Introduction

Consumers demand high quality produce. Post-harvest losses in fresh fruits and vegetables account for an estimated 5 to 25 percent of total production (Kader, 2002). Therefore, losses of fruits and vegetables due to quality negatively affect the farm business. Furthermore, damaged product can lead to issues with microbial food safety.

Quality is a set of characteristics that impart value to the buyer or consumer (Kader, 2002). Quality attributes can be external (appearance, touch or defects), internal (texture, flavor or odor), or hidden (nutritive value or food safety) (Pattee, 1985). Quality can affect everything from the consumers eating experience to their health if the product is unsafe.

Ensuring the quality of horticultural products requires careful attention to pre- and post-harvest management practices. Post-harvest losses are usually related to a quality attribute of the product, such as a physical, cosmetic, food safety or nutritional characteristic. If the quality of the product is compromised, it can likely not be restored. Therefore, it is important to focus on those practices that prevent problems. The best practices are often related to the specific crop in a certain environment but there are many common principles and methods that will aid in protecting the value of your product and return on investment.

This publication will cover the biological and environmental factors involved in product deterioration and the pre- and post-harvest practices that can maintain quality and safety. The pre- and post-harvest practices are the primary means by which you can control the change in the products living tissue.

The Living Plant Organ

Fruits and vegetables are living organs. From the moment of harvest, the organ will continue to metabolize the substrates (carbohydrates, organic acids, proteins and fats) available through respiration. Substrates that are consumed through respiration will not be replenished. As such, the rate of deterioration is proportional to the rate of respiration. Therefore, faster respiration rates will lead to loss of saleable weight, poorer flavor and overall reduced product quality (Cornell University et al., 2012). Understanding the biological and environmental factors that govern deterioration of the product will help to inform practices that can reduce loss and maintain quality and safety.

Product Biology and Deterioration

Respiration, ethylene production, water loss, physiological breakdown, physical damage and pathological breakdown are the five primary biological factors involved in the deterioration of horticultural products.
Respiration

Respiration is the process whereby substrates are broken down to produce energy for the living plant organ. Energy is released as heat, along with carbon dioxide, water and oxygen. The rate of respiration hastens the loss of substrates and subsequent senescence and deterioration of the product. Energy released as heat can build up around the commodity, which can further increase respiration if not vented. If a commodity has inappropriate venting, carbon dioxide can build up around it, decreasing oxygen and potentially leading to fermentation. Increased temperature is closely associated with increased respiration.

Reducing the rate of respiration involves paying close attention to temperature management. Products should be removed from direct sun and cooled as soon as practical for your operation. Ensure appropriate ventilation for the product, as this also helps to reduce heat and buildup of ethylene and carbon dioxide around the product.

Ethylene Production

Ethylene is a compound produced by all plant cells that affects growth and development. Ethylene can be beneficial or detrimental, depending on the fruit or vegetable. It is detrimental to most non fruit vegetables (broccoli) and ornamentals. Exposure to ethylene increases water loss and energy expenditure in the plant organ. Its production increases with maturity, physical injury, increased temperature and water stress. Exposure to ethylene can result in a number of undesirable characteristics, including yellowing of green vegetables, lignification of asparagus, spotting in lettuce and sprouting in onion and potato.

Avoid mixing or holding ethylene-sensitive produce with produce that is considered a high-ethylene producer (cantaloupe or tomato with brassicas or asparagus). In smaller operations with rapid turnover, ethylene management may be less critical. However, proper ventilation during transport will help ensure a quality product. Also, avoid wounding (physically damaging) the product, as this can increase ethylene production and cull wounded produce immediately.

Water Loss

Water loss occurs through the plants dermal system (cuticle, stomata, epidermal cells, etc.). Water loss is heavily influenced by environmental factors such as temperature, relative humidity and air movement. Water loss results in weight loss of the product and is visualized as shriveling or wilting. The product can also be soft or limp or lose crispness and juiciness.

Reducing the respiration rate will decrease water loss. Therefore, removing the product from heat and cooling will reduce water loss. Relative humidity is an important factor in water loss as well. In general, it is important to have a high relative humidity, though specific products have associated optimal relative humidity. Temperature and relative humidity are inversely correlated, so as temperature goes down, relative humidity goes up. Increasing the relative humidity can be done by wetting the storage room floor with potable water, adding crushed ice to tolerant crops or using potable water to mist the product (leafy vegetables, cool-season root crops or immature fruit crops), among other methods. Do your research on your specific crop before making any management decisions on relative humidity or storage.

Physiological Breakdown

Physiological disorders can develop from a number of factors. Primarily physiological disorders are caused by temperature abuse
or nutritional imbalances. Inappropriate atmosphere is also a factor that can lead to physiological disorders and decay.

Temperature can cause physiological disorders through freezing injury, chilling injury, heat injury or sunburn. Freezing injury is the collapse of tissues and complete loss of the product. Chilling injury is a result of holding temperatures above their freezing point and below 49°F-59°F, resulting in browning and/or the product appearing water soaked. Heat injury is a result of exposure to direct sunlight or high temperatures and results in bleaching, scalding or product softness. Removing a crop from the field just after harvest, avoiding direct sun and managing cooling and holding will help to ensure a high quality product with minimal losses.

Proper nutrient management is essential for crop productivity, product quality and environmental quality. Nutritional imbalances that can lead to poor quality and decay result from inappropriate pre-harvest nutrient management practices. Calcium content is related to improved firmness and decreases the incidence of rot. Calcium deficiency causes blossom end rot in tomatoes and bitter pit in apples. Over-fertilizing with nitrogen leads to a number of issues related to product size and respiration rate, increased incidence of decay, storage rots and loss of flavor. Soil testing and developing an appropriate nutrient management plan for crop demand is essential in maintaining quality and safety.

Physical Damage

Physical damage or product wounding can be caused primarily by mechanical shock and abrasion or cuticle disruption. Wounding can provide a nutrient rich medium for human and plant pathogens to grow. Wounding also accelerates water loss and increases ethylene and carbon dioxide production, browning and decay. The opportunities for wounding are many and varied in an agricultural system. Commodities will respond poorly when they are treated poorly. Therefore, it is best to make those harvesting aware that they are food handlers, handling a living organ.

Pathological Breakdown

Microorganisms that can cause decay can be introduced through the seed, during crop growth, during harvesting and post-harvest handling or during distribution (Barth et al., 2009). The onset of ripening and senescence in commodities renders them more susceptible to infection by plant and human pathogens. In addition, stresses such as physical or physiological damage, make commodities more susceptible to human and plant pathogens.

Sanitizing production and processing equipment on a regular basis and following good agricultural practices (GAPs) and good handling practices (GHPs) will reduce human and plant pathogens in the production system and aid in maintaining product quality and safety.

Product Environment and Deterioration

Temperature

Temperature is one of the most important factors in maintaining product quality and safety. The term $Q_{10}$ refers to a single chemical reaction and is known as the temperature accelerating factor. For each 10°C (18°F) increase the rate of chemical reaction (respiration) will increase approximately twofold or threefold (Preece and Read, 1996). As such, higher temperatures cause greater rates of respiration which, in turn, accelerates the use of stored substrates in the plant organ and water loss. This is of particular concerns for plants that have few reserves, such as leafy greens. Temperature also
influences the growth rate of human and plant pathogens.

Once harvested, produce continues to gain heat through respiration and conduction. Lowering temperature as fast as possible and removing the product from sun will slow the rate of respiration, reduce the incidence of pathogens and extend the product shelf life.

Relative Humidity

Relative humidity is the ratio of water vapor in the air at a certain temperature to the maximum amount of water vapor that the air can hold at that same temperature. Essentially, water loss from the product is dependent on the deficit between the commodity and the surrounding air. Water loss influences the development of decay, incidence of physiological disorders and uniformity of ripening.

If you store your product, monitor storage rooms by measuring temperatures in multiple locations. The use of plastic strip curtains on doorways will help reduce the flow of warm air and water loss.

Product Biology and Environment

Understanding product biology and environment will help you to adopt appropriate management strategies that will improve or maintain product quality, safety and shelf life. Other environmental factors that should be considered are presence of light (potato storage), presence of ambient ethylene (broccoli storage) and the atmospheric composition. These are less of an issue to small growers who might have rapid turnover, have limited storage or do not ship their products in specialized packages.

Pre- and Post-Harvest Practices for Product Quality, Safety and Shelf Life

Pre-Harvest

The following are practices or considerations that can aid in maintaining quality and safety. Each practice should be put in the context of the specific production system in question.

- Avoid over-fertilizing with nitrogen to reduce quality disorders and susceptibility to decay-causing pathogens, among others.
- Avoid over-irrigation in weeks prior to harvest to increase firmness and reduce storage problems.
- Installation of drip irrigation can reduce the spread of disease.
- Choose quality cultivars that are resistant to common pests and use clean, high-quality planting materials.
- Practice field sanitation, such as removing culls from the field, sanitizing field bins and removing diseased product, to prevent the spread of plant and human pathogens.
- When using manures, ensure that proper application methods and time intervals between planting and harvest are followed.

Harvest and Post-Harvest Practices

Product quality is largely determined by pre-harvest practices and growing conditions. The intrinsic quality of the product cannot be improved during post-harvest management. As such, post-harvest management aims to reduce the metabolic rate, reduce water loss, minimize wounding and prevent physiological disorders (Cornell University et al., 2012). The following practices or considerations are non-comprehensive and should be set in the context of your operation.

Harvest

- Harvest at proper maturity for your product.
Harvest early when product temperatures are their lowest, except watermelon, which should be harvested later in the day to prevent cracking.

- Remove the product from the field as quickly and efficiently as possible.
- Provide shading with a light colored tarp to cool and protect from direct sunlight.
- Round the tips of harvesting utensils and sharpen often to prevent wounding.
- Trim fingernails and remove jewelry to reduce product injury.
- Sanitize field containers and prohibit their use for any purpose other than carrying produce.
- Harvesting containers should be smooth and free of rough edges.
- Do not pick up produce that has fallen to the ground as this can spread human and plant pathogens.
- Train pickers to recognize proper maturity stage and to handle produce with care.
- Cool produce as soon as possible after harvest.
- Disinfect all equipment that comes into contact with produce to reduce the spread of human and plant pathogens.

Packing

- Cure root and tuber crops and bulb crops before packing, storing or marketing.
- Pre-sort produce to remove damaged, diseased, immature or over mature product.
- Provide shade for produce that has yet to be packed.
- Do not wash green beans, cabbage, okra, peppers or summer squash before packing due to bruising.
- Provide clean, sanitary conditions for all packing and harvest supplies.

Transport

- Avoid overfilling of containers and stack heavier produce on the bottom to reduce compression damage.
- Make sure vehicles and produce have adequate ventilation to prevent heat gain.
- Avoid mixed loads if possible or increase the space between ethylene producers and ethylene sensitive crops.

Conclusion

The production of high quality produce requires careful attention to management practices pre- and post-harvest. Many practices that ensure a quality product also ensure product safety. It is important to remember that you are selling a living product that responds poorly to poor treatment. Producing a high quality, safe product will ensure that you have a marketable product with minimal loss to your farm business.

References


