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Postharvest losses in agriculture produce

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Abstract
Harvest is a major event for any food that is derived from plants. As a plant part is severed from the plant it loses its source of supply of nutrients and its repository for metabolic waste products. Until the detached plant part undergoes conventional food processing, it continues to live, respire, transpire, and senesce, ultimately leading to death. Postharvest deterioration continues until the item is either processed or consumed. Handling techniques have been developed to slow the physiological processes to provide a product that is satisfactory to the consumer.

Keywords: Fruit, vegetable, postharvest deterioration, loss prevention, processing

Introduction
Food crops are categorized as agronomic or horticultural. Agronomic (field) crops are primarily the grains and oilseeds that are harvested in a dry to semidry state and tend to be relatively stable to handling and storage as long as they are protected from moisture and insects. Horticultural (garden) crops, which comprise fruits, vegetables, and nuts, tend to be much more perishable, requiring sophisticated handling systems to transport them from field to consumer. Estimates vary widely on how much of a crop is actually consumed (Bourne, 1977 and Pantastico *et al*., 1976) [1, 2]. Processing techniques such as canning, freezing, and drying are designed to minimize these losses and extend the length of the season they are available for consumption. Postharvest handling techniques that manipulate the storage environment extend the life of the product while keeping it in a fresh state. Minimal processes such as cutting, slicing, and dicing increase the appeal and convenience of the item frequently at the expense of greater perishability (Wiley, 1994) [3]. Losses of edible product begin in the field during harvesting and loading; continue during transport to the processing plant, packinghouse, or market; during storage at any point in the distribution scheme; and during food preparation or even by the consumer at the point of consumption. Losses may be complete resulting from the discarding of part (removal of outer leaves) or all (discarding a rotten fruit) of a given item. Frequently losses are more subtle and less tangible such as loss of acceptability, nutritional quality, or economic value. An understanding of the scope of losses incurred for a particular fruit or vegetable requires an understanding of the complexity of the handling and distribution system for that item (Kader, 2013 and Shewfelt *et al*., 1993) [4, 5].

Key concepts provide insight into the perishability of most fresh horticultural crops. Physiological deterioration of a fresh item begins at harvest and continues until processing or consumption. Respiration is the metabolic breakdown of food constituents to release the necessary energy to sustain the healthy tissue. Transpiration is the release of moisture from the surface of the fruit or vegetable.

Senescence is genetically programmed deterioration that leads to cell and tissue death (Kader, 2013) [4]. Quality refers to the properties of a particular fruit or vegetable that make it unique and influence its purchase and consumption by the consumer. Shelf life is the time period a product can be maintained at an acceptable level of quality (Shewfelt *et al*., 1993) [5]. Although most harvested products are at their peak of quality at harvest, climacteric fruits continue to ripen after detachment from the plant. These fruits (eg, apples, bananas, pears, and tomatoes) will develop color, flavor, and textural attributes during postharvest storage. In many cases climacteric fruits do not develop full flavor off the plant, but the perishability of the fully ripe fruits precludes distribution.

Causes of losses

Many factors contribute to losses of fresh products during postharvest handling and storage. Mechanical injury results in cuts or bruises that decrease purchase acceptability. Such damage may not be immediately evident as softening and discoloration associated with bruising takes time to develop. Thus it is frequently difficult to determine the cause of the injury and how to take corrective action. Microbes can invade plant tissue, particularly when it has been mechanically damaged. Until recently, postharvest pathologists were primarily interested in plant pathogens present in the field or introduced during handling that lead to decay and spread from item to item within bulk containers. More recently, introduction of human pathogens by contamination from irrigation water, untreated animal manure, or association with raw meats or their exudates has led to safety concerns in fruits and vegetables that are not thoroughly washed or cooked prior to consumption (Shewfelt *et al*., 1993) [5].

As mentioned, physiological processes occur in the fruit or vegetable after detachment from the plant. Increased respiration accelerates tissue degradation and can lead to flavour development, which may be desirable in the form of ripe-fruit flavour or may be undesirable off-flavours. Excess transpiration results in shrinking, wilting causing rejection of squash, lettuce, or broccoli, and so on.

Physiological disorders can develop during storage from pre-harvest nutritional deficiencies, postharvest stress conditions, or an interaction of pre-harvest and postharvest factors leading to unacceptable quality or reduced shelf life. Some fruits and vegetables are susceptible to chilling injury, which develops at low temperatures above the freezing point. Chilling injury produces different symptoms in different crops including abnormal ripening, surface lesions or pitting, increased susceptibility to decay, browning discoloration, and off-flavour development. Chilling-susceptible products include bananas, beans, cucumbers, grapefruit, melons, and tomatoes (Wang, 1994) [6]. Other physiological disorders can result from improper mineral nutrition during growth and development; during exposure to low levels of oxygen (O_2), high levels of carbon dioxide (CO_2), or high levels of ethylene (C_2H_4) during storage; or an interaction of these and other factors. As consumer demand increases for more fresh fruits and vegetables to meet nutritional concerns and provide more convenience to fit them into a busy lifestyle, more fresh items are sold in a cut or otherwise minimally processed form. Cutting tends to break apart cells, leading to loss of cell material; accelerate respiration, leading to more rapid degradation of the tissue; and increase surface area, resulting in surface evaporation. Composition of the gaseous atmosphere that is most likely to preserve quality of these products can result in the production of off-odours and flavours. Cutting appears to decrease the losses due to chilling injury in susceptible fruits and vegetables.

Prevention of losses

The goal of postharvest handling is to minimize the loss of product quality between harvest and either processing or consumption. The first line of defence is prevention of physical injury. Environmental conditions during storage and handling represent the next line of defence. Addition of chemical compounds can prevent losses. Finally, sophisticated packaging techniques are being developed and used that employ one or more of the preceding lines of defence. Physical protection of products from injury is used to minimize mechanical damage. Reduction of mechanical injury can be achieved by decreasing the number and height of falls of individual items or containers during handling. When falls are unavoidable, damage due to impact can be minimized by cushioning, which can be achieved by foam padding, liquid foam, water, or even product that will be discarded. Impact damage of one fruit on another can be reduced by decreasing dumping operations and using spacer bars in conveyor lines to minimize fruit-to-fruit contact. Vibration damage tends to increase with an increase in the size of bulk handling and the distance from field (or orchard) to packing facility. Packing the product in wholesale or retail packages close to the field, reducing or eliminating tractor-drawn vehicles from field to packinghouse, and use of paved roads for transport will reduce vibration damage. Likewise, microbial decay and insect damage can be reduced by physical protection. Since mechanical damage frequently provides a route for invasion, any means of mechanical protection will help decrease microbial and insect damage. Once endogenous protective barriers such as rind or peel are penetrated, chances for future losses are increased.

A greater incidence of pests and disease in the field will be reflected in greater problems during postharvest handling. By leaving these problems in the field, similar problems during handling and storage will be reduced. Physical removal of diseased or infected items during sorting or grading to prevent the spread of pathogens reduces subsequent infections. To prevent cross-contamination from human pathogens, all areas in which fresh fruits and vegetables are handled should be kept free from insects, birds, their droppings, and any raw animal products. The relatively short handling periods of fruits and vegetables are such that insect infestation is not usually a major problem. With grain products, however, storage times are long, and insects, and the microbes they deposit during their visits, pose a more serious threat. Physical barriers are an important part of an insect-protection plan. In addition, screening products from light affects quality. Light enhances chlorophyll breakdown and thus speeds yellowing of green vegetables. Light also enhances chlorophyll synthesis in non-green vegetables such as potatoes. This greening is a quality defect as it is an indicator of light-catalyzed synthesis of toxic alkaloids such as solanine. Light enhances β-carotene synthesis in tomatoes, but the effect on colour quality is much more significant pre-harvest than postharvest.

Manipulation of environmental conditions is also an important tool available to postharvest handlers. In general, lowering the temperature while maintaining high relative humidity increases the shelf life of a product by reducing the rates of respiration and transpiration. Composition of gaseous atmosphere can be either modified or controlled in the storage room, container, or consumer package to slow ripening and senescence.

Proper temperature control is the most important tool in preventing postharvest losses. As the temperature is lowered, rates of respiration and transpiration decrease. The growth of microorganisms is also slowed by lower temperatures. For most fresh products, storage at temperatures as close to freezing as possible will extend shelf life. Freezing should be avoided as inadvertent freezing and thawing of fresh items leads to breakage of cell membranes and loss of desirable texture. Quick cooling after harvest to remove field heat is imperative in items like strawberries and green vegetables that respire rapidly and perish quickly. Hydro cooling and icing are used for products that can withstand water, but water is an excellent vehicle for spreading microorganisms. Forced-air cooling is another effective method, while vacuum-cooling is used for high value items with a large surface area like lettuce. Slower cooling such as room cooling is permissible for products being stored for a longer time such as apples, but the final temperature should be as close to optimal as possible. When calculating refrigeration requirements, it must be remembered that respiring plant material evolves heat, known as the heat of respiration.

Prevention of chilling injury can be achieved by storing susceptible commodities at temperatures above the critical storage temperature, which ranges from 40ºC for snap beans to 150ºC for bananas. A complete list of optimal storage temperatures is available (Hardenburg *et al*., 1986) [7]. In commercial practice a compromise temperature between 5 and 100ºC is frequently used to store most fresh items. At this temperature it is assumed that damage to chilling-susceptible product will be minimal while the decrease in shelf life to nonsusceptible items will not be economically significant. Ice is usually added to green vegetables to lower the temperature and increase relative humidity (RH) without changing room temperature. The success of these strategies depends on a rapid turnaround of fresh product to minimize losses. Maintenance of a high RH lowers transpiration of heavily transpiring products. Just as each commodity has an optimal storage temperature, it also has an optimal RH. If the RH is too high, microbial growth is enhanced. If it is too low, shriveling or wilting can result. Rapid changes in temperature of a product can lead to condensation on the surface and increased susceptibility to microbial decay.

Food additives are effective agents for the protection of plant products, but they are coming under greater scrutiny as consumers become more wary of chemicals. Microbial inhibitors help prevent the growth of spoilage microorganisms. Fumigants have been used to disinfest products from insects. External waxes are applied to porous fruit such as citrus fruits and cucumbers to slow water loss. These waxes also enhance appearance by providing gloss.

Low-dose irradiation has been approved in many countries for the inhibition of sprouting in potatoes and onions, insect disinfestations, and shelf-life extension. In some crops like strawberries, irradiation is effective in extending shelf life, but in others damage is induced at doses lower than effective for extension. Irradiation appears to be a safer technique for disinfestations than chemical fumigation, but questions of consumer acceptance of irradiated product have limited willingness of the food industry to adopt it as a widespread technique.

Shelf life of fresh products may also be extended by modification of the composition of atmospheric gases. Respiration and other metabolic processes are slowed with a decrease in oxygen and an increase in carbon dioxide. In some crops such as apples, pears, and onions, long-term storage is enhanced by controlling the atmosphere. Other crops such as lettuce and most root crops are susceptible to CO_2. Optimal storage atmospheres for crops have been published (Hardenburg *et al*., 1986) [7]. Controlled-atmosphere storage usually occurs in large storage rooms where the gaseous atmosphere is monitored and changed to maintain the desired composition. In modified-atmosphere storage the initial gaseous composition is established but changes as respiration leads to decreased O_2 and increased CO_2 in the container. Atmosphere modification is very effective at maintaining texture and appearance but can lead to the development of off-flavours. Modified atmosphere packaging (MAP) is the major technique used to preserve fresh-cut products. MAP is most effective when used in conjunction with temperature reduction. In fresh-cut vegetable products like lettuce, the consumer has shown a willingness to sacrifice some losses in fresh flavour for added convenience. It is not clear that the consumer is willing to make the same sacrifice for fresh-cut fruits.

Advances in film technology have introduced greater sophistication in packaging of fresh products. Packaging protects the product by confining it, preventing contamination, shielding from mechanical damage and pests, permitting atmosphere modification, and providing instructions for optimal handling. The type of container used and its function can change as the item moves through handling and distribution. In general, the fewer handling steps and product transfers, the less opportunity for damage.

Plastics are being widely used in the packaging of fresh fruits and vegetables. They are employed at the pallet level for containerization and prevention of moisture loss around as well as used for MAP within shipping cartons, retail packages, or even individual items. Barrier films have different transmission properties to permit or exclude specific gases such as water vapour, CO_2, O_2 and C_2H_4, depending on specific requirements of the individual items. These films permit in-package atmosphere modification, extending the advantages of the technology to the supermarket shelves. Determination of the best initial composition of gases has been limited by the variation of the individual items in response to differing atmospheres. While accumulation of CO_2 and C_2H_4 could be detrimental to product quality, absorbers of these compounds can be included in sachets enclosed in the package or imbedded in the packaging material itself (Labuza, 1996) [8].

A logical extension of MAP is shrinking of the film tightly around the individual produce item. Although generally considered a type of modified atmosphere, individual plastic films are really more analogous to externally applied waxes, which change the diffusion properties of the item with the external atmosphere. These films slow transpiration while modifying the internal gaseous composition. Shelf life of some products like lemons is dramatically extended while other products develop off-odours and off-flavours due to altered metabolism. Edible films such as sucrose polyesters and proteins permit moisture control and changes in respiration of whole and cut products either as a retail item or within a retail package (Krotcha *et al*., 1994) [9].

Conclusion

Postharvest deterioration of agriculture products continues till the items are either processed or consumed. Many factors are responsible for losses of fresh products during postharvest handling and storage. Numbers of methods have been developed for minimizing and correcting these losses to facilitate the consumer, middle man and producer.

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