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

Section III

Good Manufacturing Practices for Harvesting and Handling Fresh Produce

Introduction

Harvesting of fresh produce represents the transition from GAP to GMP. At the moment when a fruit or vegetable is detached from the plant, production has been completed and the manufacture of the finished product has begun. The finished product may simply be a packed carton or it may consist of any number of handling, trimming, bunching, and postharvest or packaging treatments to complete an item that is ready for shipping.

For clarification, the USDA and some commodity groups have developed harvesting and handling food safety guidelines that are entitled Good Handling Practices (GHP). These are largely based upon the GMP criteria defined by the FDA and others with some modification to apply to fresh produce. For the sake of simplicity, the term GMP is used here with the understanding that GHP is an equally valid and perhaps more appropriate term for some postharvest practices.

Microbiological contamination can occur during the harvest operation. Contamination may be introduced by workers, from the soil, from harvest equipment such as knives or clippers, from field containers or harvest-aid surfaces, during field-side accumulation or staging, or from transport vehicles. The first step in developing a food safety program for harvest operations is to review the process and identify potential safety hazards.

The principle of preventing contamination is the key to minimizing food safety risk. It should not be expected that remedial actions such as washing will eliminate contamination that may occur at harvest. A comprehensive set of Sanitation Standard Operating Procedures (SSOP) must be developed that are specific to the harvest operation. Effective training of all personnel involved in harvesting is essential. The development of SSOP is discussed in Module 7 of this Section.

Worker Health and Hygiene

Good worker hygiene is critical to a food safety program for harvest operations, especially for products that are harvested manually, because every fruit or vegetable is touched by human hands. The specifics of personal hygiene are discussed in detail elsewhere in this manual. It is important to re-emphasize the importance here and to restate that personnel practices should be thoroughly addressed in the SSOP for harvest operations. Here is a review of some essential points, as well as some harvest-specific practices.

Toilets and handwashing facilities must be provided in a manner that meets or exceeds relevant laws. Even if no laws exist, they must be provided as part of any effective food safety program. Eating, drinking beverages other than water, smoking, spitting, etc., must not be allowed in the workplace. Worker training that addresses proper behavior is essential and periodic reinforcement training is necessary. Training must be documented. If gloves are used, there must be a formal written policy. Workers who are required to stand inside bins or gondolas should wear appropriate disposable shoe coverings or dedicated footwear (rubber boots) that is cleaned and sanitized regularly.

Children under the age of 13 are not permitted in fields under any circumstances. The presence of any child in diapers compromises the rule of absolutely no human feces in the field. Further, a worker who changes the child's diaper will have a high probability of contaminated hands. Most third-party auditing companies will give an automatic failure to an operation if a young child is present in the field.

Worker health can be critical to the safety of the product. Managers must be vigilant in observing the work force and taking note if someone has a chronic cough or is visiting the toilet frequently. Any worker who appears to have an illness or injury that could lead to contamination of the product should not be allowed to perform a task that requires them to have direct contact with the product or any food-contact surface, including packaging materials.

Harvest Methods

Generally there are two methods of harvesting: manual and mechanical. The choice of harvesting method depends largely upon the characteristics of the commodity and the market. The general principles of GMP, often modified for raw agricultural commodities in the form of GHP, apply to any method but there will be some unique requirements for food safety depending on the method.

Manual harvesting simply means that the product is separated from the plant or removed from the growth media (soil) by the hands of a harvest worker. This technique is employed for delicate commodities such as strawberries or grapes and for commodities that may naturally separate from the plant at maturity, such as most cantaloupes. For these products there is no substitute for human hands and eyes for the selection and careful handling that is required. Many fruits and vegetables are harvested by hand but with the use of an implement such as a knife, clippers or prong.

There is an adage that the hands of the harvest worker are the most important hands that ever touch the product. In the second that it takes a harvest worker to drop product on the ground or throw it roughly into a field container, all of the investment in farming has been lost. Proper training of harvest workers to protect the integrity of product is essential to the profitability of a company and to the safety of the product.

Mechanical harvesting means that a machine is utilized to detach the fruit or vegetable from the plant. In general, mechanical harvesters are more likely to cause injuries to a product than manual harvesting. Products that can withstand some rough handling, such as carrots, potatoes or radishes, are best suited for mechanical harvest. More recently, mechanical harvesters have been developed for blueberries and citrus. Mechanical harvest aids also may be employed to perform specific tasks in the operation. There are numerous examples of products that may be harvested either manually or mechanically, such as leafy greens, celery, and blueberries. Typically, products that are harvested mechanically are further handled by machines so that there may be little or no contact between the product and the hands of workers.

Mechanical harvesting has its own set of GMP considerations. The SSOP for mechanical harvesting must include a rigorous program for the cleaning and sanitation of the harvest machine. Once a machine becomes contaminated it can spread the contamination throughout the field and onto the harvested product.

Field Packing

Some produce is packed in the field directly into the final shipping unit. This may be done with or without some form of washing or other cleaning step. This practice is called field packing. In field packing, the finished product may be manufactured directly by the harvest worker at the ground level as is often the case with strawberries. In a typical strawberry operation, the harvest worker picks the fruit and places them in a small basket or clam shell container that is intended for retail sale. These retail containers are positioned in cartons, which are ready to be palletized. The worker harvests, selects for quality and packs in a single operation. When this process is complete the fruit will receive no further contact with human hands. Other workers on a truck or trailer may palletize the cartons.

In other field packing operations, such as for melons, broccoli, celery or cauliflower, workers walking through the field pull the melons from the vine or cut the other products from the plant with knives. Commodities typically are placed on some type of machine that is passing through the field with the harvest crew. The packing process is conducted by workers on this field pack machine. The fruit or vegetable might be packed in a carton naked or it might receive a plastic over-wrap prior to being place-packed in a carton. The finished carton typically is palletized in the field.

A final example of field packing involves products that are harvested, tossed into trailers or wagons, and transported to an area near the field where they may be further handled and packed. Cabbage is a good example. Workers cut the heads with knives, trim the soiled outer leaves and toss the heads into a trailer. At the packing station, cabbage heads are unloaded from the trailer, outer leaves are further trimmed, heads are sorted for size and quality, and place-packed into cartons for palletizing.

There is debate within the produce industries and public agencies about the relative safety of field packing versus the use of a packinghouse where sanitizing treatments may be applied. An example of this is the tomato industry in the State of Florida, where field packing is now specifically prohibited unless a sanitizing step is included in the field operation. All tomatoes must be taken to a packinghouse and washed or rinsed with water containing an approved sanitizer. The relative risks are not clear regarding the exposure of tomatoes to water versus packing the product dry and relying on consumers to wash the tomatoes at the point of use. Risks associated with water are addressed later in Module III of this Section.

Risk Factors in Harvest Operations

Methods employed in the harvest process vary widely and food safety risks are present in all systems. All of the previous examples of harvest operations have common issues for food safety that must be properly addressed in their specific SSOP following a thorough evaluation to identify unique hazards. It is impossible to cover every scenario, but several common harvest elements are highlighted below.

Equipment sanitation is sometimes overlooked in harvest operations. There must be a well-defined process and schedule (SSOP) for cleaning and sanitizing all field equipment, including but not limited to cutting tools, buckets, bins, trailers, field pack machinery and any other harvest aid or accessory. All food contact surfaces should be clean and free of visible soil, oil, grease or chemical contaminants. Some traditional food contact surfaces are very hard to clean. Sanitation verification methods are discussed in Module 6 of this Section.

Microbes have the capacity to attach themselves to surfaces through the production of certain chemicals, resulting in the formation of biofilms. In very simple terms, biofilms might be considered analogous to biological "glue" that holds a pathogen on the surface and interferes with the cleaning and disinfection of the product surface. Biofilms are discussed further in Module 6.

Field sanitation should be reviewed frequently. Prior to the initiation of harvest, a manager should inspect the fields for the presence of animals or indications that animals have been present. The presence of animal tracks, feces or indications that animals have fed on the crop requires that this area of the field be clearly marked and that workers be instructed not to enter the marked area. Obviously no product should be harvested from the area. Domestic animals are not permitted in fields. Garbage or any debris that might attract or harbor animal pests should be removed.

Contact with the soil can directly transfer soilborne microorganisms to the product or to equipment surfaces. Avoid direct contact of finished product containers, cartons, bins, reusable plastic containers (RPC), etc., with the soil. Harvested products that are dropped onto the soil should not be picked up and packed. This requirement is rather difficult to enforce and requires emphasis during worker training. Since many products grow in contact with the soil (melons, cucumbers) and others do not (staked tomatoes, tree fruits), workers may find it difficult to understand why the requirement exists.

Field transportation is another risk factor. Field vehicles, including trucks, tractors, trailers and gondolas, used for fruits and vegetables should never be used for the transport of animals or animal products, manure in particular. This could lead to cross contamination of the produce. If a farm has animal production in addition to fresh produce production, trucks and tractors that are used in animal enclosures may transfer contamination to the produce field. There should be a SSOP for the cleaning and sanitizing of field vehicles.

Temporary storage areas often are needed near the field for harvest containers, RPC, cartons and other harvest materials. The storage area should be clean and free of any materials that are not needed for the harvest operation. An appropriate pest control program should be in place to deter entry of animals, insects, etc.

Decayed or damaged product poses an increased risk for the growth of human pathogens. Research has demonstrated relationships between some plant pathogens and human pathogens. A fruit or vegetable that has been exposed to a plant pathogen may be more susceptible to subsequent infection by a human pathogen, which can grow more readily in conjunction with the decay-causing microorganism. A specific example of this relationship is found with species of *Pseudomonas*, a decay-causing microbe, and *Salmonella*, a human pathogen. Additional work has shown that the presence of *Erwinia* decay can increase the likelihood that *Salmonella* will be present.

Harvest workers should avoid handling product with decay, especially fruit, and leave any rotten or damaged product in the field. They also should take care not to inflict rough handling injury to the produce. Bruises, fingernail punctures, cuts and scrapes create a point of entry for human pathogens and for decay-causing microorganisms. Further, damaged produce has increased rates of respiration and ethylene production that shortens its quality shelf-life. In the instant that it takes a harvest worker to damage the product, all of the investment in production is lost.

All of the above examples reinforce the basic concept that prevention of contamination is favored over the expectation that remedial cleaning or washing treatments can remove contamination. Harvest workers often are working in a hot, unpleasant environment and may be paid for piece work rather than hourly. They are motivated to move quickly to increase their earnings so proper training of workers and vigilance of field managers is necessary to ensure that workers are adhering to the food safety program. Quality inspections of product in the field or at the packing facility should be communicated back to the harvest foreman and reinforcement training of workers should be conducted as needed.

Conclusion

In general, harvest practices that enhance the safety of the product will also enhance the product quality and thus increase profitability. During training of workers and managers, it is appropriate to emphasize that food safety is good for business. A safe, high quality product requires attention to all harvest details and implementation of food safety practices at each step.

Summary

Conduct a review of harvest operations to identify potential risk factors.

Develop and implement detailed SSOP specific to those processes that can increase risk.

Emphasize worker health and hygiene. Conduct a comprehensive training program for new employees and conduct frequent refresher trainings to re-emphasize concepts.

Inspect fields for potential sources of contamination and correct any deficiencies.

Clean and sanitize all tools, equipment and vehicles.

Keep records of all activities specified by the SSOP.

Introduction

Cooling is an essential process for almost all fruits and vegetables unless they are intended for marketing directly from the field in local markets. It offers a number of benefits for perishable commodities. Cooling improves the shelf life and helps preserve quality by reducing the rates of respiration, ethylene production, water loss and spoilage caused by plant pathogens. It also limits the growth of some human pathogens, thus proper cooling is a strategy for helping to ensure the safety and quality of fresh produce.

Pre-Cooling

Pre-cooling is a term used to describe the rapid removal of field heat from produce soon after harvest. At the time of harvest, the temperature of the product usually is near or slightly above the ambient temperature in the field. Once the product is detached from the plant, water movement from the plant through the fruit or vegetable ceases and heat energy begins to accumulate as a result of exposure to the sun as well as from the heat of respiration in the living tissues. Rapid cooling usually enhances quality and safety both. There are exceptions, such as some varieties of apples or onions, which may have better storage and shipping characteristics if they are allowed to lose some water. The target temperature for pre-cooling depends upon the type of commodity and its specific temperature requirements. A number of different methods are utilized for cooling. It is important to describe these in order to identify the food safety practices that apply to each.

Cooling Methods

Room Cooling

This is the simplest and slowest of all methods. Produce is simply placed in a cold chamber and heat energy from within the product is transferred to surrounding air. The rate of cooling can be increased by increasing the flow of air around the product. Various types of air jets and fan configurations have been employed to facilitate increased air movement. Apples are typically cooled in this manner since rapid cooling is not critical for this fruit. A drawback to this method is that during busy shipping times the product may not have cooled sufficiently for loading into trucks. The risk of loading and shipping warm product is discussed in Module 6 on Transportation.

Forced-Air Cooling

This method also requires that product be placed in a cold chamber, but fans, tarpaulins and a system of air ducts serve to force the cold air directly through the containers of produce. The moving air causes the rapid transfer of heat energy from the product into the air stream. Heat is then removed from the air by the refrigeration system. A well designed forced-air unit might cool strawberries from the field temperature to 4°C in as little as 45 minutes compared to 12 hours or more in a passive room cooling situation. Forced-air cooling is especially suited to products that should not be exposed to water, such as berries or grapes. Common cold rooms can be adapted to forced-air cooling relatively inexpensively by constructing a duct or baffle system with a fan to pull air through a stack of product that is partially covered with a tarpaulin or other material to direct the air flow.

Vacuum Cooling

A sturdy airtight chamber is utilized to hold the product. The atmospheric pressure within the chamber is reduced by vacuum pumps, which causes the water inside the product to vaporize. As the water vapor is lost from the product surface evaporative cooling occurs. The technique is most effective for products that have a high surface to volume ratio such as leafy greens. The disadvantage for vacuum cooling is that with each decrease of 5-6°C in product temperature there is a loss of approximately 1% of the product weight, which is mostly water. Vacuum coolers can be very large in order to accommodate a rail-car load of product, but more commonly they are portable enough to be moved to different locations as needed.

Hydro-Vac Cooling

A standard vacuum cooling chamber is equipped with a system to deliver a fine mist of water onto the product. This offers two distinct advantages. The mist on the product surface contributes to the evaporative cooling effect and the amount of water lost from the product itself is reduced.

The water applied should be of potable quality and an appropriate sanitizer may be included.

Hydro-Cooling

Water is used as the medium to rapidly absorb heat energy from the product. Containers filled with produce may be placed on a conveyor in a flow-through system or simply placed in a batch type chamber. A large volume of cold water is pumped over the product to remove heat energy. The process is effective because a given weight (e.g., kilogram) of water can absorb more heat than an equal weight of air. This process is commonly employed for peaches, nectarines, asparagus, sweet corn and other commodities. Alternatively, commodities may be placed directly into a tank of cold water. Usually the water is pumped so that there is a flow toward a conveyor on the opposing side to remove product from the tank. This system has been employed for melons. It is an effective cooling method, but there are risks for food safety and strict adherence to water sanitation procedures are discussed in Module 3.

Icing

Ice may be applied directly to a product. Broccoli, sweet corn and green onions are examples of products that often are treated with slurry of ice and water pumped directly into the carton, which is made of wax-coated paper so that it does not break with the exposure to water. This is called package-icing. The penetration of ice into the carton of product is extensive so that cooling is rapid and thorough. Additionally, ice may be blown onto the top of pallets after they are loaded into a truck. This is called top-icing. Cooling facility operators are able to calculate the amount of ice needed for a given amount of product based on the product temperature. Ice should be made from potable water.

Risk Factors in Cooling

In all of the cooling methods noted, the two media that absorb heat energy from the product are air and water. Each of these presents specific concerns for food safety.

In the methods that utilize air (room cooling and forced-air cooling), the risk of microbiological contamination is relatively low. Obviously, air quality is of concern. Microorganisms can be present in the air on dust particles and in water droplets, which become vehicles for the transfer of microbes onto the produce. Ideally, the air should be clean and free of pathogens. Animals, compost storage and potential chemical contaminates should not be located near the air intake of cooling chambers. The chambers themselves should be subjected to a rigorous cleaning and sanitizing program and SSOP (see Module 7) should be developed for this process.

Water as a cooling medium is of much greater concern than air. Water represents the single critical point capable of amplifying an error in sanitation practices that may have occurred during production, harvesting or in subsequent handling steps. A small microbiological risk introduced into recirculated water can become a very large problem because the microbes can be dispersed throughout the total amount of product in contact with the water.

Water-related risks can be reduced by subjecting equipment to thorough cleaning and sanitizing, using potable water to fill the reservoir, and the proper use of water sanitizers. Ice should be manufactured with potable water and ice should be properly stored and handled to prevent contamination. Cooling facility operators should monitor water quality, pH, temperature and the concentration of sanitizers.

The purpose of water disinfection is to prevent cross contamination of the produce, particularly in systems where water is recirculated. Water sanitizers should not be expected to disinfect the product, especially if the product has a rough surface as with cantaloupes. Water can be internalized (infiltration) into the product and if living microbes are present they can be internalized as well. Internalization is discussed in Module 3.

Summary

Cooling is the primary tool that is available to postharvest managers for extending the quality shelf life of perishable commodities and for reducing the rate of growth of plant and human pathogens.

Several cooling methods are available and each presents its own special challenges for food safety management.

The use of water in any form presents overriding concerns for food safety.

Postharvest managers must have a clear understanding of the principles of water quality management.

SSOP must be developed for every aspect of cooling.

Appropriate record keeping must be implemented for all cooling methods.

Proper water quality management requires monitoring water temperature, pH and levels of sanitizers.

Introduction

Microorganisms are everywhere in the production environment for fresh fruits and vegetables. All products have naturally occurring microbiota on the surface, most of which are harmless to people. Pathogens that are carried to the surface by contaminated irrigation water, organic fertilizer, splashing soil, wild animal feces, etc., can coexist with the natural flora in many cases or simply survive and have no interaction. This is especially relevant for parasitic spores and enteric viruses. Cleaning can dramatically reduce this microbiological load. It also removes soil, some pesticide residues, sooty mold and other materials that are unattractive to consumers. After harvest, cleaning is often the first step in preparing a product for market.

It also is important to remind the reader that human pathogens do not occur naturally on fresh fruit and vegetables. They are present on the product only if contamination occurs. There are some exceptions in the diverse category of fresh produce, most notably sprouted seeds and mini-greens. Contamination "naturally" present inside the seed has been shown in model system research to result from internalized cells passed seed generation to seed generation. Bacteria that can infect plants, insects and humans, termed cross-over or cross-host pathogens, are known to be part of the normal plant colonizers. This does not truly alter the principle that human pathogens of greatest concern are invariably brought to the plant.

Many of the principles discussed in this Module are intended primarily to assist handlers with the prevention of cross contamination from a source of pathogens onto product that is not contaminated. Remember the basic principle that prevention of contamination is favored over reliance on remedial action to remove or inactivate the pathogen.

Cleaning

There are a few examples of products that are not cleaned at all prior to the immediate steps to consumption, such as grapes, strawberries, raspberries, blackberries and head lettuce. These items are delicate and exposure to water, even if the water is heavily sanitized, can lead to rapid decay.

Other products may be dry cleaned by simple brushing, either by hand or on a machine, to remove excess soil. Examples of this are fresh garlic, onions or even cantaloupes. High velocity air blowers or vacuums might be used to assist with the removal of dust or, in the case of bulb onions, the dried outer scales.

The large majority of fruits and vegetables are exposed to water in some manner to facilitate cleaning. It is critically important that handlers understand the concept of water quality and methods for managing the microbial levels in water.

Handlers of fresh fruits and vegetables sometimes have the misconception that cleaning and treatment with sanitized water is a sterilization step. This is not true. Sterilization is the complete inactivation of any microorganisms. Pasteurization is intended to eliminate all human pathogens. This is accomplished only by cooking or an equivalent thermal or nonthermal process such as ultra high pressure, special frequency radio waves or irradiation.

Sanitizing is simply the reduction of the microbial load to an acceptable level through chemical treatment. In most postharvest operations the produce itself is not sanitized. Rather, the use of sanitizers is for the benefit of water, food contact surfaces, etc., discussed later.

Water Quality at the Source

Water is categorized based upon its microbiological quality. Potable water would be water of quality that is safe to drink, which means that it is free of any human pathogen, essentially free of coliform bacteria and free of unacceptable levels of a long list of chemicals and heavy metals. Microbiologically potable water should be the starting point for source water used in postharvest operations or for spray application of agricultural chemicals, even though the addition of relatively large amounts of any sanitizer or antimicrobial would render the water unfit to drink.

Another category would be agricultural water for use in irrigation. Traditionally there was not a microbial standard for agricultural water, but recently some industries have adopted the level of 126 colony forming units (CFU) of indicator *E. coli*/100 ml water. This is the most stringent level established by the U.S. Environmental Protection Agency (EPA) as the standard for full body contact with recreational water as noted in Section II on GAP.

Water may be contaminated at the source and thus can be inherently bad. Utilization of this type of water for any purpose that exposes it to the edible portion of the product is not acceptable. Further, water can serve as the vehicle for spreading contamination from one place to another. The role of sanitizers in water is to help prevent the spread of contamination from any source within or among lots of fruits and vegetables during washing or other aqueous postharvest treatments. Water sanitation helps prevent a localized problem from becoming a very widely dispersed problem. For all of the following discussion on postharvest practices, we will assume that we are starting with water of potable quality.

Water Uses in Postharvest Operations

Water is used in many ways for the preparation of fresh produce for market. Many uses are discussed in this Section. Any use which may have been inadvertently omitted still has the same concerns for water quality management. Management concerns are introduced in this discussion and are addressed in detail throughout the Module.

Dump tanks are reservoirs or tanks of water into which products are emptied from field containers to facilitate movement onto a packing line. Tomatoes, mangoes and many other products often are handled in this manner. For many commodities, dump tank water should be heated to a temperature that is approximately 6°C higher than the pulp temperature of the product. If warm product is submerged into cold water, the intercellular space inside the product will contract as it cools and draw minute amounts of water through the stem scar or other natural openings or points of detachment. Water congestion can also occur through small cuts or abrasions to the interior of the product. If human pathogens or decay-causing microorganisms are present at these openings or wound sites, or in the dump tank water, they can more easily infiltrate the product and may begin to multiply. Outbreaks of illness as well as high rates of decay have been associated with such infiltration. The SSOP for dump tank water management should address initial water quality, sanitizer use, water heating and verification monitoring.

Water commonly is used as a spray rinse as part of a packing line. Typically the product would be treated with water as it passes over a bed of revolving brushes to clean the surfaces. A relatively low level of sanitizer such as chlorine, chlorine dioxide, ozone or peroxyacetic acid might be utilized in spray water.

Water can be used as a means of conveyance. Apples, cherries, citrus, chopped lettuce and other small leafy greens often are transported in a water flume. This involves a relatively large amount of water that may be recirculated and used for an extended period of time, thus the maintenance of appropriate sanitizing conditions is critical since any contamination can quickly spread to a large volume of product.

Bananas are typically placed in large tanks of water immediately after the hands of bananas are cut from the stalk. This allows latex to exude from the stems into the water and avoids the occurrence of latex stains on the fingers, which is unattractive to consumers. Although large tanks of water may be used for extended periods, the risk of infiltration is minimal because the bananas have positive internal pressure that forces the latex from the cut stems. Human illness has not been associated with consumption of fresh bananas. Even so, water quality management in banana operations should be addressed in a SSOP.

Waxes or fungicide solutions, commonly used for mangoes, peaches and other fruits, may be formulated from water. Sanitizers generally are not compatible with the wax or fungicide. For example, the addition of chlorine to a fungicide mix might result in binding and inactivation of the fungicide. This situation demands that potable water be used for preparation of wax and fungicide solutions and that all mixing and storage containers are thoroughly sanitized and protected from contamination during use.

Finally, water is used for cooling either as liquid (hydro-cooling) or in the form of ice (icing). This was discussed in Module 2.

It is clear from the above examples that the use of contaminated water, or the introduction of any amount of microbial contamination into water, can lead to the spread of the contamination throughout the product that comes in contact with the water. Every operation that involves the use of water has unique requirements for the management of water quality. Remember that sanitizers for the treatment of water are intended to prevent cross contamination. They are not intended to sanitize the produce.

Water Sanitizing Agents

There are a number of sanitizing agents and processes available to treat water. These include various halogens, "active" oxygen, ultraviolet light, copper ionization and combinations of treatments in a process described as "hurdle" technology. All of these have specific management considerations.

Halogens

The halogens include chlorine, fluorine, bromine and iodine. Although there have been attempts to commercialize water sanitizing products with all of the halogens, chlorine is the only one of major importance today and is the focus of the following discussion.

Chlorine is by far the most widely used sanitizer for water due to the number of benefits that it offers. It is relatively inexpensive and effectively reduces pathogens, including many key human pathogens as well as decay-causing plant pathogens and spoilage microorganisms. Proper dosing reduces the transfer of pathogens from contaminated product to noncontaminated product, and can kill some pathogens on the product, depending on the nature of the surface.

Chlorine compounds that are utilized for sanitizers are in two categories: those that result in the formation of hypochlorite in water and those that lead to the formation of chlorine dioxide.

Three chemicals that form hypochlorite in solution are approved for use as a water sanitizer in fresh produce applications. These are liquid sodium hypochlorite ($NaOCl$), solid calcium hypochlorite ($CaOCl_2$) and gaseous chlorine (Cl_2).

Liquid sodium hypochlorite is the formulation available as bleach in the local supermarket, but these products are not approved for agricultural food contact uses. This form typically is 5.0 to 6.0% active ingredient. Industrial forms of bleach may be as high as 12.0 to 15.0% active ingredient. Either formulation of the liquid material must be diluted to provide the desired level of sanitizer for fresh produce. Only formulations specifically labeled for contact with fresh produce should be used.

Calcium hypochlorite in the form of granular material or compressed tablets is widely used for treating swimming pool water. This is a concentrated material with a content of active ingredient of approximately 65%. It is important to note that not all swimming pool chlorine is acceptable for fresh produce applications. In swimming pools, cyanuric acid may be used as a chlorine stabilizer and in some formulations the cyanuric acid may be combined directly with the calcium hypochlorite. Cyanuric acid is not approved for food contact. It is critically important that the user study the label to know if the calcium hypochlorite formulation contains cyanuric acid and if the material is approved for food contact.

Gaseous chlorine is available from industrial sources. This is the most concentrated of any of the chlorinating materials. Usually chlorine gas is the least expensive form of chlorine, but it is extremely dangerous and must be handled with care. The use and placement of chlorine gas tanks and injection engineering is generally regulated by government authorities for worker protection as well as general public safety.

Chlorine exists in water in several forms. It is important to review some of the basic chemistry in order to understand how to manage chlorine effectively as a sanitizer. It also is important to understand the distinction between free, bound and total chlorine.

Chlorine in solution that is available to function as a sanitizer is called free chlorine. During the processing of fruits and vegetables, organic matter may accumulate in the water. Some of the free chlorine will bind to the organic matter to form certain amines or other compounds. This is described as bound chlorine. Bound chlorine is not available to serve as a sanitizer since it is inactivated once it becomes bound. Total chlorine is the combination of free active chlorine plus any bound inactive chlorine. The significance of this will become obvious in the following discussion.

The rate of sanitizing capacity of chlorine is affected by pH. Sodium and calcium hypochlorite as well as chlorine gas all dissolve in water to establish a balance of hypochlorous acid and hypochlorite ion.

$$HOCl \rightleftharpoons H^+ + OCl^-$$

At a pH below neutral (<7.0), the equilibrium shifts toward hypochlorous acid. This is the form of chlorine that functions best as a sanitizer where short contact times are typical. In the scientific literature free chlorine sometimes is defined as undissociated hypochlorous acid.

At a pH >7.0, hypochlorous acid dissociates to form a hypochlorite ion and the hydrogen ion. Hypochlorite ion, in practical terms, is relatively ineffective against pathogens.

It is highly undesirable to allow the pH of water to drift away from the neutral point. Generally the range of 6.5 to 7.5 is recommended. At lower pH the acid form is corrosive for equipment and at the higher pH the sanitizer is not as effective. Figure 3.1 illustrates the relationship between pH and the percentage of chlorine that is free and available as a sanitizer.

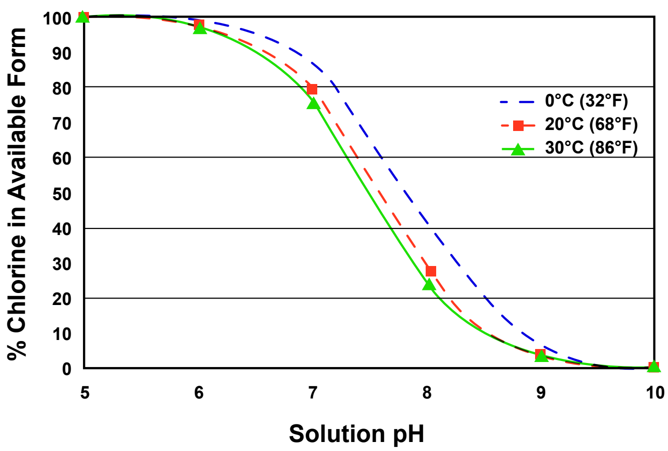

Figure 3.1. Influence of pH and water temperature on the percentage of chlorine available to serve as a water sanitizer.

A water management program utilizing any of the forms of chlorine that yield hypochlorite must include a strategy for managing pH. This is complicated by the fact that the addition of sodium or calcium hypochlorite to water will tend to raise the pH, while the addition of chlorine gas to water will lower pH.

If pH is too high, use an acid to reduce it. Food grade hydrochloric (muriatic) acid and phosphoric acid both are approved for this purpose, but these inorganic acids are strong and care must be taken not to overdose the water. They are commonly used because they are inexpensive and effective. An approved organic form is citric acid, which is not as powerful as the inorganic forms and may be easier to manage. It also is a more expensive acidifier.

If pH is too low, it can be raised with an alkaline material like sodium bicarbonate, soda ash or diluted sodium hydroxide. Some systems that utilize chlorine gas will bubble the gassed water through a bed of carbonate to neutralize the acid before it comes in contact with the fresh produce.

Note that temperature has minimal impact on the relationship between pH and chlorine availability. This indicates that pH management practices will be identical for cold water in hydro-coolers or for warm water in dump tanks.

Managers must consider the impact of chlorinating materials on the quality of the produce. Some commodities, such as peaches, can be irreversibly discolored if exposed to either low or high pH so the management of pH is a concern for product quality as well as food safety.

Safety of the work environment also must be considered when handling chlorine. In situations where wash water may be unusually soiled, especially with organic matter, the use of large amounts of chlorine can create odors that are irritating and possibly detrimental to workers' health. The use of concentrated chlorine gas is particularly dangerous if leaks occur. Finally, the over-addition of acid with a rapid reduction in pH can cause off-gassing of chlorine into the air. Adequate ventilation of packinghouses is necessary and attention to appropriate safety precautions is absolutely essential.

Relatively low amounts of chlorine can kill many pathogens, but higher concentrations are typically used so that during periods of exposure to high amounts of organic matter the level of sanitizer remains high enough to be effective. A general recommendation is to maintain 100 to 150 ppm free chlorine, but this may vary depending upon the specific use of the water. Dump tank water, which typically becomes heavily soiled, may require more chlorine than a cleaner procedure such as a flume for pre-washed product. Managers should consider the specific application when choosing the level of chlorine to be maintained.

In addition to maintaining a suitable chlorine concentration, managers should maintain pH in the range of 6.5 to 7.5 as noted earlier.

Tanks and flumes should be drained often, cleaned and refilled with potable water. The frequency of draining and cleaning depends upon the specific process and how quickly the water becomes soiled. If water is recirculated, it may be filtered through screens, sand filters or other suitable devices to help remove soil and organic matter. This will help reduce the demand for chlorine, improve the efficacy of sanitizing and reduce costs. Pumping water to a sedimentation sump, often with the addition of small amounts of a flocculation agent, is also useful in combination with mechanical filtration.

A means for the accurate measurement of chlorine is essential. Various types of test kits are commercially available, as well as paper test strips and titration methods. Any of these manual testing procedures are acceptable if calibrated to the performance of the system. Paper test strips are the least accurate but can be used effectively. An indirect estimation of chlorine can be accomplished electronically with an instrument that measures the oxidation-reduction potential (ORP) of water.

Chlorine concentrations and pH may be maintained manually or automatically with suitable equipment. Manual adjustment requires frequent measurements and addition of appropriate chemicals. It is generally better to have a slow constant feed of chemicals with periodic verification that the system is operating at the desired conditions than to monitor at set times and add large amounts if the levels dropped too low. Automated systems employ electrodes that continuously monitor ORP and pH. When water conditions need adjustment, a controller activates pumps that inject the chemicals until the electrodes sense that conditions are within the set range. If an automated system is used, its operation should be verified periodically with a manual test.

Keep accurate records of all water management activities. Managers should record the date, time, water conditions and actions taken to make adjustments as needed. A detailed SSOP must be developed for any procedure that involves water.

Refer to Demonstration P-9. This exercise shows the method for calculation of the amount of chlorine needed to give a desired concentration and the effects of pH and organic matter on free chlorine levels.

Chlorine dioxide (ClO_2) has become a widely accepted alternative to the use of hypochlorite for water sanitation because of the numerous advantages it offers. It is effective against many bacteria, fungi and virus and has good biofilm penetration. It is readily soluble in water, even at low temperatures, and does not break down in the same manner as other chlorine compounds. The water pH has a low impact upon its efficacy as a sanitizer. In most applications it has lower off-gassing and is less corrosive to equipment than hypochlorite materials.

Chlorine dioxide also presents challenges that must be managed. In concentrated form, it is unstable and should not be shipped. It is explosive in concentrations above approximately 10%. A number of companies have developed methods for on-site generation that are convenient and affordable. No attempt is made here to discuss commercial products, but a simple search online will reveal an abundance of technical information about chlorine dioxide and its applications.

Managers should follow manufacturer's label requirements for the use of chlorine dioxide. In all cases, potable water is used for preparing the formulation. Relatively low rates are adequate for misting produce on a retail display and for a clean water rinse, spray or flume in a packinghouse. For biofilm penetration and sanitizing flumes and packing line equipment, up to 100 ppm is used. For storage room walls and floors, up to 200 ppm has been recommended. At the higher concentrations protective masks and clothing are recommended. Safety and health of workers always must be a priority concern.

Chlorine dioxide can be measured reasonably accurately with simple test strips but an electronic sensor or handheld meter is preferred. The frequency of measurement will depend upon the specific application, e.g., single use in a spray versus repeated use in a flume. All management practices should be defined in the corresponding SSOP.

Active Oxygen Materials

Active oxygen materials are effective water sanitizers. Included in this category are hydrogen peroxide (H_2O_2), peroxyacetic acid (CH_3CO_3H) and ozone (O_3). These are more powerful oxidizers than any of the chlorinating materials previously discussed.

Peroxyacetic acid is a mixture of acetic acid and hydrogen peroxide. There is only moderate impact of pH on efficacy and the presence of organic matter in the water does not inactivate the materials. The reaction products are water, acetic acid and oxygen, which are safe for workers and are of less concern for environmental discharge than residues and reaction byproducts of chlorination. Follow manufacturer's recommendations for the concentrations and methods of monitoring the concentration.

Ozone can be a very effective alternative to chlorine for water sanitation in closed system applications. It is a strong oxidizer that kills pathogens rapidly with no harmful residues. There are disadvantages. Ozone presents inhalation health risks for workers and state laws in the U.S. vary regarding the methods for protecting workers. The start-up cost is quite expensive relative to other water treatments discussed and there is a high electrical cost as ozone generation must be done onsite. It cannot be manufactured and transported due to its high instability.

Light Irradiation

Ultraviolet (UV) light illumination is effective in clear water, but as the water gains suspended solids and the light tubes become soiled the light penetration is dramatically reduced. Wavelengths in the range of 235-285 nm have peak germicidal efficacy. Commercial systems usually are designed so that water circulates around self-cleaning tubes with an ultraviolet lamp in a closed system to give maximum exposure of the light to the water and to protect workers from harmful UV irradiation. Systems are available in small and large capacity at reasonable cost.

Copper Ionization

Copper ionization has been promoted as a means of sanitizing water, but research information on its effectiveness is limited. There are reports from industry that this method is best used in combination with chlorine systems.

Water is passed through a small chamber with two electrodes that have low voltage applied. Positively charged copper and silver ions are released into the water stream. These ions kill bacteria by attacking their outer membranes. Copper ionization works best in applications with long contact times, generally much longer than typical postharvest washing and cooling systems. Growers have installed copper ionization generators to inject into well water as it is pumped for packinghouse operations. However, levels that can be used (0.5–1.0 ppm) without unsightly residues are not effective for rapid inactivation of *E. coli* and *Salmonella* and at least 5 ppm chlorine should be maintained in conjunction with the copper treatment.

Hurdle Technology

Hurdle technology employs a combination of any number of treatments to create multiple steps for disinfection. As each "hurdle" is cleared, the safety of the product is further enhanced.

A hypothetical case of hurdle technology could be the following. Hypochlorite could be used at high concentration in a dump tank. The product would be rinsed and then pass on to a bed of brushes and sprayed with a relatively low concentration of chlorine dioxide or peroxyacetic acid. After the product has been graded by workers, it might pass under UV light on active rollers that would turn the commodity for maximum exposure of the product surface to the light. At this point the product would be packaged and would not be touched again by workers or machinery.

Caution

Managers should always read the label and follow manufacturer's guidelines for any chemical that is used for postharvest treatment. All federal, state and local laws pertaining to sanitizer use should be followed.

Summary

Cleaning procedures for fresh fruits and vegetables are commodity specific.

Pre-clean very dirty commodities prior to other post harvest operations.

Choose a water sanitizing method that is appropriate for the application.

Sanitizers are used to treat the water. They cannot be expected to serve as a "kill step" for pathogens on the surface of produce.

Check the levels of any sanitizer frequently.

Always use potable water to start a post harvest process and change the water as often as necessary to maintain sanitary conditions.

Consider the risk of infiltration in dump tank systems and monitor product pulp and water temperatures.

Use screens or filters in processes involving recycled water. Investing in filtration reduces chemical costs and is essential in ozonation systems.

If hypochlorite is used, there must be a program for managing water pH.

Design equipment for easy access and thorough cleaning and sanitizing.

Use all chemicals according to the manufacturer's label specifications.

Develop an appropriate SSOP and keep records of all cleaning and sanitizing operations.

Introduction

The condition of packing and storage facilities is one of the most obvious indicators of a company's commitment to a Good Manufacturing Practices (GMP) program. Failure to give attention to the general maintenance and cleaning and sanitation (C&S) of facilities will be apparent to any visitor. This Module covers general facilities management. The specific practices for C&S are covered in Module 5.

Physical Condition of the Facility

First and foremost, packing and storage facilities should be in good repair. They should be inspected regularly for damage to the roof, walls, floors, windows, doors and door seals, lighting, structural support and any other part of the physical plant. Repairs and maintenance should always be completed in an effective and timely manner. Records of inspections and maintenance activity should be a part of a SSOP.

Facilities should be designed so that they are easy to clean and sanitize. Workers are not as likely to give attention to areas that are difficult to access, are poorly drained or have any other design flaw that would impede the C&S processes.

Floors should have an adequate number of drains that are properly distributed throughout the facility. This will facilitate easier cleaning and removal of water that may be spilled during normal operation of the facility. The drains themselves should be inspected regularly to ensure that they are not blocked and they must be cleaned regularly.

All lighting should be properly protected to help prevent breakage and to avoid the scatter of glass or brittle plastic in the event that breakage does occur. Trash containers should be covered and should be emptied daily or more often if conditions warrant.

Surrounding Environment

Areas surrounding the facility should also be inspected to identify and remove potential risks. Hazardous waste, fuel, pesticides or other chemical contaminants should never be stored in or near a packing and/or storage operation.

Garbage cans and dumpsters should be covered so they do not attract insects, birds, rodents or other pests. This is especially important if they contain any food waste, which can be a source of microbiological contamination. Dumpsters and other trash containers should be emptied daily or more often if necessary.

Animal production near a fruit and vegetable handling facility presents a significant risk of microbiological contamination. Pathogens may be transferred to the facility by the wind, runoff from heavy rain, vehicles or people.

Pest Control

Pest control is an issue that impacts every single area of packing and storage facilities. There are three basic requirements for a pest control program. These are to eliminate any habitat for pests, take steps to exclude pests from within the facility and surrounding areas, and finally to implement a program for eliminating (trapping) pests that do find a way to enter. Domestic animals are absolutely prohibited from food handling areas at all times.

Birds are a problem for fresh produce operations throughout the world. The large majority of packing facilities are not fully enclosed and birds may be able to move practically unrestricted throughout. Once inside an enclosure, birds may roost in hard to reach areas. There is a trend in the fresh produce industry to fully enclose all buildings where fruit and vegetables are handled, but many companies have not reached this goal.

Many species of birds are carriers of *Salmonella* and other human pathogens. When they are allowed to nest or if they move freely they may leave fecal contamination on walls, floors, packing machinery, packaging materials or on the product itself. Cleaning is quite difficult because the contamination may be splattered by the water used for washing equipment, walls or floors. Bird droppings in processing water, e.g., dump tanks, hydrocoolers, etc., present a special concern because the water may spread the contamination as discussed in the previous module.

Managers should adhere to the basic requirements for effective pest control as stated above. Remove habitats, in this case birds' nests and roosting platforms, from within the facility and from outside areas in proximity to the facility. Take steps to block entry points. Windows should be screened properly. Louvered windows are particularly attractive as a nesting location. Netting is available to cover beams or other structural areas that house pipes, cables, etc., that are attractive roosting areas for birds. Netting can be customized with openings to allow for changing light bulbs or performing other routine maintenance.

Bird deterrent devices, such as those with spikes extending outward, can be installed on surfaces where birds might roost. Auditory devices are available that emit recorded sounds of birds of prey, which may help discourage smaller birds from the area. Exclusion and deterrence are the primary options for dealing with birds because they are so hard to trap once they have entered a facility. Local housing or health codes may not permit birds to be killed at the site.

Rodents also are problematic pests because they can be carriers of human pathogens. Rats and mice are able to move through very small openings and they will nest in almost any place where they can isolate themselves from human traffic.

The basic rules for pest control apply to rodents as well. Eliminate habitats. Clean and organize storerooms so that they are not cluttered with items that are not needed for the work activities within the facility. Store packaging materials and other supplies away from direct contact with walls so it will easier to see if rodents are present. Cartons and other containers that are intended specifically to contain produce should not be used for general storage or for any other purpose.

During routine inspections of the facility pay special attention to areas that are dark and not frequently traveled by workers. Rodents are not as likely to nest in well-lit areas.

Restrict access points for rodents to enter the facility. Make sure that door and window seals are in good repair and there are no holes in walls, especially near the ground. Do not leave doors open longer than necessary.

Implement a trapping program inside and outside the facility. Sticky traps are effective for small mice but larger rats may escape from the sticky traps. Specially designed box traps, sometimes called "tin cats," should be placed at appropriate intervals. These traps must be inspected frequently. Dead rodents must be removed and the numbers recorded. Poison baits are not allowed inside a food handling facility of any kind.

Food scientists have long studied the behavior of rodents around food processing and handling facilities. Pest pressure may come from landscape installations or neighboring property and entry may be facilitated by people, trucks or anything else that moves into or out of the facility. Long-term studies with traps have shown that the most rodents are caught near doors.

Insect pests, especially cockroaches, are potential carriers of human pathogens. Flies also can transmit pathogens from bathrooms into the handling and storage facilities or directly onto the product. Toilets should be cleaned and workers should be instructed to place used toilet paper directly into the toilet. Incidents of illness caused by *Shigella*, a pathogen that is found only in humans and not other animals, have been linked to the transmission of the bacteria from dirty toilets to the product by flies.

Storage areas for packaging materials seem to be especially attractive for all types of pests. Since the packaging materials will contain food, it is important that C&S of these areas be thorough and that they are well illuminated to discourage pests. The presence of pests or fecal matter on packaging material is reason for automatic failure of any GMP inspection. Many inspectors will request that the review of a facility begin in the packaging storage area, or they may seek out areas where workers do not like to clean, because these are places where problems are most likely to exist.

Potential Sources of Contamination from Outside the Facility

Contamination can enter a facility in many ways, so daily operation should be assessed to identify potential contamination routes. Bins or other field containers that have been in contact with the soil, mud, fecal matter or compost should never be taken inside a facility. C&S of field containers after each use is highly recommended.

Ideally, trucks or trailers used to haul bins of produce from the field would not enter the facility to off-load. This would be done in an adjacent area. The parking or staging area should be kept free of debris and should be washed periodically. Vehicles that have been used inside an animal production area should not be allowed to enter areas where produce is off-loaded.

Employees should wear clean clothes to work. Placement of foot baths at entrances can help reduce the likelihood of workers bringing in contamination on their shoes.

Packing Machinery and Sanitary Design

Inspect the packing equipment frequently to make sure that it does not have loose parts, flaking paint, rust, excess lubricants or any other potential hazard that might contaminate food. Motors should have catch pans installed underneath so that excess lubricants do not drip onto the product. Only food grade lubricants should be used.

If purchasing new equipment or building a new facility, you should evaluate the sanitary design. Buildings and machinery can be designed in a way that facilitates easy C&S, making the programs more effective and less expensive due to reduction in chemical costs and personnel time required to complete assigned tasks.

Conclusion

Keeping packing and storage facilities clean and well maintained is critical to fresh produce safety. Internal and external factors both can impact safety in addition to anything that enters the facility, including workers. A comprehensive C&S program defined in SSOP must be implemented for all areas. C&S is discussed in Module 5 and SSOP development is discussed in Module 7.

Summary

Packing and storage facilities must be clean and in good repair.

Assess surrounding areas to identify and remove external risks.

Remove garbage and other waste from the facility and surrounding areas.

Never store hazardous chemicals in or near the facility.

Pest control programs are essential for food safety.

Pay special attention to packaging material storage areas.

Develop comprehensive SSOP and keep records of all GMP activities.

Introduction

Transportation provides a number of links in the chain of movement of fresh fruits and vegetables from the field to the consumer. A typical transportation scheme might include hauling from the field to the packinghouse, from the packer's shipping department to a repacker who might regrade and add value by applying a particular packaging treatment, from the repacker to distribution center (DC), from the DC to supermarkets, and finally from the market to the consumer's home. Any number of variations might exist in this pattern of movement, but regardless of the logistics, it is clear that there are numerous potential food safety risks and numerous opportunities for quality deterioration during transport. Thus it is critical that a comprehensive food safety and quality program give adequate attention to the management of the transportation environment.

Methods of Transportation

In the United States, the introduction of transportation by rail in refrigerated cars was a turning point in the commercial distribution of perishable produce. Western production locations, especially in California, were provided a link by rail to the large population centers in the east. Although railroads are still important in commerce in numerous countries, such as for the transport of bananas across Russia, they have yielded to refrigerated trucks, which today transport the vast majority of our perishable products. Air transport is utilized most commonly for products that are highly perishable, have high value and must be delivered to distant markets. The following food safety considerations apply to all modes of transportation.

Transportation Unit Inspection

Prior to loading a container or trailer, which will hereafter be referred to as a unit, a thorough inspection should be performed. Often an inspection sheet has two categories, one for the functionality of the unit and the second for food safety concerns. The functionality is simply the ability of the unit to serve its transportation role effectively. Food safety concerns are linked to the unit's functionality, since safety of the product can depend directly on the operation of the unit.

The shipping manager or a designated employee with training for unit inspections should perform a thorough evaluation. Food safety risks include visible filth, bad smells, or wet areas that are indications that something has been hauled previously that would be inconsistent with the food safety requirements for fresh produce. The driver or transportation manager should be asked for a history of previous loads. If the unit has been used for chemicals, fish, meat, chicken, eggs or any other animal product, there should be a record of C&S of the unit. Ideally, the transportation company would be able to provide a copy of its SSOP for C&S. Even if the unit has been cleaned, the presence of objectionable odors would indicate that the procedure was not thorough and should be repeated.

The physical condition of the unit is an indication of its functionality. If a trailer or container has a cooling system that delivers cold air from the top of the unit, inspect the air delivery chute to make sure that it is not torn or otherwise damaged. If the chute is damaged the cold air may "short cycle", or find a path back to the cooling coils without actually passing through the load of produce. Likewise the front bulkhead should be examined for damage that might allow short cycling. If the refrigeration system delivers cold air to the bottom of the load, be sure that the floor channels are open and there are no obstructions to air flow. This will be less of a concern if the cargo is palletized.

Hermetic seals should be in good condition. Inspect all seals around doors. If there is a side door, be sure to open it and inspect those seals as well. Door seals that leak and allow cold air to escape may prevent the unit from maintaining the desired temperature. Floor drains should have a plug that can be removed for cleaning. Sometimes these plugs are lost or are not properly installed, allowing cold air to escape. Inspectors should note the presence and condition of these plugs. A note of caution: tightly sealed transport units in long-haul distribution could have insufficient air exchange, allowing oxygen to be depleted and humidity to increase due to product respiration. This could promote off-odors, superficial mold growth and accelerated decay.

Note any physical damage to the walls or doors. If the integrity of the wall or door covering is broken, the insulation can become wet. This negates the insulating properties and the damp area is a haven for growth of microorganisms that could lead to product contamination.

The refrigeration system should be tested to ensure that it is working properly. Temperature is critical to product safety and quality. When products are stored at their optimum temperature there will be less decay and shelf life is extended. Refrigeration also reduces the growth of some human pathogens.

In general, excessively high temperature promotes product decay and growth of human pathogens. Very low temperature can damage sensitive products and in the extreme can freeze the product. The optimum temperature is specific to the fruit or vegetable being transported. In the fresh produce industry loads may be mixed, or contain multiple products that may not have the same temperature requirements. If temperature must be compromised, it typically is set to give the best possible conditions for the portion of the load having the highest value.

In trailers and containers, product must be stowed in a manner that allows good air circulation throughout the cargo. Air will follow the path of least resistance. This is most likely to be a problem with produce that is not palletized and is solid-stacked. If conditioned air cannot pass easily through or around the packed boxes, heat of respiration will accumulate and temperature will increase during shipping. Excellent transportation handbooks are available from the University of California at Davis that give guidance for all important aspects of loading cargo.

Cold Chain Management

Maintenance of the cold chain is critical. This simply means that once the product is cooled to its optimum temperature it should be maintained at or near that temperature throughout all handling steps.

Loading is a step where the cold chain is easily broken. Never load cooled product into a hot truck or vice versa. Refrigerated highway trailers are not designed to rapidly or significantly cool packed product. The truck should be pre-cooled and as soon as the load is placed the doors should be closed and the refrigeration unit activated. Ideally, product would be loaded from an enclosed refrigerated dock. The dock doors should be designed so that when the unit is positioned for loading it is sealed to the dock space. This helps to ensure that the cold chain is preserved and pests are excluded.

A temperature monitoring device (recording thermometer or temperature data logger) should be properly installed in the load of product. It should be tamper proof and should have sufficient battery or be otherwise designed so that it operates for the duration of the trip. Placement in 2-3 locations is ideal but typically one device is placed at the rear of the load near the end of the air-chute or below the load line for bottom air units. Temperature records from certified thermometers are admissible in legal proceedings in which temperature management is a concern for quality and safety.

The loading pattern for the product in the unit is important for maintaining proper transit temperatures. Product should be placed so that air moves as uniformly as possible throughout the load. When air channels are blocked, the heat of respiration can accumulate in dead zones and raise temperatures to undesirable levels. In most palletized loads, the air can only circulate around the product and not through it. Optimal pre-cooling prior to loading is important for cold chain control.

The containers used for air transport are not typically equipped with mechanical refrigeration systems but other temperature management strategies are available. Styrofoam or other packaging material with good insulating properties may be used to help prevent the absorption of heat energy by the product. Dry ice or liquid nitrogen both have been used to help maintain the cold environment. Managers should be sure that product is cold when it is loaded, minimize the staging time so that the product is exposed to high temperatures as little as possible, and when the product arrives to its destination, quickly move it in to a refrigerated environment. Containers that are left on the tarmac prior to loading or upon arrival will warm quickly. Air containers sometimes are placed directly into refrigerated rooms until the product can be unloaded. Recooling by commodity brokers at destination is often practiced; asparagus is a good example.

SSOP

There must be a SSOP for inspection and for C&S of all types of transportation units. These are discussed in detail in the next Modules.

Summary

Transportation units should be cleaned, sanitized and in good repair.

Conduct a thorough inspection of the unit before loading. Look for factors affecting the functionality of the unit as well as food safety hazards.

Refrigeration systems and all related components should be functioning properly.

Precool the product prior to loading and precool the unit. Never load cold product into a hot unit or vice versa. Loading hot product into a cold unit can result in excessive condensation.

Stow the cargo in a manner that allows proper air circulation.

Implement a program for cold chain management and use temperature recorders during transit.

Develop appropriate SSOP for transportation and keep records.

Introduction

It is important to implement cleaning and sanitation (C&S) procedures at every step from "farm to fork" to help prevent the transmission of human diseases in foods. Food residues serve as substrate for the growth of human pathogens and can attract and support all types of pests that transmit those pathogens. Further, C&S can help improve the shelf life and quality of perishable commodities because it reduces the load of decay-causing microorganisms.

The development of effective C&S protocols is a complex process. In the fruit and vegetable industry there are many different surfaces that require C&S on a regular basis. This Module addresses many of the technical aspects of C&S but managers are urged to obtain assistance from professionals who understand the concepts and can assist with the numerous decisions that are involved.

C&S is implemented in two distinct steps: clean first and then sanitize.

Cleaning

Cleaning is simply the complete removal of unwanted matter (soil) by using appropriate detergent chemicals and scrubbing in the proper manner. Managers first must identify areas and items to be cleaned and choose the appropriate tools, chemicals and application methods for each area. Always follow label instructions for cleaning agents.

What Do I Clean? Literally everything must be subjected to C&S. All surfaces that contact fruits and vegetables directly must be given special attention. This includes, but is not limited to, hands, gloves, utensils, knives and other cutting tools, harvest containers, cutting boards, tables, conveyors, ice makers, ice storage bins and aprons. Surfaces that are not in direct contact with food also must be cleaned, including walls, ceilings, floors, light fixtures, fans and drains.

What Should I Know About Cleaning Tools? The cleaning tools themselves can be a major source of microbial cross contamination if they are not cleaned, sanitized and properly stored after use. These include brooms, mops, squeegees, buckets, sponges, scrapers, foaming equipment, pressure washers, water guns and any other cleaning tool. Once they are cleaned, they should be dried and stored in a dry secure location.

Tools should be properly identified for the locations in which they are used and should only be used in these locations. For example, tools that are used to clean toilet facilities might be labeled with red paint or tape. These should be used solely for that purpose. Tools that are used to clean walls and floors might be labeled with a yellow color and those used for packing machinery might be blue. Workers should understand the meaning of the coding system and take care to keep tools in their proper locations.

Minimize the use of wood for any purpose. Common wooden handles on tools can absorb water and harbor microorganisms. Plastic or metal tools are more appropriate because they can be cleaned more thoroughly. Tables in food handling areas should not be constructed of wood, even if the wood is coated with food-grade paint. The paint can chip and exposed wood can harbor microorganisms.

What are the Types of Soils? Once the areas to be cleaned and the proper tools have been identified, the types of soils that must be removed are assessed. Different soils require different detergents. Personnel need to have a clear understanding of the types of substances they are cleaning and the basic chemistry of removal. In a fresh fruit and vegetable operation we can identify four general types of soils:

1. Those that dissolve in water include simple carbohydrates, or sugars, complex carbohydrates such as starch, and simple salts.
2. Those that dissolve in alkali include proteins, starches that are bound to proteins or fats, and bacterial films known as biofilms. Biofilms are discussed in more detail later.
3. Those that dissolve in acid include salts associated with hard water that may contain calcium, magnesium

or other minerals. More complex mineral films may contain iron and manganese.

4. Those that dissolve with surfactants include fats, oils, grease, many food residues, inert soils such as sand or clay, fine metal films and some biofilms.

The type of cleanser used must be suited for the type of soil and the surface to be cleaned, discussed in more detail later.

What are biofilms? Biofilms are a collection of microorganisms, mainly bacteria, growing together in a matrix of polymers (glue-like material) secreted by the microorganisms themselves. Biofilms are formed by the attachment of bacteria to a surface, colonization on the surface and subsequent rapid growth to form the film. Biofilms can accumulate on almost any surface, but generally are most problematic on packing line machinery, floors and in pipes.

Once microorganisms grow into biofilms, C&S becomes more difficult because the microbes continue to secrete adhesives that make them more difficult to remove. They have resistance to biocides because even if a layer or two of microorganisms are removed the biofilm structure protects other microbial cells. If the biofilm is not completely removed during C&S it remains a continual source of microbes that may cause spoilage of food or illness in humans.

Why is Water Important? Water is a critical factor in the cleaning process. Surface cleaners consist primarily of water and detergent. Water is the universal solvent and is the basis for all surface cleaners. Cleaning with water alone is the yardstick with which we measure the effect of cleaning chemicals that are added to water. It comprises approximately 95-99% of cleaning solutions and has many functions in the cleaning process. It is used as a prerinse to remove gross amounts of soil. It softens soils left on the surface, carries detergent to the surface to be cleaned, carries wastes away from the surface being cleaned and rinses detergent off the surface. Water quality, particularly its mineral hardness, can drastically alter the effectiveness of a detergent. This is why knowledge of the cleaning water quality is important before it is used in the C&S process.

The Role of Soaps, Detergents and Surfactants

Soaps and detergents are different chemicals, although both help to emulsify fats and suspend soil particles. Soaps are made from fat and lye, while detergents are made from synthetic chemicals. Detergents may contain alkalis, acids, surfactants, corrosion inhibitors, water conditioners (which usually are chelating agents), oxidizing agents such as chlorine and enzymes.

Soaps and detergents aid water in removing soils. Both act by reducing the surface tension of water. This increases water's interaction with the soil so that it surrounds and lifts soil from the surface and allows water to flush the soil away.

There are several characteristics of a good soap or detergent. It must have rapid and complete solubility in water; cause good swelling of the soil to be removed; have good wetting capability of surfaces; have good dispersion, suspension, and rinsing properties, and be noncorrosive to surfaces. Ideally it would not be toxic to workers and it must be cost effective.

Surfactants, or surface active agents, play a complex role that is similar to that of soaps and detergents. Specifically, they are designed make water "wetter," or lower the surface tension of a solution. They also foam, emulsify and disperse soils in solution. Surfactants may have anionic, cationic or non-ionic (neutral) chemical structures.

Following are some general recommendations for the type of detergent that might be used for specific surfaces:

Type of Surface	Recommended Cleaning Substance
Stainless steel	Non-abrasive acid or alkaline
Metals (copper, aluminum, galvanized materials)	Moderately alkaline with corrosion inhibitors
Wood	Detergents with surfactants
Rubber	Alkaline substances
Glass	Moderately alkaline substances
Concrete floors	Alkaline substances

Application of Cleaners

Having completed the decisions regarding what is to be cleaned and the type of chemicals that will be used, we are ready to consider the manner in which cleaning will be accomplished.

There are three general methods for the application of cleaners:

1. Manual cleaning, in which equipment is manually disassembled for hand scrubbing and washing;

2. Semi-automatic cleaning, which involves some type of mechanization like pressure washing, foaming, or rinsing to assist the mechanical process, and;

3. Automated, or mechanical, clean-in-place (CIP) type of process.

Manual Cleaning

This obviously is the most labor intensive method. It requires that managers train and supervise workers so that they have an adequate understanding of the process and conduct the practices properly.

Simple equipment is used for manual cleaning, such as mops, buckets, scrubbing and pads. The choices for cleaning chemicals are limited to those materials that are milder and less irritating for the workers to handle. Low temperatures that do not present risk for injury are required. The soaking of surfaces under foam or in detergent solutions will not be effective for cleaning unless manual agitation or direct scrubbing also is involved.

Manual cleaning utensils should be dedicated to the task for which they are designed. This will optimize cleaning effectiveness and reduce the risk of cross contamination. For example, scrubbing brushes should be of the proper stiffness, abrasive pads should be of adequate coarseness, pressure sprayers should be adjusted to optimal pressure, etc.

Sponges, mops and cloths all retain water and should not be used for routine cleaning. When they are used for a major cleaning operation, they should be thoroughly washed, sanitized, squeezed to remove water and dried properly before being stored in a clean and secure location. Storing these materials when they are wet for an excessive period allows microorganisms to grow and become a source of contamination the next time they are used.

During training, managers must emphasize to workers the proper use of cleaning equipment. Workers must not mix uses. For example, never use floor brooms or floor squeegees on tables or other food contact surfaces. Never use green pads for cleaning waste barrels on grading or packing tables. Never use the same brush to clean floors and food contact surfaces. Always keep utensils for food contact surfaces completely separate from all other utensils.

Semi-Automatic Cleaning

Pressure washing can be extremely useful for cleaning walls, floors, large equipment and tables. Pressure settings may vary with different types of equipment, but in general a pressure of <15 bar is considered low, 15 to 30 bar is considered medium and 30 to 150 bar is considered high pressure. The recommended pressure for cleaning in food handling settings is <45 bar. At higher pressure, spray can form aerosol mist from irritating chemicals and atomization of water can spread soil and microorganisms.

Foam cleaning is useful for hard to clean surfaces. Foaming adds to the retention time of the detergent on the surface, especially for vertical surfaces from which water drains away quickly. Foam is generated by the addition of detergent to water with the application of compressed air. This causes the formation of tiny bubbles that release detergent slowly over time.

A typical foaming technique would be to pre-rinse to remove loose soil and residue. Work in small sections and foam from the bottom up before rinsing from the top down. Foam that is too wet will run off the surface too quickly. Allow the foam to remain on the surface for 10 to 15 minutes, being aware of surfaces that are susceptible to corrosion if exposure to detergent is excessive. There usually is no advantage to foaming hot solutions. Workers should wear protective equipment, e.g., goggles, gloves, suit and boots.

Automated Cleaning

This is sometimes referred to as clean-in-place (CIP) and is the cleaning of production equipment without disassembly. Examples of surfaces for which CIP is utilized include tanks, heat exchangers, pumps, valves, pipelines and any other enclosed surface. Cleaning solutions contact the surface by any combination of pumping, circulating or automatic spraying. Contrary to manual cleaning, CIP may involve high chemical concentrations and high temperatures.

The effective use of CIP involves turbulent flow in order to have good scrubbing action. Product pumps are designed for smooth laminar flow, which is not a good characteristic for CIP. Specially designed CIP pumps work with high volume at high velocity. Pipes run completely full with no headspace and the flow is chaotic and turbulent.

Sanitizing

Sanitizing is a procedure for treating food contact surfaces that destroys most disease-producing bacteria and viruses, substantially reduces the number of other undesirable microorganisms and does not adversely affect the product or its safety for the consumer.

Surfaces must be properly prepared for sanitizing. First and foremost, the surface must be physically clean. One cannot sanitize a dirty surface because organic soils will consume the sanitizer or form a protective barrier over contamination. Detergent residues must be rinsed well because they will neutralize many sanitizers. Many detergents are alkaline with a negative charge while many sanitizers are acidic with a positive charge. Sanitizing can be done with either heat or chemicals.

Thermal Sanitizing

This can be done with dry heat, but most often involves the use of hot water or steam. The exposure to heat should be for a specific time at a specific temperature. Steam and hot water both are effective, but both are expensive and present a physical hazard to workers. Worker safety should be the first priority. Steam has limited application because it is difficult to regulate and difficult to monitor contact time and temperature. Hot water (80-85°C) for >30 second exposure time is an effective method of sanitizing most surfaces and it is noncorrosive and easier to apply than steam.

Following outbreaks of *Salmonella*-related illnesses associated with the consumption of fresh mangoes from Brazil, packinghouse operators in Brazil implemented a system of hot water treatment of recyclable plastic containers that were used for harvesting the fruit. This proved to be quite effective. In general, thermal sanitizing has had limited application in fresh fruit and vegetable handling facilities.

Chemical Sanitizing

Chemical sanitizers are a group of compounds that have dramatically different properties, yet they all achieve a common purpose. Some are chlorine or iodine based. Quaternary ammonium compounds (quats) have become widely used in recent years. There also are acid-anionic sanitizers, such as peroxide and peroxyacetic acid.

Several factors must be considered in the selection of a chemical sanitizer: the type of equipment and kind of surface to be sanitized, water hardness, the microorganisms likely to be associated with the product or the processing environment, and the sanitizer's effectiveness under practical conditions that include temperature, contact time and corrosion potential.

Choose the appropriate method for applying sanitizers. The method might be as simple as spraying the sanitizer onto the surface. It might also be the immersion of disassembled equipment in sanitizer solution. Fumigating, or fogging, the chemical agent into the air is sometimes used. Finally, CIP may be the method of choice for surfaces that are not easily accessible.

Chlorine-based sanitizers are the most commonly used sanitizers in food applications. All forms of chlorine are broad spectrum germicides. They act on microbial membranes, enzymes and other proteins, and deoxyribonucleic acid (DNA). Management of chlorine was discussed earlier under water treatment.

The use of iodine-based sanitizers dates back to the 1800s. They have a broad spectrum of activity as antimicrobial agents. They are powerful in acidic aqueous solutions and are generally used in the range of 12.5 to 25 ppm available iodine. They can cause permanent staining on some surfaces, especially plastics.

Quats are cationic surfactants with fair wetting properties. They react strongly with the cell membranes of certain microorganisms. They are more effective than chlorine against yeasts, molds and gram-positive microorganisms like *Listeria monocytogenes*. They are less effective against gram-negative bacteria such as *Salmonella*, *E. coli* and coliforms in general.

There are a number of considerations for the effectiveness of quats. They are cationic and thus are incompatible with most soaps and anionic detergents, so surfaces must be thoroughly rinsed between the cleaning and sanitation steps. They are excellent environmental sanitizers for floors, walls, drains and equipment, are noncorrosive to metals and are stable at high temperature. Their effectiveness is severely limited by high water hardness.

Workers should follow the label recommendations for the use of quats and all other chemicals, but some typical recommended use levels for quats are as follows: equipment sanitizing 200 ppm; floors and drains 800 ppm; floor mats 1,800 ppm; foot baths 2,400 ppm, and walls and ceilings for mold 2,000-5,000 ppm. Quats may be used at <200 ppm without a rinse step. Take care to use quats in a manner that does not cross contaminate fresh produce.

Acid-anionic sanitizers are surface-active sanitizers that are negatively charged. They serve the dual function of providing an acid rinse and sanitizing in one step. They must be used at low pH since activity above about pH 3.5

is minimal. Their acidity, detergency, stability and non-corrosiveness make them highly effective against a broad spectrum of bacteria and viruses but they are not very effective against yeasts and molds.

Hydrogen peroxide has a long history of use as a sanitizer. It has largely been replaced by peroxyacetic acid (PAA), discussed earlier in Module 3, which is an equilibrium mixture of acetic acid and hydrogen peroxide in an aqueous solution. It is a strong oxidizing agent with a stronger oxidizing potential than chlorine. The pungent acetic acid odor may be objectionable to workers. It is used to control odor and remove biofilms from food contact surfaces and is a versatile agent for sanitizing floors, walls and indoor processing and packaging facilities.

The advantages of PAA are that it is nonfoaming, is effective at relatively low temperatures (5 to 40°C) and is environmentally safe since it breaks down to oxygen, carbon dioxide and water. The disadvantages are that it is corrosive to soft metals, its concentration is difficult to monitor and it is rapidly decomposed by organic matter.

When working with concentrated chemicals, follow the label instructions carefully. Handlers must always store concentrated chemicals in the original container. Work with proper dilutions and wear protective equipment recommended by the manufacturer.

Verification of Sanitation

Take steps to verify that the C&S program is effective. Many food processors routinely use an ATP (adenosine triphosphate) analysis to detect unwanted residues of organic matter on surfaces that have been subjected to C&S. This method gives immediate feedback on the cleanliness of the surface and corrective actions can be taken, if needed, prior to start-up.

Surfaces may also be swabbed and the swabs cultured to detect the presence of specific microorganisms. This method is always retrospective as results are not generally known for 24-36 hours. During this time the equipment may have been in use.

If surfaces are still contaminated following C&S, managers should analyze all steps to determine the weakness in the C&S procedure. Perform C&S on a regular schedule. When there is any unusual circumstance that may cause contamination, implement the process again.

The details of C&S methods should be written in a single document that is called the Sanitation Standard Operating Procedure (SSOP). Considerations for the development of a SSOP are discussed in the final Module of this Section.

Summary

Cleaning and sanitizing (C&S) are two distinct procedures. You must clean first and then sanitize.

All surfaces in a food production and handling system must be subjected to C&S.

Choose the correct tools, processes and chemicals for C&S. Solicit advice from a trained professional.

Workers should be trained to understand the C&S process and must know how to handle chemicals safely.

Develop a SSOP for each individual C&S operation.

Keep records of what you do.

Introduction

Sanitation Standard Operating Procedures (SSOP) are defined by the USDA-FSIS as a description of all procedures an official establishment will conduct at specified intervals, before and during operations, sufficient to prevent direct contamination or adulteration of product(s). Traditionally, SSOP were associated with the manufacturing of food and were focused specifically on cleaning and sanitation practices. For the fruit and vegetable industries, SSOP are more broadly defined to cover procedures defined by GAP as well as GMP, thus farming practices are included. Any procedure with potential impact on the safety of fresh produce should be covered by a SSOP.

Purpose of the SSOP

SSOP are useful for many reasons. In addition to describing the basic sanitary practices, they provide a schedule for key activities and serve as the basis for training all employees in food safety principles. This helps to ensure that every employee, from production workers to management, has an understanding of acceptable behavior in the company.

SSOP provide the foundation to support a routine testing or monitoring program. The records from this program can help to identify trends and prevent recurring problems, which in turn encourages planning to correct deficiencies that can be anticipated. All of this leads to overall improvement of the food safety program. Finally, buyers and inspectors are afforded a perspective of the commitment that the company has to food safety.

Development of the SSOP

A SSOP is a written plan. It must be signed and dated by an official of the company when it is initiated and again when there is any revision to the original document.

Typically, preoperational activities are defined separately from those activities that are conducted during the operation of a facility. For example, a major preoperational cleaning and sanitation of a packing facility would be described apart from the routine cleaning of a restroom or break room that must be conducted periodically throughout the day.

A SSOP should identify the individuals, either by name or by title, responsible for the implementation of the procedures described in the document. The company must maintain records that demonstrate that the SSOP is being executed and that corrective actions are taken when there is a deficiency in the process. Managers have considerable flexibility in the way that records are kept. They may be paper copies or may be computerized. Any functional format is acceptable as long as it accurately describes the process in a clear and concise manner and allows for documenting the implementation and monitoring of the SSOP.

A SSOP is specific to a process in the company. There is not necessarily a right or wrong way to write a SSOP as long as it accurately describes the points that are made above. Companies that must develop a series of SSOP, which would be the case for any fruit or vegetable operation, are best served by developing a standard format. Each new SSOP is numbered or otherwise identified and placed in a book for easy reference. Inspectors and auditors will appreciate the fact that the SSOP is well organized and information is easily accessible.

A typical SSOP would have a title followed by a statement of purpose, objective or relevance. The scope of work would be described and the individual responsible would be identified. A list of materials, equipment or tools needed to carry out the task would be included, as well as procedures for storing, mixing and measuring the concentration of chemicals.

The actual procedure is described and the frequency of the activity is noted. Appropriate record sheets are included that have a signature line for the responsible individual to affirm that the work has been done. An additional signature might be required from a supervisor or manager to indicate that the work is acceptable to the company. Clearly the format of the SSOP could vary considerably.

Verification of a SSOP

Verification that a SSOP is effective is critical to its purpose. In the case of cleaning and sanitation (C&S), a visual inspection is the easiest way to verify a process. One might use a flashlight and a scraper to help see and smell a surface. A worker who is a good observer and uses common sense usually will be able to determine if a C&S process has been conducted effectively.

In many instances the existence of records are sufficient for an inspector or auditor to be assured that the objectives of the SSOP have been fulfilled. For example, purchase orders for cleaners and sanitizers and a well-maintained inventory of their use would normally be adequate verification that a SSOP is being implemented.

In some cases a more sophisticated test may be required to support common sense observations. For example, swabs of an equipment surface can be used to take samples for microbiological analysis, which could include an evaluation of indicator organisms or specific human pathogens. Obviously this requires laboratory capability and results will not be available immediately. Another technique involves bioluminescence monitoring. A swab is analyzed for the presence of adenosine triphosphate (ATP), which is an indicator that organic matter is present. A limitation of the technique is that it does not identify the origin of the organic material, which might be microbial or simply food residue. Results from ATP testing are immediately available. These were discussed in the C&S verification component of the previous Module.

If testing indicates that a cleaning and sanitizing program has not been effective, it will be necessary to review the process and validate all parameters. It is important to confirm that the right chemicals were used at the right concentrations for the appropriate application time and temperature. Review the amount of mechanical force (scrubbing) that was performed, or if pressure washing was used verify that the pressure setting was appropriate. A thorough evaluation will identify deficiencies that can be corrected before repeating the process.

Examples of SSOP Considerations

Following is a discussion to guide the development of a SSOP for cleaning and sanitizing cold storage facilities. Note that this is only a general discussion. A real SSOP would be specific to the location.

First, conduct a thorough inspection to identify any areas that could harbor microorganisms. These areas will require more meticulous C&S than the larger surfaces, e.g., ceilings, walls and floors. Problem areas in a cold room might include drains, cracked hoses, hollow framework, open bearings, filters, areas of standing water, condensate on walls or pipes, porous surfaces such as wood, insulation, or door seals, and light switches. Determine how these problem areas will be replaced, repaired or simply meticulously cleaned. Make note of this in the SSOP.

Define a C&S schedule. At least once per season remove equipment from the coolers and thoroughly clean and sanitize all surfaces from the top down. Walls might be cleaned and sanitized monthly while floors and drains could be treated weekly. Dry cleaning, or sweeping, might be done daily depending upon the nature of the product being stored. Note that these are merely examples of scheduling and are not intended to be specific recommendations.

After setting a schedule, note the types of surfaces and choose appropriate cleansers and sanitizers. Reputable suppliers of chemicals can assist with this decision. Quaternary ammonium compounds (quats) often are used in cold storage areas because they are effective against *Listeria monocytogenes,* which is a serious microbial concern in a cold environment.

Describe the C&S process. This typically will entail steps for pre-rinsing, cleaning, rinsing, sanitizing and possibly rinsing again. Ceilings, walls and floors are cleaned from the top downward. Surfaces are brushed to remove gross contamination before cleaners are applied, followed by scrubbing and rinsing. Clean drains with brushes small enough to reach all areas. Pay special attention to the problem areas that were identified initially. After cleaning, apply a high level sanitizer (800 ppm quat), let stand for 20 minutes, rinse, apply low level sanitizer (200 ppm quat), rinse again and allow all surfaces to dry. Clean all tools and store in an appropriate manner.

Be aware of special risks associated with cold storage facilities. Contamination can be brought into a room on the bottoms of pallets or on the wheels of forklifts.

Other areas within the operation may be more complex. Transportation units provide an excellent example of a situation that may have numerous types of surfaces. There can be wood, aluminum, steel, rubber seals and the refrigeration coils that may require dry or gaseous cleaning and sanitizing steps. Each of these might require different

C&S tools, chemicals and processes, all of which would be described in the SSOP.

As mentioned, SSOP applies to farming operations as well as packing facilities. Recall that SSOP are intended to prevent direct contamination of foods. On farms, this might occur with contaminated irrigation water, inadequate toilet facilities, workers who do not practice good hygiene, unclean harvest equipment, etc. A SSOP should be developed to address each of these potential hazards.

Summary

Repeated, systematic application of GAP and GMP as defined in SSOP is an essential step in the assurance of the safety of the product.

The purpose of a SSOP is to describe procedures that prevent direct contamination or adulteration of a food product.

A SSOP is a written plan. Employee training is a critical part of the plan.

Each risk area at every step of harvesting and subsequent handling of fruit and vegetables should have a SSOP that addresses a method for risk reduction.

Keep records of all activities specified in the SSOP.