the breeding programmes in tropical climates where refrigerated storage capacity is in short supply. This should be a high priority method for reducing losses in horticultural products.

Farmers should be encouraged to grow varieties that hare long storage life. For example, Martin and Degras (1978) point out that different Jam varieties differ in storability from a week to several months. Extension agents and experiment stations should be encouraged to include inherent storage life as one of the considerations to be taken into account when deciding which types of crops and which varieties of those crops should be recommended to farmers.

There are no known adverse environmental effects from the efforts of plant breeders to extend the inherent storage life of horticultural crops. However, the results of plant breeders' work may need to be monitored. The U.S. Food and Drug Administration established regulations for release of new varieties of edible plans a when it wee discovered that a new potato variety that wee released in 1969 had an unusually high content of the toxic glycoalkaloids that are naturally present in potatoes. The FDA regulations apply to any plant material that provides more than 2% of the U.S. diet. The regulations require that plant breeders must establish ah two point a before

releasing a new variety:

(i) that the content of the major nutrients is no lower than the average found in existing varieties of that commodity and (ii) that toxic substances naturally present in the commodity are no higher than normal for existing varieties.

2.1.9 Shorten the time between harvest and consumption

In developing countries a considerable amount of produce is wasted because of poor transportation systems and poor marketing procedures. Much produce is spoiled because it is stored beyond its inherent shelf life before marketing is completed.

Improving transportation and marketing facilities, spreading the harvest season by growing varieties that mature at different times, and staggering the planting dates of annuals and reducing the number of steps between producer and consumer are methods that can be used to shorten the time between harvest and consumption.

2.1.10 Processing

Considerable quantities of fruit a and vegetables are processed by dehydration, canning and freezing in developed countries. In developing countries. In developing countries small amounts of these commodities are processed for local consumption although large volumes of some commodities are processed for export (e.g., canned pineapple).

Canning and freezing require a high capital cost, high energy costs and expensive packaging and are unsuited for widespread use in less developed countries. Dehydration or sun drying is the simplest and lowest cost method of preservation and should be more widely used in developing countries because it converts a perishable commodity into a stable item with long storage life. Some excellent quality dehydrated products can be made from roots and tubers; this kind of processing should be encouraged.

Environmental effects. Occupational hazards in the fruit and vegetable processing industry are the normal hazards associated with machinery, for which adequate safety measures are well developed. The National Institute for Occupational Safety and Health in the U.S. (NIOSH) have no complaints en safety hazards in processing plants that handle horticultural products. The U.S. Occupational Safety and Health Administration (OSHA) have no regulations specific to the fruit and vegetable processing industry other than the board guidelines that apply to industry in general.

The fruit and vegetable processing industry is not on the list of occupational groups in which excess cancer incidence is reported by the U.S. National Cancer Institute.

There are occupational risks to some workers with specific horticultural products. For example, Barber and Husting (1977) report isolated cases of contact dermatitis among workers handling raw fruits and vegetables, including carrots, asparagus, mangoes, cashew fruits and nuts, and some citrus fruits. Fruit and vegetable handlers may also suffer contact dermatitis due to sensitivity to specific insecticides and fungicides. Indirect effects of handling fruits and vegetables include chapping and moniliasis from exposure to moisture, photosensitization dermatitis from sunlight, and parasitism from mites. Products that cause photosensitization include fig, rue, lime, bergamot, paranips, parsley, carrots, fennel, dill and pink rot celery. Raw pineapple fruits contain the proteolytic enzyme bromelain which causes skin irritations to workers in pineapple processing plants. This problem is overcome by supplying workers who handle cut fruit with rubber gloves.

2.1.11 Heat treatment

Some of the organisms that cause rotting are inhibited or killed at elevated

temperatures that are below the injury threshold of the product. For example, hot water dipping of mangoes at about 50C for a few minutes kills many pathogens without adversely affecting the quality of mango. Heat treatment is however not a desirable procedure for most fruits and vegetables. When applicable, very rigid temperature controls are needed.

There is little adverse environmental effect from heat treatment. Small amounts of heat are dumped into the environment.

2.1.12 Sanitation

All handling, storage, cleaning and washing equipment for horticultural products should be kept in a sanitary condition in order to minimize the risk of spreading infection. Diseased or damaged units should be sorted out and properly disposed of because their presence promotes the growth of fungi and bacteria. Insects infesting cull piles may fly to good produce and introduce pathogenic organisms and increase losses. Wash water should be changed at regular intervals before it becomes heavily contaminated with fungi and bacteria and spreads infection. In some cases the wash water is treated with chlorine or some other chemical in order to reduce the count of

viable organisms. The sanitation programme in the People's Republic of China is considered an exceptionally important element of pest control.

The environmental effects of good sanitation practice are minimal.

2.1.13 Use of chemicals

A number of chemicals may be applied to horticultural products in order to obtain a desirable post-harvest effect. Most of these are applied after harvest, but a few are applied in the field in order to obtain a specific post-harvest response. For example, the sprouting of onions in storage can be delayed by spraying the onions with maleic hydrazide (MH) in the field while the tops are still green. Chemicals used pre harvest whose scale propose is to achieve a post-harvest effect should be included in the list of post-harvest chemical treatments.

Post-harvest chemicals are classified into groups below (Pantastico 1975). Many of these are not used commercially and are of research interest only:

a. **Fungicides which prevent or delay the appearance of rota and molds in the**

product. Examples are, sodium orthophenylphenate (SOPP), benomyl, thiabendazole (TBZ), sodium hypochlorite, and sulphur dioxide (SO2). Methyl formate (Erinol), ethyl formate and (in some countries) ethylene oxide are frequently applied to dried fruits to kill infestations of insects and molds. Sulphur dioxide and benzoic acid are frequently, and propionic acid, ascorbic acid or sorbic acid sometimes, added to processed fruit products, especially juices, to inhibit the growth of yeasts and molds.

b. **Chemicals that delay ripening or senescence. Examples are: the kinins and kinetins that delay chlorophyll degradation and senescence in leafy vegetables, gibberellins that retard the ripening of tomatoes and hold citrus fruits on the tree beyond normal maturity, and auxins that delay physiochemical deterioration of oranges and green beans.**
c. **Growth retardants that inhibit sprouting and growth. Examples are maleic hydrazide which is applied pre-harvest and inhibits sprouting in a number of stored commodities, e.g., onions and potatoes. A number of chemicals are applied post-harvest to potatoes to control sprouting, for example, CIPC, TCNB and MENA. Daminozide (Alar) give a increased fruit firmness, bettor colour and early maturation in apples.**
d. **Chemicals that hasten ripening and senescence. Examples are ethylene and compounds such as Ephephon that release ethylene, abscisin, ascorbic acid,**

hydroxyethyl hydrazine (BOH), acetylene and substances that release acetylene such as calcium carbide, and certain alcohols and fatty acids.

e. Chemicals that may hasten or delay ripening and senescence depending on the dose and the commodity on which they are used. Examples are 2, 4-D; 2,4, 5-T; indoleacetic acid (IAA) and naphthalene acetic acid (NAA).
f. Metabolic inhibitors that block certain biochemical reactions that normally occur. Examples are cycloheximide, actinomycin D, vitamin K, maleic acid, ethylene oxide, and carbon monoxide.
g. Ethylene absorbants. These delay ripening and senescence because they remove the ethylene produced by the fruit. They are usually placed in clove proximity to the commodity and leave no residue on it. An example is potassium permanganate- impregnated alumina or vermiculite (fur fir).
h. Fumigants to control insects or sometimes molds. Ethylene dibromide and methyl bromide are the most commonly used fumigants.
i. Colouring. The use of artificial colours is sometimes permitted in order to improve the appearance of a fruit. For example, fresh grange a from Florida may have artificial colour added to the akin for cosmetic purposes. Since most people do not eat orange skins other than for marmalade it is considered to be a harmless addition.

In warm climates ethylene is used to degreen lemons, oranges and tangerines

imparting a brighter colour to the skin. Ethylene is a naturally occurring metabolite of ripening fruits.

j. **Food additives. A number of compounds are permitted to be added to processed horticultural products for preservative or functional effect. The major preservatives are sulphur dioxide, benzoic acid or benzoates, and sorbic acid or sorbates. Functional additives include antioxidants, colouring, flavouring, thickeners, emulsifiers, etc. The use of food additives in the U.S.A. is regulated by the Food and Drug Administration (FDA). Other countries have an equivalent government agency to regulate the use of additives. At the international level the Joint FAO/WHO Expert Committee on Food Additives (JECFA) formulates general principles governing the use of food additives and makes recommendations regarding their examination and control. Food additives will not be discussed further because they are only used in processing and formulating horticultural product a and are not applied to raw horticultural products. One exception is sulphur dioxide which is used to fumigate fresh grapes in cold storage in order to control growth of yeasts and molds.**

There are two important differences between the use of chemicals in the field and the use of post-harvest chemicals:

i. **Smaller quantities of post-harvest chemicals are used. For example, the normal** dose of CIPC for controlling sprouting of potatoes is about 30 grams per ton and the normal dose of ethylene dibromide for fumigation of fruit a and vegetables is about 30 grams per ton. These levels contrast with the use of field chemicals where doses of one to several kg. per hectare are commonly used.

ii. The chemicals are not broadcast over the field but are applied in the confined apace of the storage chamber.

It is impossible to obtain figures for the quantities of post-harvest chemicals that are used because this is considered proprietary information by the companies that manufacture and formulate them. However, all post-harvest chemicals are classed as "minor use" by the U.S. Environmental Protection Agency because the quantities used are relatively small.

In the U.S. a company must produce experimental evidence of the toxicity, safety, and usefulness of a new agricultural chemicals before it can be registered for use as an agricultural chemical. Each use must be cleared through registration for every commodity to which it is applied. The Environmental Protection Agency has the responsibility for registering pesticides and setting tolerances. Table 7 (Appendix 1 - Pages 6-10, incl.) lists the post-harvest chemicals that are cleared for use in or on raw agricultural commodities by the U.S. Environmental Protection Agency and the tolerance for each commodity for which they are registered. This list is kept under

continuous review. Any changes that are made in the list are published in the U.S. Federal Register. The FAO/WHO Codes Alimentarius Commission recently published "Guide to Codes Maximum Limits for Pesticide Residues" and plants update this fiat at regular intervals.

In addition to the chemicals listed in Table 7 a large number of materials are exempted from the tolerance in post-harvest pesticide formulations. Most of these are inert ingredients that do not affect the pest but do improve the functional properties of the pesticide formulation. Examples of these chemicals are, surfactants, solvents, diluents, synergists, preservatives, stabilizers, antioxidants, thickeners, emulsifiers, and antifoam agents. Most of these substance are Generally Recognized As Safe (GRAS) by the U.S. Food and Drug Administration.

The use of post-harvest chemicals in the U.S. is strictly controlled and monitored. The chemical suppliers usually described in detail on the label and/or in supplementary literature exactly how, when, and how much of the chemical is to be used. This is backed up by the agricultural extension service of each state which keeps in close contact with the farmer. Most states have a cadre of inspectors who regularly draw samples of horticultural products and submit them to a central analytical laboratory to assay for chemical residues. Few violation of the regulations are detected, and most samples tested are found to be well below the tolerance. Most other developed

countries maintain close supervision and control of the use of post-harvest chemicals on horticultural products.

The situation may be quite different in the less developed countries where governments usually do not have the expertise or back-up analytical laboratories to monitor adequately the use of post-harvest chemicals on perishable crops. It is difficult to obtain information on this topic, but from a general knowledge of how governments in LDCs operate, it appears to be a matter that deserves investigation. Presumably, the pesticide tolerances for the major export crops (e.g., fresh bananas) are effectively monitored by the large corporations who operate this trade and by the developed countries that import these commodities. One cannot be so sanguine about the horticultural crops that are indigenously produced and consumed in the less developed countries.

The U.S. Cancer Institute has prepared a list of 26 chemicals or industrial processes associated with cancer induction in man. (Table 8 Appendix 1 - Page 11) None of the items found in this list are found in Table 7.

The International Labour Office in Geneva, Switzerland, has compiled a list of 69 compounds that are listed as carcinogens by one or more of the following countries: Australia, Belgium, Finland, Federal Republic of Germany, Italy, Japan, Sweden,

Switserland, United Kingdom, Union of Soviet Socialist Republics, United States of America. (Table 9 - Appendix 1 - Page 12) None of these 69 compunds appear in Table 7.

The fact that none of the chemicals listed in Table 7 appear in either of the above two carcinogen lists coca not guarantee that they are not carcinogenic because the question of what causes cancer is not completely resolved. Apart from carcinogenicity there is also the question of other ways in which chemicals may be harmful to human health, e.g., teratogenity and mutagenicity. The question of the safety of the chemicals that are added to foods is changing rapidly because much research and regulatory attention is being devoted to this issue in a number of countries.

The whole issue of harmful chemicals in the environment is complex and not very clear at the present time. However, we can make two reasonable assupmtions about chemicals added to horticultural products:

1. **The developed countries have the expertise to engage in the debate on the harmfulness of chemicals, to evaluate the risks and benefits of their use, to enact new legislation controlling their use as new knowledge becomes available and to establish the inspection-analysis-prosecution machinery to ensure that the legislative intent is carried out. It is reasonable to assume that any proven grave**

rick from the use of chemicals will soon be brought under control in the developed countries.

2. **Most of the less developed countries have little of the kind of expertise listed above. There is a real risk that chemicals will be improperly used and their improper use will not be brought under control, with the potential to cause harm to human health and the environment. Therefore, the use of post-harvest chemicals in a given country should be discouraged until adequate inspection services analytical laboratories have been established to ensure that these chemicals are used safely.**

Environmental effects. Misuse of certain post-harvest chemicals may lead to seriuos environmental harm. As far as can be determined little is known about the ultimate effects of post-harvest chemicals on the environment when they are correctly used. It seems to be generally assumed that since the compounds are used in small quantities in confined areas, and since most of then decompose into nonactive substances there are no adverse environmental effects. Although this is a reasonable assumption there is little concrete evidence either for or against this widely held opinion.

2.2 Pests

The major causes of lose in perishable produce after harvest are certain pathogenic

fungi and bacteria. Viruses and nematodes play a minor role in postharvest losses; rodents and insects are also generally of lesser importance in contrast to the significant damage they cause in food grains.

In addition to the direct lone in quantity of food resulting from microbial infections, a partial loss results because of effect on appearance and/or quality resulting from disfiguring surface infections of fruit, root, and tuber crops. Other secondary adverse effects may include a decline in shelf life, possible contamination with mycotoxins, acceleration of ripening because of release of ethylene in pathogenesis by certain fungi, and in some instances deterioration of canned fruit crops because of the presence of heat-resistant hydrolytic enzymes formed by decay fungi in fruit tissues prior to the canning process.

The loss in the post-harvest period may originate from infections that were initiated by fungi during the growing season well in advance of harvest. Much of this pre-harvest infection involves a group of fungi that are capable of infecting healthy developing fruits either by direct penetration, e.g., anthracnose deseases caused by species of colletctrichum or by invasion via natural openings much as lenticels or stomates or through breaks in the tissue at the points of attachment of fruits to the plant. In many cases the infection process may be incomplete. Thus, sub-cuticular mycelium may be formed which remains in a latent stage until the post-harvest period

when changes in susceptibility may occur and the pathogen mycelium may ramify through the tissue.

Many of the fungi (e.g., species of Penicillium, Rhizopus, and Gectrichum) and bacteria (e.g., species of Erwinia, Bacillus and sometimes Clostridium) involved in decay problems associated with the post-harvest period may be considered as opportunistic pathogens. They are usually incapable of penetrating unijured tissue or aggressively attacking vigorous healthy plants during their active growth period. However, they do have the ability to parasities fleshy plant organs when tissues are bruised, injured by insects, or otherwise placed under environmental stress. In many cases tissues are invaded by a succession of organisms which may interact in a synergistic manner.

Each species of root, tuber or fruit is affected by specific groups of fungal or bacterial pathogens. It is important that broad non-specific designations of these organisms be avoided (i.e., molds or rot organisms). The species of fungi or bacteria associated with specific decay problems should be properly identified. For example, it has been clearly shown that species of Knisopus differ markedly in their susceptibility to specific fungicides.

The main factors affecting disease development are:

1. **Most susceptibility**
2. **maturity**
3. **wounds and wound healing**
4. **temperature of the commodity**
5. **relative humidity (especially in storage)**
6. **packaging**
7. **handling in general**
8. **concentration of inoculum**

The basic methods of control involve three different approaches 1) prevention of infection 2) elimination of incipient or latent infections, and 3) prevention of spread of the pathogen in the host tissue.

Losses due to micro-organisms may be reduced by:

1. **refrigeration**
2. **improved handling procedures**
3. **pre- and post-harvest chemical control**
   Although every effort needs to be made to minimize or reduce dependence on chemicals, in many cases no viable alternatives exist. A wide range of fungicides are now available that are effective and safe to use. Incipient infections can be

eliminated or reduced by application of certain fungicides such as benomyl which have the capacity of diffusing into host tissue and killing the pathogen in situ. Certain fungal pathogens initiate infections of fruits and vegetables during the growing season and these can be controlled best by timely application of fungicides prior to harvest. It is essential to ensure that chemical controls are used properly.

4. **preventing contamination during the washing process**
   In the case of tomatoes and possibly other fleshy vegetables when warm product is washed in cold water infection is augmented. Because of the temperature differential air in the tissue contracts and this draws water, often containing soft rot bacteria' into the tomato via wound e and fresh stem scars. If soft rot bacteria are present, water deeper than about 0.3 m increases the risk of infection because of the pressure differentials inside and outside the fruit. If washing is needed' proper, prompt drying is essential in order to prevent rapid growth of spoilage organisms in superficial wounds and lenticels. Sweet potatoes and yams have a longer shelf life when stored unwashed.

Unresolved problems

The actual physiological processes involved in the rapid deterioration of cassava after harvest are act yet fully understood, although much research is in hand. For many

other commodities also, knowledge is lacking about changes in physiological processes in the post-harvest period. In particular there is a need to determine the relationships of those changes to the increased susceptibility of perishable products in the pool-harvest period.

Date is lacking with respect to the effect of chemicals, singly or in combination, AS used in the growth period on the storability of commodities. Fertilizer, weed control chemicals and vine killers for potatoes are examples of the chemicals used which may affect storage characteristics or disease susceptibility

The physiological basis for resistance of perishables to post attack needs to be known. Mechanisms of resistance of micro-organisms to different fungicides and bactericides are also little understood.

Biological control systems should be further explored. For example, it is known that, by dipping root stocks into suspensions of an avirulent strain of the grown gall bacterium that produces a very specific antibiotic (bacteriocin) later infection by the grown gall (bacterium) of stone fruits can be prevented. Other similar antagonistic relationships are known to exist: they may offer possibilities for more techniques for biological control of insects. Biological controls are an important feature in the plant protection programmes of the People's Republic of China.

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2.3 Marketing and distribution

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The approach of the market specialist to the problem of food losses in perishables is to identify the place in the market chain where losses of unusual magnitude occur. The physical place where such losses are registered is less important than the position in the chain whore losses occur and the relation of the specific loss situation to the total market chain. In relating losses incurred at a specific situation to the total chain, the objective is to find out whether the lose can be explained by defects further up or down the chain or by the system as a whole.

Losses in perishable produce occur everywhere from the field to the ultimate consumer and depend on the degree of perishability of the produce; they are inherent

in the very nature of the product. Since the market chain or system refers to specific operations, handling, transportation and trade practices, there is a close correlation between the type and magnitude of loss incurred by a specific product and the chain or system wherein it moves. This implies that for a given commodity moving in a particular chain, there is something like a standard loyal of loss inherent in the chain, the reduction of which could not be obtained by improving isolated operations taking place within the chain. It would require a change in the total market system itself. To avoid losses or even significantly reduce them et isolated stations in the chain may not be a realistic proposition. However, any obvious isolated practice that leads to heavy losses, such as faulty packaging, must be corrected.

Marketing methods and conditions vary widely from country to country and any attempt to attribute losses to a particular point in marketing chains or to any specific system or marketing runs into difficulty because it is not possible to generalize on a wide basis. For this reason, a systems approach should be adopted for dealing with food losses whereby all the factors applicable to a given situation and in an individual country have to be considered before any meaningful diagnoses can be made. Any success achieved in reducing losses at the "grass roots" level particularly where applied to traditional marketing systems should receive wide publicity as such successes are not often known beyond their immediate area of application.

Management of losses is essentially action-oriented. It is effected within a given market system for which "norms" of foes lovers can be established. Managing the losses with reference to acceptable levels would be quite similar to management by objectives. Each marketing system has its own rationale and is affected by policy decisions with regard to production, marketing and consumption. The latter will have a direct incidence on the effect of any measures that might be implemented for the reduction of losses. An examination of the type of production and marketing system would be helpful in revealing how susceptible a given market system or sub-system may be for the introduction and application of measures aimed at bringing losses down to a desirable level.

Traditional subsistence systems are widespread throughout the developing world sad are characterized by local exchange or barter trade, sharply limited geographical movements of produce and typical small units of sale or barter. Losses do occur but they tend to be overestimated and may be difficult to reduce. The subsistence economy sets its own limits: the chain from field to consumer is usually short, both in time and distance. Practically everything is consumed because every quality finds a ready consumer. Improvement of the system in terms of reduction of losses may be limited to the provision of shade. Recommendations might not go beyond encouraging the producer to collect his fruits and vegetables under a tree or build a make-shift shed or tent.

The situation is quite different when one looks at the emerging marketing systems where a surplus production economy is rapidly replacing the previous subsistence or semi-subsistence economy and the marketing system is not well adapted for the teak of collecting, moving and distributing massive surplus production. Losses of unusual magnitude do regularly occur in the system and here there is good scope for the introduction and application of specific measures to reduce losses depending on the readiness of the systems to transfer the improvement down or up the chain. Most measures that focus on gentler handling, better conditioning, faster transportation and proper storage would seem to be effectively applicable only within an improved market infrastructure including suitable roads. Quality consciousness and the introduction and acceptance of some forms of quality separation by the trade and the consumer must precede the demand by the farmer for bottle, and therefore higher cost, boxes or containers. This again can hardly be expected if the higher prices paid for better quality cannot be transferred down the chain to the producer. Much closer communication relating producer capacity to retailer/consumer demand is a prerequisite to such developments, sad the more efficient management of marketing enterprises.

In some regions particularly high levels of lose have been observed when governmental and quasi governmental agencies participate directly in horticultural crop marketing. This to a great extent is due to faulty management inexperience in the

commissioning and operation of cold stores, lack of technical knowledge in despatch and transportation techniques, the absence of a sales operation to set oh the buying programme and generally unrealistic pricing policy. The scope for remedial action in these incompletely integrated sub-marketing systems is great. This may deserve priority in any action programme for the reduction of losses. The crops which have typically been the object of intervention programmes by Governments are potatoes and onions, but other crops such as oranges have in vein. areas been included.

2.4 Socio-economic aspects

A complete analysis of the post-harvest system would include not only the "physical" but the "human" aspects; that is, a study of those social, psychological and economic factors which influence the behaviour of the people involved in post-harvest activities. It is these people, the subsistance farming families or those individuals who produce, process or market on a commercial basis, who are required to change their behaviour when schemes are launched to reduce post-harvest losses. Any technological change required of a producer is likely to produce social and/or economic changes. Additionally, the nutritional status, e.g., of children or mothers, may suffer, Introduction of even simple machinery can displace women's paid labour; production of a marketable surplus may provide the family's first cash income. Preliminary diagnostic studies make it possible to ascertain the possible effects of such

technological changes and to identify the socio-economic constraints influencing the producers and their acceptance of proposed changes. The prime task of such studies would be to locate where losses occur, who is responsible and who bears the loss. A range of social and economic relationships also needs to be explored with respect to any proposed remedies. For examples, who will be the primary beneficiaries of the proposed interventions (landlord, middleman, owners of capital, urban consumer or the producer?); what changes in responsibilities or functions are required; what additional obligations or risks may be incurred and by whom? In brief, who losses, who grains (as perceived by -the people concerned) in monetary, time' social end psychological terms?

To make studies of this type it is clearly necessary to involve applied social scientists, economists and nutritionists at an early stage of planning an' activities related to reduction of post-harvest losses. Despite the fact that the producers' attitudes to lose and understanding of its implications may be limiting factors in motivating the adoption of change, their skills and knowledge ought not to be ignored or underrated. All concerned with post-harvest operations should be involved in the planning of improvements.

It is of particular importance to identify which members of the producer's, handler's or processor's family are responsible for the various post-harvest activities. Efforts can

then be made to ensure that the right people are included in training programmes, credit schemes and other services which may be planned.

Is order to make a systematic approach to the reduction of post-harvest losses it may be seen that co-ordination is necessary with activities developed to alleviate related problems . A post-harvest system cannot be vi owed in isolation from ether aspects of rural development. In this connection the Programme of Action adopted at the 1979 World Conference on Agrarian Reform and Rural Development provides guidance regarding priorities for action.

2.5 Future developments for horticultural products

Brand new concepts that eventually lead to extensive new technologies usually burst upon us without warning. It is impossible to forecast when, or in what form such major breakthroughs will appear. Hence, such dramatic advances in post-harvest handling of horticultural products cannot be discussed in this report. But we can discuss probable future trends by extrapolating presently known trends into the future.

Processing

Rising standards of living can be expected to increase demand for canned and frozen horticultural crops as well as the demand for convenience foods that contain one or more horticultural crops as a major component. Losses after processing are usually very low. On the other hand, they are energy-intensive and the disposal of the discarded packaging materials as solid waste creates some environmental problems.

Large scale factory processing of horticultural crops concentrates large quantities of waste materials much as skins, cores, and seeds in one place in contrast to the highly dispersed distribution of waste from commodities that are consumed fresh at home. Traditionally, little attention has been given to dispose. of this waste material and it has caused environmental problems. In recent years, attention has been drawn to this problem, e.g., the joint UNEP/FAO sponsored seminar on agricultural residues held in Rome in January 1977. Many governments now require food processing plants to upgrade the handling of their waste materials.

New Chemicals

The large chemical corporations continue to search for new chemicals to control the pests and diseases that attach crops and products. The cost of testing mud. registering a new agricultural chemical is now SO high that only the larger corporations can afford to take the risk, and even they are mainly interested in pesticides for major crops such

as maize, wheat, soybeans and cotton because they cannot expect to recover the costs of developing a new chemical unless potential sales are high. After a chemical has been registered for use with a major crop, it can also be registered for a minor crop at much leas cost if it is shown to be effective.

New chemicals for post-harvest treatment of horticultural crops will continue to appear but mainly as spin-offs from use on major crops. It is unlikely that many new chemicals will be developed especially for post-harvest application because of the relatively low volume of sales anticipated for such application, which is insufficient to justify the high cost of obtaining the initial registration.

Irradiation

Irradiation of horticultural products kills infesting insects thus permitting products to be shipped into areas that have a quarantine against certain insects. It also delays sprouting of bulbs and tubers, permitting long-term storage of commodities such as onions, potatoes and yams without sprouting.

Although several decades of research have been devoted to this peaceful use of atomic energy there is almost no commercial use of irradiation technology even though it continues a to be energetically advocated by the International Atomic Energy

Commission and a total Or 26 commodities have received restricted or unrestricted clearance in on or more of 19 countries having legislation on irradiated food (Vas, 1977). Maxie et al (1971) concluded after a lengthy study that irradiation was, in general, not as effective as good commercial refrigerated storage for fruits and vegetables. A 1976 report point d out that after a quarter of a century Of world-wide work on this promising technology there is today only one truly commercial application, namely, the inhibition of potato sprouting in Japan.

Radiation technology has not been wider, adapted in commercial practice for the following reasons:

a. **It costs more than chemical treatments. Chemical treatments usually cost about 10 cents to $1.00 par ton of product. Irradiation probably, costs several times as much although contact figures are difficult to obtain. The twelfth session of the Joint FAO/WHO Codex Alimentarius Commission in 1978 noted that the economic feasibility of the irradiation process still required practical demonstration.**
b. **The rood must be passed through the irradiator thus creating an additional handling stage which adds to the cost, and may increase bruising and wounding of the commodity.**
c. **Irradiated vegetables may be more susceptible to storage rots and fungi because the natural would bearing processes are impaired. Irradiated potatoes sometimes**

darken when cooked. Irradiated onions contain a small piece of unsightly black tissue in the centre of the onion a bare the growing tip is killed by the radiation.

d. **Much more elaborate safety precautions are required for an irradiator than for chemical treatments.**
e. **The softening of vegetable tissue caused by irradiation makes the commodity more liable to bruising during subsequent handling and transportation.**

To sum up, it appears that irradiation technology for horticultural products is unlikely to be widely used under present circumstances. Although the International Atomic Energy Commission continues to maintain a vigorous programme to introduce irradiation as a food preservation technique it seems unlikely that irradiation will be widely used unless all chemical treatments are banned or some now major breakthrough in irradiation technology is developed.

Drying Technology

Since drying is the lowest cost preservation technology it should develop as a major method of preservation of horticultural products especially in LDCs. Much drying can be accomplished by means of solar energy. Simple drying systems can be established as small-scale localized unite for single families or villages. The fact that the quality of dried products is not necessarily as high as the canned or frozen product need not be

a liability in developing countries where low price is so important and the expectation of quality and convenience is not as high as in the developed countries.

Wider Use of Chemicals

The advantages of chemical treatments (effective, low coat, easy to apply) will surely lead to their greater use in LDCs. This could result in danger to human health and the environment if the chemicals are misused or abused.

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3. Roots and tuber crops

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3.1 The root/tuber crop resource

Useful insights into the post-harvest loss complex of root crops are provided by a

study of their characteristics. The principal roots and tubers are derived from nine species. They are all of high Moisture content, and their parenchyma cells are packed with starch grains. These materials show variable degrees of inherent keeping life, from some species of yam, like Dioscorea alata which remains dormant for 3-4 months to cassava in which there is no natural dormancy. When such material is stored in the fresh state, respiration and transpiration continue with inevitable losses of water and dry matter. Prolonged high levels of transpiration result in a change of texture affecting quality and weight loss. The dry matter loss, caused by superation constitutes a real food value as distinct from the moisture loss which only has an economic value. Sprouting at the end of dormancy can result in dramatic loss as the physiological state is altered. At this stage the stored starch is transformed to sugars and utilized by the elongating shoots with appreciable loss of both food value and moisture.

The main root/tuber crops are cassava (Manihot esculenta Crantz), the yam (Dioscorea spp.), the potato (Solanum spp.), the sweet potato (Ipomoea batatas L. (Lam) and the edible aroids (Colocasia spp. and Xanthosama sagittifolium). With the yam, the potato, and the aroids many different species are used in the cultivated complex. Differences between these are usually sufficient to merit separate treatment. A list of the more frequently used root/tuber species is given in Appendix 2.

Tare (Colocasia esculenta var esculenta) illustrates the system of maintenance of

continuous food supply well. This species which has no seasonal growth constraint is planted in moist situations conducive to year-round growth. By systematic replanting whenever material is harvested, continuous supplies are assured. A similar absence of seasonality in cassava (Manihot esculenta) together with its ability to produce mature roots at various time intervals after planting permits year-round harvesting in most ecological systems. By opting for continuous food supply the opportunity for post-production losses is restricted to the food preparation phase. The same benefits accrue from the use of crop scheduling

Maintenance of food supplies ever restricted periods through storage is an essential feature of yam-based food supply systems. The success with yam storage lies in recognition of the limits to the potential for storage and in producing an environment conducive to keeping the material in sound condition. Perceptive farmers like those in Nigeria and the Ivory Coast often construct different stores to meet the separate requirements of D. alata and the different culivars in the D. rotundata/cavenesie complex. These systems work well within the normal period of yam tuber dormancy. They are so successful in West Africa that improvements in the beat indigenous practice could hardly be expected without recourse to the technologies of reduced temperature storage, the use of controlled gas environments or ionising radiation. These latter technologies are however not commonly applicable in developing countries because of cost and lack of know-how.

Considerable quantities of roots and tubers are transformed into more durable products by drying, fermentation and commination in different combinations and sequences producing a variety of materials each with distinctive characteristics. Other benefits that often accrue from transformation include the removal of toxic substances naturally present and the convenient-to-use nature of the transformed product. Although the ultimate keeping potential is constrained by environmental conditions, transformations have good prospects for long-form maintenance of root/tuber crop supply because they convert a perishable commodity into a form with stability similar to that of the cereal grains.

A feature of much of the indigenous processing technology is its high labour requirement. Because of this, food supply strategies based on transformation tend to be restricted to economic environments where labour is available. As a result root crop transformation is widely practiced among subsistence economies whore labour inputs have zero or low cash value. Attempts are being made to establish root/tuber crop transformation commercially, but success has been variable. Radical changes in the entire system of production may be required, as has been suggested with yam (D. rotundata/cavonenais) in Nigeria for manufacture of instant pounded yam.

3.2 The major root/tuber crops

3.2.1 Cassava (Manihot esculenta Crantz)

Known variously as manioc, yuca, tapioca and mandioca, the edible portion of cassava is a starchy root which matures in harvestable state in 8-24 months according to cultivar and climate. In addition to the roots, the leaves also have potential for use as food as for instance in pert e of Central and West Africa. Cassava cultivars are often grouped into "sweet" with relatively low contorts of cyanogenic glucosides and "bitter" with high cyanogenic glucoside content although many intermediate forms exist. The "sweet" types may be eaten raw or lightly boiled without harm while the "bitter" forma require processing to remove cyanogenic glucosides.

The cassava roots have no natural dormancy and are highly susceptible to deterioration. The nature of this deterioration is as yet not fully understood, although two factors, one an indigenous physiological one and the other associated with microbiological infection, have been identified. The physiological deterioration' of which the symptoms are tissue discolouration, can commence as soon as 24 hours after harvest. Acting independently of, but usually following, the physiological changes, microorganisms, both fungi and bacteria develop in the flesh of the roots causing additional damage and loss: this microbial deterioration usually develops only 5-7 days after harvest. (Booth, 1974; Lozano, Cook and Castano, 1978).

This rapid post-harvest deterioration of cassava roots places serious constraints on their use with fresh produce trade and on the holding of buffer stocks for large-scale processing.

The short storage life of fresh cassava imposes constraints on its distribution and use. As a result, the choice of market for which production is intended becomes influenced by location. The range over which production for the fresh market extends is therefore a function of the distance from their markets and the efficiency of transport. The time of delivery rather than distance per se is the important limiting factor. In the vicinity of Bogota, Colombia, up to an 8-hour interval from harvest to delivery is acceptable. With the current status of road a and vehicles this permits production within a 300 km radius. With more effective preservation or a faster delivery system, this range could be extended. It is claimed that the market for fresh cassava in Colombia is so structured that as quality deteriorates, the price is lowered, thereby enabling roots of decreasing quality to be bought by successively poorer income groups.

Techniques to extend the fresh life of cassava roots have been independently developed in several countries. At the Instituto de Investigaciones Tecnologicas in Colombia deterioration has been delayed by coating tubers with a film of paraffin wax (IIT 1973). At CIAT fresh tubers were shown to have improved keeping characteristics when plant stoma are out and removed but tubers are loft unharvested for up to 14

days. Tubers so treated remained sound for as long as 30 days. This technique has much to commend it, but has not yet been tested on a large scale. Other practices developed in joint CIAT/TPI projects include storage in earth silos' and storage of roots in plastic bags and in absorbent packs. These methods appear to have some utility in small and medium scale production but have not yet been proved in large-scale commercial operations. None of those techniques have as yet attained general application.

The transformation of cassava to more durable forms, frequently in forms more convenient to use than fresh roots, is partly associated with the detoxification process for the removal of hydrocyanic acid. From the crop loss point of view these products are important since they are frequently more able to avoid the rapid deterioration of the fresh tubers. Cassava products may be classified in a variety of ways, but for simplicity these may be regarded as food starch ant whole root products. These latter may be fermented or unfermented and may either be "flour" or "gari" types.

Cassava starch is extracted from roots after pealing, washing, reaping, squeezing settling and drying. Two types of starch are produced, sour or fermented and sweet or unfermented. Sweet starch is dried immediately following extraction while sour stanch is stored for 3-4 weeks when some fermentation involving lactobacilli and yeasts occurs. Sour starch is favoured for baking and commands a better price than sweet

starch at least in some countries. This latter has similar conformation to corn starch with which it competes disadvantageously.

Gari, the most commonly used form of cassava in West Africa, accounts for some 70% of the entire cassava production in Nigeria. It is estimated that between 4 and 5 million tone of roots are used each year for this purpose. Although there are close parallels between the production of gari and of Brazilian "farinha de mandioca", the West African variant has some distinctive features.

The effect of the longer fermentation affects the taste by the production of lactic acid, as wall as well as reducing the content of free hydrocyanic acid. Production at levels of indigenous technology is highly labour-intensive, but this constraint is being progressively removed through a variety of innovations aimed at increasing labour productivity. The hygroscopic nature of gari is a major constraint to its keeping quality. 1a a humid atmosphere it can absorb sufficient moisture to make it vulnerable to the growth of fungal organisms. The recent practice of packaging gari dried to a safe moisture contort of around 12% in sealed polyethylene bags enables the product to be kept in good condition for extended periods.

Farinha de mandioca is the Brazilian product from which gari derives. The stages of preparation are similar to those for gari, the roots being washed, peeled, grated,

pressed, toasted and classified by size. Unlike gari, the mashed or grated mass is not permitted to ferment. The heating dries the product and allows some gelatinization and dextrinization of the starch as also occurs in gari making.

Other durable cassava products include cassava flour, dried chips and "cossettes' from which flour can subsequently be prepared by milling or grinding.

3.2.2 Tam (Dioscorea Spp.)

With yams, storage life is determined by dormancy since attempts to store yams after sprouting has commenced are impractical. During the period of dormancy the metabolic processes continue at reduced rate thereby keeping dry netter losses at relatively low levels. The various yam species have different periods of dormancy with 3-6 months for <u>D. rotundata</u> and <u>D. alata</u> and 1-2 months with <u>D. cavenensis</u> or <u>D. trifida</u>. Pathological factors are also of great importance in causing postharvest losses in yams.

Traditionally, in West Africa, yams are stored in "yam barns" where good but uncontrolled conditions for storage exist by building the barns in the deepest available

shade. This prevents heating by the nun and also helps to maintain high humidity. Several other indigenous yam storage systems are used but moat of these are less satisfactory than the "barn" or "claie verticale".

It is generally believed that these systems are well adept d to the yam varieties and to the climatic conditions prevailing in West Africa and offer little scope for improvement at current levels of technology.

Of the methods used to extend storage only the use of ionising radiation has been an unreserved technical success. The practical application of this technique is not yet generally available. Reduced temperature storage is limited by possibility of chilling damage around 10-12 C and by the growth of fungal organisms at temperatures around 14 C. Treatment with chemicals used to suppress sprouting in other crops has had little success but active research is being pursued by TPI. Controlled gas storage has not thoroughly been investigated.

Transformation of yams to more durable forma is possible but these methods have not yet met with much commercial success. Traditional products such as "amala" are variable. This may be related to the intrusion of undesirable dark colours into the final product from the use of a mixture of varieties and the failure to deactivate the polyphenol oxidases during processing rather than to any inherent basic defect of the

process. The attempts of commercial organizations to produce an instant pounded yam failed more as a result of nontechnical problem such as the logistics of raw material supply than to technical defects in the process. New processes recently developed at the University of Ife, Nigeria, may provide the required answer. A yam flake product developed to pilot project level in the West Indies has not continued long in production at a commercial level.

3.2.3 The Potato (Solanum Spp.)

The potato, Solanum tuberosum, originally of highland tropical origin, but developed mainly as a temperate crop, is now being developed as a lowland tropical crop. Selections tolerant to high temperature and short days are being made in several parts of the tropics. At higher elevations in the tropics it is already established as a crop of some importance.

She extension of potato growing to these areas is a major concern of International Potato Centre (Centro Internacional de Papa - CIP). This Centre works together with existing bodies selecting areas for activity on the basis of comparative advantages. This approach forms a rational basis for co-operation and avoids the sometimes

unintended, but nonetheless real, tendancy towards replacement of national effort with that of an international organization.

The work on post-harvest lose in this Centre is integrated with that of the social science unit permitting a broader view of the problem. This approach, taking account of social, economic and ecological factors, could provide useful guidelines in the development of other work on post-production losses. An account of the studies in the Mantaro Valley is given by way of an illustration of the CIP approach.

The Mantaro Valley lying some 300 km to the South-East of Lima has been described by Mayer (1979). It is a riverine valley acme 60 km in length and from 2 to 22 ho in breath. Three broad ecological zones are recognized. The valley floor is some 3,200 - 3,450 m above sea level. The eastern slopes between 3,400 and 3,950 m and the western slopes of similar elevation.

Finally a high zone above 3,900 m. The flat riverine soils of the valley floor have a high productivity with a capacity to support a diversified agriculture and a high population density. In this zone a contrast between large and small farm a is noticed. In the zone of sloping land above 3,450 m soil productivity declines as dose the number of crop species. The practices on the East and West slopes differ. On eastern slopes potatoes maintain their place in cropping systems but play a diminished role on western slopes.

Under the more severe conditions of the High Zone potatoes become the most important component of the cropping system occupying some 57% of the arable land. These zones are constrained by three main environmental factors: precipitation, temperature and water balance. These are all subject to changes relative to elevation. Generally precipitation and exposure to frost increases with increasing elevation.

Several products are made from potatoes including chuno, papa seca, tungush and potato starch. Ecological zone and economic circumstances result in different comparative advantages between choice of product. The most common product at low elevation is papa seca, a parboiled dried product which requires, fuel for boiling but which utilized what would otherwise be a waste product. This restricts production to the lower zones where fuel supplies are more assured. Hybrid or native varieties are used for papa seca since this process would not be sufficient to remove the glycoalkaloids present in the bitter varieties. Processing into chuno or tongosh which eliminates the bitter principle requires no cooking. The process however requires heavy night frosts and open areas on which to expose the potatoes to natural freeze drying. These conditions are all readily met in the high blue. Locally produced potato starch competes with commercially produced corn starch. It is clear from this example that changes due to the technological superiority of one process over another is unlikely since a different technique is adapted to meet different complexes of factors.

Potato Storage

Potatoes are stored for use as seed or for food or sale. Different methods of storage have been described by CIP (Werge, 1977) from which the following summary has been taken. Ho recognizes three main systems: house' out-building and field. Peruvian rural houses according to Stein (1961) appear to have been cosigned with storage of agricultural produce in view. The convenience and security of storage in the house is evident. The actual technique of storage adopted appears related to the itended use for the potatoes. Potatoes to be boiled in their skins are kept is the attic where the conditions permit drying and some shrivelling, causing the potatoes to become sugary and thus more favoured. Potatoes which are to be pealed before cooking may be stored on the ground where they love leas moisture and HO remain firm.

Seed potatoes may be left on the ground on a thin layer of straw or eucalyptus leaves, in piles against the walls of houses or in shallow bins or "trojas". Where animals may have access to them if they are loft on the ground, the potatoes may be placed on a platform or chaclanka of eucalyptus branches in the rafters and covered lightly with et raw.

Field storage is more frequently adopted at higher evaluations. Here strawlined clamps, covered in turn with straw and soil, may be used. The cool moist conditions

reduce dehydration but the system is vulnerable to flooding which may result in dramatic crop losses. At elevations of about 3,000 m ventilation with air at ambient temperature assists the storage process.

An interesting series of low-cost potato stores have been developed by the storage unit at CIP. These are developed and adapted to take advantage of prevailing conditions to facilitate storing. Control over the storage environment is attempted by using natural ventilation systems coupled with adequate insulation and shading. Where appropriate humidity modification using simple measures is also being researched. In the case of seed tubers, these are stored in simple low-cost stores exposed to natural diffused light which, to some extent, replaces the need for controlled low temperature storage.

3.2.4 Sweet Potato (Ipomoea batatas (L.)

Sweet potato is a crop of considerable unrealized potential. The roots are widely used as a carbohydrate food and recently attention has also been drawn to the nutritional value of its leaves as food. The ability of the roots to become suberized at high temperature and humidity in the classical curing process, gives the crop potential for

extended storage. Storage is particularly successful when kept at relatively cool temperatures, although, it held below 12C, chilling damage can occur. The most successful storage occurs in the southern states of America and in Japan, and successful storage for extended periods has still to be achieved in the Tropics.

There is interest in transforming the roots to more durable forms. In Trinidad, at the University of the West Indies, a sweet-potato-based flour was shown to have utility in wheat flour substitution in bakery products. There is interest there and elsewhere in the preparation of breakfast foods from sweet potato tubers. The manufacture of dried sweet potato flakes is already an established industry in the United States.

3.2.5 Taro (Colocasia esculenta) and Other Edible Avoids

The edible corms of these crops are normally eaten fresh after boiling or baking. Estimates in Fiji showed high peeling and trimming losses during preparation as food. The fresh corms to not normally remain sound for long periods, and signs of deterioration become apparent a few days after harvest. Observations in Fiji indicated that packaging in plastic bags enhances keeping quality. In the South Pacific it is traditional to keep taro by transforming it into a fermented product of which "Poi" is

the Hawaiian variant. It is of interest to note that the presence of oxalic acid raphides in the corms acts as a deterrent to rats.

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4. Fruits and vegetables

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4.1 General considerations

Many post-harvest losses are direct results of factors before harvest. Fruit a and vegetables that are infected with pests and diseases, inappropriately irrigated and fertilized, or generally of poor quality before harvesting, can never be improved by post-harvest treatments. Very often the rate of commodity loss is faster if the quality at harvest is below standard. Thus, the processes in the attainment and maintenance of quality from production, harvesting, handling and marketing must be considered a

unified system. The success of preserving the harvest-fresh quality of produce demands control of each step in the system, depends on the previous stop and therefore is a chain of interdependent activities.

The small size and isolation of many vegetable farms make it logical to employ manual harvest labour which is often relatively cheap and non-organized. Traditional methods of harvesting are still employed using a minimum of mechanical aide. Many of the farmers may know their market but do not analyze it and plant without much concern for it. Price considerations are usually given more weight than the quality of the produce. Early harvesting of carrots, chayote, snap beans, squash and bottle gourd give better quality, but lower yield. On the other hand, vegetables may be harvested before reaching prime quality if the prevailing market price is high duo to the scarcity of the product. Knowledge of maturity indices is often inadequate in moat instances visual indices being used. Therefore, more experienced farmers can deliver better quality products than those with less experience.

The deterioration of a product starts during the harvesting operation. The more carefully a product is handled, the slower the deterioration process during subsequent handling operations. However, the farmers mar be unaware or indifferent to the condition of the product after harvest, and harvesting procedures may thus be rather careless. The only constraint is to avoid external injury. Until farmers are convinced

that careful handling will increase profits, it will be difficult to persuade them otherwise.

In many countries contract buying is practiced where the contractor takes charge of the harvesting and may exert strict supervision of the operation.

The general problems for each fruit and vegetable group are summarized in Table 10:

Table 10 - General problems for each fruit and vegetable group at each handling step

	Handling Steps*					
Types of Fruits/Veg.	**Harvesting**	**Packing**	**Transporting**	**Grading**	**Storage**	**Retail**
Fruits	Right stage of maturity	Over-packing; improper container	Rough handling; poor road conditions	Uneven ripening	Chemical changes; shrivelling	Over-ripening; shrivelling; browning
Roots	Excessive moisture may lead	Mechanical injury in sacks	Bruising	Malformation	Sprouting; improper curing;	Sprouting

	to rotting				shrivelling	
Tubers & Corms	Mechanical injury	Mechanical injury in sacks	Bruising	Malformation	Improper curing; sprouting & greening	Sprouting; rotting; shrivelling weight loss
Leaves	Excessive wilting; rotting under high moisture conditions	Unsuitable container size; mechanical injury	Rough handling; high transit temperature	Over-trimming; mixed sizes	Wilting at low relative humidity; shrivelling	Over-trimming; excessive wilting; bacterial soft rot
Flowers	Flower shedding	Improper packaging	High transit temperature	Loose curd; insufficient wrapper leaves	Yellowing of curds	Loosening of curd; fading of colour
Stems	Improper method of harvesting	Breakages of tissues	High transit temperature	Malformation	Elongation of existing structure	Shrivelling

Bulbs	Maturity	Bruising and other mechanical injuries	Improper conditions in sacks	Misshapen	Sprouting	Shrivelling and sprouting

*** Attacks by micro organisms can occur in all steps of the post-harvest system either directly or resulting indirectly from actions or conditions occurring in each of the steps.**

In meet of the developing countries the world, harvesting methods are very simple. Picking poles, to which a hook or cutting knife is attached' are generally used. Fruit blemishes and injury are usually unavoidable. Quite often the fruits fall to the ground becoming subject to field infestation. Planning, preparation and organization in the harvesting operations are necessary. Suitable harvesting tools, hand gloves, containers and supplies are needed by the harvesters. The grower should exert strict supervision on the harvesting operation.

Grading is a thing that most farmers are loath to do until they are convinced it will bring them added revenues or increases the acceptance of their products. A farmer may separate different varieties if they are distinguishable, but consumers in the

tropical countries usually are more price conscious than quality conscious. That is not to say that they are unmindful of the quality, but if good quality products are too highly priced, they are often willing to settle for a poorer quality product. With the variety of vegetables offered for sale, shore is usually no difficulty in Betting cheaper substitutes. Thus, initially, for local markets, grading should be limited to only what is necessary. Deformed fruits and those with splits, punctures and incipient rotting should be removed. If the market is conditioned to accepting sound fruit with harmless surface blemishes (e.g., russet, windscarring, or mite injury), it is well not to attempt to change the situation for the time being. The following are likely to occur in the absence of proper sorting and grading procedures:

i. Presence of rotten items which contaminate food products at later handling stages.
ii. Customer deception wherein good produce on top of the containers conceals items of low quality at the bottom of the pack.
iii. Growers do not maximize their income because best prices for their product are not obtained.

Containerization is probably, the weakest aspect in the distribution chain of fruits and vegetables. In general, packaging materials of unsuitable quality, such as large sacks, rough wooden boxes, second-hand cartons, bamboo baskets, or rattan containers are

liable to cause produce to suffer from bruising, crushing' and puncturing. The use of suitable containers alone will do much to maintain the quality of fruits and vegetables. Farmers often selected the cheapest and most readily available containers. For example, the use of bamboo baskets has several disadvantages. The sides are sharp and easily bruise the produce. They are too deep and without sufficient side reinforcement, thus causing the produce to be Jarred or compressed. Moreover, handlers tend to throw rather than lift the produce gently because of its weight. The use of wooden crates could solve many of the objections to the bamboo baskets. The main objection to a wooden crate.

To summarize, transport losses are due to the following:

a. **Unsuitable transport containers;**
b. **Overloading of mixed fruits and vegetables (in some developing countries people and even animals ride on top of the load);**
c. **Irresponsible driving;**
d. **Lack of feeder roads loading to highways or collection centres;**
e. **Rough roads;**
f. **Heat accumulation or very poor ventilation within the transport vehicles;**
g. **Virtual absence of refrigerated and insulated trucks;**
h. **Delays in product procurement after harvesting or at collection centres.**

In many developing countries wholesale markets, if any are integrated with retail markets. Ideally, wholesale markets should be separated from the retail ones. However, this is influenced by the structure of the marketing chain and the scale of the industry. Frequently wholesale markets are overcrowded, unsanitary and lack suitable facilities for display, storage, ripening, loading and unloading. A main contributory factor to loss of leafy vegetables is trimming at wholesale markets prior to delivery at retail stands. Examination of trimmings showed that wholesalers and retailers trimmed their produce mainly because of the presence of decaying portions of leaves, due to bacterial soft rot. Thus, prevention of rotting during transport and storage would result in substantial reduction for postharvest losses of leafy vegetables.

Storage of fresh fruits and vegetables prolongs their usefulness, checks market gluts, provides a wider selection of fruits and vegetables throughout the year, helps in orderly marketing and may increase the financial gain to the producer. Adequate storage may reduce subsequent losses, but cannot overcome pre-storage losses. Adequate storage involves proper regulation of temperature, humidity, air circulation, proper stacking pattern, regular inspection, and prompt produce disposal as soon as maximum storage life has been attained. The feasibility of the construction of cold storage facilities and the interest among farmers and handlers to utilize the cold stores would again depend upon the economics parameters of the project. One of the

greatest impediments to preserving quality through refrigerated storage is the consumers' strong preference for freshly harvested produce and resistance to stored produce.

Information on the storage temperature and humidity requirements of fruits and vegetables and the length of time they can be kept without decline in market value is either inadequate or unknown to those who need the information. If a farmer is persuaded to store his produce in cold storage and the market value decreases due to inadequate knowledge of the proper utilization of cold storage, it is not only he who will become disillusioned, but his friends also will be convinced of the non-profitability of cold storage.

Lack of capital may also force farmers to ignore the use of cold storage, even when available and effectively managed. Many growers depend on almost daily sales for their income and hence may be forced to accept a lower price immediately, rather than to store their produce in the anticipation of a higher price. There is also the storage rental price which the farmer may not be willing to pay unless he is thoroughly convinced that he will not only recover his investment, but will also profit.

The retailer usually disposes of produce which has been damaged by factors occurring further back in the marketing chain. At this stage, deterioration of perishables has

already progressed to such an extent that street vendors have little opportunity to prevent further losses, either through storage or other preventive measures, except by estimating their potential sale for the day and buying only the amount that can be disposed of.

In Malaysia, although fruits and vegetable are sold in the open market, retailers improvise beach umbrellas arranged side by aide to provide acceptable shade to the commodity during market days. After the market is over in the afternoon the umbrellas are folded and the market area is again an open space. This simple technique or similar ones could be adopted in other developing countries as a temporary measure to provide shade to the produce.

Miscellaneous losses are numerous. The moat important ones are:

a. Over-purchase of cheap but highly perishable fruits and vegetables leading to wastage due to inadequate storage facilities.
b. Rates of pay among "cargadores" (product haulers) usually depend on the number of containers that they can carry from one point to another. Hence, they disregard proper handling in their hurried attempts to make more trips.
c. Deterioration during storage occurs because some old stocks are intentionally kept too long in anticipation of eventual price increases;

d. **Maintenance of transport, storage and other handling facilities are generally poor in developing countries resulting in a continual source of losses.**
e. **There is no efficient communication link between producers and wholesalers. Losses will always occur in the absence of a dependable communication system.**

4.2 Individual fruits and vegetables

The following notes highlight some of the major problems of the more important commodities in the fruit and vegetable group. They are, however, indicative rather than exhaustive.

<u>Bananas and Plantains</u>. Harvesting is generally a one-man operation which frequently results in bruising and abrasions of fruits causing accelerated ripening and consequent decay. Latex staining is prevalent during dehanding. Bunches or hands are often piles one on top of the other without proper protection and fingers are easily detached and oftentimes wasted during transport. This is particularly true of the very open, loose bunches of certain plantain cultivars. In container transport loosely packed hands suffer considerable damage, especially on rough roads. In transit ripening and decay are usually high, notably over long distances.

<u>Mango</u>. Fruits are usually harvested at the time of the day when maximum latex flow

is favoured. Latex stain is allowed to dry on the peel, hence immediately reducing consumer acceptability during retail. The collapsibility of the non-rigid crates often used for transport further aggravates quality lose by compression and bruising. The inaccessibility of production area to roads causes serious delays in transport, in addition to a mixed-cargo typo of transport. Stacking in vehicles often does not provide for adequate ventilation. Loading and unloading operations are rather rough. Cold storage is not usually practised. Ripening is mainly aimed at improvement of the appearance for sales purposes and not for maintaining quality.

<u>Papaya</u>. Picking poles injure the fruit and there is a relatively high percentage of fruit dropping on the ground, causing breakage and bruising of ripe fruits. Peduncles are not usually trimmed hence injuring other fruit a within the pack. Rigid containers are not adequately linde, and within a single pack fruits of assorted sizes and maturity stages are often found. In bulk transport fruit e arc piled one on top of the other without any suitable padding materials. High percentage of decay, particularly anthracnose, is the main problem during ripening and in retail.

<u>Citrus</u>. Improper time of harvesting greatly enhances rind injury or oleocellosis. Leaving long stubs on fruit a injures other fruits within the pack. Containers used are large and overpacked, generally without sufficient ventilation. Containers are piled high with the bottom crates bearing the full weight of crates on top. Delays in transport due to poor

roads often cause over-ripening or yellowing of the commodity. Poor storage conditions favour decay and physiological disorders such as chilling injury can also occur if cold stores are not wolf managed.

Grapes are attacked by Botrytis, Cladosporium and Alternaria during storage. However, if the storage temperature is strictly maintained between 0 and 2C, fungal attack can be reduced to a minimum Other loss factors could be berry drop, bruises, injury, water loss, and cracking of berries. Selection of unsuitable container type for packaging of grapes may also lead to heavy transit losses. Transit delays, adverse weather conditions and improper type of carriages, e.g., steel wagons, particularly during hot months may further aggravate transit losses.

Tomato fruits are usually picked when fully ripe, and are therefore very susceptible to cracking, bruising, and consequently decay. Packaging containers often used are deep bamboo crates with insufficient aide reinforcements allowing jarring and compression during transport. Loading and unloading operations are very crude. Handlers tend to throw the pecks rather than lift them gently, on account of their weight. During retail sellers tend to pour the contents of the pack into another container, rather than transferring the fruit gently, thereby increasing bruise damage. Fruit a at the breaker stage are mixed with the fully ripe or three-quarters ripe fruits reducing the market value of the pack. Shrivelling percentage can be high since fruits are often exposed to

the sun.

<u>Onions</u>. Insufficient grading is still existent. Spouted, injured and partly decayed bulbs are usually mixed with sound bulbs in a pack. The use of slatted wooden creates is advantageous, especially during transport. Mesh bags of 40-50 kg. capacity are also used. Sacks are thrown rather than lifted, on account of their weight. Packs are piled one on top of the other with no provision for adequate ventilation. Pre-harvest spraying with sprout inhibitors is seldom practised resulting in serious sprouting during storage.

<u>Cabbage/Lettuce</u>. Improper harvesting tools contribute greatly to damage to the produce in the form of out a and abrasions. Trimming of outer leaves is usually not practised. In container transport, large crates are used (50 kg. capacity). Bruising and tearing of the leaves is of common occurrence due to the sharp edges of the containers. Containers are piled one on top of the other with the bottom crates carrying the weight of the heads above. Bulk transport likewise results in higher losses.

<u>Peas and Beans</u>. Factors such as the method of packing, suitability of containers, mode of transport, distance covered, number of transshipments, handling, and storage facilities in the consuming centres, all contribute to the degree of loss reported.

4.3 Institutional aspects

The solution to the problems of improper handling of perishable produce in the tropics is rather difficult, owing to the complexity of the problem. It requires the solving of technical problems as well as those of credit, land, transportation and marketing availability. It also requires a change of people's attitudes to proposed solutions and new innovations. Such an approach can only be accomplished over the years, tackling specific problems in a stepwise fashion. There must be concerted efforts by the private and government sectors.

Extension work is needed to show that post-harvest procedures are as important as production techniques. It is not enough to produce good quality commodities through variety improvement and proper regulation of soil and climatic factors. The whole process from planting until the harvested products reach the consuming public must be a mutual undertaking between the growers and those who will handle the product after harvest. Post-harvest handling up to the final marketing stage must be considered as a single system. The success of maintaining the harvest-fresh quality of produce demands control) each atop depending upon the previous one. If the initial quality of the product is poor, no post-harvest treatment can improve it, although careful selection and grading may salvage some good quality produce from a mixed-quality sample. Thus handling procedures from harvesting until the product reaches

the consumers are chains of interdependent activities.

The establishment of wholesale markets or cold storage facilities by Governments or other agencies must also meet the general approval of the persons who must use them. Of what use would a modern wholesale market be if the wholesalers would rather use an antiquated one that is more accessible to them? The establishment of a cold storage plant in an area accessible to the users must be accompanied by a sustained information and promotion campaign. Emphasis must be laid on the benefits of the farmer. Realistic rental rates and payments after the sale of product a could attract the farmer to use this facility. Above all' an essential prerequisite to the taking of a decision to erect a new wholesale market is the need to carry out a sound feasibility study to provide suitable information for the decision-making to use.

The establishment of co-operatives has done much in certain countries but only whore the organizations are effectively run and the members are aware of their responsibilities as well as the benefits. The farmers involved in cooperatives have a greater bargaining power and control of the production planning and marketing which may spur then can to improve or maintain the quality of their produce. They may also be encouraged to obtain credit.

Technical knowledge of post-harvest handling has been increasing and there is a need

to translate this body of knowledge into systems and techniques that the farmer can understand and use. Agricultural extension information must be reliable. The extension worker must have a, good grasp of his job and must know where to turn when he cannot solve problem himself.

A continuing problem is the low educational lover of farmers in developing countries and their skepticism towards new methods they have never tried or seen before. Farming, especially of fruits and vegetables, is not looked upon as an attractive occupation. Often farming is an occupation of last resort. Vagaries of weather make farming a risky business and knowledgeable and enterprising farmers are few.

In a way, acceptance of improvements and innovation are tied up with the economic progress of a nation. If the buying power of the people is increased, they are more willing to accept the increase in prices associated with the improvement in the post-harvest handling of fruits and vegetables.

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Table 2 Production of Root/Tuber Crops in Developing Countries (thousands of tons)

Crops	Africa	Latin America	Near East	Far East	South Pacific	Total	% 1975
Cassava	42,884	32,201	1,128	27,643	221	104,037	59.7
Potatoes	2,039	8,951	4,206	8,445	-	23,641	13.6
Yam	19,279	291	260	30	200	20,060	11.5
Sweet Potatoes	5,539	3,379	94	8,764	560	18,336	10.5
Taro	3,569	-	59	90	262	3,980	2.2
Others	1.446	811	-	1,674	390	4,321	2.5
Total	74,716	45,633	5,747	46,646	1,633	174,375	

Source: FAO Production Yearbook

Table 3 Production of Major Vegetables, 1978 (thousands of tons)

Vegetable	World	Developed Countries	Developing Countries	Centrally Planned
Tomatoes	47,087	19,301	14,475	13,310
Cabbage	32,098	10,593	3,631	17,874
Watermelon	23,635	4,946	11,044	7,645
Onions	18,243	6,158	6,788	5,297
Carrots	10,073	4,417	700	4,956
Cucumbers	9,819	3,480	1,384	4,955
Peppers, green	5,999	1,742	2,270	1,988
Melons	5,864	2,325	2,118	1,321
Pumpkins	4,885	1,116	2,382	1,387
Peas, green	4,551	3,116	584	851
Cnuliflower	4,283	2,243	997	1,043
Eggplant	4,031	1,229	1,504	1,298
Beans, green	2,429	1,407	548	474

Garlic	2,111	449	1,074	588
Artichokes	1,254	1,084	170	-

Data from FAO Production Yearbook 1978

Table 4 Production of Major Fruits 1978 (thousands of tone)

Fruit	World	Developed Countries	Developing Countries	Centrally Planned
Crapes	56,030	35,658	11,264	9,981
Bananas	36,892	582	35,163	1,047
Oranges	34,110	14,637	18,344	1,129
Apples	31,280	15,753	4,370	11,157
Plantains	20,391	-	20,391	-
Citrus, nor orange	16,804	10,778	5,558	469
Mangoes	13,782	14	13,501	266
Pears	7,651	4,555	876	2,221

Pineapple	6,836	980	4,896	961
Peaches	6,787	4,560	1,168	1,058
Plums	5,241	2,465	481	2,296
Dates	2,264	39	2,625	-
Apricots	1,584	667	511	406
Strawberries	1,564	1,052	140	371
Papayas	1,514	54	1,424	36
Avocados	1,284	157	1,127	-

Data from FAO Production Yearbook 1978

Table 5 Reported Production and Loss Figures in Less Developed Countries

Commodity	**Production (1.000 tonnes)**	**Estimated Loss %**
Roots/Tubers		
Carrots	557	44
Potatoes	26,909	5-40

Sweet Potatoes	17,630	35-95
Tams	20,000	10-60
Cassava	103,486	10-25
Vegetables		
Onions	6,474	16-35
Tomatoes	12,755	
Plantain	18,301	35-100
Cabbage	3,036	37
Cauliflower	916	49
Lettuce		62
Fruits		
Banana	36,898	20-80
Papaya	931	40-100
Avocado	1,020	43
Peaches, apricots nectarines	1, 831	28

Citrus	22,040	20-95
Grapes	12,720	27
Raisins	475	20-95
Apples	3,677	14

Data from National Academy of Sciences report, 1978

Table 6 Storage Life of Potato and Onion Varieties

Variety (months)	**Normal Storage Life**
POTATOES	
Necksack	11-12
Russet Burbank	10-11
Kennebec	6-7
Katahdin	6-7
Sebago (Northern USA)	5-6
Norland (late harvest)	4-6
Norchip	4-5

Superior	4
Norgold Russet	3
Norland (early harvest)	1
Sebago (Southern USA)	1
White Rose	1
ONIONS	
Spartan Sleeper	7-8
Downing Yellow Globe	7
Premier	5-6
Fiesta	5
Yellow Sweet Spanish	4-5
Excel	3-4
Golden Beauty	3
Italian Red	1-2
Walla Walla Sweet Spanish	1-2

Table 7 Post-Harvest Pesticide Tolerances on Raw Horticultural Commodities U.S. Environmental Protection Agency, July 1, 1977

Captan (180,103)	100ppm	beet greens, cherries, lettuce, spinach
	50 ppm	apricots, celery, grapes, leeks, mangoes, nectarines, onions (green), peaches, plums (fresh prunes), shallots
	25 ppm	apples, avocados, blackberries, blueberries (huckleberries), cantaloupe, crabapples, cranberries, cucumbers, dewberries, eggplants, garlic, honeydew melons, muskmelons, onions (dry bulb), pears, peppers, pimentos, pumpkins, quinces, raspberries, summer squash, tomatoes, watermelons, winter squash
	2 ppm	beets (roots), broccoli, brussels sprouts, cabbage, carrots, cauliflower, collards, cottonseed, kale, mustard greens, peas (dry and succulent), rutabagas (roots), soybeans (dry and succulent), sweet corn (kernels plus cob with husk removed), turnip greens,

	0.25ppm	turnips (roots) taro (corm)
Methoxychlor (180.120)	7 ppm	sweet potatoes and yams
Inorganic bromides (from fumigation with methyl bromide)		
(180.123)	100 ppm	pomegranates, asparagus, ginger root
	75 ppm	potatoes, sweet potatoes, avocados
	50 ppm	green beans, lima beans, garlic, sweet corn, cabbage
	30 ppm	beets (roots), carrots, citrus, citron, salem-artichokes, kumquats, lemons, limes, okra, oranges, parsnip (roots), peppers, pimentos, relishes, rutabagas, salsify roots, cucumbers, grapefruit, horseradish, summer squash, tangerines, turnips (roots), yams
	20 ppm	apricots, cantaloupe, cherries eggplant, grapes, honeydew melons, mangoes, muskmelons, nectarines, peaches, onions, papayas, pineapples, plums, fresh prunes, pumpkins, tomatoes,

		watermelons, winter squash, zucchini
	5 ppm	apples, pears, quinces
Inorganic Bromides (from fumigation with ethylene dibromide)		
(180.146)	10 ppm	beans (string), bitter melons, cantaloupe, Cavendish bananas, citrus fruits, cucumbers, guavas, litchi fruit, litchi nuts, longan fruit, mangoes, papayas, peppers (bell), pineapples, zucchini squash
	25 ppm	(total organic plus inorganic bromine) cherries! plums, fresh prunes
Calcium Cyanide (180.125)	5 ppm	cucumbers, lettuce, radishes, tomatoes
Piperonyl butoxide (180.127)	8 ppm	almonds, apples, beans, blackberries, blueberries (huckle berries), boysenberries, cherries, cocoa beans, copra, cottonseed, crabapples, currants, dewberries, figs, gooseberries, grapes, guavas, loganberries, mangoes, muskmelons, oranges, peaches, peanuts (determined on the nut with shell removed), pears, peas, pineapples' plums (fresh prunes), raspberries, tomatoes, walnuts

Sodium dehydroacetate (180.159)	65 ppm	strawberries
	30 ppm	bananas, of which residue not more than 10 parts per million shall be in the pulp after peel is removed.
Tetraiodoethylene (180.162)	15 ppm	cantaloupe
Ethoxyquin (180. 178)	3 ppm	apples and pears
CIPC (180.181)	50 ppm	potatoes
Diphenylamine (180.190)	10 ppm	apples
2,6-dichloro-4-nitroaniline (180.200)	10 ppm	carrots, grapes, lettuce, rhubarb, sweet potatoes
	20 ppm	sweet cherries, apricots, peaches, nectarines
	15 ppm	plums (fresh prunes), blackberries, boysenberries, celery
Chlorosulfamic acid (180.201)	8 ppm	asparagus, carrots, cauliflower, celery, potatoes, and radishes

1,2, 4,5-Tetrachloro-3-nitrobenzene		
(180.203)	25 ppm	potatoes
Aluminum phosphide (180.225)	.1 ppm	almonds, cashews, dates, filberts, Brazil nuts, pistachios, peanuts, pecans, walnuts
2,2-Dichlorovinyl dimethyl phosphate		
(180.235)	1 ppm	lettuce
	0.5 ppm	cucumbers, mushrooms, tomatoes, radishes
Thiabendazole (180.242)	10 ppm	apples, citrus fruits, pears
	3 ppm	potatoes, bananas
	0.4 ppm	banana pulp
Boron (180.271)	8 ppm	citrus fruits, (total, includes boron naturally occurring in the fruit).
Benomyl (180.294)	35 ppm	pineapples
	15 ppm	apricots, cherries, nectarines, peaches, plums (including fresh prunes)
	10 ppm	grapes, mushrooms
	7 ppm	apples and pears

	1 ppm	bananas of which not more than 0.2 ppm shall be in the pulp after the peel is removed
sec-Butylamine (180.321)	30 ppm	citrus fruits
Thiophanate-methyl (130.371)	15 ppm	apricots, cherries, nectarines, peaches, plums, prunes
Pyrethrins (180,126)	1 ppm	almonds, apples, beans, blackberries, blueberries (huckle berries), boysenberries, cherries, crabapples, currants, dewberries, figs, gooseberries, grapes, guavas, loganberries, mangoes, muskmelons, oranges, peaches, pears, peas, pine apples, plums (fresh prunes), raspberries, tomatoes and walnuts
	0.05ppm	potatoes
o-Phenylphenol and its (180.129)	125 ppm	cantaloupe, of which not more than 10 ppm shall be in the sodium salt edible portion
	25 ppm	apples, pears
	20 ppm	carrots, peaches, plums, fresh prunes

	15 ppm	sweet potatoes
	10 ppm	citrus, citron, cucumbers, grapefruit, kumquats, lemons, limes, oranges, peppers (bell), pineapples, tangerines, tomatoes
	5 ppm	cherries, nectarines
Hydrogen cyanide. (180.130)	50 ppm	citrus fruits -
	25 ppm	almonds, cashews, pecans' walnuts
Biphenyl (180.141)	110 ppm	citrus fruits (and hybrids thereof)
2,4-D (180.142)	5 ppm	citrus fruits, lemons
Thirem (180.132)	7 ppm	bananas of which not more than 1 ppm shall be in the pulp after the peel is removed
	0.5 ppm	onions (dry bulb)
Copper carbonate, basic (180.136)	3 ppm	pears
Ethylene oxide	50 ppm	black walnut meats, whole spices

(180.151)		
Maleic hydrazide (180.175)	50 ppm	potatoes
	15 ppm	onions

Note: Maleic hydrazine is applied pre-harvest solely for its ability to retard post-harvest sprouting

Table 8 Chemicals or Industrial Processes Associated with Cancer Induction in Man

Chemical or Process	**Main Type of Exposure**
Aflatoxins	environmental, occupational
4-aminobiphenyl	occupational
Arsenic compounds	occupational, medicinal, environmental
Asbestos	occupational
Auramine manufacture	occupational
Benzene	occupational
Benzidine	occupational

Bis(chloromethyl) ether	occupational
Cadmium industries	occupational
Chloramphenicol	medicinal
Chlormethyl methyl ether	occupational
Chromium industries	occupational
Cyclophosphamide	medicinal
Diethylstilbestrol	medicinal
Haematite mining	occupational
Isopropyl oil	occupational
Melphalan	medicinal
Mustard gas	occupational
2-Naphthylamine	occupational
Nickel	occupational
Chlornaphazine	medicinal
Oxymethalone	medicinal
Phenacetin	medicinal

Phenytoin	medicinal
Soot, tars and oils	occupational, environmental
Vinyl chloride	occupational

(Data taken from U.S. National Cancer Institute report entitled "Estimates of the Fraction of Cancer in the United States Related to Occupational Factors" September 1978).

Table 9 List of Carcinogens

Acetylamino fluorane	Diethyl sulfate
Alkali	4-Dimethylaminoazobenzene
0-Aminoszotoluene	N,N'Dimethylbenzine
2-Aminobenzidine	1,1-Dimethylhydrazine
4-Aminobiphenyl and its salts	N,N'-Dimethyinitrosoamine
Antimony trioxide production	Dimethyl sulfate
Arsenic and arsenic compounds	Dioxane
Asbestos	Epichlorobydrine
Auramine	Ethyleneimine

Benzpyrene	Ethyl thyocarbamide
Benzene	Gasoline or petrol
Benzidine and its salt	Hexamethylohosphorictriamide
Beryllium	Hydrazine
Bichromic acid and salts	Kepone
Bis(chloromethyl)ether	Magenta
Cadmium and cadmium oxide	4,4'-Methylenebis(2-chloraniline)
Chloromethyl methyl ether	Methyl chloromethyl ether
Chlorinated biphenyl	Methylene dianiline
Chloroform	Methyl nitrosocarbamide
Chromates	Monomethyl hydrazine
Chromic acid and its salts	1-Naphthylamine and its salts
Chromium compounds in chromate	2-Naphthylamine and its salts
production	Nickel and its compounds
Chromite ore processing	4-Nitrobiphenyl and its salts

Coal tar	Nitrosamines
Cobalt and its salts hydrocarbons	Particulate polycyclic aromatic
Crocidolite	p-Phenylendiamine
N'N'-Diacethylbenzene	1,3-Propane sultone
4,4-Diamino diphenylmethane	2-Propiolactone
Dianisidine and its salts	Propyleneimine
Diazomethane	Thallium
1~2-Dibromoethane	o-Tolidine and its salts
3,3'-Dichlorobenzidine and its	Trichloroethylene
salts	Vinyl chloride
3,3'-Dichloro 4,4'-diamino-	Vinyl cycloexene dioxide
diphenylmethane	Yellow fatty dye

A tabular compilation of values from Australia, Belgium, Finland, Federal Republic of Germany, Italy, Japan, Sweden, Switzerland, United Kingdom' Union of Soviet Socialist Republics, United States of America. Occupational Safety and Health Series, No. 37, 1977, compiled by the International Labour Office, Geneva

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Sigles et abréviations utilisés dans cette publication

AGRIS	Le système bibliographique international de la FAO
AGSI	Service de Gestion Agro-Industrielle et de Post-Récolte de la FAO
APV	Agents Polyvalents de Vulgarisation au Bénin
AROs	Advanced Research Organisations
ASIP	Programme d'Investissement dans le Secteur Agricole en Zambie
BMZ	Ministère fédéral de la Coopération économique et du Développement en Allemagne
CARDER	Centres d'Action Régionale pour le Développement Rural au Bénin
CIAT	Centre International d'Agriculture Tropicale, Colombie
CIP	Centre International de la Pomme de terre, Pérou

CIRA	Centre International pour la Recherche Agronomique
CIRAD	Centre de coopération Internationale en Recherche Agronomique pour le Développement, France
COSCA	Étude Collaborative du Manioc en Afrique
CPI	Conseil Phytosanitaire Interafricain
CRDI	Centre de Recherche pour le Développement International
CRTBP	Cultures à Racines et Tubercules, Bananes à cuire et Plantain
DANIDA	Agence Danoise pour le Développement International
DPV	Division de la Protection des Végétaux en République de Guinée
FAO	Organisation des Nations Unies pour l'Alimentation et l'Agriculture

FIDA	Fonds International pour le Développement Agricole, Italie
FSA	Faculté des Sciences Agronomiques de l’Université Nationale du Bénin
GASGA	Groupe d’Assistance aux Systèmes concernant les Grains Après récolte
GCM	Grand Capucin du Maïs
GCRAI	Groupe Consultatif pour la Recherche Agricole Internationale
GIS	Systèmes d'Informations Géographiques
GRZ	Gouvernement de la République de Zambie
GTZ	Coopération Allemande au Développement
ICRTCR	Comité inter-centre de recherche sur les cultures à racines et

IFPRI	Institut International de Recherche pour la Sécurité Alimentaire, États-Unis
IIBC	Institut International de Lutte Biologique, Royaume-Uni
IITA	Institut International d'Agriculture Tropicale
INCV	Institut National des Cultures Vivrières, Togo
INERA	Institut de l'Environnement et de Recherches Agricoles au Burkina Faso
INP*h*O	Réseau d'information sur les opérations de post-récolte de la FAO
INRAB	Institut National de Recherches Agronomiques du Bénin
MDR	Ministère du Développement Rural au Bénin
NRI	Institut des Ressources Naturelles, Royaume-Uni
OAU	Organisation pour l'Unité Africaine

ODA	Administration pour le Développement International, Royaume-Uni
ONASA	Organisation Nationale pour la Sécurité Alimentaire, Bénin
PASDA	Programme d'Appui au Développement du Secteur Agricole au Bénin
PGLB	Programme Guinéen de Lutte Biologique
PHMD	Division de Phytiatrie à l’IITA
PTD	Programme de Développement Participatif de Technologies
SNRA	Systèmes Nationaux de Recherche Agricole
SNRVA	Services Nationaux de Recherche et de Vulgarisation Agricoles
SPFP	Programme Spécial de la FAO pour la Production et la

	Sécurité Alimentaires
SPV	Service de Protection des Végétaux
TAC	Comité Consultatif Technique du GCRAI
TCP	Projet de coopération technique de la FAO
TT & TU	Unité de Test et de Transfert de Technologies à l'IITA
UAW	Université d'Agriculture de Wageningen, Pays Bas

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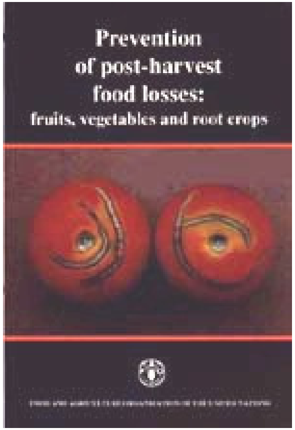

Prevention of post-harvest food losses fruits, vegetables and root crops a training manual

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Foreword

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Despite the remarkable progress made in increasing food production at the global level, approximately half of the population in the Third World does not have access to

adequate food supplies. There are many reasons for this, one of which is food losses occurring in the post-harvest and marketing system. Evidence suggests that these losses tend to be highest in those countries where the need for food is greatest.

Both quantitative and qualitative food losses of extremely variable magnitude occur at all stages in the post-harvest system from harvesting, through handling, storage, processing and marketing to final delivery to the consumer. Although the subject of food losses had been on the agenda of many meetings, it was not until the 1974 World Food Conference and the 7th Special Session of the UN General Assembly that special attention was given to it. In response, the 1977 FAO Conference approved the establishment of a Special Action Programme for the Prevention of Food Losses. Initially, this programme focused on staple food grains but, since 1983, at the request of the FAO Conference, additional attention has been given to perishable food commodities: roots and tuber crops, fruits and vegetables.

As part of this programme, FAO has organized numerous regional, subregional and national workshops and training sessions to help technical officers to recognize and reduce post-harvest losses and enhance the efficiency of marketing operations. In 1985, a training manual (FAO Training Series No. 10, to be revised and reissued as FAO Training Series No. 17/1) on the prevention of post-harvest food losses in grain crops was published. The present manual, on the prevention of post-harvest food losses in

fruits, vegetables and root crops, is based on material previously developed during FAO's training programmes and is now being published as a companion to the volume on grain crops in the FAO Training Series. This manual also complements and updates FAO's Marketing Guide No. 2, *Marketing Fruits and Vegetables.*

I trust that this manual will be of assistance to all those providing practical training for the prevention of post-harvest food losses in perishable crops.

C.H. Bonte-Friedheim
Assistant Director-General
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Preface

This manual, Volume II of the training manual on the prevention of post-harvest food losses, presents material from a wide variety of disciplines associated with the prevention of food losses and development of marketing operations, particularly those in fruit, vegetables and roots and tubers. It is directed to field staff, project

supervisors, teachers at agricultural schools and at training institutions, and extension personnel connected with the handling and marketing of those commodities.

This manual should serve as a reference work on the prevention of post-harvest food losses. For specific training purposes, the manual takes up a number of crops and techniques from which the trainer can select according to local conditions. Trainers are encouraged to supplement the material by practical work and by detailed worksheets or handouts covering special topics of local interest.

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1. Introduction

1.1 The importance of post-harvest losses

Time and money are required to cultivate food products, and unless the farmer is providing food only for his own household, he automatically becomes part of the market economy: he must sell his produce, he must recover his costs, and he must make a profit.

Estimates of the post-harvest losses of food grains in the developing world from mishandling, spoilage and pest infestation are put at 25 percent; this means that one-quarter of what is produced never reaches the consumer for whom it was grown, and the effort and money required to produce it are lost-forever. Fruit, vegetables and root crops are much less hardy and are mostly quickly perishable, and if care is not taken in their harvesting, handling and transport, they will soon decay and become unfit for human consumption. Estimates of production losses in developing countries are hard to judge, but some authorities put losses of sweet potatoes, plantain, tomatoes, bananas and citrus fruit sometimes as high as SO percent, or half of what is grown. Reduction in this wastage, particularly if it can economically be avoided, would be of great significance to growers and consumers alike.

1.2 Causes of losses vary widely

Factors affecting post-harvest food losses of perishables vary widely from place to place and become more and more complex as systems of marketing become more complex. A farmer who is growing fruit for his family's consumption probably doesn't mind if his produce has a few blemishes and bruises. If he is producing for a market at

any distance from his own locality, however, he and his workers, if he has any, must have a different attitude if he hopes to get the best money return on his work.

Figure 1. Principal marketing and distribution channels for fresh fruit, vegetables and root crops

By knowing his market, the grower can and must judge how important are the requirements of appearance, maturity and flavour for his produce. Furthermore, the grower must decide whether the investment in packaging will in fact pay for itself in increased value of the crop. It will be of no value to buy expensive containers for his produce if the field hands pitch them around and damage the contents. It is more important for the grower to change the attitude of himself and his workers toward reducing post-harvest losses than it is for him to think that buying fancy packaging will automatically solve his problems and improve his income. The farmer must give careful attention to:

- **Market demand for the products he will grow; he must know the market and his buyers**
- **Cultivation**
- **Harvesting and field handling**
- **Packing or packaging**

- **Transport**
- **Market handling; possibly storage or refrigeration**
- **Sales to consumers, wholesalers or agents**
- **Perishability of the produce.**

The following sections will discuss these among other factors. The grower must recognize that small changes in attitudes toward the prevention of post-harvest food losses may profit him more than changes in the techniques of the marketing chain, whether containers or transport improvements, and may cost him less in the long run. He must instruct his family, field workers, and others in the methods of reducing his losses.

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2. Nutrition and fresh produce

2.1 The contribution of fresh produce to human nutrition

Most people eat a mixed diet of foods from plants and animals. In most societies,

starchy staple foods, particularly cereal grains, are the main source of energy in the human diet. In certain areas, especially in the humid tropics, root and tuber crops, together with plantains and similar plants, are either the staple food or a supplement to cereal staples.

Fruit and vegetables are important sources of essential minerals and vitamins in the human diet. When eaten together with some root (potato, sweet potato) and leguminous (pigeon peas, beans, lentils) crops, they provide a proportion of protein requirements as well as variety in flavour and colour.

2.2 Energy requirements

- **Starches and sugars, formed within the plant for its own use, are used as energy foods. Starch is the main component of root and tuber crops and also of plantains and green bananas.**
- **Oils and fats are also energy foods. Fresh produce contains only small amounts except for avocados, which contain 15-25 percent oil.**

2.3 Food for body growth and repair

- **Proteins are essential to the building and repair of muscles and organs. They are needed in large amounts by growing children. Fresh produce is low in protein content, although on a dry-weight basis some root crops such as sweet potato and potato as well as leaves of several crops have protein contents approaching that of animal products. Cassava has very low protein content.**
- **Minerals are required for health but only in small amounts as compared with energy foods and proteins. Sodium, potassium, iron, calcium, phosphorus and many trace elements are essential. Vegetables contain significant amounts of calcium, iron and some other minerals.**
- **Vitamins are essential for the control of chemical reactions in the body. Fruit and vegetables, and to a lesser extent root crops, are important sources of vitamin C and other essentials. Table 1 lists the important vitamins derived from fresh produce.**
- **Fibre or "roughage" is found in large amounts in fresh produce. Though indigestible, it plays an important part in the function of digestion, and a diet containing high fibre content is shown by medical studies to reduce susceptibility to disease.**

2.4 Loss of food value in fresh produce

The keeping and the preparation of fresh produce after harvest affects its nutritional value in several ways, for example:

- **Dry-matter content (the energy supply) is reduced with time as the continuation of living processes within the produce uses up stored food reserves.**
- **Vitamin C content decreases with time after harvest, and little may remain after two or three days.**
- **Cooking partially destroys vitamins C and B1. Raw fruit and vegetables are particularly valuable provided they are grown and handled hygienically.**
- **Peeling may cause significant loss of food value, especially in potatoes, where the protein content is just beneath the skin.**
- **Water used in cooking vegetables or fruit contains the dissolved minerals and trace elements of the food and should not be thrown out but used in soups or in preparing other foods.**

Further information on the food value of fresh produce can usually be obtained at

national nutritional councils or departments of health.

TABLE 1. Vitamins supplied by fruit, vegetables and root crops

Vitamin	Name	Source
A	Retinol	From carotene in dark green leaves, tomatoes, carrots, papayas
B1	Thiamine	Pulses, green vegetables, fruit (cereal grains have B. in germ and outer-seed coat)
B2	Riboflavin	Green leafy vegetables and pulses
B6	Pyridoxin	Bananas, peanuts
PP	Niacin (nicotinic acid)	Pulses, peanuts
-	Folic acid	Dark green leaves, broccoli, spinach, beets, cabbage, lettuce, avocados
C	Ascorbic acid	Dark green leaves, spinach, cauliflower, sweet pepper, citrus, guava, mango, papaya

Source J. Srhuur, FAOR, Barbados.

3. Pre-harvest factors in produce marketing

3.1 Pre-harvest influences on post-harvest performance

The overall quality and condition of fresh produce cannot be improved after harvest. The final potential market value of his produce depends on the grower's decisions on what and when to plant and on the subsequent cultivating and harvesting practices. The adoption of good post-harvest practices described in the later sections of this manual can extend the useful post-harvest life of fruits and vegetables but only to the extent that their quality and condition at harvest permit.

Growers in general rely on their own experience and local traditions in selecting crops and in cultivation practices, but if they want or need assistance they may need to be referred to agricultural extension officers or possibly to research and development specialists of their national department of agriculture or its equivalent.

3.2 Market factors for the produce

Market factors affecting farmers' decisions on the growing of specific crops are:

- **potential purchasers for the produce: neighbours, townspeople, retailers, jobbers or middlemen, commission agents?**
- **quality requirements of the buyer: size, shape, maturity, appearance, perishability of the produce;**
- **pricing limitations of the buyer.**

A commodity can be "too good" as well as "too bad": one that greatly exceeds market requirements may not bring higher prices and thus be a waste of labour and resources.

An important limitation of most markets is that only certain varieties of a commodity are traded and others are unacceptable. In Indonesia, for example, 242 varieties of mango have been recorded by the Agricultural Seed Experiment Station in East Java, but only seven have any commercial potential beyond certain villages. The non-marketable mangos, however, constitute about 70 percent of the total production, and the local grower can effectively increase his market share only by replacing existing trees with those of the desirable varieties.

In international trade, this specification of variety is of critical importance. Countries

wishing to export have little choice but to offer what will be bought by importing countries. This holds true among developing countries. For example, the Association of South East Asian Nations (ASEAN) has consciously promoted trade in fruit and vegetables, many of which are common in the various countries, but there are still distinct preferences for different cultivars between countries.

New varieties are not easily introduced into developing countries and established as profitable crops. Apart from physical conditions and cultivation practices, problems may include the overcoming of traditional human conservatism unless there are compelling economic incentives.

3.3 Influence of production practices

Pre-harvest production practices may seriously affect post-harvest returns in quality and quantity and result in the rejection or downgrading of produce at the time of sale. Some of them are:

3.3.1 Water supply (Irrigation). Growing plants need a continuous water supply for both photosynthesis (the process by which plants convert light to chemical energy and

produce carbohydrates from carbon dioxide and water) and transpiration (the giving off by a plant of vapour containing waste products). Bad effects can be caused by:

- **too much rain or irrigation, which can lead to brittle and easily damaged leafy vegetables and to increased tendency to decay;**
- **lack of rain or irrigation, which can lead to low juice content and thick skin in citrus fruit;**
- **dry conditions followed by rain or irrigation, which can give rise to growth cracks or secondary growth in potatoes or to growth cracks in tomatoes (see colour section, Figure 3).**

3.3.2 Soil fertility, use of fertilizers. Lack of plant foods in the soil can seriously affect the quality of fresh produce at harvest. On the other hand, too much fertilizer can harm the development and post-harvest condition of produce. Some of the effects are:

- **lack of nitrogen can lead to stunted growth or to the yellow-red discoloration of leaves in green vegetables, e.g. cabbage;**
- **lack of potash can bring about poor fruit development and abnormal ripening;**
- **calcium-moisture imbalance can cause blossom-end rot in tomatoes and bitter pit in apples;**
- **boron deficiency can lead to lumpiness in papaya (see colour section, Figure 4);**

hollow stem in cabbage and cauliflower; the cracking of outer skin in beets.

These are a few of the commoner soil-nutrition problems that can be readily identified at harvest. The problem of fertilizer balance in soils and its effect on crops is complex and depends also on other conditions such as temperature, moisture, acidity of the soil and reactions among different fertilizer chemicals. Severe soil-nutrition problems need reference to specialist advice, if available.

3.3.3 Cultivation practices. Good crop husbandry is important in achieving good yields and quality of fresh produce. Certain aspects are particularly important, such as:

- weed control-weeds are commonly alternate or alternative hosts for crop diseases and pests, and those growing in fallow land near crops are as important as those growing among the crop. Weeds also compete with crops for nutrients and soil moisture;
- crop hygiene-decaying plant residues, dead wood, and decaying or mummified fruit are all reservoirs of infection causing post-harvest decay. Their collection and removal are crucial factors in the reduction of post-harvest losses.

3.3.4 Agricultural chemicals. These are of two types:

- **Pesticides and herbicides are used as sprays or soil applications to control weeds, disease and insect pests. They are dangerous because they can damage produce by producing spray burns if used incorrectly, and they can leave poisonous residues on produce after harvest. In most countries there are laws to control the use of pesticides, which should be used only in recommended concentrations. Strict observance of the recommended delay between the last spraying and the harvesting is required in order to keep poisonous spray residues from reaching the consumer. Advice on regulations should come from extension or other agricultural department officers.**
- **Growth-regulating chemicals are used in the field mainly to improve the marketability of fruit in order to control the time of fruit set and to promote uniform ripening. They are of little importance to small-scale production. Their effective use requires specialist knowledge, and they are mainly applicable to large-scale commercial production.**

3.4 When is fresh produce to harvest?

A critical time for growers of fruit and vegetables is the period of decision on when to

harvest a crop. Normally any type of fresh produce is ready for harvest when it has developed to the ideal condition for consumption. This condition is usually referred to as harvest maturity. Confusion may arise because of the word maturity since, in the botanical sense, this refers to the time when the plant has completed its active growth (vegetative growth) and arrived at the stage of flowering and seed production (physiological maturity) as shown in Figure 3.1. Harvest maturity thus refers to the time when the "fruit" is ready to harvest and must take into account the time required to reach market and how it will be managed en route. This time lag usually means that it is harvested earlier than its ideal maturity.

3.4.1 How is harvest maturity identified? Most growers decide when to harvest by looking and sampling. Judgements are based on:

- **Sight-colour, size and shape**
- **Touch-texture, hardness or softness**
- **Smell-odour or aroma**
- **Taste-sweetness, sourness, bitterness**
- **Resonance-sound when tapped.**

Experience is the best guide for this kind of assessment. Newcomers to fresh produce-growing may find that learning takes time. Harvest maturity can readily be observed in

some crops: bulb onions when their green tops collapse and potatoes when the green tops die off. Other crops can be more difficult: avocados remain unripe off the tree after maturity.

Figure 3.1 The comparison of physiological and harvesting maturity is shown here. In the various crops. harvesting maturity may be at a very different stage of the plant's development from that of physiological maturity. (Source: Improvement of post-harvest fresh fruits and vegetables handling, FAO(RAPA)/AFMA, Bangkok, 1986)

Large-scale commercial growers combine observation with more sophisticated measurement:

- **time-recording, from flowering to harvest;**
- **environmental conditions, measuring accumulated heat units during the growth period;**
- **physical properties, including shape, size, specific gravity, weight, skin thickness, hardness, etc.;**
- **chemical properties (important in fruit processing, less so in vegetables), sugar/acid ratio, soluble solids content, starch and oil content;**
- **physiological characteristics, including respiration rate, acidity or alkalinity (pH).**

The final decision on harvesting will take account of the current market value of the expected yield, and also the time during which the crop will remain in marketable condition. With seasonal crops, growers are often tempted to harvest too early or too late in order to benefit from higher prices at the beginning and end of the season.

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4. Perishability and produce losses

4.1 What are the principal causes of losses?

All fruits, vegetables and root crops are living plant parts containing 65 to 95 percent water, and they continue their living processes after harvest. Their post-harvest life depends on the rate at which they use up their stored food reserves and their rate of water loss. When food and water reserves are exhausted, the produce dies and decays. Anything that increases the rate of this process may make the produce inedible before it can be used. The principal causes of loss are discussed below, but in the marketing of fresh produce they all interact, and the effects of all are influenced by external conditions such as temperature and relative humidity.

4.2 Physiological deterioration

An increase in the rate of loss because of normal physiological changes is caused by conditions that increase the rate of natural deterioration, such as high temperature, low atmospheric humidity and physical injury. Abnormal physiological deterioration occurs when fresh produce is subjected to extremes of temperature, of atmospheric modification or of contamination. This may cause unpalatable flavours, failure to ripen or other changes in the living processes of the produce, making it unfit for use.

4.3 Mechanical damage (physical injury)

Careless handling of fresh produce causes internal bruising, which results in abnormal physiological damage or splitting and skin breaks, thus rapidly increasing water loss and the rate of normal physiological breakdown. Skin breaks also provide sites for infection by disease organisms causing decay.

4.4 Diseases and pests

All living material is subject to attack by parasites. Fresh produce can become infected

before or after harvest by diseases widespread in the air, soil and water. Some diseases are able to penetrate the unbroken skin of produce; others require an injury in order to cause infection. Damage so produced is probably the major cause of loss of fresh produce.

The influences of all three causes are strongly affected by the various stages of post-harvest operations, discussed below. Furthermore, they all have great effect on the marketability of the produce and the price paid for it.

4.5 Types of fresh produce

Commodities entering the trade in fresh produce include a wide variety of plant parts from a large number of plant families and species. The words fruit, vegetables and root crops have no real botanical meaning but are terms of convenience used for horticultural and domestic purposes. As commodities, however, they may be conveniently grouped in relation to the type of edible plant parts, their response to post-harvest handling and their storage characteristics.

4.5.1 Roots and tubers. These are underground parts of plants, adapted for the storage of food materials. They are the means by which the crop survives unfavourable

seasonal conditions, and they provide the food reserve enabling the plant to make rapid growth when conditions are favourable. They include:

Edible part	**Crop**	
Swollen stem tuber	Irish or white potato	(Figure 4.1a)
Compressed stem tuber (corm)	Dasheen, tannia, eddoe	(Figure 4.1b)
Root tuber (from fibrous root)	Sweet potato	(Figure 4.1c)
Root tuber (from main tap-root)	Carrot, turnip	(Figure 4.1d)

In most of these, the stored food material is starch, but in some tap-root tubers, such as carrots, it is mostly sugars.

Figure 4.1 Roots and tubers

4.5.2 Edible flowers. Plant breeders have produced various vegetables with dense massed flower heads that can be eaten when the flowers are immature buds. These have long been popular in temperate countries but in recent years have become well-

known in the tropics, where cultivars that can be grown in warm conditions or at higher altitudes have been developed. In contrast to the massed flower head, the pineapple, one of the most widely produced tropical fruits, is formed by the fusion of a mass of immature and unfertilized flowers clustered around the plant's main stalk, which becomes the core of the fruit. Examples of such flowers are:

Edible part	**Crop**	
Massed flower heads	Broccoli, cauliflower	(Figure 4.2a)
Fused mass comprising unfertilized flower parts and main flower stalk	Pineapple	(Figure 4.2b)

4.5.3 Vegetative growth (leaves, stems, shoots). These common green vegetables are important sources of minerals, vitamins and fibre (roughage) in the diet. They vary greatly, but typical examples are:

Edible part	**Crop**	
Whole above-ground vegetative growth (before flowering)	Cabbage, lettuce	(Figure 4.3a)
Leaves only	Dasheen (callaloo), spinach	(Figure 4.3b)
Swollen leaf base	Onions (including dry bulb	(Figure 4.3c)

	onions), leeks	

4.5.4 Reproductive structures. These are fleshy, seed-bearing structures eaten principally for their fleshy parts. They are mostly well-known fruits having a high sugar content when ripe and are normally eaten at that stage. Some, such as tomatoes and peppers, are used as salads or vegetables. In addition, some vegetables, such as immature green seed pods of some crops, are eaten before the seeds harden.

Figure 4.2 Edible flower structures

In a few crops the immature seeds only are eaten:

Edible part	**Crop**	
Fleshy fruits with single seed (drupe)	Mango, avocado, plum	(Figure 4.4a)
Fleshy fruits with several seeds	Tomato, citrus (orange, grapefruit, mandarin, lime), cucumber, pepper, aubergine, banana	(Figure 4.4b)
Immature green pods with partly developed seed	Green beans, yard-long beans (asparagus bean, bodi), okra	(Figure 4.4c)

Immature seed only	Pigeon pea, green pea	(Figure 4.4d)

Most of these examples are indigenous to the tropics and subtropics and are chilling-sensitive when held in storage.

4.6 The post-harvest physiology of fresh produce

Growing green plants use the energy provided by the sunlight falling on their leaves to make sugars by combining carbon dioxide gas from the air with water absorbed from the soil through the roots. This process is known as photosynthesis. The plant either stores these sugars as they are or combines the sugar units into long chains so that they form starch. The sugars and starches, known as carbohydrates, are stored in various parts of the plant and are used later to provide the energy for its further growth and reproduction. Starches are stored by root crops over the dormant period to supply the energy for renewed growth when dormancy ends. The energy for growth in both cases is released by the process of respiration, which occurs in all plant parts before and after harvest.

What is the normal pattern of activity of fresh produce after harvest? How is this activity affected by conditions after harvest, and what effect does this have on losses?

Figure 4.3 Vegetative structures

We referred earlier to physiological deterioration as one of the causes of post-harvest loss in fresh produce. The word physiology means the study of processes that go on within living things. When fresh produce is harvested, these processes of living continue, but in modified form. Because the crop can no longer replace food materials or water, it must draw on its stored reserves, and as these are used up, the produce undergoes an ageing process that is then followed by breakdown and decay. Even if produce is not damaged or attacked by decay organisms, it will eventually become unacceptable as food because of this natural rot. The principal normal physiological processes leading to ageing are respiration and transpiration (Figure 4.5).

Figure 4.4 Reproductive structures (fruits)

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4.7 Respiration

Respiration is the process by which plants take in oxygen and give out carbon dioxide. As shown in Figure 4.5, oxygen from the air breaks down carbohydrates in the plant into carbon dioxide and water. This reaction produces energy in the form of heat.

Respiration is a basic reaction of all plant material, both in the field and after harvest. It is a continuing process in the growing plant as long as the leaves continue to make carbohydrates, and cannot be stopped without damage to the growing plant or harvested produce.

Fresh produce cannot replace carbohydrates or water after harvest. Respiration uses stored starch or sugar and will stop when reserves of these are exhausted; ageing follows and the produce dies and decays.

4.7.1 Effect of air supply on respiration. Respiration depends on a good air supply. Air contains about 20 percent of the oxygen essential to normal plant respiration, during which starch and sugars are converted to carbon dioxide and water vapour. When the air supply is restricted and the amount of available oxygen in the environment falls to about 2 percent or less, fermentation instead of respiration occurs. Fermentation breaks down sugars to alcohol and carbon dioxide, and the alcohol produced causes

unpleasant flavours in produce and promotes premature ageing.

4.7.2 The effect of carbon dioxide on respiration. Poor ventilation of produce because of restricted air supply leads also to the accumulation of carbon dioxide around the produce. When the concentration of this gas rises to between I and 5 percent in the atmosphere, it will quickly ruin produce by causing bad flavours, internal breakdown, failure of fruit to ripen and other abnormal physiological conditions. Thus, the proper ventilation of produce is essential.

4.8 Transpiration, or the loss of water

Most fresh produce contains from 65 to 95 percent water when harvested. Within growing plants there is a constant flow of water. Liquid water is absorbed from the soil by the roots, then passed up through the stems and finally is lost from the aerial parts, especially leaves, as water vapour.

Figure 4.5 Photosynthesis and respiration

The passage of water through the plants is called the transpiration stream. It maintains the high water content of the plant, and the pressure inside the plant helps to support it. A lack of water will cause plants to wilt and perhaps to die.

The surfaces of all plant parts are covered by a waxy or corky layer of skin or bark limiting water loss. Natural water loss from the plant occurs only through tiny pores, which are most numerous on the leaves. The pores on the plant surfaces can open or close with changing atmospheric conditions to give a controlled rate of loss of water and to keep the growing parts in a firm condition.

Fresh produce continues to lose water after harvest, but unlike the growing plant it can no longer replace lost water from the soil and so must use up its water content remaining at harvest. This loss of water from fresh produce after harvest is a serious problem, causing shrinkage and loss of weight.

When the harvested produce loses 5 or 10 percent of its fresh weight, it begins to wilt and soon becomes unusable. To extend the usable life of produce, its rate of water loss must be as low as possible.

4.8.1 The effect of moisture content of the air on water loss. Air spaces are present inside all plants so that water and gases can pass in and out to all their parts. The air in these spaces contains water vapour, a combination of water from the transpiration stream and that produced by respiration. Water vapour inside the plant develops pressure causing it to pass out through the pores of the plant surface. The rate at which water is lost from plant parts depends on the difference between the water

vapour pressure inside the plant and the pressure of water vapour in the air. To keep water loss from fresh produce as low as possible, it must be kept in a moist atmosphere.

4.8.2 The effect of air movement on water loss. The faster the surrounding air moves over fresh produce the quicker water is lost. Air movement through produce is essential to remove the heat of respiration, but the rate of movement must be kept as low as possible. Well-designed packaging materials and suitable stacking patterns for crates and boxes can contribute to controlled air flow through produce.

4.8.3 The Influence of the type of produce on water loss. The rate at which water is lost varies with the type of produce. Leafy green vegetables, especially spinach, lose water quickly because they have a thin waxy skin with many pores. Others, such as potatoes, which have a thick corky skin with few pores, have a much lower rate of water loss.

The significant factor in water loss is the ratio of the surface area of the type of plant part to its volume. The greater the surface area in relation to the volume the more rapid will be the loss of water.

4.9 Ripening of fruits

Fleshy fruits undergo a natural stage of development known as ripening. This occurs when the fruit has ceased growing and is said to be mature. Ripeness is followed by ageing (often called senescence) and breakdown of the fruit. The fruit referred to here includes those used as vegetables or salads, such as aubergine, sweet pepper, tomato, breadfruit and avocado.

There are two characteristic types of fruit ripening that show different patterns of respiration:

- **Non-climacteric fruit ripening-refers to those fruits which ripen only while still attached to the parent plant. Their eating quality suffers if they are harvested before they are fully ripe because their sugar and acid content does not increase further. Respiration rate slows gradually during growth and after harvest. Maturation and ripening are a gradual process. Examples are: cherry, cucumber, grape, lemon, pineapple.**
- **Climacteric fruit ripening-refers to fruits that can be harvested when mature but before ripening has begun. These fruits may be ripened naturally or artificially. The start of ripening is accompanied by a rapid rise in respiration rate, called the respiratory climacteric. After the climacteric, the respiration slows down as the fruit ripens and develops good eating quality. Examples are: apple, banana, melon, papaya, tomato.**

In commercial fruit production and marketing, artificial ripening is used to control the rate of ripening, thus enabling transport and distribution to be carefully planned.

4.9.1 The effect of ethylene on post-harvest fresh produce. Ethylene gas is produced in most plant tissues and is known to be an important factor in starting off the ripening of fruits. Ethylene is important in fresh produce marketing because:

- **it can be used commercially for the artificial ripening of the climacteric fruits. This has made it possible for tropical fruits such as mangoes and bananas to be harvested green and shipped to distant markets, where they are ripened under controlled conditions;**
- **natural ethylene production by fruits can cause problems in storage facilities. Flowers, in particular, are easily damaged by very small amounts of the gas. Ethylene destroys the green colour of plants, so lettuce and other vegetables marketed in the mature green but unripe state will be damaged if put into storage with ripening fruit;**
- **ethylene production is increased when fruits are injured or attacked by moulds causing decay. This can start the ripening process and result in early ripening of climacteric fruit during transport. All produce should be handled with care to avoid injuries leading to decay. Damaged or decaying produce should not be stored;**

- **citrus fruit grown in tropical areas remains green after becoming fully ripe on the tree. It develops full colour after harvest only if "degreened" by the use of (manufactured) ethylene gas. The gas concentration, temperature, humidity and ventilation have to be carefully controlled in specialized rooms, so degreening is economically viable only for high-value export or domestic markets. In most tropical countries fully ripe green citrus fruit is acceptable to local populations.**

4.10 Post-harvest damage to fresh produce

Physical damage to fresh produce can come from a variety of causes, the most common being:

4.10.1 Mechanical injury. The high moisture content and soft texture of fruit, vegetables and root crops make them susceptible to mechanical injury, which can occur at any stage from production to retail marketing because of:

- **poor harvesting practices;**
- **unsuitable field or marketing containers and crates, which may have splintered wood, sharp edges, poor nailing or stapling;**
- **overpacking or underpacking of field or marketing containers;**

- **careless handling, such as dropping or throwing or walking on produce and packed containers during the process of grading, transport or marketing.**

Injuries caused can take many forms:

- **splitting of fruits or roots and tubers from the impact when they are dropped;**
- **internal bruising, not visible externally, caused by impact;**
- **superficial grazing or scratches affecting the skins and outer layer of cells;**
- **crushing of leafy vegetables and other soft produce.**

Injuries cutting through or scraping away the outer skin of produce will:

- **provide entry points for moulds and bacteria causing decay;**
- **increase water loss from the damaged area;**
- **cause an increase in respiration rate and thus heat production.**

Bruising injuries, which leave the skin intact and may not be visible externally cause:

- **increased respiration rate and heat production;**
- **internal discoloration because of damaged tissues;**
- **off-flavours because of abnormal physiological reactions in damaged parts.**

4.10.2 Injuries from temperature effects. All fresh produce is subject to damage when exposed to extremes of temperature. Commodities vary considerably in their temperature tolerance. Their levels of tolerance to low temperatures are of great importance where cool storage is concerned:

- **Freezing injury-all produce is subject to freezing at temperatures between 0 and -2 degrees Celsius. Frozen produce has a water-soaked or glassy appearance. Although a few commodities are tolerant of slight freezing, it is advisable to avoid such temperatures because subsequent storage life is short. Produce which has recovered from freezing is highly susceptible to decay.**
- **Chilling injury- some types of fresh produce are susceptible to injury at low but non-freezing temperatures. Such crops are mostly of tropical or subtropical origin, but a few temperate crops may be affected (Table 2).**

Effect of chilling injury	**Symptom**
Discoloration	Internal or external or both, usually brown or black
Skin piking	Sunken spots, especially under dry conditions
Abnormal ripening (fruits)	Ripening is uneven or fails; off-flavours
Increase in decay	Activity of micro-organisms

TABLE 2. Susceptibillty of fruits and vegetables to chilling injury at low but non-freezing temperatures

Commodity	Approximate lowest safe temperature C	Chilling injury symtoms
Aubergines	7	Surface scald, *Alternaria* rot
Avocados	5-13	Grey discoloration of flesh
Bananas (green/ripe)	12-14	Dull, gray-brown skin color
Beans (green)	7	Pitting, russeting
Cucumbers	7	Pitting water-soaked spots, decay
Grapefruit	10	Brown scald, piking, watery breakdown
Lemons	13-15	Pitting, membrane stain, red blotch
Limes	7-10	Pitting
Mangoes	10-13	Grey skin scald, uneven ripening
Melons: Honeydew	7-10	Pitting failure to ripen, decay

Watermelon	5	Pitting, biker flavour
Okra	7	Discoloration, water-soaked areas, piking
Oranges	7	Pitting brown stain, watery breakdown
Papaya	7	Pitting failure to ripen, off-flavour, decay
Pineapples	7-10	Dull green colour, poor flavour
Potatoes	4	Internal discoloration, sweetening
Pumpkins	10	Decay
Sweet peppers	7	Pitting *Alternaria* rot
Sweet potato	13	Internal discoloration, piking, decay
Tomatoes: Mature green	13	Water-soaked softening, decay
Ripe	7-10	Poor colour, abnormal ripening, *Alternaria* rot

Source Lutz, J.M. and Hardenburg, R.E., 1966, The commercial storage of fruits, vegetables and florist And nursery storks, Agricultural Handbook No. 66, USDA, Washington

Sensitivity varies with the commodity, but with each there is a temperature below which injury occurs: the lowest safe temperature (LST). Within a single commodity

type, the LST may vary between varieties (Table 2). Fruit is generally less sensitive when ripe.

Symptoms of chilling injury may not develop until the produce is removed from cold storage to normal market (i.e. ambient) temperatures. When susceptible produce has to be held for some time in storage, it must be kept at a temperature just above its LST. This means that such crops will have a shorter marketing life than non-sensitive crops because respiration has continued at a relatively fast rate during storage at higher than normal cold-storage temperatures.

- High temperature injury - if fresh produce is exposed to high temperatures caused by solar radiation, it will deteriorate rapidly. Produce left in the sun after harvest may reach temperatures as high as 50 degrees Celsius. It will achieve a high rate of respiration and, if packed and transported without cooling or adequate ventilation, will become unusable. Long exposure to tropical sun will cause severe water loss from thin-skinned root crops such as carrots and turnips and from leafy vegetables.

4.10.3 Diseases and pests. Diseases caused by fungi and bacteria commonly result in losses of fresh produce. Virus diseases, which can cause severe losses in growing crops, are not a serious post-harvest problem.

Insect pests that are mainly responsible for wastage in cereals and grain legumes are rarely a cause of post-harvest loss in fresh produce. Where they do appear, they are often locally serious, e.g. the potato tuber moth.

Diseases. Losses from post-harvest disease in fresh produce fall into two main categories.

Loss in quantity, the more serious, occurs where deep penetration of decay makes the infected produce unusable. This is often the result of infection of the produce in the field before harvest.

Loss in quality occurs when the disease affects only the surface of produce. It may cause skin blemishes that can lower the value of a commercial crop. In crops grown for local consumption, the result is less serious since the affected skin can often be removed and the undamaged interior can be used.

Fungal and bacterial diseases are spread for the most part by microscopic spores, which are widely distributed in the air and soil and on dead and decaying plant material. Produce can become infected:

- through injuries caused by careless handling, by insect or other animal damage, or through growth cracks (see colour section, Figure 1);

- through natural pores in the above- and below-ground parts of plants, which allow the movement of air, carbon dioxide and water vapour into and out of the plant;
- by direct penetration of the intact skin of the plant (see colour section, Figure 2). The time of infection varies with the crop and with different diseases. It can occur in the field before harvest or at any time afterwards.

Field infections before harvest may not become visible until after harvest. For example, decay of root crops caused by soil moulds will develop during storage. Similarly, tropical fruits infected at any time during their development may show decay only during ripening.

Infection after harvest can occur at any time between the field and the final consumer. It is for the most part the result of invasion of harvesting or handling injuries by moulds or bacteria.

Post-harvest diseases may be spread in the field before harvest by the use of infected seed or other planting material. Many diseases can survive by using weed plants or other crops as alternate or alternative hosts. They are also spread by means of infected soil carried on farm implements, vehicles, boots, etc. and from crop residues

or rejected produce left decaying in the field.

Post-harvest diseases can also be spread by:

- **field boxes contaminated by soil or decaying produce or both;**
- **contaminated water used to wash produce before packing;**
- **decaying rejected produce left lying around packing houses;**
- **contaminating healthy produce in packages.**

***Pests*. Although relatively few post-harvest losses of fresh produce are caused by attacks of insects or other animals, localized attacks by these pests may be serious.**

- **Insect damage is usually caused by insect larvae burrowing through produce, e.g. fruit fly, sweet potato weevil, potato tuber moth. Infestation usually occurs before harvest. Post-harvest spread is a problem where produce is held in store or is exposed to lengthy periods of transport.**
- **Rats, mice and other animal pests again are sometimes a problem when produce is stored on the farm.**

4.11 Loss assessment

There are no generally accepted methods for evaluating post-harvest losses of fresh produce. Whatever evaluation method may be used, the result can refer only to the described situation.

In the appraisal of an existing marketing operation, the accurate evaluation of losses occurring is a problem. It may be suspected that losses are too great, but there may be no figures to support this view because:

- **records do not exist;**
- **records if available do not cover a long enough period of time;**
- **the figures available are only estimates made by several observers;**
- **records may not truly represent a continuing situation; for example, losses may have been calculated only when unusually high or low;**
- **loss figures may be deliberately over- or understated for commercial or other reasons in order to gain benefits or to avoid embarrassment.**

Consequently, if accurate records of losses at various stages of the marketing operation have not been kept over a period of time, a reliable assessment of the potential cost-effectiveness of ways to improve handling methods is virtually impossible, and the marketing position of the grower is difficult to strengthen. It is evident that the grower who wants to reduce his post-harvest losses must maintain

reliable records.

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5. Harvesting and field handling

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5.1 Handle with care

The quality and condition of produce sent to market and its subsequent selling price are directly affected by the care taken during harvesting and field handling. Whatever the scale of operations or the resources of labour and equipment available, the planning and carrying out of harvesting operations must observe basic principles.

5.2 Objectives

The objective of the grower should be:

- **to harvest a good quality crop in good condition;**
- **to keep the harvested produce in good condition until it is consumed or sold;**
- **to dispose of the crop to a buyer or through a market as soon as possible after harvest.**

5.3 Planning

To meet these objectives, success in harvesting and marketing must depend on planning from the earliest stages of production, particularly in regard to:

- **crop selection and timing to meet expected market requirements;**
- **contacts with buyers so that the crop can be sold at a good price when ready for harvest;**
- **planning harvest operations in good time; arranging for labour, equipment and transport;**
- **providing full supervision at all stages of harvesting and field handling.**

5.4 Labour

With small-scale family production for local markets, the labour supply will probably not be a problem. As the scale of commercial production and the distances between the rural producer and urban consumer increase, more exacting requirements will have to be met in regard to training and supervising labour. It is economically sound in terms of return to invest more in proper packing and handling of the produce before it leaves the farm. Growers will have to train their own field labour, accepting whatever support local extension workers are able to provide.

5.4.1 Training workers. This training should cover general aspects of produce-handling for all workers and specific training for those engaged in tasks requiring greater skill.

General training. For everyone concerned with harvesting and field handling, general training should include:

- **Demonstrations of the causes and effects of damage to produce, emphasizing the need for careful handling at all times to avoid mechanical injuries from such causes as:**

    1. **Wooden containers with rough edges, splinters, protruding nails or staples;**
    2. **Overpacking containers which are to be stacked;**

3. **Damaging produce with long fingernails or jewellery;**
4. **Dropping or throwing into containers at a distance;**
5. **Throwing, dropping or rough handling of field containers.**

- **An explanation of the need to avoid the contamination of harvested produce from such causes as:**

1. **Placing the produce directly on to the soil, especially wet soil;**
2. **Using dirty harvesting or field containers contaminated with soil, crop residues or decaying produce: containers must be kept clean;**
3. **Contact with oil, gasoline, or any chemicals other than those used specifically for authorized post-harvest treatments.**

***Specific training*. Workers allocated to specialized tasks, such as crop selection and harvesting, and the post-harvest selection, grading and packing (if applicable) of the crop should be given specific training. This will include demonstration and explanation of:**

- **the methods of evaluating the readiness of the crop for harvest, and the rejection of unsuitable produce at harvest, according to market requirements;**
- **the actual technique to be employed in harvesting produce, e.g. breaking the**

stem or plucking, clipping, cutting or digging;

- **the use of harvest containers, and the transfer of produce to field or marketing containers;**
- **the selection of marketable produce at the field assembly point and (if applicable) grading for size and quality;**
- **the correct application of post-harvest treatment (where produce is to be packed on the farm directly into marketing packages), e.g. fungicides, wax coating;**
- **the method of packing market packages or other containers.**

5.5 When are conditions right for harvesting a crop?

When the crop is ready for harvest, labour and transport are available, and operations organized, the decision as to when to start harvesting will depend largely on:

- **weather conditions;**
- **the state of the market.**

The flexibility of the marketing date will depend on the crops. Some, such as root crops, can be harvested and sold over a long period, or stored on the farm to await favourable prices. Others, such as soft berry fruits, must be marketed as soon as they

are ready or they will spoil.

When the decision to harvest has been made, the best time of day must be considered. The aim is to dispatch the produce to market in the best possible condition, that is, as cool as possible, properly packed and free from damage.

The basic rules to observe are:

- **harvest during the coolest part of the day: early morning or late afternoon;**
- **do not harvest produce when it is wet from dew or rain. Wet produce will overheat if not well ventilated, and it will be more likely to decay. Some produce may be more subject to damage when wet, e.g. oil spotting and rind breakdown in some citrus fruits;**
- **protect harvested produce in the field by putting it under open-sided shade when transport is not immediately available. Produce left exposed to direct sunlight will get very hot. For example, aubergine and potatoes left exposed to tropical sunlight for four hours can reach temperatures of almost 50 degrees Celsius.**

Produce for local markets can be harvested early in the morning. For more distant markets it may be an advantage-if suitable transport can be arranged-to harvest in the late afternoon and transport to market at night or early the next morning.

5.6 Harvesting technique

5.6.1. By hand. In developing countries, most produce for internal rural and urban markets is harvested by hand. Larger commercial producers may find a degree of mechanization an advantage, but the use of sophisticated harvesting machinery will be limited for the most part to agro-industrial production of cash crops for processing or export or both. In most circumstances, harvesting by hand, if done properly, will result in less damage to produce than will machine-harvesting.

Hand-harvesting is usual where fruit or other produce is at various stages of maturity within the crop, that is, where there is need for repeated visits to harvest the crop over a period of time. Machine-harvesting is usually viable only when an entire crop is harvested at one time.

***Root and tuber crops*. Most staple roots and tubers that grow beneath the soil are likely to suffer mechanical injury at harvest because of digging tools, which may be wooden sticks, machetes (or cutlasses, pangas or bolos), hoes or forks.**

Harvesting of these crops is easier if they are grown on raised beds or mounds, or "earthed up" as is common in potato-growing. This enables the digging tool to be pushed into the soil under the roots or tubers, which then can be levered upwards,

loosening the soil and decreasing the possibility of damage to the crop (Figure 5.1).

Other root crops, such as taro, carrots, turnips, radishes, etc. can be loosened from the soil in a similar manner by inserting the tool into the soil at an angle and levering the roots upwards. This method can also be used for celery if it has been earthed up or buried to blanch the stems.

Figure 5.1 Damage in harvesting roots' tubers and other underground crops is more easily avoided if crops are grown in mounds or raised beds.

***Vegetables*. Either the whole or a part of vegetative growth can be harvested by hands only or sharp knives. Knives must be kept sharp and clean at all times or they may spread virus diseases from plant to plant. Harvesting methods vary with plant parts harvested:**

- **leaves only (spinach, rape, etc.) and lateral buds (Brussels sprouts): the stem is snapped off by hand;**
- **above-ground part of the plant (cabbage, lettuce): the main stem is cut through with a heavy knife, and trimming is done in the field (the cut stem must not be placed on the soil);**
- **bulbs (green onions, leeks, mature bulb onions): immature green onions can**

usually be pulled from the soil by hand; leeks, garlic and mature bulb onions are loosened by using a digging fork as for root crops (such as carrots) and lifted by hand (Figure 5.1). Simple tractor implements are available for undermining bulbs and bringing them to the surface.

Flower structures. Immature flower heads (cauliflower, broccoli) can be cut with a sharp knife and trimmed in the field; broccoli can be snapped off by hand and subsequently trimmed;

Mature flowers (squash, chayote, pumpkin): flowers are plucked individually by hand, or whole shoot-bearing flowers are harvested as a vegetable.

Fruits. Many ripe fruits and some immature seed-bearing structures such as legume pods have a natural break-point of the fruit stalk, which can easily be broken at harvest. Fruit and other seed-bearing structures harvested in the immature or unripe green state are more difficult to pick without causing damage to either the produce or the plant. These are best harvested by cutting them from the plant, using clippers, secateurs or sharp knives. The clippers may be mounted on long poles for tree fruits, with a bag attached to the pole to catch the fruit (Figure 5.2).

Plucking methods vary according to the kind of produce being harvested:

- **ripe fruits with a natural break-point, which leaves the stalk attached to the fruit, are best removed by a "lift, twist and pull" series of movements, e.g. apple, passion fruit, tomato (Figure 5.3);**
- **mature green or ripe fruits with woody stalks which break at the junction of the fruit and the stalk are best clipped from the tree, leaving up to a centimetre of fruit stalk attached. If the stems are broken off at the fruit itself. disease may enter the stem scar and give rise to stem end rot, e.g. mango, citrus, avocado (see colour section, Figure l);**
- **immature fruits with fleshy stems can be cut with a sharp knife, e.g. zucchini, okra, papaya, capsicum; these can also be harvested by breaking the stem by hand, but this method may damage the plant or fruit and the rough break will be more susceptible to decay than would a clean cut.**

5.6.2 Mechanical aids. Because the supply of fresh produce to domestic markets in developing countries comes mainly from relatively small-scale producers with limited resources, mechanical systems for "once over" crop harvesting are likely to be rare. There is scope, however, for the use of mechanical aids in modest commercial operations, especially where tractors are available.

Figure 5.2 Picking poles are used to harvest tree fruit which cannot be reached from the ground or a ladder. Both the factory-made (a) and home-made (b) types have a

cutting device and a catching bag (Figure 5.2a is adapted from A manual of post-harvest handling systems for perishable food crops. No. 001 Mango, Ministry of Agriculture. Lands and Food Production. and UCA. Trinidad and Tobago, 1986.)

The jobs where such aids are likely to be of use are:

- **in harvesting potatoes, onions and possibly some other root crops, simple tractor-drawn harvesters to lift up the crops and leave them on the soil surface;**
- **in transporting produce from the harvesting point to the assembly area to await transport, tractors to draw trailers of laden containers or to carry either containers on pallets or bins.**

5.7 Harvesting and field containers

The packing of produce directly into marketing packages in the field at harvest reduces the damage caused by multiple handling and is used increasingly by commercial growers. It is not a common practice in rural areas, where produce is sent to nearby markets and elaborate packaging cannot be justified, but commercial growers can view it as cost-effective if the packaging takes produce in better condition to market, where it can command a higher price.

Figure 5.3 A natural break-point occurs on many mature fruits at the junction of stem and stalk. At harvest time. thumb pressure applied there should be accompanied by lifting, pulling and turning the fruit

At all stages of harvesting and handling, methods should aim at avoiding damage to produce and providing ventilation to prevent temperature rises.

5.7.1 Selecting field containers for harvesting. These must be of a size that can be conveniently carried by the harvest worker while moving through the field:

- **harvesting bags with shoulder or waist slings can be used for fruits with firm skins like citrus and avocados. They are easy to carry and leave both hands free. They should be designed for opening at the base to allow produce to be emptied through the bottom into a field container without tipping the bag;**
- **plastic buckets or other containers are suitable for harvesting fruits that are more easily crushed, such as tomatoes. The containers should be smooth, with no sharp edges or projections to damage the produce;**
- **baskets are often used for harvesting but may have sharp edges or splinters that can injure produce. If they are not sturdy, they may bend out of shape when lifted or tipped-especially if they are large-and crush or otherwise damage the contents;**

- **bulk bins, usually of 250 to 500 kg capacity, are used by commercial growers, where crops such as apples or cabbages are sent to large-scale packing houses for selection, grading and packing. Bins can be carried by a fork-lift attachment on a tractor to move the produce from harvesting points to assembly areas.**

When unventilated bulk bins are used in the field, produce should be left in them only briefly, and protected from sun or rain. Produce held in bulk for long will overheat and be more subject to decay. Bulk bins transported over long distances must be perforated to minimize heat build-up in the contents.

5.8 Post-harvest hauling

5.8.1 Field and farm transport. Routes for the movement of produce within farm fields should be planned before crops are planted. Farm roads should be kept in good condition because great damage can be inflicted on produce carried over rough roads in unsuitable vehicles.

Containers must be loaded on vehicles carefully and stacked in such a way that they cannot shift or collapse, damaging their contents (Figure 8.1). Vehicles need good shock absorbers and low-pressure tyres and must move with care. Jolting of laden

containers can aggravate damage to produce on rough roads, even at low vehicle speeds.

5.8.2 Transport from the farm. The destination of the produce leaving the farm will usually be one of the following:

- **A local market - produce is usually in small containers carried sometimes by animals or in animal-drawn carts, but mostly by vehicles owned or hired by growers; public transport is sometimes used.**
- **A commercial packing house or processing plant-produce carried by trucks may be in palletized field containers, in bulk bins or in hand-loaded sacks or wooden or plastic boxes; where vehicles wait in the sun or rain for long periods before unloading, only the top part of the load should be protected by a covering; grass or leaves are not recommended for this purpose because they restrict ventilation and may be a source of disease; complete enclosing of the load with a tarpaulin is disastrous because it restricts ventilation and the temperature of the produce rises rapidly.**
- **A city market - this applies only where produce is packed in marketing containers on the farm; the conditions under which these should be carried are discussed in the section on transport.**

6. Packaging of fruit, vegetables and root crops

6.1 Why packaging is necessary

Most fresh produce ready for market is composed of large numbers of small units of similar size which must be moved in amounts conveniently handled by one person. This is best achieved by using containers of capacities from 3 to 25 kg, up to dimensions of about 60 per 40 per 30 cm. Some commodities (e.g. potatoes) may be marketed in 25 or 50 kg sacks, and other large items, such as whole bunches of bananas, are moved without packaging. Leafy vegetables can be sold loose or tied in bundles and not packaged.

Most developing countries use traditional baskets, sacks and trays to carry produce to markets. These are usually of low cost, made from readily available materials such as dried grass, palm leaves or bamboo. They serve the purpose for fresh produce carried over short distances, but they have many disadvantages in big loads carried long distances.

Large commercial quantities of produce need better packaging in order to minimize losses and achieve the most economical use of transport. The aim is to protect the produce from damage in handling, transport and storage and to provide easily handled and counted containers of uniform size.

Packages of standard size can reduce the need for repeated weighing and can facilitate handling, stacking and loading. A wide variety of package types is fabricated from paper and paper products (compressed cardboard and corrugated cardboard, called fibreboard in some areas), wood and wood products (sawn timber and compressed chips) and plastics, both pliable and rigid. Each type must be considered in terms of its utility, cost and capacity to enhance the value of the produce.

Economy in packaging is always a desirable goal. A study in Thailand showed that a plastic crate, while costing five times as much as a traditional bamboo basket of similar capacity, was still useful after 20 times the number of journeys, putting the cost per journey of the plastic crate at about one-quarter of that of the bamboo basket. The crate also provided better protection of produce, easier handling and better stowing, and was easier to clean.

Perhaps improvements in the design and construction of indigenous containers might, in the context of the small-scale grower, prove to be a better solution than buying

plastic crates.

6.2 Damage suffered by packaged produce

6.2.1 From injuries

- ***Cuts or punctures***

Cause: sharp objects piercing package; splinters in bamboo or wooden containers; staples or nails protruding in containers;

Effect: deep punctures or cuts in produce, leading to water loss and rapid decay

- ***Impact (shock)***

Cause: throwing or dropping of packages; sudden starting or stopping of vehicle, causing load movement; speeding vehicle on rough road;

Effect: bursting of packaging, bruising of contents

- ***Compression (squeezing or squashing)***

Cause: flimsy or oversized containers; containers overfilled or stacked too high or both; collapse of stacked containers during transport;

Effect: bruising or crushing of contents (Figure 6.1)

- ***Vibration (shaking)***

Cause: vibration of the vehicle itself and from rough roads;

Effect: wooden boxes come apart, damaging produce

6.2.2 From the environment

- ***Heat damage***

Cause: exposure of packages to external heat, e.g. direct sunlight, or storage near heating system; natural buildup of internal heat of produce owing to poor ventilation within package, in storage or vehicle;

Effect: fruit becomes overripe or softens; produce wilts and develops off-flavours; decay develops rapidly; cardboard cartons may become dry and brittle, easily damaged on impact;

- ***Chilling or freezing damage***

Cause: low or subzero ambient temperatures; exposure of sensitive produce to temperatures below chilling or freezing tolerance level during storage;

Effect: damage to chilling-sensitive produce; breakdown of frozen produce on thawing; plastic containers become brittle and may crack;

- ***Moisture and free-water damage***

Cause: exposure to rain or high humidity; condensation on packages and produce moved from cold store to damp atmosphere at ambient temperature; packing wet produce in cardboard containers;

Effect: softening and collapse of stacked cardboard containers; squashing of produce in collapsed containers; decay promoted in damaged produce;

- ***Damage from light***

Cause: plastic sacks and crates not treated with an ultraviolet inhibitor eventually break up when exposed to direct sunlight;

Effect: disintegration of plastic sacks damages produce when it is moved; fracturing of plastic crates can cut or bruise produce;

6.2.3 From other causes

- ***Chemical contamination***

Cause: contamination of containers stored near chemicals; damage to produce by containers treated with preservatives, e.g. boxes made from wood treated with pentachlorphenate (PCP) (see colour section, Figure 5); contamination of produce from boxes affected by mould growth;

Effect: flavour contamination or surface damage and discoloration of produce in contact with container; decay of produce owing to contaminating moulds; wood-rotting moulds cause collapse of boxes;

- ***Insect damage***

Cause: insects present in packed produce; wood-boring insects in wooden boxes;

Effect: consumer resistance and legal problems from presence of insects (e.g. spiders, cockroaches) in packed produce; spread of wood-destroying insects in infected boxes;

- ***Human and animal damage***

Cause: contamination and eating by rodents and birds; pilfering by humans;

Effect: rejection of damaged produce by buyers or inspectors; loss of income through loss of produce.

6.3 The cost-effectiveness of packaging

The use of packaging represents an added cost in marketing and the price of the marketed product must take account of the capital outlay and unit-packaging cost as well as expected profit. To make an exact assessment of the added value is difficult because many factors may offset the cost of packaging, for example:

- **losses should be significantly reduced;**
- **presentation and quality of the product may make it more desirable, a competitive advantage;**
- **marketable life of the produce may be extended.**

It is clear, however, that packaging must not exceed the willingness of the market to accept the added value of the product, i.e. the extra cost involved.

6.3.1 Prevention of injuries to produce. Suitable packages and handling techniques can reduce the amount of damage to which fresh produce is exposed during marketing:

- **to keep the packaging itself from damaging produce during handling and transport, wooden boxes or cardboard cartons must be properly assembled; nails, staples and splinters are always a danger in wooden boxes;**
- **individual items of produce should be packed to avoid rubbing against each other during handling and transport; loose-fill packs are particularly susceptible to vibration damage;**
- **bruising results from overfilling containers or from the collapse of boxes; collapse may be caused by weak walls of boxes, by the softening of cardboard walls because of moisture or by the failure to stack boxes so that the side and end walls support those above; stacks of boxes should never exceed the height that has been recommended by the maker;**
- **produce in woven jute sacks or nets is especially susceptible to shock damage; sacks of 25 or 50 kg capacity are normally used for relatively low-value produce, such as root and tuber crops, and are often roughly handled on account of their weight; where possible, handling of bagged produce should be minimized by stacking sacks in unit loads on pallets or in pallet boxes.**

6.3.2 Effect of packaging on other types damage

- ***Heat, chilling or freezing***

Packaging in general has poor insulating qualities and will have little effect on preventing damage from heat or cold. Lack of ventilation in packaging delays cooling and may contribute to high-temperature damage arising from heat generated by the produce itself. Recently developed expanded polystyrene packages have good insulating properties and are used, topped with ice, to transport vegetables with high respiration rates.

The availability and cost of such packages make them inappropriate in most developing countries.

- ***Moisture and free water damage***

High humidity and free water (e.g. rain) quickly weaken cardboard boxes, which get soggy and collapse when wet. This problem can be overcome in manufacture only by waxing the cardboard or by facing it with moisture resistant plastic.

Decay of produce packed in wet sacks or in wet wooden or cardboard boxes will be accelerated.

6.3.3 Chemical contamination. Packaging will not protect produce from contamination by outside sources of chemicals. The containers themselves become impregnated and contribute to the contamination.

Sacks and "knocked down" wooden or cardboard boxes awaiting assembly should not be stored in the same area as chemicals.

6.4 Selection of packaging for fresh produce

Packaging can be a major item of expense in produce marketing, so the selection of suitable containers for commercial-scale marketing requires careful consideration.

Besides providing a uniform-size package to protect the produce, there are other requirements for a container:

- **it should be easily transported when empty and occupy less space than when full, e.g. plastic boxes which nest in each other when empty, collapsible cardboard boxes, fibre or paper or plastic sacks;**
- **it must be easy to assemble, fill and close either by hand or by use of a simple machine;**
- **it must provide adequate ventilation for contents during transport and storage;**

- **its capacity should be suited to market demands;**
- **its dimensions and design must be suited to the available transport in order to load neatly and firmly;**
- **it must be cost-effective in relation to the market value of the commodity for which used;**
- **it must be readily available, preferably from more than one supplier.**

6.4.1 Size and shape of packages. Packages should be of a size which can be easily handled and which is appropriate to the particular marketing system. The size should be no larger than is compatible with these requirements, especially with wooden boxes. The ratio of weight of the container to that of the produce it contains is important. Where transport charges are calculated on a weight basis, heavy packaging can contribute significantly to the final cost of the saleable product.

The shape of packages is also significant because of the loading factor: the way the load is positioned on the transport vehicle for maximum capacity and stability. Round baskets, whether cylindrical or tapered, hold considerably less produce than do boxes occupying the same space. A cylindrical basket contains only 78.5 percent by volume compared with a rectangular box occupying the same space.

6.4.2 The need for ventilation in packages. Suitable packaging for any product will

consider the need to keep the contents well ventilated to prevent the buildup of heat and carbon dioxide. The ventilation of produce in containers is a requirement at all stages of marketing, but particularly during transport and storage. Ventilation is necessary for each package, but there must also be an adequate air flow through stacked packages. A tight stack pattern is acceptable only if packages are designed to allow air to circulate through each package and throughout the stack. Sacks and net bags must be stacked so that air can circulate through the contents.

The effectiveness of ventilation during transport also depends upon the air passing through the load.

6.5 Packaging materials

Packaging for fresh produce is of several types:

6.5.1 Natural materials. Baskets and other traditional containers are made from bamboo, rattan, straw, palm leaves, etc. throughout the developing world. Both raw materials and labour costs are normally low, and if the containers are well made, they can be reused.

Disadvantages are:

- **they are difficult to clean when contaminated with decay organisms;**
- **they lack rigidity and bend out of shape when stacked for long-distance transport;**
- **they load badly because of their shape;**
- **they cause pressure damage when tightly filled;**
- **they often have sharp edges or splinters causing cut and puncture damage.**

6.5.2 Wood. Sawn wood is often used to make reusable boxes or crates, but less so recently because of cost. Veneers of various thicknesses are used to make lighter boxes and trays (Figure 6.2). Wooden boxes are rigid and reusable and, if made to a standard size, stack well on trucks.

Disadvantages are:

- **they are difficult to clean adequately for multiple use;**
- **they are heavy and costly to transport;**
- **they often have sharp edges, splinters and protruding nails, requiring some form of liner to protect the contents.**

6.5.3 Cardboard (sometimes called fibreboard). Containers are made from solid or corrugated cardboard. The types closing with either foldover or telescopic (i.e. separate) tops are called boxes or cases. Shallower and opentopped ones are called trays. Boxes are supplied in collapsed fore, (that is, flat) and are set up by the user. The setting-up and closing of boxes requires taping, glueing, stapling or the fixing of interlocking tabs (Figure 6.3).

Cardboard boxes are lightweight and clean, and can readily be printed with publicity and information on contents, amounts and weights. They are available in a wide range of sizes, designs and strengths.

Disadvantages are:

- **they may, if used only once, prove an expensive recurring cost (if multiple use is intended, the boxes may be easily collapsed when empty);**
- **they are easily damaged by careless handling and stacking;**
- **they are seriously weakened if exposed to moisture;**
- **they can be ordered economically only in large quantities; small quantities can be prohibitively expensive.**

6.5.4 Moulded plastics. Reusable boxes moulded from high-density polythene are

widely used for transporting produce in many countries. They can be made to almost any specifications. They are strong, rigid, smooth, easily cleaned and can be made to stack when full of produce and nest when empty in order to conserve space.

Disadvantages are:

- **they can be produced economically only in large numbers but are still costly;**
- **they have to be imported into most developing countries, adding to the cost and usually requiring foreign currency for their acquisition;**
- **they often have many alternative uses (as washtubs, etc.) and are subject to high pilferage rates;**
- **they require a tight organization and control for use in a regular go-and-return service;**
- **they deteriorate rapidly when exposed to sunlight (especially in the tropics) unless treated with an ultraviolet inhibitor, a factor adding to the cost.**

Figure 6.3 Fresh produce is carried in a variety of cardboard containers

Despite their cost, however, their capacity for reuse can make them an economical investment. The Thailand study mentioned above showed plastic containers still usable after more than 100 journeys.

6.5.5 Natural and synthetic fibres. Sacks or bags for fresh produce can be made from natural fibres like jute or sisal or from synthetic polypropylene or polyethylene fibres or tapes. "Bags" usually refers to small containers of up to about 5 kg capacity. They may be woven to a close texture or made in net form. Nets usually have a capacity of about 15 kg. Bags or sacks are mostly used for less easily damaged produce such as potatoes and onions, but even these crops should have careful handling to prevent injury.

Disadvantages are:

- **they lack rigidity, and handling can damage contents;**
- **they are often too large for careful handling; sacks dropped or thrown will result in severe damage to the contents;**
- **they impair ventilation when stacked if they are finely woven;**
- **they may be so smooth in texture that stacks are unstable and collapse; they are difficult to stack on pallets.**

6.5.6 Paper or plastic film. Paper or plastic film is often used to line packing boxes in order to reduce water loss of the contents or to prevent friction damage.

Paper sacks can have walls of up to six layers of kraft (heavy wrapping) paper. They

can have a capacity of about 25 kg and are mostly used for produce of relatively low value. Closure can be done by machine-stitching across the top (recommended only for large-scale crop production) or in the field by twisting wire ties around the top by means of a simple tool (Figure 6.4).

Disadvantages are:

- **walls of paper are permeable by water or vapour and gases (walls may be waterproofed by incorporating plastic film or foil, but sacks then retain gases and vapour);**
- **heat can be slow to disperse from stacks of sacked produce, thus damaging fruit or leafy vegetables;**
- **limited protection to contents if sacks are mishandled.**

Plastic-film bags or wraps are, because of their low cost, widely used in fruit and vegetable marketing, especially in consumer-size packs. In many developing countries, however, large polythene bags are and should not be used to carry produce, especially to market.

Disadvantages are:

- **they offer almost no protection from injury caused by careless handling;**
- **they retain water vapour thus reducing water loss from the contents; but where temperature changes occur, they cause a heavy buildup of condensation leading to decay;**
- **they cause a rapid buildup of heat if bags are exposed to sunlight;**
- **they permit only slow gas exchange; this combined with vapour and heat leads to very rapid deterioration;**
- **they should not be used for carrying produce; even with perforations for ventilation, plastic bags should not be used unless the package can be refrigerated.**

Consumer packs wrapped in plastic are not recommended under tropical conditions except perhaps in stores with refrigerated display cabinets.

Prevention of post-harvest food losses: a pictorial review

Injury infection: stem-end rot is caused by infection of the scar the stalk has been broken away from the fruit

Anthracnose of sweet pepper: the unripe green fruit becomes infected in the field but decay develops only as fruit ripens

Growth cracks: tomato skin hardens when growth stops during a dry period; when growth resumes after rain, the skin cracks

Papaya lumpiness: a deficiency of boron during growth turns the seeds brown and gummy

Chemical damage: fruit packed in softwood boxes treated with pentachlorphenate (P.C.P.) only peaches in contact with box were damaged

Packing-house disorrder: efficiency suffers if work is carried out on the floor

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