

FOOD SAFETY AND QUALITY ASSURANCE ISSUES



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SECTION V

FOOD SAFETY AND QUALITY ASSURANCE ISSUES

MODULE 1

SAFETY AND QUALITY ASSURANCE*

Learning Outcomes

- *Participants will be able to describe the difference between quality and safety.*
- *Participants should be aware of programs used for food safety and quality assurance and the uses and limitations of such programs for the fresh produce industry.*

Practical

- *Experiment/Demonstration – Product Integrity and Produce Contamination*

Additional Resources

- *Part II. FDA Publications – FDA Publishes Final Rule to Increase Safety of Fruit and Vegetable Juices*
 - *Part V. Fundamentals of HACCP*
-

Safety vs. Quality

Visual V.1-1

FOOD SAFETY

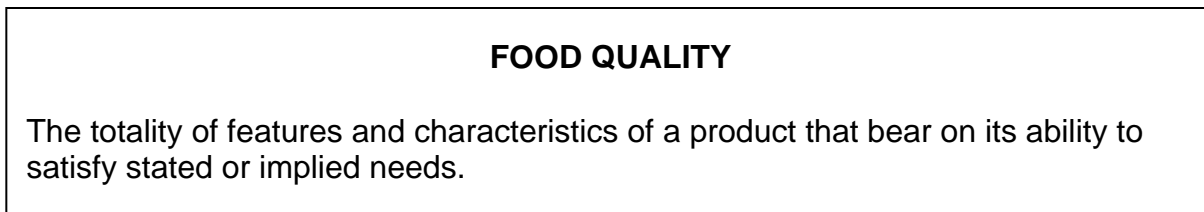
Assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use.

Food safety is defined 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 (FAO/WHO, 1997). Thus food safety assurance involves the reduction of risks

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which may occur in the food. Implementation of Good Agricultural Practices and Good Manufacturing Practices, as discussed in Sections II and III, are primary steps in reducing the risks associated with fresh fruits and vegetables.

Visual V-1.2



Quality is defined by the International Organization for Standardization (ISO) as “the totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs.” In other words, good quality exists when the product complies with the requirements specified by the client (van Reeuwijk, 1998). This means quality is a term defined by the consumer, buyer, grader, or any other client based on a number of subjective and objective measurements of the food product. These may include measures of purity, flavor, color, maturity, safety, wholesomeness, nutrition, or any other attribute or characteristic of the product.

Using these definitions, safety is a component of quality. In fact, many experts have argued that safety is the most important component of quality since a lack of safety can result in serious injury and even death for the consumer of the product.

Safety differs from many other quality attributes since it is a quality attribute that is difficult to observe. A product can appear to be of high quality, i.e. well colored, appetizing, flavorful, etc. and yet be unsafe because it is contaminated with undetected pathogenic organisms, toxic chemicals, or physical hazards. On the other hand, a product that seems to lack many of the visible quality attributes can be safe.

Obvious quality defects can result in consumer rejection and lower sales, while safety hazards may be hidden and go undetected until the product is consumed. Since assuring safety is vital to public health, achieving safety must always take precedence over achieving high levels of other quality attributes.

Safety and Quality Assurance Programs

Visual V.1-3

A safety or quality assurance program should focus on the prevention of problems, not simply curing them.

Safety and quality assurance should be ongoing processes incorporating activities beginning with selecting and preparing the soil and proceeding through to consumption of the product. Both safety and quality assurance should focus on the prevention of problems, not simply curing them since, once safety or quality is reduced, it is virtually impossible to go back and improve it for that item. It is possible however, to assure that the same problem does not affect future products.

In order to assure adequate quality control of the product from seed to harvest to the consumer, a strong, semi-independent quality assurance (QA) program or department is needed. This program needs to be independent of production management. For companies large enough to have a separate QA department, it should report directly to the corporate president (Gould and Gould, 1993).

QA requires many diverse technical and analytical skills (IFT, 2001). QA personnel continually monitor inputs into production as well as the products to insure compliance with compositional standards, microbiological standards, and various government regulations. A QA manager can halt production, refuse acceptance of raw material, or stop the shipment of product if specifications for a product or process are not met.

Although safety is a component of quality, safety assurance frequently is not included in quality assurance programs. Sometimes safety and quality assurance may be separate but complementary programs to ensure safety issues receive appropriate emphasis. Although it is impossible with current technologies to eliminate all potential food safety hazards associated with fresh produce to be eaten raw, the importance of safety to consumer health makes it imperative that safety programs be a primary component of all produce production and handling operations.

Development of produce safety programs involves looking at each unit operation individually from cultivation and harvest through the retail market. There will be some steps at which contamination may occur and can be controlled. In many cases the controls will be simple, common sense practices that the industry has followed for years. In others, the existing infrastructure and common practices will need modification in order to reduce or prevent contamination.

Good Agricultural Practices, Good Manufacturing Practices, Sanitation Standard Operating Procedures, and HACCP-like activities are programs which may be used at various stages in the farm to table chain to improve the safety of fresh fruits and vegetables.

Good Agricultural Practices and Good Manufacturing Practices

The production of safe food products requires that the safety assurance system be built upon a solid foundation. Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs) are key to providing a sound safety assurance program (FDA, 1998).

GAPs and GMPs are guidelines established to ensure a clean and safe working environment for all employees while eliminating the potential for contamination of the food products. When applied to fresh produce production, GAPs and GMPs address the issues of production site selection, adjacent land use, fertilizer usage, water quality and usage, pest control and pesticide monitoring, harvesting practices (including worker hygiene), packaging, storage, field sanitation and product transportation. The International Commission on Microbiological Specifications for Foods stated in 1986 that “Good agricultural practices in growing crops, combined with acceptable hygienic methods during harvesting, packing, and transporting of vegetables are more important than microbiological testing” in minimizing risks for microbial contamination of fresh produce (Food Science Australia, 2000). GAP and GMP programs were discussed in detail in Sections II and III of this manual.

Standard Operating Procedures and Sanitation Standard Operating Procedures

Visual V.1-4

Standard Operating Procedures (SOPs)

Detailed descriptions of each step in the flow of the product and the way that these steps are performed.

A Standard Operating Procedure (SOP) is a set of written instructions that document a routine or repetitive activity used by an organization (U.S. EPA, 2001). SOPs detail the work processes that are to be conducted or followed. They document the way activities are to be performed to facilitate consistent conformance to safety and quality system requirements. SOPs are intended to be specific to the organization or facility whose activities are described. They assist that organization in maintaining their safety and quality control and in ensuring compliance with regulations.

Visual V.1-5

Sanitation Standard Operating Procedures (SSOPs)

The procedures that must be followed in order to make sure that cleaning and sanitation activities are performed correctly.

A key component of a safety plan is to establish Sanitation Standard Operating Procedures (SSOPs). This involves the development of detailed descriptions of the cleaning procedures and sanitation operations that must be performed to prevent contamination or adulteration of the product (FSIS, 1996). SSOPs also describe the frequency with which each procedure is to be conducted and identify the employee(s) responsible for the implementation and maintenance of each procedure.

Visual V.1-6

An SSOP usually includes:

- Activity name
- Place where it is performed
- List of the equipment and material necessary to perform it
- Frequency of performance
- Approximate time to perform it
- Responsible Individual
- Description of every step necessary to perform the procedure

The establishment of standardized procedures for each sanitation activity helps assure that the activities are being performed properly. In addition, order and discipline are imposed, training is facilitated and dependence on an individual's criteria of proper sanitation is reduced.

The SSOPs for an operation should detail the sanitation procedures to be used before (pre-operational sanitation) and during (operational sanitation) operation (FSIS, 1996). Pre-operational sanitation will result in clean facilities, equipment, and utensils prior to starting the operation. Information which might be included in pre-operational SSOPs:

- Descriptions of equipment disassembly, reassembly after cleaning, use of acceptable chemicals, and cleaning techniques
- The application of sanitizers to product contact surfaces after cleaning

Routine sanitation operations that must be performed during the product handling operations make up the operational SSOPs. Established procedures for operational SSOPs will vary with the operations but might include:

- Equipment and utensil cleaning, sanitizing and disinfecting during production, and as appropriate, at breaks, between shifts, and at mid-shift.
- Employee hygiene
- Product handling

Hazard Analysis Critical Control Point

Visual V.1-7

Hazard Analysis Critical Control Point (HACCP)

HACCP is a systematic approach to the identification, evaluation, and control of food safety hazards. Preventing problems from occurring is the paramount goal underlying any HACCP system.

A food safety assurance program often used by the food processing industry is the Hazard Analysis Critical Control Point (HACCP) system. HACCP is a systematic approach to the identification, evaluation, and control of food safety hazards. Preventing problems from occurring is the paramount goal underlying any HACCP-like system. These systems focus attention on the parts of the process that are most likely to affect the safety of the product.

Visual V.1-8

Use Of The HACCP System In Production Agriculture Is Limited

When fruits and vegetables are to be consumed fresh, there are no steps that can eliminate or reduce biological hazards to acceptable levels after contamination. Basically, controlling contamination through the application of Good Agricultural Practices and Good Manufacturing Practices are the only ways to reduce hazards.

HACCP has limited usefulness in fruit and vegetable production since, with present technologies, verifiable control of hazards may not be feasible. In addition, when fruits and vegetables are to be consumed fresh, there are no steps that can eliminate or reduce biological hazards to acceptable levels after contamination. For this reason, HACCP is not mandated for fresh produce production and handling activities.

Although HACCP has limited usefulness in the production of fresh fruits and vegetables, it is a useful process for reducing hazards when produce is processed. For this reason, HACCP has been mandated in the U.S. for fruit and vegetable juice processors (FDA, 2001). Under the regulation, juice processors must incorporate HACCP principles into their safety assurance program when processing juice. (Further information about this requirement is included in the FDA Publications listed in the Additional Resources section.)

Visual V.1-9

Hazard Analysis

The process of collecting and evaluating information on hazards associated with the food under consideration to decide which are significant and must be addressed in the safety assurance program.

Although a formal HACCP program is not appropriate for fresh fruit and vegetable production and handling operations, there are steps in the production chain where hazards can be minimized. So, the use of “hazard analysis” as a series of logic steps to identify and solve potential problems is one approach to fruit and vegetable safety programs. The identification of hazards in a process is a valuable tool to recognize any control measures that can be implemented. In many instances, these measures are already in place or are common sense practices. However making a conscious effort to strengthen preventative actions can minimize or prevent the hazard’s occurrence. HACCP and its applicability to the produce industry are discussed in detail in Part V of the Additional Resources section of this manual.

Programs such as GAPs, GMPs, SSOPs and HACCP-like approaches provide the basic environmental and operating conditions that are necessary for the production of safe, wholesome fruits and vegetables. Many of the conditions and practices are specified in federal, state and local regulations and guidelines. The Codex Alimentarius Food Hygiene Basic Texts (FAO/WHO, 1997) describe the basic conditions and practices expected for foods intended for international trade.

Summary

1. Food safety is defined 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. Implementation of Good Agricultural Practices and Good Manufacturing Practices are primary steps in reducing the risks associated with fresh fruits and vegetables.
2. Quality is the totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs. It is a term defined by the consumer, buyer, grader, or any other client based on subjective and objective measurements of the food product.
3. Safety is a component of quality. Many experts believe that safety is the most important quality component since a lack of safety can result in serious injury and even death for the consumer of the product.

4. Safety and quality assurance should be on-going processes incorporating activities beginning with selecting and preparing the soil and proceeding through to consumption of the product. Both safety and quality assurance should focus on the prevention of problems, not simply curing them.
5. Although safety is a component of quality, safety assurance frequently is not included in quality assurance programs. Sometimes safety and quality assurance may be separate but complementary programs to ensure safety issues receive appropriate emphasis. The importance of safety to consumer health makes it imperative that safety programs be a primary component of all produce production and handling operations.
6. Programs such as GAPs, GMPs, SSOPs and HACCP-like approaches provide the basic environmental and operating conditions that are necessary for the production of safe, wholesome fruits and vegetables.

Module 2

Quality Attributes, Grades and Standards

Learning Outcomes

- *Participants should understand the types of quality attributes associated with fresh produce and measurement methods for these.*
- *Participants should understand the purpose of food standards, grading and inspection.*

Practical

Experiment/Demonstration – Fresh Produce Quality
Discussion Question 4

QUALITY ATTRIBUTES

There are a number of ways of studying the quality attributes of food products. One way is to look at the occurrence of the characteristics as the product is encountered and consumed. Using this system, quality attributes are often classified as external, internal, or hidden.

Visual V.2-1

QUALITY ATTRIBUTES		
<u>External</u>	<u>Internal</u>	<u>Hidden</u>
Appearance (sight)	Odor	Wholesomeness
Feel (touch)	Taste	Nutritive Value
Defects	Texture	Safety

External quality attributes are those that are observed when the product is first encountered. These attributes are generally related to appearance and feel. They are perceived by the senses of sight and touch. The smell of a product, particularly for very aromatic fruits and vegetables, may be an external attribute but usually is more closely related to internal attributes. External attributes are often play an important role in a consumer's decision to purchase produce.

Internal quality characteristics are generally not perceived until the product is cut or bitten. Acceptable levels of these attributes often affect the consumer's decision to repurchase a product. These internal attributes are related to aroma, taste, and feel (for example, mouthfeel and toughness), and they are perceived

by the senses of smell, taste, and touch. The combination of external and internal attributes determine the acceptability of a product (Pattee, 1985).

The third set of quality attributes, “hidden attributes”, are more difficult for most consumers to measure or differentiate but the perception of these contribute to the consumer’s decision to accept and to differentiate food products (Kramer and Twigg, 1970; Pattee, 1985; Shewfelt, 1987). Hidden quality attributes include wholesomeness, nutritional value, and safety of a product (Shewfelt, 1990).

Measurement of Quality Attributes

The list below provides a brief discussion of the predominant quality attributes and how they are measured. Understanding this can provide growers, shippers, and other produce industry personnel with a means of determining how well a product meets consumer expectations of quality. It should be remembered that consumers will evaluate quality mainly with their senses so objective methods used for quality evaluations must relate to these sensory assessments.

External Attributes

- Appearance includes factors such as size, shape, gloss, color, and absence of defects.
 - Size and shape are measurements often used as grade standards or to differentiate between items. The assessment of size and shape is often a subjective process although, for many products, visual guides have been developed.
 - Color is a primary indicator of maturity and is the result of the type and quantity of pigments in the product. Changes in color are often related to “freshness” or deterioration of the product. Color can be measured by many visual or mechanical methods (i.e. colorimeters and spectrophotometers).
- Firmness, or how the product feels when touched, is related to softening of the product. Firmness results from the cell wall structure and internal pressure (turgor) within the cells. Loss of firmness may result from bruising, ripening, or other breakdown mechanisms.
 - Firmness is usually measured by mechanical means (i.e. texture analyses).
- Defects may be due to production, handling, environment, diseases, and other factors.
 - Defects are usually measured visually, though some mechanical methods are being developed (i.e. ultrasound and machine vision).

Internal Attributes

- Odor or aroma is the sum of the compounds perceived by the nose. It is very difficult to determine objectively since it is a combination of qualitative (predominant) and quantitative traits in a food product. Fruits and vegetables are rich in aromatic compounds, many of which are yet to be identified.

- Limited measurements of odor can be done with gas chromatographs/mass spectrometers or similar mechanisms.
- Taste is the perception of chemical compounds on the tongue and other nerve endings of the mouth. The basic tastes are sweet, sour, bitter, and astringent.
 - Sweetness is directly related to sugars in the food and to the sugar to acid ratio. Sourness is the result of the organic acids present. Compounds such as those in citrus fruits or coffee usually impart bitterness, whereas astringency is often the result of tannins such as the phenolic compounds found in grapes. There are numerous methods of quantifying taste compounds including spectrophotometric and gravimetric methods, liquid and gas chromatography.
- Texture is “the composite of those properties which arise from the structural elements of a product, and the manner in which this composite registers with the physiological senses” (Szczesniak, 1977). Most textural characteristics, except firmness, are evaluated as mouthfeel, i.e. the impression on the tongue, palate and teeth.
 - In produce, common textural characteristics include tenderness, crispness, crunchiness, chewiness, and fibrousness. Texture is generally determined by measuring force applied to the food.

Hidden Attributes

- Wholesomeness is usually thought to be related to “freshness.” Defects in wholesomeness may be brought about by the food itself or external factors such as environment (temperature, humidity, etc.) or handling (bruising, cutting).
 - Wholesomeness is a relatively difficult attribute to measure objectively, but it is often taken into account in the grading and pricing of the product. This attribute also involves a “sanitary” component (how clean/hygienic is the product) and the presence of foreign materials. Microscopic, microbiological, and x-ray technologies are among the many techniques used to measure these attributes.
- Nutritive value is related to the presence and levels of components that support life.
 - Fruits and vegetables are valued as sources of essential vitamins and minerals, as well as fiber. In recent years, they have also been recognized as sources of antioxidants and other phytochemicals that are being studied for their role in preventing or controlling certain human diseases. The quality and quantity of these nutritional components is very important, and is essential to consumer well-being. Wet chemistry, various chromatographic methods, and other chemical and physical tests measure nutritive value.
- Safety is defined as the assurance that a food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (FAO/WHO, 1997).

- Microbiological examination is the main method used to identify and quantify the type and numbers of pathogenic microorganisms.
- Production and handling practices may be evaluated to assure steps were taken to minimize the risk of microbial contamination.

Food Standards

Food standards give precise criteria to ensure that products are fit for their stated purposes. They provide common frames of reference for defining the product. This makes standards useful to consumers, the industry and regulatory authorities (Boutrif and Bessy, 1999). Included in standards may be specifications for labeling, packaging, methods of analysis and sampling.

Visual V.2-2

Food standards are used to:

- Provide consumers with information about the product
- Maintain product quality uniformity
- Establish market value
- Prevent economic fraud

Standards are used to provide consumers with information about the product, to maintain product quality uniformity, to establish market value, and to prevent economic fraud. Without standards, different foods could have the same names or the same foods could have different names (FDA, 2000).

In order to be successful, a produce company must sell their product. Continued sales result from satisfaction during initial experiences with the product. It is therefore in the best interest of a company to establish internal standards and/or respond to client standards for products to assure client satisfaction.

Visual V.2-3

Areas in which produce industry standards may be established include:

- Safety
- Nutrition
- Quality
- Value

Areas in which produce industry standards may be established include (Gardner, 1993):

- Safety – standards for toxicological and microbiological hazards, and procedures and practices to ensure that these standards are achieved

- Nutrition – maintaining nutrient levels through practices that promote high quality product
- Quality – providing product with desirable levels of flavor, aroma, palatability, and appearance
- Value - attributes such as convenience, packaging, and shelf-life.

There are various bodies that set food standards. For products sold internationally, these include the Codex Alimentarius Commission (CAC), the International Standards Organization, ISO (ASQ, 2000), and various markets, such as the European Union. Many individual countries like Australia and the U.S. have been leaders in setting product standards. For Latin American and Caribbean markets, standards have been established by organizations such as Mercosur, Caricom, and the Andean Pact (Silva, 2000). Many of these standards can be accessed via the Internet (IAFIS, 1999).

INTERNATIONAL (CODEX) STANDARDS

The Codex Committee on Fresh Fruits and Vegetables is responsible for elaborating worldwide standards and codes of practice for fresh produce. A code of practice for the “Quality Inspection and Certification of Fresh Fruits and Vegetables” has been adopted by the Codex Alimentarius Commission (Rees and Watson, 2000). This code of practice contains provisions for packing, shipment, control, and inspection of fresh fruits and vegetables (CX/FFV 00/12, Codex, 2000). Inspection and certification are conducted at the point of origin or the point of destination by a national official or an officially recognized service person. Codex standards are a combination of grading for quality and inspection for wholesomeness, safety and freedom from economic fraud.

The objective of the Codex standards is to protect consumers' health and ensure fair practices in the trade of food (Lindenmayer, 1999). The Codex Committee on Food Import and Export Inspection recommends that, in consideration of standards, public health protection issues be given the highest priority.

Systems for creating standards for imported foods are established by individual countries. The imported food control system should ensure that imported products are treated neither in a more nor less favorable manner than domestic products. International norms for food import controls have been put forward by FAO in *Principles for Food Import and Export Inspection and Certification*. CAC/GL-20, 1995. These principles are designed to assist in assuring safety, wholesomeness and quality of product in international trade without resulting in unnecessary barriers to trade.

The Codex standards, guidelines and recommendations are recognized in the World Trade Organization (WTO) Agreements, however, there is no legal obligation on WTO Members to adopt them into domestic law (Lindenmayer, 1999). The Agreements do, however, impose a legal obligation on WTO

members to explain and justify a domestic measure that is more trade restrictive than the relevant Codex standard, guideline or recommendation. Consequently, members must take these international norms into account when developing domestic food law.

Fruit and Vegetable Grading and Inspection

Visual V.2-4

Grading Vs. Inspection

- *Grading* refers to a voluntary program of classification of a product based on certain characteristics, usually related to aesthetics. Grades usually do not pertain to safety.
- *Inspection* is usually a mandatory process done by government or other agencies to insure a product's wholesomeness, safety, and adherence to regulations.

Grading is usually a voluntary program used by industry. Grade standards describe the quality requirements for each grade of product, giving industry a common language for buying and selling (USDA, 2000). This assures consistent quality for consumers. Although not limited to the following, the U.S. grade standards provide:

- a voluntary means for determining levels of quality and value as a basis for: sales quotations, buyers' offers, damage claims, loan values, futures trading, military and other government purchases, and market news reporting.
- a common language for trading where the commodity cannot be readily displayed or examined by the prospective buyers.
- a guide for packing which enables packers and processors to: purchase suitable quality, use raw materials effectively, and pack products for diverse domestic and international markets.
- a means of marking official USDA quality levels on product labels.

In the U.S., the USDA Agricultural Marketing Service (USDA-AMS) provides grading services for fresh fruits, vegetables, and nuts. Users pay a fee to cover the cost of the service. Grading is voluntary except for commodities that are regulated for quality by a marketing order or marketing agreement, or that are subject to import or export requirements. Grading may be conducted at the shipping point as produce is being packed for shipment to market, or at the destination, for the receiver's use in handling the lot or to settle questions that may arise between the shipper and the receiver.

As the basis for its fresh product grading services, USDA has developed over 150 official grade standards for fresh fruits, vegetables, tree nuts, peanuts, and related commodities (Copies of the U.S. grade standards can be viewed or printed from the Internet at <http://www.ams.usda.gov/standards>). USDA also has

developed a number of specific guidelines to ensure that the grades are applied uniformly. If a request for official grading is based on U.S. grade standards, the official certificate covering the shipment will show which USDA grade the product met.

This service is different from the one conducted by the USDA Agricultural Plant Health Inspection Service (APHIS). The APHIS program inspects fruits and vegetables for the presence of unwanted pests. Thus, inspection is a mandatory program by a government branch, to insure wholesomeness and safety and to prevent economic fraud in the food industry.

Summary

1. Quality attributes are often classified as external, internal, or hidden. External quality attributes are those that are observed when the product is first encountered. These attributes are generally related to appearance and feel. Internal quality characteristics are generally not perceived until the product is cut or bitten. Internal attributes include aroma, taste, and feel (for example, mouthfeel and toughness). Hidden quality attributes include wholesomeness, nutritional value, and safety of the product.
2. Food standards give precise criteria to ensure that products are fit for their stated purposes. Standards are used to provide consumers with information about the product, to maintain product quality uniformity, to establish market value, and to prevent economic fraud. There are various bodies that set food standards. For products sold internationally, these include the Codex Alimentarius Commission (CAC), the International Standards Organization, ISO (ASQ, 2000), individual countries, and various markets, such as the European Union. For Latin American and Caribbean markets, standards have been established by organizations such as Mercosur, Caricom, and the Andean Pact.
3. Grading is usually a voluntary program used by industry. Grade standards describe the quality requirements for each grade of product, giving industry a common language for buying and selling. In the U.S., the USDA Agricultural Marketing Service (USDA-AMS) provides grading services for fresh fruits, vegetables, and nuts. Users pay a fee to cover the cost of the service. Grading is voluntary except for commodities that are regulated for quality by a marketing order or marketing agreement, or that are subject to import or export requirements.
4. Inspection is usually a mandatory process done by government or other agencies to insure a product's wholesomeness, safety, and adherence to regulations.

Module 3

Quality Attributes and Spoilage

Learning Outcomes

- *Participants should become aware of the causes of spoilage and deterioration of fresh produce and their effect on food safety.*

Practical

- *Discussion Question 4*
-

Mechanisms of Produce Deterioration and Spoilage

Visual V.3-1

Fruit, vegetables and root crops are very perishable and, if care is not taken in their harvesting, handling and transport, they will soon decay and become unfit for human consumption.

Fruit, vegetables and root crops are very perishable and, if care is not taken in their harvesting, handling and transport, they will soon decay and become unfit for human consumption. Estimates of production losses in developing countries are hard to judge, but some authorities put losses of sweet potatoes, plantain, tomatoes, bananas and citrus fruit as high as 50 percent, or half of what is grown (FAO, 1989). This figure is even higher for underdeveloped countries. Reduction in these losses, particularly if they can be avoided economically, would be of great significance to growers and consumers alike.

All fruits, vegetables and root crops are living plant parts containing 65 to 95 percent water and they continue their life processes after harvest (FAO, 1989). The post-harvest life of produce depends on the rate at which stored food reserves are used up and the rate of water loss.

The changes that occur not only lead to reduced quality but can also make the product more susceptible to contamination with microorganisms. Although the microorganisms involved in produce deterioration may be of public health significance, their effects on human health are often limited since the physiological deterioration of the product often makes the product unfit for consumption. However, the potential for the growth of harmful microorganisms along with the loss of product quality make it important to not only understand the factors involved in product deterioration, but also the steps needed to maintain the best possible quality for the life of the product.

The nature of the product itself, along with the handling and storage treatments it receives, dictates the life of the product. The table below identifies some of the principle causes of post harvest losses and poor quality for the various groups of fruits and vegetables.

Table V-2. Principle Causes of Post-harvest Losses and Poor Quality for Various Groups of Fruits and Vegetables (Kitinoja and Kader, 1995)

Product Group	Principle Causes Of Postharvest Losses And Poor Quality
Root Vegetable (carrots, beets, onions, garlic, potato, sweet potato)	<ul style="list-style-type: none"> • Mechanical injuries • Improper curing • Sprouting • Water Loss • Decay • Chilling injury
Leafy Vegetables (lettuce, chard, spinach, cabbage, green onions)	<ul style="list-style-type: none"> • Water loss • Loss of green color • Mechanical injuries • Relatively high respiration rates • Decay
Flower Vegetables (artichokes, cauliflower, broccoli)	<ul style="list-style-type: none"> • Mechanical injuries • Discoloration • Water loss • Abscission of florets
Immature Fruit Vegetables (cucumbers, squash, eggplant, peppers, okra, snap beans)	<ul style="list-style-type: none"> • Decay • Overmaturity at harvest • Water loss • Bruising and other mechanical injuries • Chilling injury
Mature Fruit Produce (tomatoes, melons, bananas, mangoes, apples, grapes, stone fruit)	<ul style="list-style-type: none"> • Decay • Bruising • Over-ripeness at harvest • Water loss • Chilling injury • Compositional changes

Deterioration, or undesirable quality changes, may be the result of biological, microbiological, biochemical/physiological, or physical changes in the product. Factors identified as causes of deterioration usually encourage the conditions that lead to quality losses. These factors are usually the result of 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/extreme environmental conditions (Satin,

2000). In addition, time is an important factor in the spoilage of produce (Potter and Hotchkiss, 1995).

Table V-3. Causes of Deterioration/Spoilage Factors in Fruits and Vegetables

Deterioration Factor	Cause
<u>Biological</u>	
• Pests (insects, rodents, birds)	Inadequate GMPs
• Microbiological	Inadequate controls
• Physiological	
Respiration	Heat
Ethylene production	Environment (temp, gas atm.)
Growth, development	Time, environment
Maturation, ripening, senescence	Time, environment
Transpiration and water loss	Packaging, RH, air velocity
Disorders, injury	Chilling, heat, freezing, gas comp.
<u>Chemical/Biochemical</u>	
• Enzymic	Environment, handling/bruising
• Oxidation	Oxygen
• Non-enzymic changes	Packaging, composition, heat
• Light oxidation	Packaging
<u>Physical</u>	
• Bruising, crushing	Handling, packaging
• Wilting	Relative humidity, packaging
• Texture changes	Environment, packaging
• Moisture change	Relative humidity, packaging, environment
Time	

Biological Causes of Deterioration

Visual V.3-2

Pests such as insects, rodents and birds, are often identified as causes of biological deterioration of produce.

Pests such as insects, rodents and birds, are often identified as causes of biological deterioration of produce. The presence of pests and/or their droppings is cause for alarm. They can result in product that is unsightly and can produce a significant food safety hazard. Pests can spread disease-causing organisms to produce. They also cause damage to the surfaces of fruits and vegetables

leading to greater susceptibility to invasion by microorganisms that can cause product spoilage and/or disease to consumers. Proper sanitation in all produce handling and storage areas is the most effective weapon against these pests.

Visual V.3-3

Spoilage microorganisms including bacteria, fungi, and viruses are major causes of food deterioration.

Spoilage microorganisms including bacteria, fungi, and viruses are major causes of food deterioration. These organisms may cause softening, off-color, and off-flavor in produce. Some microorganisms, called pathogens, will result in illness of those consuming the product if present in sufficient quantity in the foods. In general, fruits and vegetables offer considerable resistance to microbial activity. However, the softening that usually accompanies aging of products and mechanical injuries increase the susceptibility of produce to microorganisms.

Visual V.3-4

Respiration is the process by which plants take in oxygen and give out carbon dioxide.

Respiration is the process by which plants take in oxygen and give out carbon dioxide (FAO, 1989). Oxygen from the air is involved in the process of breaking down carbohydrates in the plant into carbon dioxide and water. This reaction produces energy in the form of heat. Respiration is a basic reaction of all plant material, both in the field and after harvest. Product respiration is important to fresh produce handling since the energy released as heat affects refrigeration and ventilation requirements for the products.

The rate of deterioration of fruits and vegetables is usually proportional to their rate of respiration. Lowering temperatures, minimizing bruising and damage, and increasing CO₂ in the gas atmosphere are steps to control respiration.

Table V-4. Classification of horticultural commodities according to their respiration rates (Wilson et al., 1995).

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, kiwifruit, garlic, onion, potato (mature), 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, green onion, brussel sprouts, cut flowers
Extremely high	>60	Asparagus, broccoli, mushroom, pea, spinach, sweet corn

Ethylene (C₂H₄) regulates many aspects of plant growth and development, including aging and ripening. This hormone, produced by plant tissue, is physiologically active in trace amounts (<0.1 ppm), and its rate of activity is increased by ripening, injury, disease, high temperatures (>30°C), and water stress. Ethylene production is slowed/inhibited by storing produce at low temperatures, reducing oxygen in the environment surrounding the product to less than 8% and increasing CO₂ to greater than 2%. A number of technologies, such as ethylene absorbers, have been developed to help lower the ethylene around produce.

Visual V.3-5

Based on ethylene production and respiration rates, the ripening behavior of fruits and vegetables is designated as non-climacteric or climacteric

Based on ethylene production and respiration rates, the ripening behavior of fruits and vegetables is designated as non-climacteric or climacteric (FAO, 1989):

- Non-climacteric ripening refers to products that ripen only while still attached to the parent plant. The eating quality of such products suffers if they are harvested before they are fully ripe because their sugar and acid content does not increase after harvest. Respiration rate slows gradually during

growth and after harvest. Maturation and ripening are gradual processes. Examples are cherry, grape, lemon, and pineapple.

- Climacteric products that can be harvested when mature but before ripening has begun. These fruits may be ripened naturally or artificially after harvest. The start of ripening is accompanied by a rapid rise in both respiration rate and ethylene production, called the respiratory climacteric. After the climacteric, the respiration slows down as the fruit ripens and develops good eating quality. Examples are apple, banana, papaya, and tomato.

In addition to respiration rate and ethylene production, other factors related to growth, development, maturation and ripening/senescence contribute to a product's deterioration. Sprouting (rooting) of roots, bulbs and tubers, and elongation and curvature may lead to problems in quality during plant development. Increased lignin content (fibrousness) and browning reactions during the maturation process may lead to reduced produce quality.

Plant material is constantly losing water through a process called transpiration. In the living plant, this water is replaced by water taken up through the roots. When produce is harvested, it loses its source of replacement water. Transpiration after harvest can lead to shrinking, wilting, shriveling, softening, and loss of crispiness, juiciness, and nutritional quality of produce. Adequate coating (waxes) or packaging and controlling the environment around the product through maintenance of high relative humidity, and control of circulation rate (air velocity) may control transpiration.

Visual V.3-6

Freezing injury, chilling injury, heat injury, and CO₂ injury may cause physiological damage that can contribute to produce deterioration.

Physiological damage may result from pre-harvest environmental conditions or inadequate post-harvest storage and handling. Freezing injury (when the product is held below the freezing point), chilling injury (occurring in many tropical and sub-tropical crops held below 5-15°C), heat injury (exposure to very high temperatures), and CO₂ injury (high CO₂ concentrations in the surrounding atmosphere) may cause physiological damage that can contribute to produce deterioration. Some of the resulting symptoms are surface and internal discoloration (browning by phenoloxidases), pitting/hardcore, water soaked areas, failure to ripen/uneven ripening, off-flavor, accelerated decay, bleaching, surface burning, and desiccation. These and other disorders due to physiological damage can be prevented by proper harvest and post-harvest handling of the products.

Chemical Factors of Deterioration

Enzymes are proteins that occur naturally in plant tissues and catalyze a number of important biochemical reactions. Some enzyme-catalyzed reactions are beneficial while others result in quality deterioration. Enzyme-catalyzed reactions can result in softening of tissue due to the breakdown of structural material; development of off-flavors through the breakdown of lipid components; and loss of color and undesirable browning. Enzymes also may catalyze fermentation of sugars, breakdown of ascorbic acid, and many other deterioration reactions. Bruising, ripening, cutting, temperature, and presence of co-factors (e.g. Fe and Mg) increase the rate of degradative enzyme activity.

Degradative oxidation is initiated by the presence of oxygen. Oxidation can result in ascorbic acid breakdown, some pigment (color) loss and the formation of off-flavors. Non-enzymatic browning and light-induced oxidation are not very common deterioration factors in horticultural products.

Physical Causes of Deterioration

The high moisture content and soft texture of fruits and vegetables make them susceptible to mechanical injury, which can occur at any stage from production to retail marketing (FAO, 1989). This damage may occur because of:

- poor harvesting practices
- unsuitable field or marketing containers and crates, which may have splintered wood, sharp edges, poor nailing or stapling
- overpacking or underpacking of field or marketing containers
- careless handling, such as dropping or throwing or walking on produce and packed containers during the process of grading, transport or marketing.

Physical injuries are not only unsightly but also accelerate water loss, provide sites for fungal and microbial infection, and stimulate the product's production of carbon dioxide and ethylene leading to more rapid decay. Cushioning, good handling practices, and proper packaging are some of the ways to minimize physical damage.

Time is a factor that plays a very important role in product decay. All products eventually lose their minimum acceptable quality (MAQ), thus, age becomes a very important factor in product deterioration and rapid transport to the consumer is essential.

Summary

1. All fruits, vegetables and root crops are living plant parts containing 65 to 95 percent water. They continue their life processes after harvest. The changes that occur not only lead to reduced quality but can also make the product more susceptible to contamination with microorganisms. The nature of the

product itself, along with the handling and storage treatments it receives, dictates the life of the product.

2. Deterioration, undesirable quality changes, may be the result of biological, microbiological, biochemical/physiological, or physical changes in the product
3. Pests such as insects, rodents and birds, are often identified as causes of biological deterioration of produce. They can result in product that is unsightly and can produce a significant food safety hazard. Pests can spread disease-causing organisms to produce. They also cause damage to the surfaces of fruits and vegetables leading to greater susceptibility to invasion by microorganisms that can cause product spoilage and/or disease to consumers. Proper sanitation in all produce handling and storage areas is the most effective weapon against these pests.
4. Spoilage microorganisms including bacteria, fungi, and viruses are major causes of food deterioration. These organisms may cause softening, off-color, and off-flavor in produce. Some microorganisms, called pathogens, will result in illness of those consuming the product if present in sufficient quantity in the foods. In general, fruits and vegetables offer considerable resistance to microbial activity. However, the softening that usually accompanies aging of products and mechanical injuries increases the susceptibility of produce to pathogens.
5. Respiration rate, ethylene production, transpiration, and other factors related to growth, development, maturation and ripening/senescence contribute to produce deterioration.
6. Injury due to freezing, chilling, heat, and CO₂ buildup may cause physiological damage that can contribute to produce deterioration. These and other disorders due to physiological damage can be prevented by proper harvest and post-harvest handling of the products.

References

- ASQ. 2000. ISO 9000 Standards for quality. Amer. Soc. Qual. Available via the Internet at <http://www.iso-9000-2000.com>
- Boutrif, E. and Bessy, C. 1999. Basic approaches to consumer protection – FAO/WHO Model Food Act – Control procedures. Presented at Conference on International Food Trade – Beyond 2000: Science-based Decisions, Harmonization, Equivalence, and Mutual Recognition, Melbourne, Australia October 11-15.
- Codex. 2000. Codex committee on fresh fruits and vegetables. Available via the Internet at <http://www.codexalimentarius.net>
- FAO. 1989. Prevention of post-harvest food losses: Fruits, vegetables, and root crops a training manual. FAO Training Series No. 17/2, Rome, Italy. Available via the Internet at <http://www.fao.org/inpho/vlibrary/t0073e/T0073E00.htm>
- FAO/WHO. 1997. Codex Alimentarius Food Hygiene Basic Texts. Joint FAO/WHO Food Standards Programme, Codex Alimentarius Commission. Pub. # M-83.
- FDA. 1998. Guide to minimize microbial food safety hazards for fresh fruits and vegetables. U.S. Food and Drug Administration. Available via the Internet at <http://www.cfsan.fda.gov/~dms/prodguid.html>
- FDA. 2000. Food standards. Available via the Internet at www.fda.gov/opacom/morechoices/smallbusiness/blubook/foodstds.htm
- FDA. 2001. FDA publishes final rule to increase safety of fruit and vegetable juices. Food and Drug Administration News Release, U.S. Food and Drug Administration. Available via the Internet at <http://www.fda.gov/bbs/topics/NEWS/2001/NEW00749.html>
- Food Science Australia. 2000. Packaged minimally-processed fresh-cut vegetables. In Food Safety and Hygiene- A Bulletin for the Australian Food Industry, Food Science Australia. May. Available via the Internet at <http://www.dfst.csiro.au/fshbull/fshbull21.htm>
- FSIS. 1996. FSIS Pre-HACCP Standard Sanitation Operating Procedures Reference Guide. Food Safety and Inspection Service, U.S. Department of Agriculture.
- Gardner, S. 1993. Consumers and food safety: A food industry perspective. In Food, Nutrition, and Agriculture – Consumer participation in food control.

- J.L. Albert, ed. FAO, Rome. Available via the Internet at <http://www.fao.org/docrep/v2890t/v2890t00.htm>
- Gould, W.A. and Gould, R.W. 1993. Total Quality Assurance for the Food Industries. 2nd ed. CTI Publications, Baltimore, MD, USA.
- IAFIS. 1999. Food standards library. Available via the Internet at www.iafis.org/fiic/stan/stan1.htm
- IFT. 2001. Introduction to the Food Industry – Lesson 1. Food Quality and Safety Assurance. Edited by Claus, L., Montecalvo, J., and Pappas, A. Available via the Internet at http://www.ift.org/education/food_industry/lesson1.shtml
- Kitinoja, L. and Kader, A.A. 1995. Small-scale postharvest handling practices – A manual for horticultural crops. 3rd Edition. University of California, Davis. Available via the Internet at <http://www.fao.org/wairdocs/x5403e/x5403e00.htm>
- Kramer, A., and Twigg, B.A. 1970. Quality Control for the Food Industry. 3rd ed. AVI, Van Nostrand Reinhold Co., New York.
- Lindenmayer, I. 1999. Harmonization of food regulations and food quality/safety measures based on Codex standards, guidelines, and recommendations. Presented at Conference on International Food Trade – Beyond 2000: Science-based Decisions, Harmonization, Equivalence, and Mutual Recognition, Melbourne, Australia October 11-15.
- Pattee, H. E. 1985. Evaluation of Quality of Fruits and Vegetables. AVI, Van Nostrand Reinhold Co., New York.
- Potter, N. N., and Hotchkiss, J.H. 1995. Food Science. 5th ed. Chapman & Hall, New York.
- Rees, N. and Watson, D. 2000. International Standards for Food Safety. Aspen Publishers, Gaithersburg, MD.
- Satin, M. 2000. Trends in post-production technology. FAO, Rome, Italy. Available via the Internet at http://www.fao.org/inpho/vlibrary/grey_lit/g0002e/g0002e.htm
- Shewfelt, R.L. 1987. Quality of minimally processed fruits and vegetables. J. Food Qual. 10:143.
- Shewfelt, R.L. 1990. Quality of fruits and vegetables. Food Technol. 44(6):99-100.

- Silva, J.L. 2000. Food laws and regulations in Latin America and the Caribbean. Presented at IFT Annual Meeting, Dallas, TX. June 10-14.
- Szczesniak, A.S. 1977. An overview of recent advances in food texture research. *Food Technol.* 31(4): 71-75.
- USDA. 2000. Fruit and vegetable programs. Available via the Internet at www.ams.usda.gov/fv/fvstand.htm
- U.S. EPA. 2001. Guidance for Preparing Standard Operating Procedures. Office of Environmental Information, U.S. Environmental Protection Agency. EPA/240/B-01/004. Available via the internet at <http://www.epa.gov/quality1/qs-docs/g6-final.pdf>
- van Reeuwijk, L.P. 1998. Guidelines for quality management in soil and plant laboratories. FAO, Rome. Publication #M-90. Available via the Internet at <http://www.fao.org/docrep/w7295e/w7295e00.htm>
- Wilson, L.G., Boyette, M.D., and Estes, E.A. 1995. Postharvest handling and cooling of fresh fruits, vegetables, and flowers for small farms. Part I: Quality maintenance. Horticultural Information Leaflet #800, North Carolina Cooperative Extension Service. Available via the Internet at <http://ces.ncsu.edu/depts/hort/hil/hil-800.html>