Improving the Safety and Quality of Fresh Fruits and Vegetables: A Training Manual for Trainers

Section V

Food Safety and Quality Assurance Issues

Introduction

Fresh fruit and vegetable growers, packers, shippers, retailers and consumers all have long recognized, at least intuitively, that product quality is the primary factor affecting profitable trade in the produce industry. Only in the past twenty years or so has food safety also become a driving force in conducting business. This has resulted in a plethora of opinions regarding the relationship of safety to quality. In commerce perhaps the safety factor is not often given greater importance than the overall quality, but when an outbreak of illness occurs, safety overrides all other quality considerations.

In this Module we will define quality and safety terms and discuss the ways in which the two concepts can be integrated to provide consumers an abundant supply of safe food with the best possible quality.

Food Safety

Food safety is defined by the World Health Organization (WHO) as the assurance that the food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use. Reasonable assurance of safe food requires the reduction of risks that may occur during production, handling, and preparation for consumption by the end-user.

It is beyond the scope of this Module to identify every microbiological, chemical or physical cause of human illness or injury, but many common risks will be discussed in this Section. Identifying risks is critical to food safety because it is difficult to control a hazard if it is not known to exist. The point of GAP and GMP is to reduce risks that occur during production and handling of fruits and vegetables in order to minimize the occurrence of illness or injury.

Food Quality

The International Organization for Standardization (ISO) defines quality as "the totality of features or characteristics of a product that bear on its ability to satisfy the stated or implied needs." Webster defines quality more simply as the "degree of excellence." There also is an adage of the farmer who stated that he could not really describe quality, but he knew it when he saw it.

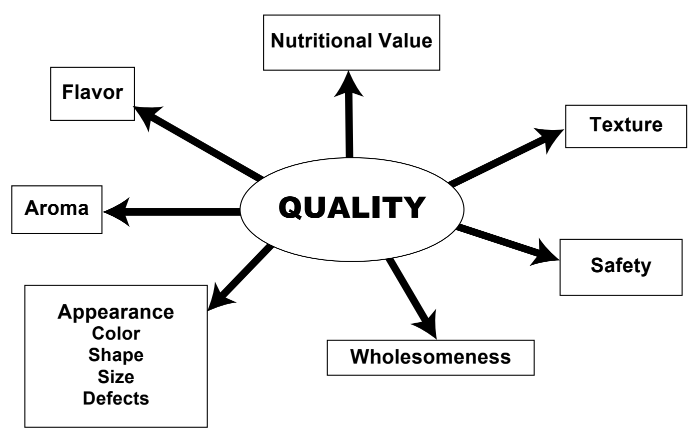
Some aspects of quality can be measured, such as purity, color, maturity, ripeness, nutritional value, etc. Other characteristics are highly subjective, such as flavor, which can only be assessed by the person doing the tasting. Aroma, an important component of flavor and quality perception, can be measured for the presence of signature volatiles, but consumers vary in their sensitivity to these volatiles. In commerce, the "quality" of fresh produce as it applies to pricing is influenced strongly by supply and demand.

Understanding that quality is made up of many factors that are often subject to interpretation that varies from person to person highlights the complexity of defining quality.

Safety is a Component of Quality

Safety is a component of quality. It can be argued that safety is the most important component of quality since a failure to assure safety can cause serious injury or death to the consumer. It is difficult, usually impossible, to determine if a product is safe by simply looking at it.

Figure 1. An illustration of a few of the components of quality, including safety.



Note that each of the quality parameters in Figure 1 is unique in some way and may or may not be obvious to our senses. Obviously, we can see the appearance and smell the aroma. Flavor and texture can be assessed subjectively by eating or objectively by biochemical or mechanical techniques. Safety is seldom obvious. A product may have high appearance or flavor quality, but have poor safety quality due to contamination with pathogens or chemicals. Alternatively, a product might have poor market quality but still be safe to eat.

Obvious quality deficiencies such as bruising or other injuries typically lead to lower pricing, lower sales or outright rejection. In contrast, safety hazards might go undetected until the product is consumed. Safety assurance is vital to public health.

Although it is impossible with current technologies to eliminate all potential food safety hazards associated with consumption of raw produce, food safety programs should be the foundation upon which all other quality management programs are built.

Safety and Quality Assurance Programs

Managers of fresh produce operations are required to be focused on crop productivity, harvest efficiency, pack-out maximization, and dozens of other management criteria that are involved in the profitability of the enterprise. Quality assurance (QA), including safety assurance, is an ongoing process that must be a part of every agricultural practice from field selection through the ultimate consumption of the product.

Once quality is compromised it is virtually impossible to restore it. Thus managers must focus on the prevention of quality and safety problems rather than reliance on remedial action to correct management errors. It also is important to learn from mistakes that impact quality so that those can be avoided in the future.

A strong, semi-independent QA program is essential. For large companies, QA may be a discrete department within the company. Although the QA program may be managed independently of production management, there must be good communication and collaboration between QA managers and all other managers.

QA management requires many diverse technical and analytical skills. QA personnel continually monitor, or train other managers to monitor, inputs into production and the final product to ensure compliance with compositional standards, microbiological and other safety requirements, and various government regulations. All of this must conform to the expectations of the customer since profitability ultimately depends upon consumer acceptance. A QA manager may halt production, refuse acceptance of raw material, or stop the shipment of product if specifications are not met. They must have the trust and confidence of company owners since their decisions can impact profit.

Historically in fresh fruit and vegetable industries, safety assurance was not included in QA programs. Periodic outbreaks of illness with fresh produce during the past two decades have brought about change in the way that safety assurance is integrated into the overall QA program. Progressive companies will have periodic food safety training of managers from all divisions of the company so that those managers can in turn train the workers under their supervision.

A process analysis, in which each unit operation in the company is isolated and studied individually, will help identify the steps where contamination may occur. In some cases the control steps may be simple common sense practices that the industry may have followed for years. In others, the existing infrastructure and practices may need significant modification in order to reduce or prevent contamination.

Good Agricultural Practices (GAP, Section II), Good Manufacturing Practices (GMP, Section III), and Sanitation Standard Operating Procedures (SSOP, Section III, Module 7) all are based upon the principles of Hazard Analysis Critical Control Point (HACCP) programs used for processing industries. While HACCP is not specifically applicable to fresh produce operations, all of the practices covered in this manual are HACCP-like in the sense that management systematically applies principles of food safety in a stepwise fashion (Module 4).

In summary, the development of an effective QA program must include adoption of GAP and GMP, development of and adherence to SSOP, establishment of specifications for grades and standards (Module 2), defining quality and spoilage attributes, and attention to phytosanitary issues.

It is important to note that management practices that help maintain the highest level of product quality often help to assure its safety. During the process of risk assessment, these practices become more obvious and will serve as the backbone of the food safety program.

Rapid Detection and Remedial Actions

Methods for rapid detection of microbiological contamination are under development with considerable investment from the public and private sectors. Some of the methods that are reported to be most effective are proprietary. Detailed discussion of this topic is beyond the scope of this Module. Companies that seek to implement testing are likely to hire a professional service company to conduct the tests.

Remedial action, essentially a "kill step," to eliminate microbiological hazards also is of great interest. The ultimate kill step is to cook the product, but obviously any such thermal treatment negates the whole concept of "fresh" fruit and vegetables. Nonthermal technologies that preserve freshness are under development. The technology that is most publicized is irradiation. Gamma irradiation and electron-beam irradiation have been tested for various food types but have not gained widespread consumer acceptance and for many products the techniques are too costly for implementation.

Summary

Food safety is the assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use.

Quality is the degree of excellence of the food.

Safety is a component of quality.

Food safety is an absolute condition, while quality is subject to interpretation.

Food may appear to have high quality but be unsafe. Alternatively, food may appear to be of poor quality but be perfectly safe for consumption.

Companies must have quality assurance (QA) programs that place an emphasis on food safety.

Management practices that help maintain quality often help to reduce the risk of contamination and help to ensure safety.

QA programs must encompass all steps from field selection to final consumption of the product. This is particularly challenging at the consumer level where the grower and handler has no control.

Prevention of contamination is favored over any remedial action to try to restore quality and safety to a product.

In the future, we may expect that techniques will be developed for rapid detection of pathogens that will be useful for the assurance of safety.

Introduction

Quality entails some attributes that are subjective. For business purposes, e.g., for uniformity of produce quality in commerce, it is essential to have practical, objective grades and standards that define quality. In this Module we discuss the ways that quality is measured and the regulations that define quality for business practices.

Quality Attributes Defined

It is not possible to clearly differentiate each quality attribute from all others as they all relate to each other in some manner. However, experts have classified some quality characteristics for the purpose of evaluating them in the course of conducting business and for scientific studies. These fit into three general categories: external, internal and hidden attributes.

External attributes are the ones that are perceived immediately when the product is encountered. These are the ones that are seen and felt. Appearance quality includes color, size, shape, and the presence or absence of defects. Defects may be due to a myriad of causes such as insect injury, environmental factors (sunburn, splitting from excessive watering, etc.), handling injury (bruising, cuts, scrapes, etc.) or decay. Aroma may be sensed externally but is more commonly measured as an internal characteristic of the flesh. Collectively, the external attributes are the factors most likely to influence the consumer's decision to purchase or reject a product.

Internal attributes typically are not obvious until the product is cut or bitten, although a trained evaluator may make an accurate prediction of internal quality based on external characteristics. For example, a watermelon might appear to be ripe to an average customer in the supermarket, but for a trained observer there may be external characteristics that indicate the fruit will not have good eating quality. Aroma, flavor, texture, color, turgidity and firmness are a few examples of internal quality characteristics.

The combination of internal and external characteristics will determine if the customer is likely to make a second purchase of the product. For some fruits and vegetables the appearance quality may still be good long after flavor and other sensory quality attributes have deteriorated, resulting in disappointment for the consumer and reluctance to purchase the product in the future.

Hidden attributes include wholesomeness, nutritional value, and safety. As the name implies, these are almost impossible for the average consumer to assess. However, the perception of the hidden attributes may play a large role in the customer's decision to purchase. For example, wholesomeness and nutritional value are generally associated with an appearance of freshness. Items that are wilted or are not brightly colored may not be perceived to be wholesome and may be rejected at the point of sale. Information about nutritional value sometimes is posted at the point of sale.

Perception of safety is difficult. The media can have a strong influence on consumers' perceptions of safety, especially during an outbreak of foodborne illness, when country or state of origin may influence consumers' choices.

Measurement of Quality

Only a few quality attributes can be measured by purely objective methods. Any method for quality evaluation must somehow relate to the sensory evaluation that consumers make at the point of purchase. Quality measurement is critical because growers, packers, shippers, inspectors and scientists all need standards upon which to base the effectiveness of their own work and to be able to make legitimate comparisons of their work to that of others.

External Attributes

Size is easily measured and is used as a grade standard for almost all commodities. Numerous types of mechanical sizing methods are in use in the produce industry today. These usually function by measuring the physical dimensions or weight of the product. In small operations, sizing may be done manually and aids are available to assist workers with the evaluation.

Shape is more difficult to characterize than size but for many products visual guides have been developed. A typical grade standard might use the descriptors "well formed" or "having a shape characteristic of the product," but obviously these are subject to some degree of interpretation and may vary by variety within a commodity group.

Color is a complex attribute but it can be quantified. Color is caused by the number and type of pigments found in the commodity. Colorimeters have been developed for nondestructive measurement of external color. There are biochemical methods for specific pigment analysis. As a practical measure, the human eye is an excellent colorimeter. Visual aids have been developed to assist the eye with color evaluation. Changes in color often may be correlated with maturity, ripeness or freshness of a product.

Defects and their causes were mentioned earlier and their presence is an important quality criterion. In a packinghouse the personnel that grade products will evaluate defects visually and remove product of inferior quality. Visual aids have been created to assist workers with identifying and assessing the severity of some defects.

Optical equipment has been developed for use on packing lines to evaluate any or all of the preceding external quality attributes almost instantaneously, although limitations in their effectiveness do exist. Support equipment can receive a signal from the optical evaluation to direct the product to a specific path within the packinghouse. These optical graders are most often employed for fruit and fruit type vegetables that have smooth skin.

Firmness can be described as the degree of softness. It is related to the structural integrity of cell walls and membranes in the flesh of the product. Softening is part of the normal ripening process and can also be related to bruising. There are various mechanical means for firmness measurement that are used in laboratories. One that is employed in some fruit industries, e.g., peaches, apples and kiwifruit, is the measurement of puncture pressure. A probe is pushed into the tissue of the product and resistance to penetration is measured as pounds or kg force required for penetration. This is useful for a number of different fruit types but obviously it is a destructive test. Nondestructive methods measure resistance of the product to deformation when pressure is applied. To date there are no rapid, nondestructive methods available for large scale use in packinghouses. Consumers may conduct their own firmness test by squeezing the product at the point of purchase.

Internal Attributes

Although appearance quality may be most important in the decision to purchase, flavor (taste) is perhaps the single most important quality attribute for the consumer for repeat purchases. Unfortunately, taste cannot be determined with certainty until the product has been purchased and eaten.

The four basic tastes are sweet, sour, bitter and astringent. Sweetness is related to sugars and the sugar to acid ratio. Sourness is caused by acids. Bitterness and astringency are related to a large number of different compounds. For practical purposes taste is best determined by a panel of people (trained or untrained) who are willing to do taste tests. In the laboratory there are numerous methods for quantifying the biochemical constituents that have flavor.

Aroma, odor and smell all refer to the sum of the volatile compounds sensed by the nose. They impact overall taste because of the sensory interactions in the mouth and nose. Fruits and vegetables are rich in aromatic compounds, many of which have not been characterized with biochemical analysis. While aroma can be an important quality criterion to the consumer, it is difficult to measure or even to describe in practical terms.

Texture is related to the structural elements of food. The most obvious element, firmness, might be described as the resistance felt when chewing. Other textural characteristics are collectively described as mouthfeel, i.e., the sensory impacts on the tongue, palate and teeth.

In fresh produce the common textural characteristics include tenderness, crispness, crunchiness, chewiness and fibrousness. It is difficult to write descriptors for most of these for a sensory panel. Objectively, texture is most often determined by applying force to the food and measuring the resistance to shearing or deformation.

Hidden Attributes

Wholesomeness was described earlier as the perception of freshness. It is relatively difficult to measure in any practical manner but it may be important for marketing and pricing at the point of sale. Discriminating customers are likely to reject products that do not appear wholesome. This attribute does involve a sanitary component in that the product must appear to be clean and free of foreign material or decay. Perception also can be influenced by production practices, i.e., some consumers view organically grown product as more wholesome than conventionally grown.

Nutritional value is related to the presence and amounts of constituents that support life. Fresh fruits and vegetables are recognized as good sources of vitamins, minerals and fiber. More recently researchers have identified that they are sources of antioxidants and other phytochemicals that have roles in preventing or controlling some diseases. The types, quality and quantity of these constituents that individuals consume can directly impact their health.

Safety, defined earlier, is the assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use. Detecting and monitoring safety risks are difficult. Microbiological techniques are used to determine the presence of pathogens. Chemical analysis is required to detect pesticides or other chemicals. Physical hazards may be found by x-ray or other imaging techniques. Some tests are destructive so not every piece of product can be tested. The implementation of an effective safety assurance program is essential in order for a test to reasonably predict the safety of the entire lot of product.

Quality Standards

Food standards consist of precise descriptors for the criteria that define the quality of the product. They provide common frames of reference that can be used as a basis for business transactions and for disputes to be settled by regulatory authorities.

It is critical for the business community to have these grades and standards that provide uniformity in the determination of the quality of fresh produce. When a sales person is speaking with a customer on the phone about the quality of the product offered for sale, usually neither of the parties is able to look at the product at that moment and they may be thousands of miles apart if the transaction is an international one. There must be a common language or terminology that both parties understand. This helps to establish market value and to prevent economic fraud. Without standards, the description of product quality could easily be misrepresented or misinterpreted. There are several types of standards in use today and all are based upon the various quality criteria discussed previously.

Official standards, discussed later in more detail, are those set by governments and their regulatory bodies. These usually are binding upon the produce industry as a matter of law and are used not only for the initiation of a business transaction but also for settlement of disputes if the transaction is not completed successfully. It is important to note that official standards still do not exist for every produce item. In these cases, disputes have to be resolved within the companies that conduct trade.

Industry standards may be set by commodity producer groups who typically wish to set a standard for their product that may be higher than the official standard. These may be voluntary for producers, but those producers who do not participate in the program may not receive certain benefits that are offered to members of the group. For example, at the present time there are programs under development by the leafy greens and tomato industries to set food safety standards that are expected to exceed the standards that are in place for other commodities. If and when these standards are accepted widely by a commodity group they may be adopted as law and thus become official standards.

Association standards, as the term implies, are those set by trade associations for their members. In the U.S. these standards may be binding upon members if they are based upon an official USDA Marketing Order. There are many examples, but one that is familiar to many customers in the U.S. is the Vidalia onion standard. This requires that only certain types of onions grown in specific locations within the State of Georgia may be labeled as Vidalia onions.

Buyer standards, or specifications, are those set by businesses who wish to establish their own standards to generate customer confidence and loyalty. Although these specifications are not necessarily based on law, they have become a powerful tool in trade. In the area of food safety in particular, many retailers have imposed specific requirements upon their suppliers for certain conditions to be met. These usually involve audits or inspections of farms and facilities to assure compliance with the buyer's requirements, particularly food safety requirements.

Consumer standards are not written or formal, but they may be the most important of all standards. These are the criteria that the consumer will use at the point of purchase to decide if he/she will buy the product.

International Standards

For most countries, especially the U.S., the food supply is an international one. The National Geographic Society recognizes almost 200 independent countries and the U.S. imports food from approximately two-thirds of these countries. The products imported are regulated largely by the USDA and the FDA. There are many other regulating bodies that have set standards for international trade and it is useful to review a few of those here.

In conjunction with World Trade Organization (WTO) Agreements, the Codex Committee on Fresh Fruits and Vegetables has the responsibility for developing standards and codes of practice for fresh produce. A code of practice known as "Quality Inspection and Certification of Fresh Fruits and Vegetables" has been adopted by the Codex Alimentarius Commission. This code contains provisions for packing, shipping, control and inspection of fresh produce.

Codex standards are a combination of grading for quality and inspection for wholesomeness, safety and freedom from economic fraud. Inspection and certification are conducted at the point of origin by a national official or a recognized service person.

The objective of the Codex standards is to protect consumers' health and ensure fair practices in the trade of food. The Codex Committee on Food Import and Export Inspections recommends that public health protection issues be given the highest priority when considering standards. There is no legal obligation for World Trade Organization (WTO) members to adopt Codex Standards into law. Individual countries establish their own standards for imported food. However, member countries must be prepared to justify to WTO any domestic standard that is more restrictive to trade than the Codex standard.

The International Organization for Standardization (ISO) is another well-known entity in many industries including food. ISO specifies requirements for food safety management systems and requires that they demonstrate the ability to control food safety hazards in order to ensure that food is safe at the time of consumption. ISO standards are applicable to all organizations regardless of size.

Phytosanitary issues are a concern for all importing countries. Domestic agencies are responsible for protecting their own food supplies from the import of exotic pests that may threaten domestic production. In the U.S., phytosanitary issues are addressed primarily by USDA Animal and Plant Health Inspection Service (APHIS), which has mandatory programs for inspection of imported food. At times, phytosanitary issues may overlap with human health issues, in which case the FDA or other agencies such as the Centers for Disease Control (CDC) may become involved.

Refer to Section VII of this Manual for a more detailed discussion of U.S. and international food laws.

U.S. Domestic Standards

The USDA Agricultural Marketing Service (AMS) has developed over 150 official grading standards for fruits, vegetables, tree nuts, peanuts and related commodities. These can be viewed at http://www.ams.usda.gov/standards. The viewer can print information for the commodities of interest.

In conjunction with the descriptions of grades, the USDA has developed a number of specific guidelines to ensure that the grades are applied uniformly. If the packer or shipper has requested an official grading based on U.S. standards, the shipping certificate will show which USDA grade the shipment has met.

It is important to note that the USDA-AMS grading process is for quality attributes other than safety.

Inspection vs. Grading

Inspection is usually a mandatory process done by a government agency to help ensure a product's wholesomeness, safety or adherence to regulations. For example, products entering the U.S. may be sampled by FDA at the port of entry and analyzed for microbiological contamination or pesticide residue. This is a mandatory exercise.

Grading is a voluntary program of classification of a product based on certain quality characteristics. This gives those in the produce industry common language for buying and selling. Users of the USDA-AMS service have to pay a fee for the service. Grading may be mandatory for products that are subject to a marketing order, marketing agreement, or that are subject to import or export requirements. Grading is most commonly conducted at the packing or shipping point but may also be implemented by the receiver to settle disputes about quality.

Grading also refers to the process conducted by company employees to remove inferior products prior to the manufacture of the package that will enter commerce. This is an essential step for quality assurance.

Summary

Quality attributes may be classified as external, internal or hidden.

External attributes are those that are obvious when the product is examined, such as size, shape, etc.

Internal attributes, such as flavor and texture, require that the product be cut or bitten.

Hidden attributes are those that usually require an analysis in a laboratory, such as safety and nutritional value.

Quality attributes may be measured by a variety of methods. Some of the attributes can be objectively quantified while others are completely subjective.

Quality standards are precisely defined descriptors for the criteria that define the quality of a specific product.

Standards are of critical importance to the business community because they provide common language to help ensure the uniformity of quality of the product.

Standards may be set by a variety of entities. Some are set by government or other agencies and are official. Others may be set by a specific commodity industry or trade association. Supermarket or restaurant chains may require their own standards. The ultimate standard is that of the consumer that makes the purchase.

International trade standards have been set by a number of different organizations. Probably the most widely known are the Codex Alimentarius Commission and the International Organization for Standardization.

Domestic standards are set by individual countries. In the U.S. this is USDA-AMS for quality attributes and USDA-APHIS for phytosanitary issues.

Inspection is usually a mandatory process done by government or other agencies.

Grading is a voluntary process that helps establish common quality criteria for buying and selling.

Introduction

Fresh fruits and vegetables are alive. At harvest they are removed from their source of water and nutrients and they begin to utilize the limited amounts of metabolites and water that are stored within to sustain life processes. In this Module the factors that influence spoilage and the relationship between spoilage and food safety are examined.

General Considerations for Spoilage and Quality Deterioration

An enormous amount of fresh fruits and vegetables is lost during production due to environmental stresses, poor production management or simply because the product fails to meet specified quality standards at the time it is harvested. Additional product is lost after harvest for a variety of reasons mentioned later.

Some experts estimate that less than half of the fresh commodities produced in the world actually is consumed. Fresh tomatoes in the U.S. are a good example. Approximately 25% of the fresh market tomatoes produced are left in the field at harvest because of problems with condition. For those that are harvested, an additional 25% are graded out and discarded in the packinghouse due to quality problems. For the remaining 50% that enter commercial channels, an unknown amount will decay before they can be consumed. These estimates are realistic and may well apply to other commodities. Clearly it is beneficial to business and to the security of our food supply to examine ways in which these losses can be reduced.

Depending on the commodity, stored reserves may be forms of carbohydrates, organic acids, fats, or proteins. Some commodities, such as strawberries, have very little stored reserves, while others such as potatoes are in fact storage organs. Quality deterioration and spoilage both are affected by the type of commodity, handling practices, the rate at which stored reserves are utilized, the rate of water loss and the level of infection by plant pathogens.

During production, unfavorable weather conditions account for the greatest loss of productivity. Drought, flooding, frost, wind damage, sunburn, etc., all contribute to losses. In some cases these factors can be mitigated with irrigation, frost protection, windbreaks, shading, and other management practices. In all cases, attempts to manipulate or control the production environment add cost to production.

In the postharvest sector, three management concerns account for most of the losses. Rough handling injury that results in bruises, cuts, scrapes, discoloration, etc., increases water loss and provides an entry for decay-causing pathogens as well as any human pathogens that may be present. Poor temperature management can cause chilling or freezing injury if the temperature is too low. When temperatures are too high, decay, excessive water loss, and undesirable physiological processes, discussed later as biological factors, can occur. Finally, poor sanitation practices, especially in operations involving the use of water, lead to decay and potential infection with human pathogens if they are present. Managers of postharvest operations must give priority to these issues at all steps in the handling system.

From the above discussion it can be concluded that water loss, mechanical injuries and temperature related disorders are common to all fresh commodity groups. It is useful to list the five commonly recognized categories of fruits and vegetables and mention additional special quality concerns for individual groups.

Root and tuber vegetables include carrots, beets, onions, garlic, potatoes, sweet potatoes, and numerous tropical root crops. Several of the commodities in this group actually benefit from controlled water loss, a process described as curing, which can extend the storage life. In storage, premature sprouting caused by high temperatures, light or excessive storage time is a quality limiting factor. Products of tropical origin are susceptible to chilling injury, which is a type of low temperature-induced physiological injury that occurs above the freezing point.

Leafy vegetables include lettuce, chard, spinach, cabbage, green onions, and a variety of leafy greens that are most commonly eaten cooked. These are particularly susceptible to water loss because of their high surface to volume ratio. Preservation of green color also is an important quality concern. Chlorophyll degradation is stimulated by exposure to ethylene, discussed later.

Flower vegetables include artichoke, cauliflower, and broccoli. A special concern for these products, not previously mentioned, is opening or abscission of the florets.

Immature fruit vegetables include cucumbers, squash, eggplant, peppers, okra, and snap beans. These are especially tender and susceptible to mechanical injury. Over-maturity at harvest results in undesirable toughness and fibrousness. All of the commodities mentioned here are susceptible to chilling injury.

Mature fruit includes tomatoes, melons, bananas, mangoes, apples, pears, grapes, stone fruit, and others. Over-ripeness at harvest may result in fruit that is too soft to withstand the rigors of packing and shipping. Temperature management is specific to the fruit type. Since most of these commodities are hand harvested, the actions of the harvest workers can have a significant impact on quality.

The quality and spoilage issues described previously are most often associated with inadequate training of product handlers, inadequate or non-existent storage structures, unsuitable or inadequate technologies for handling and storing product, ineffective quality control and adverse or extreme environmental conditions. Some of the terminology and processes mentioned above are described in more detail in the following section.

Specific Processes Involved in Spoilage and Quality Deterioration

Biological Factors

The presence of pests, specifically rodents, birds and insects and/or their droppings is cause for alarm because it represents an immediate food safety hazard. The damage that pests can cause to the surface of the commodity is an obvious quality issue, but this is secondary to the concern for food safety. Pest issues during field production were addressed in Section II and pest control during handling was covered in Section III.

Microorganisms are the direct cause of decay in fruits and vegetables. Bacteria and fungi that have the capacity to grow in the tissues of the commodity eventually cause rot. Depending on the relationship between the type of microbe, the host and the environment, decay may take months or it may happen in a matter of days. The end result is that the quality of the product is reduced and it becomes unmarketable. Decay-causing organisms secrete enzymes that cause softening (degradation of cell walls) and allow penetration of the host cells. By this mechanism, decay can spread within a container from one fruit or vegetable to another, proving the adage ‘one bad apple can spoil the whole barrel’.

It is beyond the scope of this Module to list all of the decay-causing microorganisms that attack produce or to list the common names for the resulting types of decay. The key point is that decay control is an important area of production and postharvest science. Technologies for control of decay are constantly changing, albeit slowly, and managers must keep abreast of the current knowledge in order to optimize their decay-control practices.

Microorganisms also can cause human illness as is emphasized throughout this text. Some relationships between plant pathogens and human pathogens have been identified. For example, the presence of decay-causing *Erwinia* bacteria increases the risk that *Salmonella* may be present. Further, it is known that infection with the plant pathogen *Pseudomonas* facilitates the colonization of *Salmonella* on the product surface. There are a number of known interactions between certain fungi and *E. coli* and *Salmonella*. Scientists undoubtedly will identify other such relationships in the future.

Based on this discussion of microbiology, it is critically important to reemphasize that management practices that help reduce decay and preserve quality may also help assure the safety of the product. This is an invaluable message when training managers and employees who may not understand or do not fully accept the importance of GAP and GMP. Food safety is good for business.

Physiological factors also are important for quality and safety. We must first understand that death of a fruit or vegetable is inevitable. Senescence is the term to describe the natural aging and ultimate demise of the organ. Management practices employed to extend the postharvest life of the product are delaying the onset or prolonging the period of senescence. Several physiological processes are involved.

Respiration is the process through which life is sustained. Storage reserves in the detached organ are metabolized to provide energy for cells to survive. During respiration oxygen is utilized, carbon dioxide is released and energy is provided. The following chemical equation is oversimplified but it summarizes the process.

$$\text{Stored Reserves} + O_2 \rightarrow \text{Energy} + CO_2 + H_2O$$

Each component of this equation is important. As storage reserves are depleted the organ is racing toward death. The depletion of oxygen and release of carbon dioxide into the surrounding environment can impact the respiration rate and other metabolic processes that influence quality. A portion of the energy that is created is released as heat and the water is released as vapor. The fact that the commodity is affecting its storage environment is a concern for refrigeration and ventilation requirements.

The rate of respiration of fruits and vegetables usually is an indicator of their rate of deterioration postharvest. Management practices that can help reduce the respiration rate are refrigeration, minimizing handling injury and manipulation of oxygen and carbon dioxide in the storage environment or within the product with waxes, other coatings or with packaging materials.

Respiration rate can be measured and often is expressed as either ml or mg of carbon dioxide released per g or kg of product per hour. The relative rate of respiration is commodity-specific. Knowledge of respiration rates has been useful for the development of postharvest management practices to prolong the storage life of fresh produce.

The following Table contains a summary of approximate respiration rates of selected fruits and vegetables.

Respiration Rates of Fruits and Vegetables

Class	Range at 5°C (mg CO_2/Kg-hr)	Commodities
Very low	<5	Nuts, dates, dried fruits and vegetables
Low	5-10	Apple, citrus, grape, garlic, onion, potato, sweet potato
Moderate	10-20	Apricot, banana, cherry
High	20-40	Strawberry, blackberry, raspberry, cauliflower, lima bean, avocado
Very high	40-60	Artichoke, snap bean, brussel sprouts, cut flowers
Extremely high	>60	Asparagus, broccoli, mushroom, spinach, pea, sweet corn

Another physiological process of importance to quality and safety is the product's rate of ethylene production. Ethylene (C_2H_4) is a naturally occurring plant growth regulator produced by all plants and plant parts. Although ethylene has many roles in plant growth and development, in postharvest science it is regarded as the initiator of ripening and a modulator of senescence.

Ethylene is active in cells at very low concentrations. As little as a few parts per billion is enough ethylene to influence some aspects of plant metabolism. For postharvest uses, much higher concentrations, e.g., 100 parts per million, are applied for initiation of ripening.

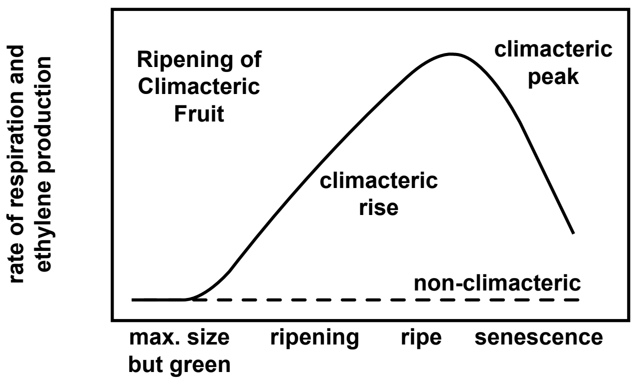
The rate of ethylene production and its activity is influenced by temperature, disease, injury to the product and environmental stress. Management strategies for reducing the effects of ethylene in the storage environment include reducing temperature, lowering the concentration of oxygen, and increasing the concentration of carbon dioxide. These strategies are highly commodity-specific and managers must understand the characteristics of the commodity before initiating such environmental modifications.

Fruits and fruit-type vegetables are categorized as either climacteric or non-climacteric based on their patterns of respiration and ethylene production. Knowledge of these fruit characteristics have enabled harvest managers to determine the optimum time for harvest. Further, postharvest managers better understand how to manipulate the storage environment, not only to provide better quality products to consumers, but to enhance the profitability of the business.

Climacteric fruit are those that exhibit auto-catalytic production of ethylene. As the rate of endogenous ethylene production increases there is a corresponding rapid rise in the rate of respiration. Climacteric fruit may be harvested when fully mature but before the onset of ripening, which can then be initiated with exogenous treatment with ethylene. This is common commercial practice with bananas and mature-green tomatoes. International trade in bananas has been possible because the fruit can be harvested green, shipped long distances and ripened with ethylene at the destination. If climacteric fruit are harvested too late, after the initiation of ripening on the mother plant, the postharvest life of the product is dramatically shortened because senescence follows ripening. Other examples of climacteric fruit include mango, papaya, apple, peach and others.

Nonclimacteric fruit do not exhibit a dramatic rise in respiration or ethylene production as they ripen. In fact there is no clear physiological demarcation between maturity and ripening. These fruit attain their best eating quality if they are allowed to ripen on the plant before harvest. Examples of nonclimacteric fruit include citrus, cherry, strawberry, grape, pineapple and others. With the exception of pineapple, these commodities do not become substantially sweeter or achieve better eating quality after harvest.

The following stylized graph depicts the climacteric curves for respiration and ethylene production. A nonclimacteric fruit would not exhibit these increases, e.g., the line would be flat.



In nature there are numerous exceptions to the rules applied above for ripening behavior of climacteric and nonclimacteric fruit. The relative magnitude of the rates of respiration and ethylene, as well as the synchronicity of the processes, varies considerably. Managers of postharvest operations must understand the specific nature of the products they handle in order to optimize quality.

Another biological factor related to quality deterioration is the capacity for some commodities to continue to grow after they are harvested. Undesirable sprouting may occur with roots, tubers and bulbs. Stem vegetables, such as asparagus, may elongate. The pattern of growth can be influenced by gravity such that the growth may curve upward if the product is lying flat. For this reason asparagus is packed and shipped in a vertical position to avoid undesirable curvature.

Physiological injury that lowers quality may occur in either the preharvest or postharvest environments. Temperature extremes are perhaps the most common cause of physiological injury. Freezing, chilling of tropical products and high heat all can be problematic.

Gas concentrations are a factor in postharvest environments. Low oxygen, high carbon dioxide and ethylene all can damage commodities. The symptoms of physiological injury vary widely and include surface or internal discoloration, pitting, water-soaked areas, hard core formation, uneven ripening, accelerated decay or senescence, desiccation and others. Many of these injuries can be avoided by proper preharvest and postharvest management.

In summary, knowledge of biological factors and their effects on product quality and spoilage is essential for the assurance that consumers receive fresh produce of the best possible quality and safety.

Biochemical Factors

It is not possible to make a clear distinction between the biochemical and biological factors that influence fruit and vegetable quality and safety. However, there are some processes in plant science that can be isolated and examined in vitro. These tend to be discussed in chemical terms.

Enzymes are proteins that occur naturally in all forms of life. They catalyze a multitude of important chemical reactions. Many of these reactions are beneficial while others result in quality deterioration. For example, softening is primarily due to enzyme-mediated degradation of cell walls accompanied by changes in cell membranes. Modification of lipids and other constituents can result in off flavors or fermentation but can also provide aromas that are desirable.

Oxidative enzyme activity is of special interest. Undesirable browning or other color changes and reduction in nutritional quality are often associated with oxidative reactions. Oxidative processes have been researched extensively because of their involvement in senescence of plants as well as animals.

Managers of postharvest operations, who deal with practical matters, seldom think of their activities in terms of product chemistry. But all reactions in fruits and vegetables are chemical reactions.

Physical Factors

Loss of water from harvested product to the surrounding environment is largely a physical process. Prior to harvest, water lost through transpiration is replaced by water taken up through the roots, but once the commodity is detached from the plant this supply of water is lost. Excessive transpiration after harvest leads to shrinking, shriveling, wilting, softening and changes in crispiness, juiciness and nutritional quality. Water loss can be mediated to some extent by application of waxes, coatings, packaging, and control of humidity and rate of air circulation in the storage environment.

Physical injury to commodities causes many undesirable changes in quality, some of which have been mentioned previously. The high water content of fruits and vegetables and the corresponding turgidity of cells make them susceptible to physical forces. Such injuries are unsightly and cause accelerated water loss, provide points of entry for decay causing microorganisms or human pathogens and cause an increase in rates of respiration and ethylene production.

As stated earlier in Section III, the hands of the harvest worker may be the most important hands that touch the commodity because in the instant that physical injury is inflicted to the product all of the investment in production is lost. Workers can also transfer human and plant pathogens to the product. This, once again, highlights the importance of worker training programs.

Time

Time is a factor in every aspect of spoilage, quality deterioration and food safety. Business managers in the produce industry should take every practical measure to ensure that fresh produce is moved from the field to the consumer in a timely manner.

Summary

All fruits and vegetables are alive. Their primary constituent is water. They are susceptible to injuries and infection that lead to quality deterioration, spoilage and food safety risks.

After harvest, fresh commodities must survive with the stored reserves and water that are present at the time of harvest.

The principle objective of postharvest management practices is to maintain quality and safety and to extend the life of the product.

Factors that influence quality deterioration may be biological (microbiological) biochemical, physiological or physical.

Undesirable quality changes include decay, discoloration, off-flavors, shriveling, irregular ripening and other symptoms that render the product unmarketable.

The presence of pests, their feces or damage inflicted by pests present food safety risks and contribute to quality deterioration and spoilage.

The principle microorganisms that cause decay of fresh produce are bacteria and fungi. Some of these microbes as well as viruses may cause illness in humans.

Some plant pathogens and human pathogens appear to have metabiotic relationships.

Physiological and physical factors that play a role in quality deterioration include respiration, ethylene production, transpiration, handling injury, ripening, senescence, a continuation of growth after harvest and environmental conditions.

Management practices that help preserve the quality and prevent spoilage may also help reduce food safety risks.

Managers and employees should be taught that effective implementation of GAP and GMP is good for business.

Introduction

Hazard Analysis Critical Control Points (HACCP) is a food safety assurance program that was developed for the food processing industries. It is a systematic approach to the identification, evaluation and control of food safety hazards. The fresh produce industry does not "process" food in the manner of other industries, but the principles of HACCP have been invaluable in the development of GAP and GMP and these programs are referred to as HACCP-like.

The term HACCP has been widely misused in the fresh produce food safety literature. The terms GAP and GMP were not formally defined by FDA until 1998 with the publication of the "Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables." Prior to this date, there was no terminology that accurately defined food safety programs in fresh produce that were the focus of many Extension and Research publications. HACCP was routinely used in a context that does not accurately reflect the work that was being done during those years.

The importance of HACCP should not be minimized, but it should be discussed in the proper context. It is important that progress in fresh produce safety not be slowed by a debate regarding terminology. Rather, focus should be placed on the goal of developing and implementing effective GAP and GMP programs that utilize aspects of HACCP such as hazard analysis.

Origin of HACCP

The origin of HACCP is traced to the beginning of manned space flight in 1959, when the National Aeronautics and Space Administration (NASA) worked with the Pillsbury Company to develop a system for processing foods in a manner that could assure the safety of food consumed during space travel. The program was effective. As it became more refined and widely utilized, the National Academy of Sciences (NAS) recommended in 1985 that the program be adopted by regulatory agencies and mandatory for all food processors.

In 1993 the NAS Advisory Committee on Microbiological Criteria for Foods formally declared that it is the responsibility of the food industry to develop and implement HACCP and that appropriate regulatory agencies must facilitate the process. Since then HACCP has been adopted as an international standard. It has been officially mandated in the U.S. by the FDA for fruit and vegetable juice processors and for many other specific food industries.

Principles of HACCP

There are seven basic principles involved in a HACCP program. The underlying theme of all of these principles is that prevention of contamination of food is favored over remedial action to inactivate contamination.

1. Conduct a hazard analysis.
2. Determine the critical control points (CCP).
3. Establish critical limits.
4. Establish monitoring procedures.
5. Establish corrective actions.
6. Establish verification procedures.
7. Establish record-keeping and documentation procedures.

Application of HACCP Principles to GAP and GMP

The utility and limitations of HACCP in fresh produce food safety programs can best be identified by conducting a brief analysis of each principle in the context of the production and handling practices used for fresh produce. First we should review the definitions of hazard and risk stated in Section I.

A ***hazard*** is a biological, chemical or physical agent that is reasonably likely to cause illness or injury in the absence of its control.

Risk is the probability that illness or injury will actually occur following exposure to a hazard. We control hazards to minimize risk.

A hazard analysis is appropriate for any food industry, including fresh produce. This requires a step by step analysis of the production and handling system. In farming systems, the use of water and compost both are potential hazards. Other potential hazards involve the personal hygiene of workers, the presence of animals in fields and contamination of food contact surfaces. Some of the same hazards exist in postharvest systems, with water and worker hygiene being two important issues. GAP and GMP include steps to reduce risks associated with these and other potential hazards.

The identification of CCP is a principle of HACCP that cannot be applied to fresh fruit and vegetable systems in the same manner that it is applied to food processing systems. Although we can identify control points, verifiable controls do not always exist for potential hazards found in the production and handling of fresh produce. For example, there is no absolute control measure to ensure that a bird or some other animal will never enter a field in production. Our only recourse in these situations is to take every practical preventative step to ensure that risk associated with such a hazard is minimized to the extent possible. This is a clear distinction between HACCP and GAP/GMP programs.

The establishment of critical limits is another principle of HACCP that cannot be applied to GAP and GMP with certainty. For example, on a farm ideally birds would never visit the field, but such intrusions are inevitable. Clearly a limit cannot be set for the number of birds that could be allowed. The use of bird deterrent devices can help minimize the risk.

In response to evidence of bird and wildlife intrusions growers do have the option of establishing no harvest zones. They also may implement more intensive microbiological testing of the product and the environment to help determine where risks exist.

Another good example is in packinghouse water quality management. We do not know, precisely, the concentration of chlorine or other water sanitizers that can absolutely kill every human pathogen. Thus we utilize sanitizers within limits based on current scientific knowledge to attempt to minimize the risk of having pathogens survive in water.

The principle of monitoring procedures applies to all food systems. The SSOP that are developed for GAP and GMP programs stipulate that monitoring must be done for the preventative measures to ensure proper and consistent implementation.

Corrective actions are an important part of GAP and GMP. As production and handling systems are monitored, appropriate action must be taken to correct any measure that is observed to be deficient. Since fruits and vegetables are to be consumed fresh, there are no corrective steps that can eliminate or reduce hazards to acceptable levels once contamination has occurred. This is another reason that HACCP is not mandated for fresh produce. Further, it emphasizes once again that prevention of contamination is key to produce safety.

Verification procedures in GAP and GMP are tenuous at best. Since there is no “kill step” to apply to fresh produce, testing the product for the presence of microbes is not feasible, although there is debate in the industry and scientific community about the value of testing. In contrast, an analysis for chemical residue might verify with some certainty if a pesticide has been misused. Likewise a metal detector can verify the absence of a metallic physical hazard in the final package. In GAP and GMP methods of control can be verified in some cases. For example, water quality management in packinghouses that utilize chlorine as a sanitizer may monitor oxidation-reduction potential (ORP) continuously and conduct a periodic verification of the chlorine level with a test strip or some other method.

The final HACCP principle, record keeping and documentation, is also an essential practice for GAP and GMP. The SSOP should state what should be done and how to do it. Each time a SSOP is completed the procedure should be documented by the individual completing the task. These records allow for monitoring of the SSOP implementation.

The following Table provides a few examples of hazard identification, preventative measures, and records that might be utilized for GAP and GMP programs. Note that it includes a number of the principles discussed above. The preparation of a similar list or table of information is a prerequisite for the development and implementation of GAP and GMP. This Table is by no means comprehensive and is intended to serve only as an example for the reader.

Adaptation of Preventive Measures			
Operation	**Hazard**	**Prevention**	**Records**
Soil use	Feces / Pathogens Chemical residue	No animals Analysis	Analyses
Fertilizer	Pathogens Heavy metals	Compost	Certificate Analyses
Irrigation water	Pathogens Chemicals	Water test	Analyses
Pesticides	Chemical Residues	Follow instructions	Certificate
Harvest	Pathogens	Hygiene	Training Hand wash
Bins	Pathogens	Clean & sanitize No contact with soil	C & S training

Conclusion

HACCP, though not directly applicable to fresh produce production and handling systems, does have attributes that can be utilized in the development pf GAP and GMP programs. Personnel in charge of food safety programs will find a thorough review of HACCP to be beneficial.

Summary

HACCP is a systematic approach to the identification, evaluation and control of food safety hazards.

The fresh produce industry does not "process" food in the manner of other industries, but the principles of HACCP have been invaluable in the development of GAP and GMP. These programs are referred to as HACCP-like.

Hazard analysis involves a detailed review of the process of growing and handling food.

When potential hazards have been identified, controls must be implemented to minimize risks associated with those hazards.

There is no "kill step" available to inactivate human pathogens if they are present on fresh produce. The underlying theme of all aspects of GAP and GMP programs is to prevent contamination from occurring.

Personnel in charge of food safety programs will find a thorough review of HACCP to be beneficial as they develop GAP and GMP for their companies.

Documentation and record keeping are essential for GAP and GMP. SSOP must specify actions and detail implementation steps. Personnel must comply with the policies in SSOP and document SSOP completion.