

Good Agricultural Practices: harvesting and cooling [1]

1. Introduction

Most fresh fruits and vegetables are extremely perishable. The safety and quality of produce when it reaches the retail market is strongly influenced by the condition of the product at harvest. Further factors that affect these characteristics include additional handling (packing), storage temperature, transportation conditions and the ultimate time between harvest and retailing. This article will discuss Good Hygiene Practices during harvest, storage (cooling) and transport. [1]

2. Harvesting procedures

Marketing safe, high-quality produce with an adequate shelf life depends on both the pre-harvest factors discussed in earlier articles and the control measures taken throughout the distribution chain. The so-called “supply-chain management program” begins with harvesting the produce.

The selection of a harvesting procedure will depend on the characteristics of the product. Mechanical harvesting is recommended for produce that can readily withstand physical handling (i.e., carrots, potatoes and radishes). It is generally used to harvest produce destined for the processing industry.

For commodities destined for the fresh market, integrity and appearance are important. Therefore, manual harvesting is widely used for these products. This is especially true for commodities such as lettuce, berries, grapes, peppers, apples etc. that can be damaged easily. With manual harvesting, personal hygiene is particularly important since there is a great deal of handling that could lead to contamination of the product. Proper hygiene during harvesting (e.g., handling of tools) is also critical to product safety.

Damage during mechanical harvesting can lead to a number of undesirable changes in produce. (See Table 1) Most fresh fruits and vegetables are harvested manually, since this can minimise damage and also allows for sorting by size and other desirable characteristics during harvest. Training and supervision of field workers is important to maximise yields and minimise damage to produce.

Microbial contamination of fresh produce can occur easily during harvest. This contamination may result from contact with field workers and from the physical environment of the produce. Environmental sources of contaminants include soil, water, air, hands, containers, etc. Preventing contamination of produce with pathogens is critical, since their presence increases the risk of illness for consumers.

Table 1.

Physical damage caused by mechanical harvesting methods may lead to:

- Water loss
 - Increased respiration rate
 - Initiation of ethylene synthesis
 - Production of undesirable colours (browning)
 - Penetration of plant tissues by micro-organisms (both plant and foodborne human pathogens)
-

3. In-field packaging operations

Some products, like grapes and strawberries, are not cooled or washed, and are packed in the field immediately after harvest. Packing in the field generates a situation where contamination can occur easily. All workers involved in the packing operations should be encouraged to follow good hygiene practices. Containers and packing materials should be handled with care and kept clean and free from dirt and other contaminants.

4. Post-harvest water quality

Water is vital to a number of post-harvest operations. It is used in dump tanks to reduce physical injury to produce as field containers are emptied onto the packing line. It may be used for rinsing at any point on a packing line. In hydrocoolers, cold water is used as a drench or in tanks to remove field heat from fruits and vegetables. It is needed for mixing solutions of waxes and/or fungicides. Finally, hot-water treatment is a measure used for insect-pest control in some commodities.

Water quality is important in reducing contamination during post-harvest cooling, washing and sanitary operations. The water used for post-harvest operations should be potable and therefore free of disease-causing organisms. Water taken and used directly from rivers or holding ponds should not be used for post-harvest washing or cooling.

As indicated by the FDA, processing water should be of such a quality that it does not contaminate produce (U.S. Food and Drug Administration). Water quality consistent with U.S. EPA requirements for drinking water, or similar standards is recommended, since water that meets the microbial standards for drinking water is considered “safe and wholesome”

The European requirements and limits for processing water are somewhat different and can be found in the EU Directives 80/778/EG and 98/83/EG. In article 2.1 of EU Directive 98/83/EG the following definition can be found for ‘water intended for human consumption’:

(a) all water either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic purposes, regardless of its origin and whether it is supplied from a distribution network, from a tanker, or in bottles or containers;

(b) all water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption, unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form.

In table 2 some specifications are presented that shall be met by processing water.

Table 2 Some US EPA specifications for drinking water

Properties	Specifications, USA
Total Coliforms	0 CFU*/100 ml
Fecal Coliforms	0 CFU/100 ml
<i>Cryptosporidium</i>	Absent
<i>Giardia lamblia</i>	Absent
pH	6.5 to 8.5
Turbidity	5 NTU**

* CFU = colony forming units

** NTU = nephelometric turbidity unit

It is useful to confirm the absence of pathogens in processing water and to determine the levels of turbidity and pH. The last-mentioned parameters are indicators of conditions that might affect the presence of pathogens in the water. Turbidity is a measure of water cloudiness and is indicative of water quality and the effectiveness of filtration. Higher turbidity levels are often associated with higher levels of pathogenic organisms. A pH value below 8 is necessary for effective disinfection with chlorine (World Health Organisation, 1996).

Pathogens present on freshly harvested fruits and vegetables accumulate in water-handling systems such as dump tanks, flumes and hydrocoolers in which the water is recirculated. Even healthy-looking produce coming in from the field can harbour large populations of pathogens, particularly during warm, rainy weather. When fruits and vegetables are immersed in water containing pathogens, they can become contaminated. Many post-harvest contamination problems result from the incorrect use of disinfectants in dump tanks and hydrocoolers (Sargent et al., 2000).

Whenever produce is dumped into water or washed with recirculated water that is not maintained properly, there is a good chance that contamination will occur.

Usually, an approved disinfectant is added to keep the water free from micro-organisms. Disinfectants such as sodium hypochlorite, calcium hypochlorite or liquid chlorine are frequently used to prevent the accumulation of pathogens. Many packers routinely add chlorine to their water-handling systems. A 50-200 ppm chlorine concentration can destroy most viable micro-organisms. However, higher concentrations are needed to kill spores. The effectiveness of this treatment in reducing product contamination can be

diminished or nullified if the relevant guidelines for processing water are not followed. If chlorine is used to disinfect processing water, it is important to monitor the free (unreacted) chlorine concentration at intervals during use. Chlorine must be added continuously to the water to replace that lost to reactions with organic matter, certain chemicals and micro-organisms (known as the chlorine demand). Samples should be taken at least on an hourly basis to monitor the chlorine concentration. All recirculated water should be changed daily, or more frequently if the water becomes extremely dirty due to a build up of organic matter that would reduce the effectiveness of the chlorine treatment. Local environmental codes must be consulted for proper disposal of chlorinated water.

Other factors that affect the efficacy of chlorine include the initial level of micro-organisms present on the fruit surface and the exposure time of the crop to the chlorinated water. In the case of tomato dump tanks, the water should be heated to about 5°C (10°F) above the pulp temperature to reduce ingress of the water (and pathogens) into the fruit. The tomatoes should not be in the tank for more than three minutes.

5. Cooling considerations

Highly perishable commodities are cooled to extend their shelf life. The cooling operation is generally meant to improve the quality. However, temperature control can also be used to inhibit the growth of any pathogenic bacteria on fresh produce. In Table 3 the benefits of cooling produce are presented. Products are generally cooled within 24 hrs of harvesting.

Table 3. Benefits of a produce cooling operation

<ul style="list-style-type: none">• Reduction of field heat• Reduction of respiration and ethylene-production rates• Minimising of spoilage• Reduction of water loss• Limiting the growth of micro-organisms
--

When possible, harvesting at night or in the early morning can minimise exposure to high daytime temperatures. The harvested crop should be collected and held in the shade with adequate ventilation. If shading is achieved by placing produce under a tree, care must be taken to prevent contamination by bird droppings. Under no circumstances should freshly harvested produce be left in direct sunlight or stored in containers where a build-up of solar heat is likely.

When produce is cooled promptly after harvest, the shelf-life is extended, appearance is improved and products are of higher quality. The amount of heat that needs to be removed during the cooling step depends on the weight, specific heat, initial temperature of the product and the final temperature required.

Commercial cooling methods

Conduction and convection are the two main heat-transfer mechanisms used for cooling produce, to remove heat following harvest. With conduction, the heat is transferred within a product to its coldest surface. With convection, the heat is transferred away from the surface of the product via a cooling medium such as moving water or air. Regardless of the cooling method used, care must be taken to ensure that the cooling medium does not contaminate the produce.

When using an air-based cooling system, it is important to maintain hygienic conditions in the facility. Special attention should be given to the air-source area. The air system should be properly maintained and the filters changed regularly. Animals should be excluded from the surrounding areas, compost storage deposits should be located as far away from air sources as possible, and any other pathogen sources that could contaminate the air used in cooling systems should be eliminated.

Cooling methods using water and ice as the cooling media have the greatest potential for contamination of fruits and vegetables. Cooling water can become a contamination problem, therefore the water should be replaced regularly (at least once a day, depending on the amount used and condition of the produce). It is essential that ice used in cooling is produced from chlorinated, potable water and stored in a hygienic manner, so that it does not contaminate the produce during the cooling process.

Water and ice used for cooling systems should be free of bacterial contamination. It is important to carry out microbiological tests on the water or ice used in cooling systems. The most commonly used tests are for total coliforms, faecal coliforms, and *E. coli* since these tests are good indicators of water contamination.

The addition of chlorine derivatives to cooling water is a common practice and it is recommended that chlorinated water is used to make the ice. Because chlorine loses effectiveness when it reacts with organic compounds, its concentration should be monitored frequently. It is important to place a water settling and filtration device in the cooling-water treatment system to remove organic material. (see paragraph 4) Cooling equipment should be cleaned and inspected frequently. Maintenance of equipment and use of appropriate hygienic procedures is critical to ensure the safety of produce. Pathogens present on freshly harvested fruits and vegetables accumulate in water-handling systems such as dump tanks and flumes in which the water is recirculated (Sargent et al., 2000).

For some commodities (e.g. apples, celery, mangoes and tomatoes), it has been observed that, when the warm fruit or vegetable is placed in cold water, a pressure differential is generated. This creates a suction effect that results in water penetrating the fruit. More research is needed to identify the commodities that show this effect and to document its practical importance. Although a definitive solution to this problem has not been found, the use of good quality water for cooling is critical to ensure product safety.

Procedures should be in place to monitor and maintain water quality whenever water is

used in produce production. One recommendation to reduce any possible contamination associated with water penetration by adjusting the cooling/wash water temperature to 5°C above the temperature of the flesh of the fruit (Showalter, 1993).

This could be an important precaution for washing systems. However, for cooling processes, it interferes with the removal of field heat. Thus, for susceptible commodities the recommendation is to cool with air or by some other cooling method, or to combine hydrocooling with an initial air-cooling step to minimise the temperature differential between the water and the produce. The use of disinfectants, such as chlorine, in the cooling water also could help to reduce the risks associated with pathogen uptake by the produce.

A variety of methods is used commercially to cool produce. It is important to know the principle of each cooling method to enable potential hazards to be identified.

Room cooling

In room cooling, heat is transferred slowly from the mass of the product (by convection) to the cold air being circulated around the stacked containers. Room cooling is used for a wide range of commodities, but the slow cooling rate is a major drawback, since products are often loaded for shipment before they are adequately cooled.

The cooling rate may be speeded up slightly by increasing the air circulation with larger or additional fans. However, this will add more heat (energy) to the room. Ceiling-jet cooling is also slightly faster modification of room cooling, because cold air is directed down over the stacked produce.

Forced-air cooling

In this method, the cooling air is pulled or pushed through containers of produce, providing greater air circulation around the produce that results in faster cooling. This method is commonly used on crops such as grapes, berries and other fruits. An even faster rate of cooling can be obtained by increasing the circulation rate of the cold air per unit weight of produce. This may be accomplished by a larger fan capacity or by increasing the degree of venting of the containers, through which the cooling air passes. Vents should be designed and constructed so that the stacking strength of the containers is maintained. Reducing the number of container stacks reduces the cooling time. However, this requires more space and may reduce the amount of produce that can be cooled per unit of time (Holdsworth, 1985).

Hydrocooling

Hydrocooling is a rapid cooling method that uses water showering down over the produce as the cooling medium. The method is based on the principle that a kg of water can absorb more heat than a kg of air. Obviously, hydrocooling can only be used for commodities and shipping containers that tolerate wetting.

Hydrocoolers generally use mechanical refrigeration, high water circulation rates and a minimal water reservoir to provide fast, uniform cooling. Systems should be designed to allow daily cleaning and disinfection. Disinfection of the hydrocooling water is critical, since it is recirculated (Sargent et al., 2000). Organisms present on the produce can

accumulate in the water, inoculating subsequent produce being hydrocooled. Chlorine concentrations of 200 ppm (free chlorine) are generally used in hydrocoolers. However, chlorine has a tendency to break down, and, therefore, the concentration should be monitored frequently. Also, the cooling water should be changed regularly.

There are two basic types of hydrocoolers:

1. *Flow through*: the produce moves on a conveyor belt through the shower.
2. *Batch type*: stationary, stacked containers of produce are showered with ice-water.

With a hydrocooler, the cooling rate can be increased by:

- Reducing the water temperature (addition of crushed or flaked ice to the water reservoir)
- Increasing the water-circulation rate
- Increasing the exposure of produce to the water.

Package icing

This is one of the oldest methods of cooling produce and is used for commodities that can tolerate contact with ice, e.g. root and stem vegetables, broccoli, and Brussels sprouts. Direct contact between the produce and the ice provides fast, initial conduction cooling. However, as the ice melts, an air space is created between the ice and the produce, and the conduction cooling stops. Subsequent cooling is by radiation and convection, both of which are slower processes than conduction.

Conventional icing involves packing finely crushed or flaked ice over the packaged produce. An alternative process uses liquid ice as the cooling medium. This is composed of 60 % ice and 40% water. Liquid ice gives a much greater initial contact between the produce and the ice and it can be applied after the boxes have been palletized. It may be used to distribute ice around the produce in the shipping containers. The amount of ice added should be adjusted to the initial produce temperature, produce weight, and the expected ambient temperatures during transit.

Vacuum cooling

In this method the produce is placed in a strong, airtight, steel chamber. Air is pumped out of the chamber to reduce the atmospheric pressure, causing the water in the produce to vaporize. Cooling occurs because the heat energy for vaporization comes from the produce. The cooling rate is related to the surface area / volume ratio of the produce. Thus, loose leafy vegetables cool faster than tight-headed cauliflower or celery.

This method is used primarily for cooling leafy vegetables, celery, cauliflower, and to a limited extent, sweet corn, carrots, and sweet peppers. A disadvantage of vacuum cooling is that, during cooling, 1 % of the produce weight (primarily water) is lost for each 5 – 6 °C drop in product temperature (Holdsworth, 1985).

Hydro-vacuum cooling, a patented modification of vacuum cooling, prevents this weight loss by providing a water shower at specific times during the cooling cycle. As with hydrocooling, monitoring and maintaining water quality is important when using this process.

Although vacuum chambers may be large enough to hold entire boxcar loads of produce, most vacuum coolers are portable. They can be moved to different shipping points as the growing season progresses.

6. Summary

1. Most fresh fruits and vegetables are harvested manually. This minimizes damage and allows for sorting by size and other desirable product characteristics. Damage during mechanical harvest can lead to undesirable changes in produce, including:

- Water loss
- Increased respiration rate
- Initiation of ethylene synthesis
- Production of undesirable colours (browning)
- Penetration of micro-organisms (both foodborne and plant pathogens)

2. Microbial contamination of fresh produce can occur easily during harvest. This contamination may result from contact with field workers and from the physical environment of the produce. Environmental contaminants include soil, water, air, hands, containers, etc. It is crucial to prevent contamination. The presence of unwanted contaminants increases the risk of illness for those consuming the produce.

3. Packing in the field generates a situation where contamination can occur easily if containers and materials are not handled with care. Good hygienic practices should be followed in handling containers and packing materials to prevent product contamination.

4. Water quality is important in reducing contamination during post-harvest cooling, washing and disinfection operations. Pathogens present on freshly harvested fruits and vegetables accumulate in water-handling systems such as dump tanks, flumes and hydro-coolers in which the water is recirculated.

Water used for post-harvest operations should be potable and free from disease-causing organisms. Post-harvest water can become contaminated easily and it quickly becomes saturated with organic matter (e.g. soil, materials leaching from the fruit, etc), therefore, procedures to ensure good water quality are critical. These include frequent filtering, regular changing of wash water and the use of disinfectants.

5. If chlorine is used for disinfection of processing water, it is important to maintain a certain level of free (unreacted) chlorine at all times during use. Samples should be taken at least on an hourly basis to monitor the chlorine concentration. All recirculated water should be changed on a daily basis, or more frequently if the water becomes extremely dirty due to build up of organic matter, which can reduce the effectiveness of the chlorine treatment.

6. Highly perishable commodities are cooled to extend their shelf life. The cooling operation is used generally for maintaining quality; however temperature control can also be used to inhibit the growth of pathogenic bacteria in the fresh produce.

7. When using an air-based cooling process, the air system should be properly maintained so that the air is clean and free from pathogens. Animals should be excluded from the surrounding areas, compost storage sites should be located as far as possible from air sources, and any other sources of pathogens that could contaminate the air used in cooling systems should be eliminated.
8. Water used in cooling systems and that used to make ice should be free from pathogen contamination. Use of chlorinated water is recommended and samples should be taken at least on an hourly basis to monitor chlorine concentrations.
9. Cooling equipment should be inspected and cleaned frequently. Maintenance of equipment and use of appropriate hygiene precautions are critical to ensure the safety of the produce.

References

1. Holdsworth, S.D. (1985). "The preservation of fruit and vegetable food products", The Macmillan Press Ltd., London, 1985 (1st edition).
2. Sargent, S.A., Ritenour, M.A. and Brecht, J.K. (2000). "Handling, cooling, and sanitation techniques for maintaining post-harvest quality", University of Florida, Co-operative Extension Service, HS719, 2000. Available via the Internet at <http://edis.ifas.ufl.edu/CV115>.
3. Showalter, R.K. (1993). Post-harvest water intake and decay of tomatoes. Hort. Technol. 3, 97-98.
4. U.S. Food and Drug Administration, "Guide to minimise microbial food safety hazards for fresh fruits and vegetables", 1998. Available via the Internet at <http://www.cfsan.fda.gov/~dms/prodguid.html>
5. World Health Organisation, "Enterohaemorrhagic *Escherichia coli* infection", Weekly Epidemiological Record 35(267) 1996.

[1] This document is partly based on the document 'Improving the safety and quality of fresh fruit and vegetables' produced by the University of Maryland, USA. ©2002 University of Maryland.