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Review

The concepts and problems of post–harvest food losses in perishable crops

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The loss of foods in the post-harvest system is not new; it has always been a problem for mankind. In these days of rapidly enlarging population in the poorest countries of the world where food is already short, there is an increasing urgency to do a better job of conserving mankind food supply in order to alleviate hunger and malnutrition. The main objective of this review is to find out the concepts and problems of post-harvest food losses in perishable crops. It examined the various concepts of post-harvest food losses, the importance of perishable crops, causes of food losses, environmental consideration and its influence on food losses. It also sought solutions to some of the identified problems. It was established from the review that the factors contributing to these food losses include; the initial quality of the crop, mechanical injury, temperature, storage atmosphere, genetic factors and environmental influence. In order to minimize these problems, the appropriate agricultural techniques such as the general principles of extending shelf-life of these crops must be put in place. There should be proper management of temperature, humidity and effective methods for preventing these losses. Since most national governments acknowledge that post – harvest food losses is complex, therefore, it requires a commitment to an integrated approach, involving numerous organizations, including local communities and groups.

Key words: Post-harvest, perishable, crop, loss, food, storage.

INTRODUCTION

Most studies on post-harvest technology have so far concentrated on grains and other durable products, which are stored dry and a substantial technology has been developed to deal with these problems. Less work has been undertaken on the perishable food crops, yet they are of great importance in many parts of the humid and sub-humid tropics and contribute the staple carbohydrate portion of the diets of some 500 to 700 million people in the developing countries (Lancaster and Coursey, 1984). In the case of the tropical perishable staple foods, which have no close analogues in temperate zone agriculture, this neglect of the traditional wisdom is especially unfortunate, as the underlying philosophies of the cultures in which they are extensively grown are not neglected [or expressed as so much pre-Galilean as non-Galilean] and are extremely alien to those of Europe, within which scientific thinking developed (Coursey, 1976, 1978a).

These perishable staple foods are very largely produced from small-scale subsistence level systems and the technologies employed in both production and utilization is usually simple and founded on long-established traditional practice. The most important are the root; cassava, yams, the various aroids, sweet potatoes and white potatoes (Coursey and Haynes, 1970), the total production of which is now around 185 million t/a; fruits such as cooking bananas, (plantains) and breadfruit are also important, still the former being a major food with a world production of over 20 million t/a, while a proportion of the dessert banana crop also is

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eaten as a staple, cooked while unripe (Burden and Coursey, 1977); there are also crop products derived from vegetative organs such as stem starches of palms and other types of plant.

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 that is referred to is, of course, the war between humankind and certain species of insects, weeds, pathogens, nematodes, rodents and other pest that daily compete with our crops, gnaw at our dwellings, infest our domestic animals or destroy our health” (Kuhr, 1979).

The statement in the foregoing vividly describes the problem humans always face to preserve food supply after they have produced it. The loss of foods in the post-harvest system is not new; it has always been a problem for mankind. In these days of rapidly enlarging populations in the poorest countries where food is already short, there is an increasing urgency to do a better job of conserving mankind’s 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.

However, fresh horticultural produce is highly perishable with some estimates suggesting a post-harvest loss of 30 to 50% in fruits and vegetables. The loss occurs due to poor pre-production and post-harvest management as well as lack of appropriate processing and marketing facilities. These losses have several adverse impacts on farmer income, consumer prices and nutritional quality of the produce. Because of the poor planting material, cultural practices including harvesting methods and handling practices, the quality of harvested produce is below standard. Absence of farm storage facility and proper pack house/packing station results in the perishable produce being marketed immediately after harvesting without primary processing and adequate packaging. The solid wastes originating from horticultural crops in metro cities, can create drainage problems and cause water logging, as well as invite stray animals near garbage dumps. These bio-wastes also deteriorate very rapidly causing unhygienic conditions, increasing atmospheric pollution and provide a breeding ground for pests (Expert Consultation, 2010).

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 these are 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 than 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 fruits and vegetables are more serious in developing countries than those in well developed countries. An additional constraint to improving this situation is that in most 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, a (FAO, 1981) considerable amount is used to produce loaf. Thus, as more fresh fruits and vegetables are needed to supply

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 g.	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 mega joule/ton/day for dry grain.	High to very high respiration rate. Heat production is typically 0.5 to 10 mega joule/ton/day at 0℃ to 5 to 70 mega joule/ton/day at 20℃.
Hard texture.	Soft texture, easily bruised.
Stable, natural shelf life is one to several years.	Perishable, 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%

Source: (FAO 1981).

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 should be given much attention as production practices, and there must be a mutual undertaking, in the stages from planting until the product reached the consuming public, between the growers and those who will handle the products after harvest.

Fruits and vegetables, roots 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 for cereals. Because of these differences it is necessary to design a different set of intervention programmes to reduce post-harvest losses in horticultural products. Typical losses range from 10 to 25%, but it is estimated that at least 5% and as much as 100% of a given crop can be lost between the field and the consumer (NAS, 1978; Coursey, 1983).

Typically, the main challenge has been to produce enough food to feed the growing population and making it accessible to people of all categories. This requires a well devised protocol to transform production policies to deliver proper market impact that would foster food accessibility as well as income of all players along all concerned value chains. It would however, make bigger impact if there are proper technologies appropriate to local conditions that enables small-scale farmers employed in agriculture to reap from farming activities. The question however, is the type of technology, the capacity of farmers to understand and implement the technology as well as appropriate time for dissemination (Nyamulinda et al., 2011).

IMPORTANCE OF PERISHABLE CROPS

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 sense 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. 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 (Tables 2 and 3).

CAUSES OF FOOD LOSSES IN PERISHABLE CROPS

There are so many causes for losses in the post-harvest food chain that it helps to classify them into 2 groups and a number of sub-groups.

Table 2. Major production of horticultural crops in developed countries and developing countries.

Commodity	Production 1978 (million tone)		Percentage of cereal production	
	World	Developing countries	World	Developing countries
Cereals	1,580.8	730.6	100%	100%
Roots and tubers	522.9	290.1	33.1	39.7
Vegetables and 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

Source: (FAO Production Yearbook 1979).

Table 3. Estimates of post–harvest losses in perishable staples (percent).

Commodity	Early TPI estimates[1]	NAS[2] (1978) estimates
Potatoes	8. 30	5 to 40
Sweet Potatoes	35 to 65. 95	55 to 95
Yam	5. 15	10 to 60
Cassava	-	10
Taro	12 to 15	-
Plantains	33	35 to 100

Source: (Coursey, 1983; Coursey and Proctor 1975; Coursey and Booth, 1977).

Primary causes of loss

These are the causes that directly affect the food. They may be classified into the following groups:

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.

Microbiological

Micro organisms cause damage to stored foods (e.g., fungi and bacteria). Micro-organisms usually directly consume small amount of the food but they damage the food to the point that it becomes unacceptable because of rotting or other defects. Toxic substances elaborated by molds (known as mycotoxins), cause some food to be condemned and hence lost. The best known 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.

Chemical

Many of the chemical constituents naturally present in stored foods spontaneously react causing loses of colour, flavour, texture and nutritional value. An example is the Maillard relation' that causes browning and dicolouration in dried fruits and other product, There can also be accidental or deliberate contamination of food with harmful chemicals such as pesticides or obnoxious chemicals such as lubricating oil.

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.

Mechanical

Bruising, cutting' excessive pooling or trimming of horticultural products are causes of loss.

Physical

Excessive or insufficient heat or cold can spoil foods. Improper atmosphere in closely confined storage at times causes losses.

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.

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.

Secondary causes of loss

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:

1, Inadequate harvesting, packaging and handling skills.
2. Lack of adequate containers for the transport and handling of perishables.
3. Storage facilities inadequate to protect the food.
4. Transportation inadequate to move the food to market before it spoils.
5. Inadequate refrigerated storage.
6. Inadequate drying equipment or poor drying season.
7. Traditional processing and marketing systems can be responsible for high losses.
8. Legal standards can affect the retention or rejection of food for human use by being too lax or unduly strict.
9. Conscientious, knowledgeable management is essential for maintaining tool in good condition during marketing and storage.
10. Bumper crops can overload the post-harvest handling system or exceed the consumption need and cause excessive wastage.

ENVIRONMENTAL CONSIDERATIONS AND ITS INFLEUNCE ON FOOD LOSSES

There is increasing recognition that managing the transition to a sustainable food security should become the new central organizing principle. Towards this end, government must take steps to modify existing policies and provide direction in the formulation of food security policies. Hence, the United Nations environment programme (UNEP) is interested in promoting the health and well being of both people and the environment, as well as sustainable development. Reducing food losses should improve nutritional status and human health especially in those countries where a large population is inadequately fed. Decreasing food losses offers an opportunity to reduce the pressure on the land and still deliver the same 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. UNEP 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 that are most desirable from the environment stand point to encourage their use and to do this in the early planning stages of the project. Hence, UNEP was concerned about the consequences of manmade chemicals that are used and discharged into the environment with resultant effect on post – harvest food losses. 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 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 perishable crops, which for reasons of their importance to human nutrition, their magnitude of production and their vulnerability to spoilage, have common characteristics and problems. To this end the United Nations environment programme and F.A.O organized a 4–day meeting in May, 1980 at FAO headquarters in Rome with 15 specialists from the various post–harvest disciplines and with broad geographical coverage to examine the present status of the post–harvest food losses occurring in perishable crops and the means to reduce these losses.

The major environmental influences on the keeping quality of food are:

Temperature

In general, the higher the temperature the shorter the storage life of horticultural products and the greater the amount of loss 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 means that the rate of growth of spoilage micro-organisms, the rate of indigenous physiological change and physical processes such as water loss and wilting are affected.

Humidity

There is movement of water vapour between 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 high moisture content and need to be stored under conditions of high relative moisture loss and wilting, exceptions of 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.

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 duration of exposure to the direct rays of the sun. The intensity of radiation is greater in tropical zones than in temperate zones. 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.

Altitude

Research findings indicate that the prevailing temperature is dependent upon the elevation when other factors are equal. There is on the average a drop in temperature of 6.5°C for each kilometre 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 direct rays of the sun.

Atmosphere

The normal atmosphere contain by volume, approximately 78% nitrogen, 21% oxygen, 1% argon, 0.03% carbon dioxide, various amount of water vapour and traces of inert gases. Modifying the atmosphere can improve the shelf 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 3per cent 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 showing down the natural rate of respiration. Many 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.

Time

The longer the time the food is stored the greater is the deterioration in quality and the greater is the chance of damage and loss. Hence, storage time is a critical factor in loss of foods especially those that have a short natural shelf life.

Biological pressure

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 except in aerosols. Micro–organisms can multiply very rapidly whenever conditions are favourable for growth. The only foods that are free from micro–organism are those that have been thermally processed such as can 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, stored food insects are ubiquitous, hiding in storage facilities and moving with store foods when they are moved. Rodents and sometimes birds can exert biological pressure similar to those of insects and micro – organisms.

WAYS OF REDUCING POST–HARVEST FOOD LOSSES IN PERISHABLE CROPS

According to Oluwole Olatunji, the then Director General, Federal Institute of Industrial Research, Oshodi, Lagos during the FIIRO technological open day 2008, entitled “Food security issue in Nigeria: FIIRO’s relevance” He said that Nigeria is the fifth on the hunger index rating in the world and the ninth largest population in the world with a very high level of poverty. He therefore enjoined the federal government to establish more food storage facilities in the country to reduce post harvest losses and reduce soaring food prices. He lamented that the nation’s food storage capacity was low, resulting in post harvest loss of above 30% of national agricultural output. Therefore, the achievement of self food sufficiency aspiration in perishable crops production of the nation, now and future can only be obtained by reducing post harvest food losses through the appropriate agricultural techniques such as the general principles of extending shelf life of these crops.

These principles will be considered under the following heading: varietal differences, harvesting, handling, sorting, packaging, transportation, storage and processing.

Varietal differences in storability

Some varieties of the same crop store better than others. Therefore, to reduce food loss and to achieve maximum shelf-life, only varieties known to store well should be stored.

Harvesting

Harvesting should be carried out as carefully as possible to minimize mechanical injury such as scratches, punctures and bruises to the crop. This should be carried out during the cool part of the day, which is early morning and late evening harvest crop at a matured green state. Immature fruits may not ripen and fruits which are already ripe will have short storage life.

Handling

Mechanical injury provides sites for pest attack and increases physiological losses. Therefore, avoid mechanical injury to the crop while 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 post harvest losses. Careful handling of fruits and vegetables to minimize bruising and breaking of the skin likewise is a well-known method of reducing post harvest 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.

Crops should not be heaped at collection centre on the farm as this will lead to rapid spoilage particularly of fruits at centre of the heap. Fruits and vegetables should not be exposed to the sun. Crops should be transferred promptly after harvest to a clean, cool, well-ventilated shed.

Sorting and cleaning

Sort out damage crops from undamaged crops. Remove dirt from sound crop before putting into transport containers.

Packaging

Use clean, smooth and ventilated containers for packaging. This is a very important factor in cutting down losses in these crops during harvesting, transportation marketing and storage. Use containers that are appropriate to the crop.

Transportation

Load and unload transport vehicles carefully. Use clean, well-ventilated vehicle covered at the top for transportation. Transport crops during the cool part of the day by driving carefully over smooth roads to minimize damage to crop. Attention must be given to commodity compatibility within a load. Ethylene-sensitive commodities such as lettuce should not be shipped with ethylene generators such as apples. A complete description of compatible and incompatible commodities is available (Ashby et al., 1987). The most common cause of freight claims is load shifting and crushing, but the costliest claims are the result of inadequate temperature control (Beilock, 1988). Other transportation steps are also important in quality maintenance, for example, from field to packing facility and from wholesale distribution point to retail outlet. The same principles that apply to long-distance ones, apply to short-distance shipments, but handling practices tend to receive less attention when the shipping distance is short. Fields and rural roads are usually bumpier than highways; thus, vehicles hauling the harvested crop from field to packaging house are generally not as capable of preventing shock and vibration damage as the tractor-trailer rigs will do. The delay of cooling of a crop is affected by the time required to load a vehicle in the field, the distance from field to packinghouse, the speed of the vehicle and the number of vehicles waiting to be unloaded at the packinghouse (Garner et al.,1987).

Storage

Only crops with high initial quality can be stored successfully, it is therefore essential to ensure that only crops of the highest quality (mature, undamaged) are stored. Separate damaged crops from wholesome crops and dispose of the damaged crop quickly several Nigerian fruits and vegetables cannot be stored in domestic refrigerator as they are susceptible to chilling injury. Examples are bananas, plantain and mango. Shelf life of a fruit or vegetable during storage is dependent on its initial quality, its storage stability, the external conditions and the handling methods. Shelf life can be extended by maintaining a commodity at its optimal temperature, relative humidity (RH) and environmental conditions as well as by use of chemical preservatives or gamma irradiation treatment (Shewfelt, 1986). An extensive list of optimal storage temperatures and RI-Is with anticipated shelf life is available (Hardnburg et al; 1986). Controlled atmosphere storage is a conunercially effective means of extending the season of apples (Lidster, 1984). Atmosphere modification within wholesale or retail packages is a further extension of this technology. Modification of the atmosphere is being achieved by setting initial conditions and using absorbent compounds to limit carbon dioxide (CO_2) and ethylene (C21-I4) concentrations (Kader et al., 1989; Labuza and Breene, 1989). They can however be stored in evaporative coolers as designed and constructed by Nigerian Stored Products Research Institute (NSPRI).

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 technique 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.

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.

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.

Suberization and curing

Potatoes, sweet potatoes, yams and several other roots and vegetables have the ability to heal skin wound 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 extended 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.

Processing

Considerable quantities of fruit and vegetables are processed by dehydration, canning and freezing in developed 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) has no complaints of 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.

Fruits and vegetables can be preserved for relatively long period by drying, freezing and canning. Drying, freezing and canning are generally preceded by blanching for better retention of quality.

Sanitation

Strict hygiene is required at all stages of handling perishable crops. This will help to minimize infection by pathogens.

CONCLUSION AND RECOMMENDATIONS

It was revealed from the review that post-harvest food losses in perishable produce are product of many variables which are inter-woven. The factors contributing to these losses includes; the initial quality of the crop, mechanical injury, temperature, humidity, handling given to the crop and storage atmosphere. It was also observed that a substantial amount of post harvest losses have their origin in the pre-harvest stage for example genetic factors, infections, pest-infestation, environmental factors and cultural practices during production stage.

In view of these factors, a good sanitation management in all pre and post-harvest operations in perishable crops will help in eliminating sources of infection and reducing levels of contamination. Proper timing and good methods of harvesting devoid of mechanical injuries will help in reducing food lose in perishable crops. It is clear that most post-harvest losses in perishable produce result from infection by fungi and bacteria (pre or post-harvest) and from inherent physiological activity although insect, rodents, nematodes and occasionally birds may cause significant losses under certain conditions.

1. Post-harvest loss in perishable crops constitutes on important issue that needs increased and continuing attention at national regional and international levels by FAO, Government 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 increase production to offset post-harvest losses.
2. Department of post-harvest technology should be established in all faculties of agriculture in Nigerian Universities. This will ensure the availability of trained manpower to conduct effective post-harvest research.
3. Good sanitation practices in all post-harvest operations is a very important factor in eliminating sources of infection and reducing levels of contamination.
4. Research/extension activities to be geared up so that available technology on post-harvest food losses reduction is made known to all users.
5. Traditional effective methods for preventing and reducing post-harvest 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 type of equipment and facilities selected.
6. 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 micro-organisms. In general, pre-harvest application of fungicides in more important in the control of post-harvest problems of fruit and vegetable crops than in root crops.
7. Techniques to reduce food losses require cultural and economic adaption. This is so because all food losses occur at a particular socio-cultural environment.
8. There is a need to establish exchange programmes (technical co-operation between developing countries) between countries of similar needs and interest but which have apparent difference in advancement in post-harvest handling systems.
9. The proper management of temperature and humidity of root crops and certain other perishable in the initial post harvest period is essential to good curing which improved wound healing and minimizes infection by micro-organism.
10. The use of post-harvest chemicals has not shown toxicological problems for now, but when they are used there is need to ensure that the dosages and residues conform to internationally recommended maximum levels e.g. of the FAO/WHO Codex Alimentarius Commission.
11. 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.
12. The Nigerian stored products research institute (NSPRI) should be given sufficient funds to execute its research programme on effective crop storage in Nigeria.
13. Scientists should come out with the production of a new packaging device capable of preserving food and cash crops such that the losses the nation has been witnessing in the agricultural sector will be eliminated.

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