SRI YN COLLEGE

(AUTONOMOUS)

DEPARTMENT OF ZOOLOGY

PROJECT WORK

TOPIC: POST HARVEST TECHNOLOGY

Submitted by:

D. Durgesh

III rd BSc BZC

No: 11806046

Submitted to:

LAKSHMI MADAM

Zoology Dept.

Valued by

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14) INTRODUCTION TO POST- HARVEST TECHNOLOGIES OF FRUIT AND VEGETABLES

Variety

Substantial differences exist in the varieties of given vegetables and fruits. Varieties differ with respect to weather, insect and disease resistance; also they will differ in size, shape, time of maturity, and the resistance to physical damage. Varietal differences further extend into warehouse storage stability, and suitability for such processing methods as canning, freezing, pickling or drying. A variety of peas that is suitable for canning may be quite unsatisfactory for freezing, and varieties of potatoes that are preferred for freezing may be less satisfactory for drying or potato chip manufacture. Because of the importance of varietal differences, large food companies commonly provide special seed of their choice to farmers whose crops they contract to buy a year in advance. They also frequently manage their own vegetable farms to further guarantee a sufficient supply of high quality uniform raw materials.

As with vegetables, the diversity of kinds of fruit is enlarged by numerous varieties of a given fruit. There are about 1000 varieties of apples and about 3000 varieties of pears, but of these only a few are commercially important. Some fruit is marketed fresh but more of it is processed into a wide range of different products. For example, apples are utilized in the following ways: consumed fresh, applesauce, canned apple slices, apple juice and cider, jellies, frozen slices and dried slices. For optimum results apple varieties must be matched to particular end uses, and processing plants frequently are equipped to manufacture the products for which the local apple varieties are best suited.

Post-harvest Losses

In a hungry and increasingly competitive world, reducing postharvest food losses is a major agricultural goal. For highly perishable commodities, such as tomatoes, squash, and peaches, as much as 30 percent of the harvested crop may be lost to postharvest diseases before it reaches the consumer. Investments made to save food after harvest are usually less costly for the grower and the consumer and less harmful to the environment than efforts to increase production. Even a partial reduction in postharvest losses can significantly reduce the overall cost of production and lessen our dependence on marginal land and other scarce resources.

Many factors contribute to postharvest losses in fresh fruits and vegetables. These include environmental conditions such as heat or drought, mechanical damage during harvesting and handling, improper postharvest sanitation, and poor cooling and environmental control. Efforts to control these factors are often very successful in reducing the incidence of disease. For example, reducing mechanical damage during grading and packing greatly decreases the likelihood of postharvest disease because many disease-causing organisms (pathogens) must enter through wounds. Chemicals have been widely used to reduce the incidence of postharvest disease. Although effective, many of these materials have been removed from the market in recent years because of economic, environmental, or health concerns. Increased interest in the proper postharvest handling of fresh fruits and vegetables has prompted the widespread use of flumes, water dump tanks, spray washers, and hydrocoolers. To conserve water and energy, most postharvest processes that wet the produce recirculate the water after it has passed over the produce. This recirculated water picks up dirt, trash, and disease-causing organisms. If steps are not taken to prevent their spread, these organisms can infect all the produce that is subsequently processed. In the past, various fungicides and bactericides have been used (alone or in combination with chlorination) to prevent the transmission of diseases. These materials have often been favoured over chlorination because they provide some residual protection after treatment. At present, chlorination is one of the few chemical options available to help manage postharvest diseases. When used in connection with other proper postharvest handling practices, chlorination is effective and relatively inexpensive. It poses little threat to health or the environment.

POSTHARVEST HANDLING

Fruit and vegetables that are fresh and have good flavour bring repeat sales and may bring higher prices. How produce is handled directly affects freshness and, with some produce, how well peak flavour is retained.

For most produce, maintaining cool temperatures (to slow deterioration) and high humidity (to prevent moisture loss) are the most effective means of preserving quality. However, there are several things producers, handlers, and retailers can do to assure that fruit and vegetables going to the market or into storage are of high quality.

Harvesting and handling:

1. Provide gentle harvesting and handling to avoid cuts, abrasions, and bruising damage that allow decay-causing micro organisms to enter the tissue.
2. Harvest produce at the peak of quality. This assures greatest value at the time the commodity begins a sales period or storage period for later sale. Because most produce begin to deteriorate at the time of harvest, the highest-quality produce will have the greatest shelf life.
3. If possible, harvest during the cool part of the day. Because temperature controls the rate at which produce deteriorates, harvesting when the produce is coolest (usually just after sunrise) will extend their quality.
4. If storage facilities are not available, harvest only as much produce at one time as you can pack or sell before the quality deteriorates. This also allows displays at roadside markets to be replenished with freshly harvested produce throughout the day, which ensures highest quality available to customers.
5. Make successive plantings and use several varieties of varying maturity to spread the harvest season. This ensures that freshly picked material will be available over an extended period.
6. Shade is cheap and important. Use trees or a shade cover on field wagons, trucks, and market areas. Hold produce in a shaded area while awaiting packing. Perform sorting and packing operations in a shaded location. Vegetables exposed to the sun will absorb solar energy and become warmer than those in the shade. This is especially true of dark-collared vegetables, such as zucchini squash, eggplants, peppers, watermelons, green beans, and tomatoes, which are often harvested during the middle of summer when solar energy is at a maximum. Workers will be more comfortable and, thus, work more efficiently in a shaded area. Shade may be

provided by an open shed, shade cloth over a simple framework, or even by a large tree.

7. At farm markets, display only good-quality vegetables for sale. Those of poor quality will never improve and will detract from sales of good-quality produce. Frequent sorting to remove poor quality material will present the best display possible to customers. Sales displays should be out of direct sun.
8. Remind customers to keep produce cool and prevent moisture loss during transportation and storage at home.
9. For commodities that loose quality rapidly and those to be shipped to market, special postharvest washing, handling, and cooling are required to maintain quality. Take care to avoid bruising in transportation to the packing shed, during unloading, washing and grading.

POSTHARVEST DISEASES

Many types of post-harvest disorders and infectious diseases affect fresh fruits and vegetables (Table 1). *Disorders* are the results of stresses related to excessive heat, cold, or improper mixtures of environmental gases such as oxygen, carbon dioxide, and ethylene. Some disorders may be caused by mechanical damage, but all are abiotic in origin (not caused by disease organisms) and cannot be controlled by chlorination or most other postharvest chemicals. However, abiotic disorders often weaken the natural defences of fresh produce, making it more susceptible to biotic diseases those that are caused by disease organisms. Further, in many cases injuries caused by chilling, bruising, sunburn, senescence, poor nutrition, and other factors can mimic biotic diseases.

Table 1. Common Post-harvest Diseases of Fruits and Vegetables (from Chlorination and Postharvest Disease Control, North Carolina State University web page: www2.ncsu.edu/eos/service)

Commodity and Disease	**Pathogena***
Apples	
Blue mold	*Penicillium expansum* (f)
Gray mold	*Botrytis cinerea* (f)
Black rot	*Physalospora obtusa* (f)
Bitter rot	*Glomerella cingulata* (f)
Grapes and small fruit	
Blue mold	*Penicillium* sp. (f)
Gray mold	*Botrytis cinerea* (f)
Rhizopus rot	*Rhizopus stolonifer* (f)
Potatoes	
Fusarium tuber rot	*Fusarium* spp. (f)
Wet rot	*Pythium* sp. (f)
Bacterial soft rot	*Erwinia* spp. (b)
Slimy soft rot	*Clostridium* spp. (b)
Peaches and plums	
Brown rot	*Monilinia fructicola* (f)

Rhizopus rot	*Rhizopus stolonifer* (f)
Gray mold	*Botrytis cinerea* (f)
Blue mold	*Penicillium* sp. (f)
Alternaria rot	*Alternaria* sp. (f)
Gilbertella rot	*Gilbertella persicaria* (f)
Sweet potatoes	
Bacterial soft rot	*Erwinia chrysanthemi* (b)
Black rot	*Ceratocystis fimbriata* (f)
Ring rot	*Pythium* spp. (f)
Java black rot	*Diplodia gossypina* (f)
Fusarium surface rot	*Fusarium oxysporum* (f)
Fusarium root and stem rot	*Fusarium solani* (f)
Rhizopus soft rot	*Rhizopus nigricans* (f)
Charcoal rot	*Marcrophomina* sp. (f)
Tomatoes and peppers	
Alternaria rot	*Alternaria alternata* (f)
Buckeye rot	*Phytophthora* sp. (f)
Gray mold	*Botrytis cinerea* (f)
Soft rot	*Rhizopus stolonifer* (f)
Sour rot	*Geotrichum candidum* (f)
Bacterial soft rot	*Erwinia* spp. (b) or *Pseudomonas* spp. (b)
Ripe rot	*Colletotrichum* sp. (b)
Vegetables in general	
Watery soft rot	*Sclerotinia* sp. (f)
Cottony leak	*Pythium butleri* (f)
Fusarium rot	*Fusarium* sp. (f)
Bacterial soft rot	*Erwinia* sp. (b) or *Pseudomonas* spp. (b)

* f = fungus, b = bacterium

The control of biotic post-harvest diseases depends on understanding the nature of disease organisms, the conditions that promote their occurrence, and the factors that affect their capacity to cause losses. Post-harvest diseases may be caused by either fungi or bacteria, although fungi are more common than bacteria in both fruits and vegetables. Post-harvest diseases caused by bacteria are rare in fruits and berries but somewhat more common in vegetables. Viruses seldom cause post-harvest diseases, although they, like post-harvest disorders, may weaken the produce.

Most postharvest fungal diseases (rots) are caused by the dispersion of tiny dustlike spores formed by the actively growing pathogen. Spores have adaptations that allow them to survive in hot, cold, or very dry conditions. They may be carried great distances by wind or water and can cover most exposed surfaces in great numbers.

Spores may remain dormant for long periods until the correct conditions for their germination and growth occur. These conditions include the presence of water (in liquid form or as high relative humidity), warm temperatures, low light levels, adequate levels of oxygen and carbon dioxide, and the presence of nutrients in the form of sugars, starches, or other organic compounds. Many immature fruits and vegetables contain compounds that inhibit the growth of some disease organisms. These compounds and the resistance they provide are often lost during ripening. Therefore, a fresh wound on the surface of a warm, wet, ripened fruit or vegetable enclosed within a shipping container provides an ideal site for postharvest pathogens to colonize and develop. Gentle handling to prevent wounding and thorough cooling immediately after harvest can significantly reduce the incidence of postharvest disease. Figure 1 illustrates the effects of temperature on the development of brown rot (*Monilinia fructicola*) in peaches.

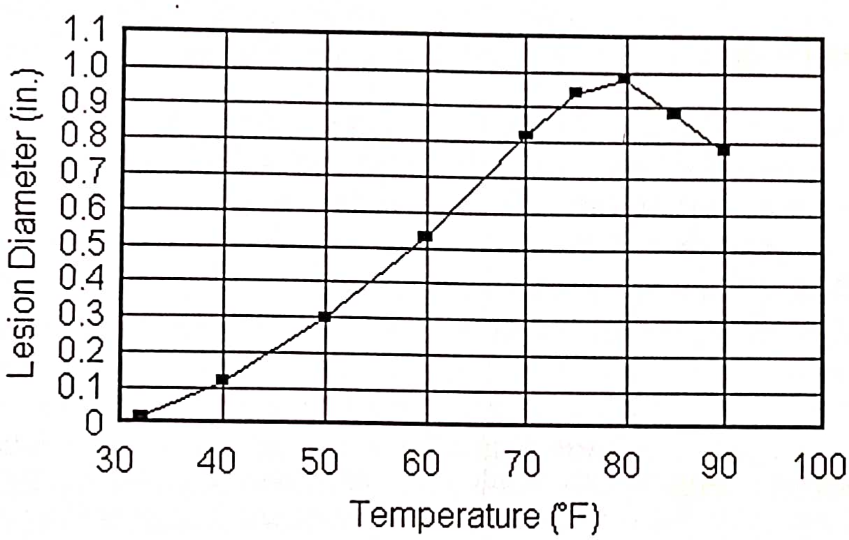


Figure 1. The effects of temperature on the growth of *Monolinia fructicola* (causal agent of brown rot) in ripe peaches. (from Chlorination and Postharvest Disease Control, North Carolina State University web page: www2.ncsu.edu/eos/service)

Spores of postharvest fungal pathogens are most susceptible to chemical control while they are germinating to produce actively growing mycelium. Under the right circumstances, germination can be rapid, often taking only a few hours. Once active growth is under way and the organism moves below the surface of the fruit or vegetable, chemical control becomes very difficult.

The potential for inoculation and infection by postharvest pathogens is always present when handling fresh produce. Understanding the several different ways by which these organisms can come into contact with the produce can be helpful in formulating control measures.

Soil and Field Conditions

Soil and decaying plant material in the field can contain post-harvest pathogens in great abundance. Hard rains and wind can splash and distribute these materials onto un-harvested produce. In addition, warm rainy conditions greatly favour the development of diseases in the field.

Contaminated Water

Water from ponds and streams should not be used for post-harvest cooling, fluming, and washing. Water from these sources is often contaminated by runoff from fields and packing houses and may therefore contain large concentrations of post-harvest pathogens. Using pond or stream water for irrigation can also contaminate produce in the field. Muddy water or water taken from the bottom of the pond is especially likely to be contaminated. Always use potable water from a well or other reliable supply.

Poor Packing House Sanitation

Pathogens brought into the packing house along with the produce will quickly contaminate all working surfaces. Disease-causing organisms will remain viable for months on surfaces such as tank walls, grading belts, and brushes. Wash all produce-handling equipment daily to remove dirt and decayed produce, and disinfect it with a strong chlorine solution on a regular schedule. Keep the packing house and the immediate vicinity clear of any overripe or rotting produce. Remove culls from the packing house and its vicinity immediately.

Air

Even the most meticulous attention to sanitation may not completely prevent contamination of fresh produce by disease organisms. Pathogens are present in the air and will infect produce under suitable circumstances. The best defence against airborne pathogens is sanitation, consistent chlorination, proper handling of the commodity, and quick and thorough cooling.

Although the skin of fruits and vegetables offers considerable protection against infection, pathogens can enter produce through a variety of openings when the produce is wetted. Various wounds, such as punctures, cuts, and abrasions, as well as stems and stem scars provide potential points of entry. The probability of a pathogen entering the produce increases with the size of the opening, the depth of submergence, the length of time the produce is in the water, and the water temperature. Even tiny natural openings (such as stomata and lenticels) can serve as pathways for disease organisms. A small amount of detergent added to the solution lowers the surface tension, increasing the ability of the chlorine to move into the small openings and destroy the pathogens.

A chlorine concentration of about 55 to 70 ppm at a pH of 7.0 is recommended for sanitizing most fruits and vegetables. A higher concentration may be needed if the pH is higher or if the temperature of the solution is more than 80 F. In actual practice, concentrations of up to 150 ppm of free chlorine have been recommended.

The Chemistry of Chlorination

Chlorine is a very irritating, heavy, greenish yellow gas with a strong, pungent door. Free chlorine is very reactive, combining with any chemical that will react with oxygen, and is never found alone in nature. Chlorine in the gaseous form is a very potent disinfectant, although it is seldom used in that form. It is much safer and easier to use when dissolved in water. Disinfection of produce using chlorine or some other chemical is nearly always done during hydro-cooling or during the process of washing the produce to remove soil.

Chlorine for disinfection may be obtained from one of three sources: pressurized chlorine gas, calcium hypochlorite (a soluble solid), or a solution of sodium hypochlorite.

Chlorine Gas

Chlorine gas is produced by the electrolysis of salt solutions (principally NaCl) and is furnished commercially in pressurized metal cylinders. Chlorination is accomplished by bubbling a metered amount of the gas into the supply water. Because of dangers involved with the use of chlorine gas and the expense of the metering equipment, the use of the gaseous form for chlorination is usually limited to large applications. Most municipal water supplies are disinfected with chlorine gas. The limited amount of chlorination required by most postharvest fruit and vegetable operations makes the use of chlorine gas impractical.

Calcium Hypochlorite

The most common source of chlorine used in post-harvest chlorination is calcium hypochlorite. It is available commercially in the form of either a granulated powder or large tablets. Most commercial formulations are 65 percent calcium hypochlorite, with the balance consisting of stabilizers and inert materials. Calcium hypochlorite is relatively stable as long as it is kept dry, and it may be stored for extended periods. The property that makes it stable also makes it difficult to dissolve completely in water. Adding granulated calcium hypochlorite directly to the water often results in undissolved particles that adhere to the produce, causing undesirable bleaching and chlorine burns. This problem is particularly common in hydrocoolers because calcium hypochlorite is very slow to dissolve in cold water. Therefore, always dissolve granulated calcium hypochlorite in a small quantity of tepid water before adding it to the wash tank or hydrocooler. Calcium hypochlorite may be obtained in tablets that are added directly to the hydrocooler or wash tank to eliminate the problem of chlorine burns. Properly used, the tablets will dissolve slowly to yield a continuous supply of chlorine to the water. However, the tablets must be positioned carefully to ensure proper mixing of the chemical with the water.

Sodium Hypochlorite

The active ingredient of most liquid household bleaches; sodium hypochlorite is commonly used when the scale of post-harvest chlorination is limited. Sodium hypochlorite is not generally available in solid form because it is difficult to store. It absorbs moisture readily from the atmosphere, causing it to release chlorine gas.

Household bleach is usually marketed as a solution of water and 5.25 percent sodium hypochlorite. Larger containers of 12.75 percent or 15 percent sodium hypochlorite solutions are also available through some laundry and swimming pool chemical suppliers. For the same amount of chlorination, a sodium hypochlorite solution is generally more expensive than granular calcium hypochlorite because of the additional shipping and handling costs associated with the water it contains.

Chlorination chemicals can be added to the water manually, or concentrated solutions of sodium or calcium hypochlorite can be injected into the wash tank or hydrocooler at a continuous and measured rate. Commercial chlorine injector systems are particularly useful in operations where a continuous supply of clean, chlorinated water is required.

Injector systems consist of a feed tank and an electrically operated pump with a variable output. Chlorine injectors should always be isolated from water supply lines with an approved check valve to prevent backflow into the fresh water system.

Chlorination Effectiveness

Chlorination is a dynamic chemical process. Its effectiveness is influenced by a number of factors. Proper chlorination requires frequent monitoring of the solution and a thorough understanding of the factors involved. These factors include the pH of the solution, chlorine concentration, water temperature, amount of organic matter present, exposure time, and the growth stage of the pathogens present.

Solution pH

The pH of a solution is a measure of its acidity or alkalinity. A solution that is neutral (neither acid nor alkaline) has a pH of 7.0. Solutions with pH numbers less than 7.0 are acid; the lower the number, the greater the acidity. On the other hand, the greater the number above 7.0, the more alkaline the solution. A change of one pH unit indicates a ten-fold change in acidity or alkalinity.

The pH of the solution has a significant effect on the level of chlorination activity. When chlorine gas or one of the hypochlorite salts is added to water, each will generate chlorine gas (Cl_2), hypochlorous acid (HOCl), or hypochlorite ions (OCl) in various proportions, depending on the pH of the solution. The form desired for chlorination is hypochlorous acid (HOCl). Hypochlorite ions are relatively inactive, and chlorine gas quickly bubbles out of the solution, causing worker discomfort and serving no useful purpose.

At a pH slightly above neutral, half of the chlorine will be in the form of hypochlorous acid and the other half in the form of hypochlorite ions. Very little will be in the gaseous form. Solutions that are more acid have a higher percentage of hypochlorous acid but are very unstable, allowing more of the chlorine to escape from the solution as a gas. To maximize the proportion of hypochlorous acid and hence the effectiveness of the solution, the pH should be kept in the practical range between 6.5 and 7.5. Because well water varies from moderately acid to moderately alkaline, the pH should be checked with a pH meter or test papers before and after the chemicals are added and frequently during operation. Furthermore, even if the water initially has a near-neutral pH, the addition of hypochlorites will change the pH.

Different sources of chlorine have different effects on pH:

- Chlorine gas decreases pH
- Sodium hypochlorite increases pH
- Calcium hypochlorite increases pH slightly.

It may be necessary to add a common acid (like vinegar) to lower the pH. Small amounts of sodium hydroxide (lye) may be used to raise the pH. Inexpensive test papers for checking both the chlorine level and pH may be obtained from most swimming pool and chemical supply houses.

Chlorine Concentration

The concentration of a small amount of chemical in a solution is measured in units of parts per million (ppm). In the case of chlorination, this unit of measure indicates the number of parts of available chlorine, by weight that there are in a million parts of solution. The quantity of calcium or sodium hypochlorite that must be added to a certain quantity of water to obtain a given concentration depends on:

- The available chlorine content of the compound
- The concentration of the compound
- The volume of water to be treated

Table 2 shows the minimum chlorine concentrations needed to kill all pathogens within one minute at two different temperatures, assuming a neutral pH. Table 3 gives the amount of 5.25 percent solution hypochlorite solution that must be added to 100 gallons of water to obtain various chlorine concentrations from 25 to 150 ppm. Table 4 gives the same information for 65 percent calcium hypochlorite granules.

Table 2. Minimum Chlorine Concentration Necessary to Kill All Pathogens Within 1 Minute at Two Temperatures at Neutral pH (from Chlorination and Postharvest Disease Control, North Carolina State University web page: www2.ncsu.edu/eos/service)

	Chlorine Concentration (ppm)	
	77 F	104 F
Fungi	30-40	10
Bacteria	20	10

Table 3. Amounts of 5.25 Percent Sodium Hypochlorite (NaOCl) Solution Required to Obtain a Specified Concentration of Chlorine in 100 Gallons of Water at Neutral pH

Pints of solution per 100 gallons of water	Approximate chlorine concentration (ppm)
0.4	25
0.8	50
1.2	75
1.6	100
2.0	125
2.4	150

Table 4. Amount of 65 Percent Calcium Hypochlorite ($Ca(OCl)_2$) Granules Required to Obtain a Specified Concentration of Chlorine in 100 Gallons of Water at Neutral pH

Ounces of granules per 100 gallons of water	Approximate chlorine concentration (ppm)
0.5	25
1.0	50
1.5	75
2.0	100
2.5	125
3.0	150

Temperature

The activity of chlorine increases with the temperature of the solution. Unnecessarily warm solutions should be avoided, however, because the chlorine escapes into the air more rapidly as the temperature increases. On the other hand, in hydrocooling the combined effects of low temperature and high pH values reduce chlorination efficiency.

Organic Matter

Chlorine has a particular affinity for soil particles and organic matter. Chlorinating dirty produce therefore depletes the chlorine supply much faster than relatively clean produce. The amount of chlorine constantly decreases with chlorination reactions. The more organic matter (such as fruit, leaves, or soil) in the tank, the more chlorine will be lost. As a result, the chlorine level should be checked and adjusted hourly, especially when large loads of produce are being processed. Extremely dirty produce (such as sweet potatoes) is commonly washed with clean water before it is placed into the chlorination tank.

Exposure Time

The effectiveness of chlorination depends greatly on the length of time the produce is exposed to the chlorine solution. Quick dips are much less effective than longer exposures. However, most of the sanitizing action of the chlorine is accomplished within the first several minutes of exposure. Prolonged exposure to strong chlorine solutions has been known to cause surface bleaching. Experience is the best guide to the correct combination of treatment time and chlorine concentration for the crop being processed.

Growth Stage of the Pathogen

Disease organisms may be either in the active vegetative form or in the form of spores. Chlorine will readily kill the vegetative form, but fungal spores are 10 to 1,000 times more difficult to kill. Therefore, chlorine treatment rarely eliminates all pathogens and sterilizes the surface of the produce. Many spores may remain on the surface to develop later should the opportunity arise. Further, chlorine kills only on contact, not systemically, and is effective only on exposed pathogens such as those suspended in water or those on the surface of produce; chlorine does not kill pathogens below the skin because it cannot contact them. Chlorination leaves no residual effect. Therefore, produce exposed to pathogens after treatment is susceptible to re-infection.

PRACTICAL RULES FOR SUCCESSFUL CHLORINATION

- **If water is not necessary in the packing process, do not use it.** Wetting the produce greatly increases the likelihood of damage by post-harvest diseases. If the produce must be washed to remove soil, there is no alternative to wetting. Hydrocooling also necessitates wetting the produce, although other methods, such as forced-air cooling, may be a viable option in some cases. When water is necessary in packing lines (for example, in dumping tanks, flumes, or a hydrocooler), always treat it to reduce the risk of disease.
- **Monitor the chlorine concentration and the condition of the water.** Check the chlorine concentration and pH frequently using test papers or electronic equipment. Automatic chlorination equipment is available that will continually monitor the condition of the solution, add chlorine, and correct the pH. Also, monitor the water temperature.
- **Avoid overexposure.** Do not allow the produce to remain in contact with the solution longer than necessary. Check circulation patterns in chlorination tanks to eliminate dead spots.
- **Change the water frequently.** Chlorination efficiency is poor in dirty water. If necessary, wash very dirty produce with clean water before it comes into contact with the chlorinated water.
- **Dispose of wastewater properly.** Before installing chlorination equipment, plan how you will dispose of the wastewater. Land application of wastewater is normally allowed, but check to see if a permit is needed. Illegal disposal of chlorinated water could result in a substantial fine.
- **Practice good sanitation.** Hose off the packing equipment and floors daily; remove any dirt and trash that has settled in the chlorination tank. Sanitize the equipment with a spray solution composed of four pints of 5.25 percent sodium hypochlorite solution in 10 gallons of water. As an alternative, steam clean the equipment with an approved detergent. Do not allow culls or decayed produce to remain in or around the packing house.
- **Protect workers.** For their safety and comfort, workers must be protected from the chlorine fumes associated with excessively high levels of chlorine. If the amount of chlorine gas in the work area is great enough to cause worker discomfort, the amount of chlorine being used is well above that required for proper post-harvest sanitation. If air-monitoring equipment is not available, chlorine concentrations can be checked by asking a person who has not been desensitized by the door to enter the work area. If he or she can smell the chlorine, the level is probably adequate. The concentration is too high if workers are continually irritated by the odour.
- **Remember that chlorination will not solve all your problems.** Even the best chlorination program may not be sufficient to prevent all post-harvest decay. Prompt handling, proper sanitation, and rapid cooling should all be part of your post-harvest disease management program. Produce infected in the field or otherwise damaged cannot be saved by chlorination.

Ozonation

Ozonation is another technology that can be used to sanitize produce. A naturally occurring molecule, ozone is a powerful disinfectant. Ozone has long been used to disinfection of municipal water, process water, sanitize drinking water, swimming pools, and industrial wastewater. The potential utility of ozone in the produce industry depends on the fact that as an oxidizing agent, it is 1.5 times stronger than chlorine and is effective over a much wider spectrum of micro organisms than chlorine and other disinfectants. Ozone kills bacteria such as E.coli, Listeria and other food pathogens much faster than traditionally used disinfectants, such as chlorine, and is free of chemical residues. Ozone is a high-energy molecule. Its half-life in water at room temperature is only 20 min., and it decomposes into simple oxygen with no safety concerns about consumption of residual ozone in treated food products.

Fresh fruits and vegetables are washed first by ozonated water, and the wash water can be recaptured and treated by a combination of ozonation and filtration. Unlike conventional chlorine based washing systems, wastewater discharged by an ozonation process is free of chemical residues, a growing concern related to the environment and groundwater pollution. Ozone can also destroy pesticides and chemical residues.

Gaseous ozone is a strong sanitation and fumigation agent can be used to sanitize foods in the storage room and during shipping to prevent bacteria, mild and yeast on the food surface and to control insects. Ozone is generated naturally by UV irradiation from the sun and from the lightning. It can be generated commercially by UV lights (at 185 nm) or corona discharge. A basic system consists of an ozone generator, a monitor to gauge and adjust the levels of ozone being produced, and a device to dissolve the ozone gas into the water. Systems cost anywhere from $10,000 to $100,000, and should be installed by an ozone sanitation company experienced in produce industry applications.

Ozone is used: i). Process water sterilization and drinking water sterilization, ii). Fruit and vegetable washing: One way to maintain or even improve the safety of fresh produce is to wash produces using ozonated water. Two types of washing systems, spray and flume, can be used to reduce microbial counts on the surface of produce. iii). Fruit and vegetable storage: Ozone can be employed in cold storage of produce to guard against mild and bacteria at a very low concentration. It cannot only destroy mild and bacteria in the air and on the surface of produce but also deodorize. iv). Process water recycling. Ozone is also used for treatment of water for recycling, since it is a powerful oxidizing agent that has been used to disinfect, to remove colori door, and turbidity, and to reduce the organic loads of wastewater.

Hydrogen peroxide

Chlorine is widely used to sanitize fresh-cut fruits and vegetables. However, its effectiveness is limited with some products, e.g., suppressing growth of *Listeria monocytogenes* in shredded lettuce or completely eliminating *Salmonella montevideo* from inoculated tomatoes. Furthermore, some food constituents may react with chlorine to form potentially toxic reaction products. Therefore, there are some alternatives to use of chlorine such as hydrogen peroxide, ozone, trisodiumphosphate.

H_2O_2 vapour treatments

In studies conducted on table grapes that had been inoculated with *Botrytis cinerea* spores were exposed to the vapour in equilibrium with 30-35% H_2O_2 at 40 °C for 10 min. This treatment significantly reduced the number of germinal spores and also reduced the incidence of decay (Forney et al. 1991). It is also reported that exposure to vapour phase H_2O_2 at a concentration of 0.27 mg/L was effective in killing Botrytis spores without causing visible injury. Higher concentrations induced browning.

In another study, cantaloupes were exposed to H_2O_2 vapour at a concentration of 3 mg/L of air for 60 min was effective in reducing microbial counts and preventing decay during storage at 2 °C for 4 weeks without injuring the melons (Sappers and Simmons, 1998). There are also many H_2O_2 vapour treatments used to extend the shelf life of various fresh and fresh-cut commodities. Samples were exposed to H_2O_2 vapour for 2-15 min at injection rates of 2.5 or 5 g of H_2O_2 /min. Following treatment, samples were packaged in plastic boxes with a perforated polyvinyl chloride film overwrap and observed spoilage at 7.5 °C. H_2O_2 vapour treatments appeared to delay or diminish the severity of bacterial soft rot in fresh cut cucumber, green bell pepper, and zucchini but had no effect on spoilage of fresh-cut broccoli, carrot, cauliflower, or celery or fresh raspberries and strawberries. Bleaching was more severe with longer exposure times and at the higher H_2O_2 injection rate.

Treatment of produce with H_2O_2 solution

Washing mushrooms with dilute H_2O_2 solutions was investigated as an alternative to H_2O_2 vapour treatments. The H_2O_2 wash was followed by a dip in erythorbate solution to control browning. The H_2O_2 wash treatment was found to be highly effective in suppressing bacterial development. The effectiveness of the H_2O_2 dip treatment depends on two factors. One is the lethality of H_2O_2 to bacteria on mushroom surfaces or washed into the H_2O_2 solution. The other is enhancement of soil removal from mushroom surfaces by the mechanical action of many small oxygen bubbles, produced at mushroom surfaces by the catalase-H_2O_2 reaction, which dislodges both soil particles and loosely attached micro organisms from mushroom surfaces.

Because of the effectiveness of H_2O_2 washing treatments for fresh mushrooms, use of H_2O_2 solution as an alternative to chlorine for disinfection of fresh-cut fruits and vegetables was tried. Various commodities, both whole and pre-cut, were screened to determine their response to immersion in 5 or 10% H_2O_2 solutions for 0.5-5 min. Observations included the extent of gas evolution from treated surfaces, an indication of the location and level of endogenous catalase activity. Vigorous gas evolution was observed when shredded cabbage, carrot sticks, celery sticks, diced green bell pepper, shredded lettuce, peeled potato, and sliced zucchini were dipped in H_2O_2 solution. However, little or no gas evolution occurred with broccoli and cauliflower florets or with whole cherry tomatoes. The latter vegetables might be expected to contain significant H_2O_2 after exposure if not treated to remove residual H_2O_2.

Residual H_2O_2 in treated fruits and vegetables might be eliminated passively by the action of endogenous catalase, given sufficient time for reaction, or actively by rinsing immediately after treatment to avoid reactions between H_2O_2 and food constituents that might affect product quality or safety. Passive approach with a water rinse or 1 min dips in 1% sodium erythrobate, determining residual H_2O_2.

Commodity	Treatment	Storage time (min)	H_2O_2 residue Test strips	H_2O_2 residue Colour test
Mushrooms, whole	5% H_2O_2+ browning inhibitor	5	None	none
Cucumber cross- cuts	5% H_2O_2	120	>25 ppm	nd
	5% H_2O_2+ H_2O_2 rinse	5	none	none
	5% H_2O_2+erythrobate	5	none	none
Cantalope cubes	5% H_2O_2	20	>25 ppm	nd
	5% H_2O_2+ H_2O_2 rinse	20	none	none
	5% H_2O_2+erythrobate	10	none	none

Use of H_2O_2 as an alternative to chlorine for disinfecting fresh-cut fruits and vegetables shows promise. Treatments appear to reduce microbial populations on fresh cut products and extend the shelf life without leaving significant residues or causing loss of quality. However, more definitive data are required to establish the technical and economic feasibility of the treatment. In particular, additional research is needed to optimize H_2O_2 treatments with respect to efficacy in delaying spoilage. The reaction between H_2O_2 and erythorbate used to eliminate residual H_2O_2 indicates a need to investigate the potential loss of ascorbic acid and other labile nutrients.

POSTHARVEST HANDLING SYSTEMS: MINIMALLY PROCESSED FRUITS AND VEGETABLES

"Minimally processed" horticultural products are prepared and handled to maintain their fresh nature while providing convenience to the user. Producing minimally processed products involves cleaning, washing, trimming, coring, slicing, shredding, and so on. Minimally processed fruits and vegetables include peeled and sliced potatoes; shredded lettuce and cabbage; washed and trimmed spinach; chilled peach, mango, melon, and other fruit slices; vegetable snacks, such as carrot and celery sticks, and cauliflower and broccoli florets; packaged mixed salads; cleaned and diced onions; peeled and cored pineapple; fresh sauces; peeled citrus fruits; and microwaveable fresh vegetable trays. Whereas most food processing techniques stabilize the products and lengthen their storage and shelf life, light processing of fruits and vegetables increases their perishability. Because of this and the need for increased sanitation, preparation and handling of these products require knowledge of food science and technology and postharvest physiology.

Physiological Responses

Minimal processing generally increases the rates of metabolic processes that cause deterioration of fresh products. The physical damage or wounding caused by preparation increases respiration and ethylene production within minutes, and associated increases occur in rates of other biochemical reactions responsible for changes in colour (including browning), flavour, texture, and nutritional quality (such as vitamin loss). The greater the degree of processing, the greater the wounding response. Control of the wound response is the key to providing a processed product of good quality. The impact of bruising and wounding can be reduced by cooling the product before processing. Strict temperature control after processing is also critical in reducing wound-induced metabolic activity, as shown in the respiration data of intact and shredded cabbage stored at different temperatures. Other techniques that substantially reduce damage include use of sharp knives, maintenance of stringent sanitary conditions, and efficient washing and drying (removal of surface moisture) of the cut product.

Product Preparation

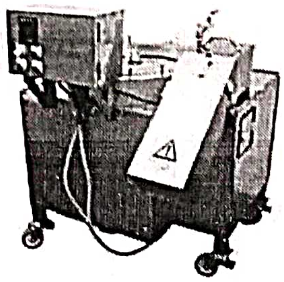
Minimal processing may occur in a "direct chain" of preparation and handling in which the product is processed, distributed, and then marketed or utilized. Many products are also handled in an "interrupted chain" in which the product may be stored before or after processing or may be processed to different degrees at different locations. Because of this variation in time and point of processing, it would be useful to be able to evaluate the quality of the raw material and predict the shelf life of the processed product.
Minimally processed products may be prepared at the source of production or at regional and local processors. Whether a product may be processed at source or locally depends on the perishability of the processed form relative to the intact form, and on the quality required for the designated use of the product. Processing has shifted from destination (local) to source processors as improvements m equipment, modified atmosphere packaging, and temperature management have become available.

In the past, processed lettuce operations often salvaged lettuce remaining in the fields after harvesting for fresh market. It is now recognized that first-cut lettuce should be used for maximum processed product quality. After trimming and coring, piece size may be reduced with rotating knives or by tearing into salad size pieces. Damage to cells near cut surfaces influences the shelf life and quality of the product. For example: shredded lettuce cut by a sharp knife with a slicing motion has a storage life approximately twice that of lettuce cut with a chopping action. Shelf life of lettuce is less if a dull knife is used rather than a sharp knife.

Sliced fruits present an attractive appearance; the portions produced being of a convenient size for eating. Rotary cutting knives are usually employed, the knives being set to cut the material being presented to them, often on a vibrating belt, into parallel slices of the desired thickness. In other slicing operations the fruit is forced through a tube containing stationary knife edges arranged radially along the length of the tube.

Dicing- the cutting of material into cubes-usually follows a preliminary slicing operation, which produces slices of the desired thickness. These slices are then fed onto a conveyor belt containing a series of studs, which hold the slices in position as the belt carries them against a rotary knife assembly, which cuts them into strips. The strips then pass through a further cutting zone at right angles to stripping section. This produces the required cube.

Shredding, the food material is torn into small fragments, the average size of the pieces depending on the type of machine and on residence time in the action zone. Shredding often precedes dehydration, the increase in surface aiding the rate process.

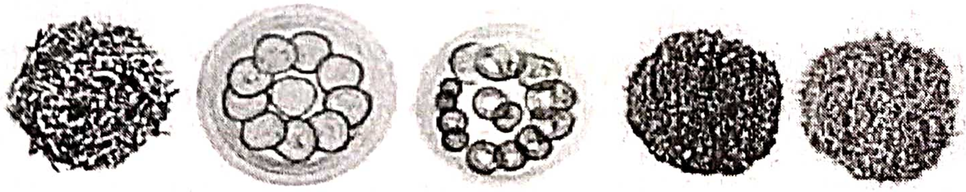


Some examples can be given for cutting and shredding:

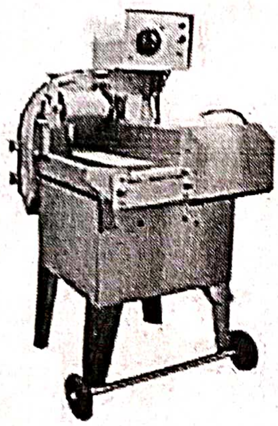
Baton cutter

This machine is ideal for cutting burdocks (deacon), carrots, potatoes, radishes, cucumbers, onions, etc. into crudités or tenuous (strip of paper). Unlike the conventional reciprocating type it uses a one-way slicing mechanism. All the operator need do is feed the raw materials (cut evenly in advance to a specified length) into the machine continuously. The blade setting size can be changed when the cutting size is changed.

Examples of precision-cut product (left to right: shredded cabbage,



thin-sliced cucumber, thin-sliced tomato, shredded parsley, shredded spinach)



Variable speed belt and knife allows a great variation of cutting sizes

Fruit and vegetables are held snugly between the top and bottom belts to ensure they are well positioned for precision cutting

Cleaning Methods

1. Soaking

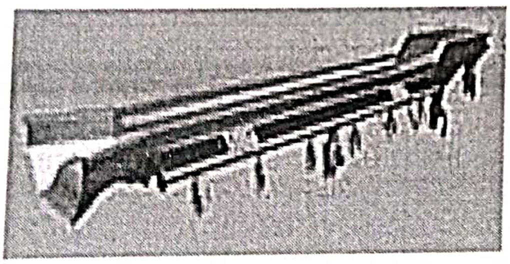
Soaking is used as a preliminary stage in the cleaning of root vegetables and other foods, which are heavily contaminated. Adhering soil is softened and some is removed, together with stones, sand and abrasive materials, which would damage the machinery, used in the later stages of cleaning. The efficiency of soaking is improved: i) by moving the water relative to the product by means of caged propeller-stirrers built into the tank, ii) by moving the product relative to the water either by means of slow-moving paddles or by feeding the raw material into a horizontal perforated drum which rotates whilst partially submerged in the soak tank. Warm water improves the efficiency of soaking but the rate of spoilage of foods may be increased.

2. Spray washing

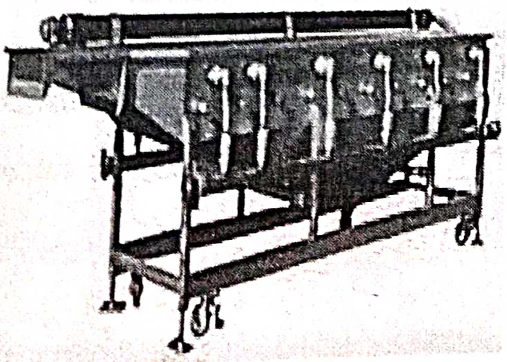
The efficiency of spray washing depends on: water pressure employed, the volume of water used, the water temperature, the distance of the food from the spray origin, the time of exposure of the food to the sprays and the number of spray jets used. A small volume of water, at high pressure, is the most effective general combination. However damage may be caused to ripe soft fruits such as strawberries and to delicate vegetables like asparagus. Spray drum washers and spray belt washers are used.

3. Flotation washing

This method depends on a difference in buoyancy between the desired and desired parts of the food to be cleaned. Thus bruised or rotten apples, which sink in water, may be removed by fluming the fruit into a tank and collecting the overflow of sound fruit. Heavy debris can be removed by fluming dirty produce over a series of adjustable weirs arranged in series.



Thin film sheeting action gently transfers product into open flume system



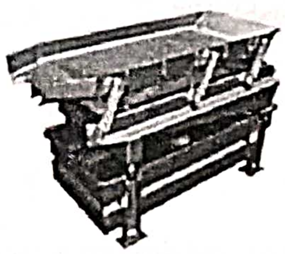
Air and water agitation system for better washing action

Ultrasonic waves are sound waves of frequencies above those detectable by the human ear, i.e. frequencies above 16 kHz. Insonation of a fluid with ultrasonic waves at frequencies of 20-100 kHz produces a rapidly alternating pressure in the path of the waves and this leads to the rapid formation and collapse of bubbles in the fluid. Cavitation and decavitation, as these effects are called, result in the release of energy in the system and this energy causes violent agitation of particles immersed in the fluid. This phenomenon may be utilised to effect the loosening of contaminants, e.g. grit in vegetables, grease or wax on fruits or dirt on eggs.

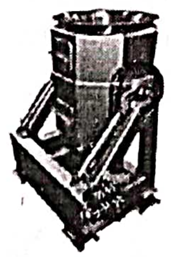
Dewatering

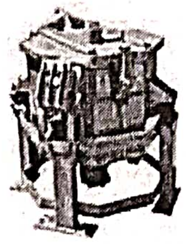
Free moisture must be completely removed after washing. Centrifugation is generally used, although vibration screens and air blasts can also be used. The process should remove at least the same amount of moisture that the product retained during processing. It has been shown that removal of slightly more moisture (i.e., slight desiccation of the product) favours longer post processing life.

Some examples can be given to dewatering equipment:



Dewatering shaker



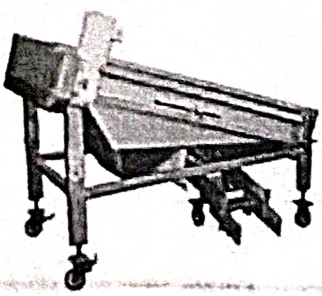


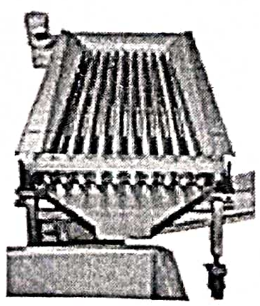
Drying centrifuges

Sorting is defined as the separation of the raw material into categories of different physical characteristics such as size, shape and colour. Grading is defined as the separation of the raw material into categories of different quality.

Sorting plays an important role in controlling the effectiveness of many food processes. They are better suited to mechanised operations such as peeling, blanching, pitting and coring. They are necessary in processes in which uniformity of heat transfer is critical (sterilization, pasteurisation) and they are advantageous in processes in which uniformity of heat transfer is desirable.

Flatbed screens, drum screens, roller sorters, belt sorters, screw sorters are used for size sorting.





Example: Roll sizer, it consists of a roller conveyor in which the gap between the rollers is arranged to increase regularly from inlet to outlet end of the conveyor. The food remains on the conveyor until it encounters a gap in the rollers through which it falls into a padded collection chute. The roller pitch may be adjusted as required.

The disc sorter, the cylinder sorter can be used for shape sorting.

The reflectance and transmittance characteristics of foods are important indicators of their processing suitability. Reflectance properties are used to indicate: raw material maturity (e.g. the colours of fruit and vegetables, meat, etc.), the presence of surface defects (e.g. bruised fruits), the extent of processing (e.g. biscuits, breads) and so on. Transmittance measurements of foods are used to determine their internal properties such as ripeness or core defects in fruits. Photometric sorting embraces most of the electromagnetic spectrum, ranging from gamma and X rays through ultra violet, visible light, infrared, microwaves and radio frequencies to measurements at mains frequency.

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