Research Signpost
37/661 (2), Fort P.O., Trivandrum-695 023, Kerala, India

Postharvest Technologies for Horticultural Crops, 2009, Vol. 2: 25-47
ISBN: 978-81-308-0356-2 Editor: Noureddine Benkeblia

2

Designing container for handling fresh horticultural produce

Clément Vigneault[1], James Thompson[2] and Stefanie Wu[1]
[1]Agriculture and Agri-Food Canada, Horticultural Research and Development Centre, 430 Gouin, Saint-Jean-sur-Richelieu, Québec, Canada J3B 3E6
[2]Biological & Agricultural Engineering Department, University of California Davis, Davis California, 95616, USA

Abstract

Fresh fruits and vegetables are packed in containers holding about 5 to 20 kg of net produce weight to facilitate handling, storage and transport to retail market. Bulk handling in pallet bins or large bags is rare and only used for large items like pumpkins or watermelons. Containers are designed to facilitate postharvest processes such as precooling, protect the produce from environmental and physical

---

Correspondence/Reprint request: Dr. Clément Vigneault, Agriculture and Agri-Food Canada, Horticultural Research and Development Centre, 430 Gouin, Saint-Jean-sur-Richelieu, Québec, J3B 3E6 Canada.
E-mail: vigneaultc@agr.gc.ca

damage, slow the loss of produce life and for other specific needs of individual produce items. This chapter describes the important factors in container design, including use of wood, plastic or corrugated fiberboard for container construction, use of the container in precooling, handling, transportation and storage, and environmental considerations and container reusability.

1. Introduction

The number of people consuming fresh fruits and vegetables is increasing and people are buying fresh produce even when it is out of season [1]. An estimated 200 million tons of fruits were produced worldwide in 1992 [2], and the actual domestic and international trade in fresh produce exceeded $70G in 2002 [3]. Along with increased demand for fruits and vegetables, people are also expecting improved produce quality from their retailers [1].

Between the harvest location and the retail market produce undergoes a number of processes including transportation and storage under various environmental conditions. Handling and storage may be for less than a week in the case of locally grown green vegetables, or may last for many months for long-lived fruits like pears or apples. During postharvest handling produce is susceptible to physical damage and deterioration. Horticultural produce losses are as high as 50% due to inefficient postharvest procedures [4]. However produce losses vary widely depending on the produce item, marketing time, and the production region. Loss data also varies because differing methods for tallying losses may be used and methods are rarely reported [4-6]. About half of the losses are due to physical injuries and improper handling during storage, and distribution [7]. A significant percentage of produce buyer and consumer complaints are traced to container failure because of poor design or inappropriate selection and use [8].

Environmental conditions, mainly temperature, affect the quality of the fresh horticultural produce. Excessively low temperature causes chilling or freezing injury. High temperature increases produce respiration rate and water loss through transpiration, causing loss in internal flesh quality, shriveling and premature softening [9]. Other factors that affect produce quality include: maturity, initial quality, humidity, environmental gas composition, mixed loads and physical stress and packing and packaging conditions.

Water loss causes the produce to shrivel or wilt, which is aesthetically displeasing and reduces the market value. Water loss also causes weight loss, a direct marketing loss. If ethylene producing produce are placed near ethylene sensitive produce, the ethylene may cause the ethylene sensitive produce to prematurely ripen. Bruises, cuts, abrasions and other injuries can produce loss during distribution and marketing, and usually speed deterioration from other causes.

Reducing the losses in postharvest fruit and vegetable operations is a worldwide goal. Quality loss can be minimized by using best harvest procedures, rapid cooling, refrigerated storage and proper handling techniques during transportation and distribution to market [6].

A well designed produce container should contain, protect, and identify the produce, satisfying everyone from grower to consumer [8]. Containers should be designed to protect fruits and vegetables against damage during transportation and distribution as well as having enough venting for rapid and uniform heat transfer during precooling and storage. Other design factors are: ease of handling, use of food grade material only and avoiding sharp features or chemicals which could damage the produce, and increase the quality of retail presentation. A recent objective in packaging industry is to extend the shelf life of the produce and decrease package disposal costs.

2. Precooling method

2.1. Importance of precooling

Precooling is the process of removing field heat after harvest [6]. From the moment fruits and vegetables are harvested, temperatures above optimum low storage conditions subject produce to excessive respiration, water loss, ethylene damage [10]. Timely and thorough precooling slows deterioration processes enough to allow produce to be marketed in good condition. Fresh produce items with high respiration rates [6] deteriorate as much in one hour at 26ºC as in one week at 1ºC [11]. The sooner horticultural produce is cooled, the better the chances are for a long storage and shelf life.

The cooling system and the container must be designed to meet the characteristics of the types of produce for which they are used. The following four precooling methods are considered [12]: forced-air cooling, hydrocooling, ice cooling, and vacuum cooling. Each precooling process can take on different forms depending on the size of the enterprise, the produce to be cooled, the conceptual vision of the designer and the economic constraints, but the basic principle of each precooling system remains the same.

During precooling process, produce is often in final containers which should be designed to allow rapid and uniform heat transfer. Therefore, to minimize energy required for each precooling process, it is essential to design a new container that facilitates the circulation of chilling fluid, such as air, water or water vapor.

2.2. Forced-air cooling

Forced-air cooling is the most commonly used precooling method. It is especially useful for produce sensitive to water exposure. It can be used to cool a wide variety of produce, but it is most commonly used for tree fruits, berries, melons and cut flowers. It does not require a water resistant container such as hydrocooling or ice-cooling methods and can cause uniform produce temperature distribution in the pallet if it and the container are well designed [13, 14]. The disadvantages of forced-air cooling are slow cooling compared with other methods and it can cause excessive water loss in some commodities if not operated optimally.

Relatively rapid produce cooling is achieved by forcing cold air through containers, allowing it to contact each piece of produce. Airflow is generated by a fan which creates a pressure gradient across the containers, causing cold air to flow through the container openings and past commodity [15,16]. The static pressure difference across the produce containers is normally in the range of 30 to 250 Pa, with a typical value of 120 Pa [17]. An airflow rate of 0.5 to 3 L s^{-1} kg^{-1} of produce is needed for adequate heat removal rates [17]. The container should be designed to minimize the quantity of air that does not pass through the container, air that does not contribute to produce cooling and results in poor energy and cooling efficiency. For example tapered wall containers allow a great deal of air to bypass the produce. Depending on the produce porosity [16] and the design of the container, up to 80% of the volume of air can bypass the produce [16,18]; considerably reducing the efficiency of a forced-air cooler.

2.3. Hydrocooling

Hydrocooling uses chilled water to remove produce heat and is commonly used for many types of tree fruits, melons, root vegetables, and stem vegetables [19-24]. Hydrocooling cannot be used with produce that is sensitive to high moisture or water contact such as berries, because free moisture on the berries promotes decay. Hydrocooling does not cause moisture loss to the produce and may even revive slightly wilted produce [25]. Hydrocooling generates faster cooling rates than forced air and liquid ice cooling, offers the possibility to uniformly distribute the electric-power demand with the use an ice storage system [26], has a high energy efficiency, and has a relatively low capital cost [6]. There are two main types of hydrocooler: water-shower and produce immersion.

Immersion design coolers are ideal for produce with a specific gravity less than water, so that the produce is immersed in water. A conveyor with raised flights is often used to move produce through the cold-water bath. Pumps or propellers are installed to help circulate the water around the produce, increasing heat transfer rates. Bennett [19] suggests using an average water speed of 0.076 m s^{-1} to quickly cool peaches. Immersion coolers normally have a longer cooling time than shower coolers.

In water-shower hydrocoolers, the produce is sprayed with cold water. This process may be performed in batches or continuously. The water is either pumped into an overhead, perforated pan that distributes the water over the produce, or is showered through spray nozzles. However, spray nozzles require more pump energy than the pan distribution system. Cooling time in shower-type coolers is dependent on produce diameter [20,27-29]. Produce with larger diameters such as cantaloupe can take 60 minutes to cool, while produce with smaller diameters, such as radishes would cool within 10 minutes or less. Leafy produce items tend to have slow heat transfer and hydrocooling is rarely recommended.

Hydrocoolers should be designed so that the distance between the water distribution pan and the top produce never exceeds 150 to 200 mm [10,30]. Water-drop distance exceeding this range can cause physical damage to some produce, such as surface pitting on cherries or increasing plant pathogen entering the horticultural produce [30].

The cooling water should be kept as cold as possible. Temperatures should be from 0º to 0.5ºC for any produce not sensitive to chilling injury. Even chilling sensitive produce can be cooled with 0ºC water if cooling time is limited [31]. They are not usually injured if their average flesh temperature does not drop below their damage threshold [31,32]. Cooling produce in containers rather than in bulk should result in more uniform produce temperature since the containers can be designed to control the water-to-produce contact time for both water-shower and produce immersion systems.

The disadvantages of hydrocooling are it requires water resistant containers and there is a high potential for cross decay contamination [30]. The cooling water should come from a clean source, not like a pond or stream. Since most coolers re-circulate water, they must be designed to control the spread of pathogens. Produce should also be washed before entering the cooler if not already clean.

2.4. Ice

Packing finely crushed or flaked ice with produce is one of the oldest and simplest technical forms of cooling [12]. This method is particularly valuable for produce shipped in non-refrigerated vehicles. Ice has a latent heat of 334 kJ kg^{-1} and absorbs heat well [10]. Ice also maintains a high humidity in the box and minimizes moisture loss once the produce has cooled to 0°C. This method involves filling packed containers or pallets with ice, or covering pallets with ice. Individual package top icing is the oldest method. Ice is shoveled, raked or blown on top of the produce in the container [33]. Fast cooling with ice requires that ice is in close contact with most of the produce.

Produce cools slowly if ice is just placed on the top of the produce [33]. This method is not efficient in large operations because opening the containers, adding the ice, closing the containers and re-palletizing them is labor-intensive. Further the coating of ice may block vent openings, restrict air movement and lead to center-load warming [34]. Individual package top icing should be used only after precooling and prior to shipping, to assist in maintaining low temperature and high relative humidity [34].

An improvement to top icing is icing by layer [33]. Crushed ice and produce are alternately layered in the pallet box. It is recommended that all points in a bulk load of green leafy vegetables be within 150 mm from ice [33]. A general rule of thumb, the mass of ice should equal one third of the produce mass. This method of icing is more labor-intensive than top icing but the cooling is faster and more uniform [34].

Liquid icing, also known as slush icing, is an effective way to distribute ice throughout a box. It is often used for cooling broccoli, sweet corn, carrots, Brussels sprouts, and cantaloupes [35]. Liquid-icing provides better contact with commodities and much faster cooling than top icing. The slurry of ice and water is pumped into the hand holes of water resistant containers. The slurry flows throughout the box, ice fills the voids, and the water drains out. The pumping system allows the injection of the slurry into the containers and the water flowing out is recycled for ulterior use. The slurry can be injected with a manually operated nozzle or an automated system. The automated system takes from 30 seconds to 10 minutes to uniformly ice a pallet load of boxes depending mainly on the pumping system capacity. The cold water of the slurry has a substantial effect on the cooling of the produce and may contribute up to 40% of the initial cooling [36]. Liquid icing can reduce the produce temperature to 0ºC in a reasonable time and maintain a high relative humidity [34].

Theoretically, one kg of ice will cause a 30°C temperature drop in three kg of produce. Commercial system performance often results in a temperature decrease of 28˚C [10] due to some inefficiency likely caused by the energy introduced by the pumping system and the heat load of the container and surrounding equipment. Furthermore, commercial ice-injection systems require much more ice than is needed just for produce cooling because much ice remains in the containers until the produce is unloaded at the retail store. This remaining ice is generally completely lost for any cooling purpose. The high ice requirement makes liquid icing an energy inefficient and an expensive cooling method. There are a number of other disadvantages. The weight of the ice reduces the amount of produce that can be transported in highway vehicle when weight limits truck capacity. Ice cooling requires a water-resistant container. In a mixed load, the water produced by the melting ice damages neighboring containers that are not water resistant, and the water is a safety hazard in warehouses. Free water can not be released from packages shipped by air freight.

2.5. Vacuum cooling

Vacuum cooling is an energy efficient method of precooling compared to other methods. It only removes heat from the produce, whereas a forced-air cooler’s refrigeration system has to remove heat also from lift trucks, lights, fans, walls, and air infiltration. During vacuum cooling process, fresh produce cool by evaporating moisture from their surfaces under a very low environmental pressure, approximately 0.5% of normal atmospheric pressure. The interior of the solid produce is cooled by heat conducted to the cold exterior surface. Vacuum cooling is compatible with produce with high transpiration rate such as lettuce, sweet corn, celery, sprouted beans and mushrooms, which can be cooled within 15 to 30 minutes [37], but some cut flowers and dense fresh produce such as carrot and rutabaga would cool very slowly. Vacuum cooling can accommodate relatively large quantities of produce while vacuum cooler capacities typically range from 4 to 20 pallets per batch [12]. However, some vacuum coolers have been built small enough to cool a single pallet or large enough to cool 60 pallets per cycle [10].

In vacuum cooling, the produce is placed in an air tight chamber in which the ambient pressure is decreased to about 2.7 kPa. At this pressure water boils temperature at field temperatures of the produce, and boiling conditions cause rapid water vaporization. Heat of vaporization comes from the produce, resulting in temperature decrease. Continuing pressure drop to 0.61 kPa absolute pressure causes water to boil at 0°C. The water evaporation from the produce causes a 1% produce weight loss for each 6°C of cooling [38,39]. A 2 to 5% weight loss is common in vacuum cooling of fresh horticultural produce. This level can cause noticeable wilting in some leafy vegetables [10]. Spraying water on produce before or during vacuum cooling allows wilting-sensitive produce to be cooled with this technique. In that case, most of the cooling effect comes from evaporation of the added water rather than produce moisture. Evaporation of the added surface water also causes faster cooling for produce with low transpiration rates. Produce such as green onions, leaf lettuce, celery and spinach are often cooled in water-spray vacuum coolers.

Rapid release of air into the vacuum chamber at the end of water-spray cooling can cause leaves to appear water-soaked. The damage is apparently caused by surface water being forced into the tissue by the rapid pressure rise around it. Damage is eliminated by releasing vacuum over several minutes.

For the use of costly vacuum cooling equipment to be economically feasible, there must be a consistent daily and annual output of cooled produce. Some vacuum coolers are trailer-mounted so they can be used year-round as production areas change. Iceberg lettuce is produced year around from North Mexico to Canada allowing the economic use of portable vacuum cooling equipment.

3. Constuction material

Produce containers are made of three main materials: wood, plastic, corrugated fibreboard. The most suitable package for any horticultural crop depends on the region, length and nature of the market chain [7]; the methods of handling and transport [40]; the environmental restrictions, the availability and cost of material; and the postharvest procedures used [6,7].

3.1. Wood

Wood is a traditional material for produce containers and has been used for most fruits and vegetables. Wood container designs include rectangular wooden crates, baskets, simple trays with raised corners, and wire bound crates. Wood is strong [41] and keeps its strength when wet. Wooden baskets and hampers are durable and may be nested for efficient transport when empty. Wire-bound crates are sturdy, rigid, have a high stacking strength and can withstand water [8]. They are customarily used for produce that is hydrocooled, such as snap beans and sweet corn [8]. An advantage with wire-bound crates is that they can be disassembled and stacked flat to reduce shipping and disposal costs. A problem with them is the difficultly in attaching labels and cleaning [8].

Wooden crates and lugs have been replaced by other materials which are less costly and lighter [8]. Current international standards have imposed restrictions limiting the reuse of wood containers. This has forced the markets to search for new designs that allow sanitization to decrease cross contamination [42]. Cost, disposal problems, and difficulty in efficient palletization have restricted their use to local grower markets where they may be re-used many times [8].

3.2. Plastic

Reusable Plastic Containers (RPCs) are durable and high-quality containers. RPCs have become common in the agri-food industry. RPCs are ideal for handling fresh horticultural produce and other food since they were specifically designed for maintaining the quality of the produce instead of fabrication ease [43]. RPCs have the potential to replace single-use containers and reduce waste and costs. They are also capable of retaining their strength after wetting and include wall openings that facilitate chilling fluid circulation, such as air [44] and water [45,46] while retaining ice inside the container during liquid ice cooling [47].

Due to RPC's versatility, its design had to take into account multiple uses with a variety of produce and postharvest procedures. The design of any new RPC should take these factors into account and certain compromises must be made to accommodate the different precooling methods. For instance, the open area must be large enough not to restrict the airflow during forced-air cooling [14] but sufficiently narrow to minimize loss of ice particles in a liquid-ice process [47,48]. The openings must be well distributed on the package walls [14] and bottom [46] to facilitate uniform cooling, whatever the method chosen [49]. Finally, they must be designed to efficiently nest or fold to minimize cost of transporting empty containers. Nestable container designs can reduce the volume of empty containers to filled containers by a ratio of 9:1. However, they have a very low efficiency in forced air cooling because air can bypass between containers [18] and should not be used for fruits and vegetables. A better RPC design is a foldable, however, it must be designed ease in cleaning and folding-unfolding operations to minimize cost.

Expanded polystyrene foam boxes are used for a limited number of commodities. They are designed for a single use and their greatest use is for stored table grapes [50]. They are strong, allowing pallets to be stacked three high in storage and do not absorb water which would come from the grapes. Although polystyrene can be recycled the package grinding equipment required for efficient reuse is rarely available.

3.3. Corrugated fibreboard

Corrugated fiberboard containers are commonly used all around the world due to their versatility, relatively low cost and light weight. The containers usually weight less than 0.5 kg [51], which allows more produce to be shipped in vehicles subject to weight limits, however, the weight can sometimes reach 1 kg.

Double-faced corrugated fiberboard is most commonly used for produce containers [8]. It is composed of a corrugated layer of fiberboard sandwiched between an inner and outer fiberboard liner. The corrugated layer contains flutes forming a series of connected arches. Dry fiberboard containers are quite strong and can support a significant weight. From the sides, the flutes act as a cushion to protect the produce against external impacts [52]. Air between the flutes provides thermal insulation.

Corrugated fiberboard boxes are usually stored flat to reduce storage space and are assembled as needed. The flat sheet takes up very little volume.

Ease of assembly should be taken into consideration when designing corrugated fiberboard boxes [52]. These containers are rarely used for long term storage because they lose a large proportion of original strength due to moisture adsorption and fatigue.

When supporting a load, corrugated fiberboard loses strength over time. For example, after supporting weight for 10 days, a fiberboard box retains only 65% of its original laboratory-determined strength [53]. Unlike wood and RPC, fiberboard tends to absorb moisture and weakens when exposed to the relative humidity generated by the produce inside the box. Laboratory testing of fiberboard is based on material in moisture equilibrium with air at 50 % relative humidity (RH) and a temperature of 22°C [53]. Fiberboard in moisture equilibrium with air at 90% RH retains only 40% of its original stacking strength [53]. Absorbed moisture also causes fiberboard to expand slightly, increasing box dimensions and sometimes causing warping. Select fiberboard boxes according to needs of the produce which could mean that they must be strong enough to withstand several weeks of initial storage and trips up to 7 days without failing from fatigue or high humidity [53]. Fiberboard can be made stronger by using waxes or other treatments, adding more fiber weight to the board, adding internal dividers and inserts, or selecting a stronger box design. Waxed fiberboard cartons (the wax is about 20% of fiber weight) are used for many produce items that must be hydrocooled or iced [8] however, most waxed boxes are neither reusable nor recyclable. The fiberboard industry is working to solve this problem.

Corrugated boxes with air vents are not as strong as unvented boxes. To minimize the loss in strength, vents should be located away from the vertical corners of the box and generally should not account for more than 5% total box wall area [6]. Boxes with greater than 5% venting must be specially designed to provide adequate strength [53].

Select container dimensions and pallet design to enable box corners to be well supported by deck boards. Two-thirds of corrugated container compression strength is in the four vertical edges [52]. If corners are not well supported, the boxes can fail and allow produce to be crushed. Nominal outside box dimensions should allow for panel bulge and variation in box placement on the pallet. Boxes must not be stacked beyond the edge of the pallet. An overhang of 25 mm results in a 32% loss of the box compression resistance since the load must be supported by two corners and the three remaining side panels [52]. Boxes should be large enough so that a pallet load extends to the edge of the pallet. Free space at the periphery of the pallet allows the load to shift during transport; and results also in presence of gaps between pallet deck boards. If the box corner is positioned over the gap, this results in the same effect as a pallet overhang. Placing box corners over deck board gaps should be avoided or a rigid sheet of fiberboard should be placed over the pallet to distribute the weight evenly [52].

Pallet loads should also be well secured so that they do not shift during handling or transport. Stacking tabs or palletizing glue can assist in prevent boxes from sliding out of alignment. The pallet and load should also be unitized (tied together with net wrapping or corner braces and banding). Do not wrap pallets with non perforated plastic film, unless it is used for modified atmosphere transport. Solid sheeting blocks box vents which often causes increased produce temperature and CO_2 and volatile accumulation. This recommendation applies to any type of box but in the case of fiberboard it has also the disadvantage of allowing moisture to condense on the inside of the plastic, weakening corrugated packaging.

Corrugated fiberboard containers allow information, labels and graphics to be printed directly on the package. This is informative and also helps marketing the produce. Printing the corrugated fiberboard containers can be done before or after the containers have been formed [8]. Post-printed method is more economical but generally allows less detailed graphics. Preprinted graphics have higher quality compared to post-printed, and are more attractive but generally more expensive.

4. Container vs cooling method

4.1. Forced air

The packing method and the containers must allow a satisfactory volume of airflow with a reasonable pressure difference across the stack [54,55]. Packs in which spaces between produce are occupied by packing material (plastic or paper wraps, or even leaves) restrict airflow and slow the cooling process. Unvented plastic-film liners wrapped around palletized boxes prevent any air from circulating through packages. This causes very slow cooling since heat at the center of the pallet load must to travel by conduction through the mass of produce to reach the air circulating around the pallet load. Heat transfer by conduction through a mass of horticultural produce is very slow. Fruits packed in shallow plastic trays cool down at an acceptable rate if the container is designed to let air pass both over and under each tray. However, well designed trays for strawberry handling resulted in a very efficient forced air cooling process when vent are placed at strategic positions [56]. These flats of strawberries without lids made air good contact with the berries as it eddies over and among them, making them well suited to forced-air cooling. Grapes packed in vented and lidded containers also cooled relatively well under forced air process despite of their compact mass [57] when air was passing between trays.

Air vent hole area in fiberboard containers should be about 5% total side panel area [10]. Vent areas less than this restricts airflow considerably, causing increased cooling time and increased cooling costs. Most corrugated fiberboard containers can have up to 5% venting without significantly reducing stacking strength [10]. However, open-top trays, as are used for berries and some vegetables, can be designed with open sides, allowing more than 15% vent area [10]. Vent size and shape should not allow vents to be blocked by produce. It is recommended to avoid round vents as produce shape often allows them to be blocked. Using a few large vents of 10 mm wide or greater instead of many small vents is recommended for fiberboard containers, but vents of 40-70 mm should be kept away from edges of the box [10].

If containers have a plastic liner or produce is packed in bags, the packaging system should be designed to allow an air passage through the containers. For example, liner-packed grapes can be packed in a carton that is slightly higher than the produce load, allowing air to flow over the top of the liner in each container.

Foam plastic boxes provide about the same heat insulation through their walls as do the two layers of corrugated board in the walls of full telescope containers. Cooling rates for foam plastic and two-layer corrugated containers are about the same considering vent size and position being the same.

Recommendations for RPC design are completely different since this material allows very strong containers even with a very high percentage of opening area. Experimental set-ups were constructed [44,58-61] to measure the effect of the width of the openings on pressure loss due to air circulation through these openings. The results showed that the effect of the width on pressure loss is negligible in the range of 3.2 to 12.7 mm [44]. Since other cooling methods such as liquid icing are desired using these containers, the width should be kept narrow enough to ensure that the ice remains inside the container [48].

Pressure drop across a box increases when the vent area in an RPC decreases below 25% of its total side area [44]. Based on energy requirements, the vent area should be between 8% and 16% of the container [62]. An opening area of 12% formed with holes spaced by less than or equal to the characteristic length of the produce results in the best cooling efficiency [62]. With this configuration, the minimum energy requirement was obtained with an airflow rate of approximately 0.8 L s^{-1} kg^{-1} . The cooling rate increases as the opening percentage increases but the energy required increased as well [62]. The optimum airflow rate for obtaining the minimum energy requirement for cooling process increases as the produce respiration increases, reaching a maximum of 1.75 L s^{-1} kg^{-1} [62].

The effect of the distribution of the openings has been measured many times for various situations [14,18,44,62,63]. For example, four 2% holes located on box edges compared with to 8% venting uniformly distributed on the package surface cause much more energy to be removed by the cooling system. With low airflow rates ($0.5\ \mathrm{L\ s^{-1}\ kg^{-1}}$) and produce with high respiration rates the four-2%-holes design caused 1.75 times more energy removal, and at high airflow rate ($2\ \mathrm{L\ s^{-1}\ kg^{-1}}$) with a low respiration rate produce caused 34 times more energy removal [62]. Vent designs with 2%-holes distributed on corners should be avoided [63].

4.2. Hydrocooling

The three main points to be respected in regard of hydrocooling and container design are: the water flow rate, water distribution uniformity and the hydrocooling process duration. The water flow over the produce surface should be between 10 to 17 $\mathrm{Ls^{-1}m^{-2}}$ to ensure efficient and uniform hydrocooling [10]. Uniform water distribution on the produce results in the shortest possible cooling time, decreases energy use, and increases cooling efficiency compared to any type of heterogeneous water distribution. The process should only be terminated once the warmer produce reaches the set point temperature.

Containers must have adequate top and bottom venting to allow cooling water to flow through the package. Top and bottom venting is often problematic in palletized corrugated fiberboard containers. These vent holes often do not align when the boxes are cross stacked. Also leaves can cause water channeling or obstruct vents and retard the cooling process.

Containers and packing material used for hydrocooling must be water resistant. Wood and plastic work well in hydrocoolers while corrugated fiberboard must be wax treated. Although, wax-dipped fiberboard containers are used in hydrocoolers, they often fail when exposed to long cooling cycles. Treating the containers with wax also increases the container cost, sometimes equal to half the total cooling cost and make them difficult to recycle. In fact, waxed corrugated fiberboard should not be recommended for hydrocooling as they offer poor water distribution uniformity and loose their strength very quickly under water treatment compared to wood or plastic material.

Water distribution inside the containers and the amount of water leaving the container by flowing through the side-walls affect the efficiency of hydrocooling [64]. Vigneault and Édmond [43] have designed a family of standard collapsible RPC compatible with different cooling methods. The design of the container base openings is one of the factors that may affect the uniformity of water distributed underneath the container, through the stacked containers during hydrocooling. Containers designed for hydrocooling should have vents covering approximately 5% of the bottom surface, be uniformly distributed and have an opening width of 3.2 mm [45].

More research has been conducted on the assumption that the cooling water is distributed uniformly over the fresh produce [64, 45]. However, in practice, water uniformity is not always guaranteed because the shape of produce affects the water distribution. Produce may block the container openings and force water to flow through the side walls. Vigneault and Goyette [45] showed that there was more water loss through container walls than container bottoms with leafy produce. Water distribution uniformity is also very important since the precooling process duration should be based on temperature of the produce showing the lowest cooling rate [15]; heterogeneous water distribution generating some produce cooling slower, extending the cooling process.

4.3. Liquid ice cooling

Containers and packing material used for ice cooling must be water resistant. Historically wooden boxes were widely used for storage and shipment of iced produce. The use of waxed corrugated cartons has become common during the last 40 years due to their fairly good resistance to moisture damage.

More recently, plastic materials have become more common place in the agri-food industry. RPCs retain their strength when in contact with free water and work well in all temperature conditions encountered in fruit and vegetable industry. When properly designed, these containers include wall openings enabling the use of other types of circulating fluid for precooling process, such as air and water, while retaining ice inside.

The uniformity of the ice distribution in the produce containers is an very important factor in rapid and uniform cooling [48]. For efficient cooling, the injected ice should remain within the container while water in the slurry should easily drain away [65]. Well designed containers and adequate ice particle size provide efficient and uniform cooling throughout the entire container and throughout the entire stack of containers and minimize energy losses [47]. For example, 12% total opening area made from 3.2 mm width slots allow a surface area large enough to promote air circulation for forced-air cooling and minimize ice losses through wall openings during liquid-ice cooling[43].

Vigneault et al. [48] preformed a study on the effect of the size ice particles on broccoli’s surface temperature, the ice remaining the in broccoli boxes, and the icing efficiencies. They determined that ice particles ranging from 4.1 to 5.1 mm was ideal. Vigneault et al. [47] derived an expression to compute the mass of ice lost through container openings during liquid-ice cooling as a function of the size of openings on the container and ice particle size. This expression can be used to compute the size of the container openings to minimize losses during liquid-ice cooling.

Containers should include handle openings to provide a convenient place for ice injection using nozzle or slot injection system of the various icing machine currently available for liquid-ice cooling process.

4.4. Vacuum cooling

Water resistant containers are not required for vacuum cooling, which reduces container cost. The type of container used in vacuum cooling has a negligible effect as long as it is not airtight and does not have an airtight liner [17]. Tightly sealed plastic film wraps act as a barrier to water-vapor release and slow cooling [66]. Tiny holes in the plastic will normally allow adequate water vapor transmission for rapid cooling while still reducing water loss during subsequent marketing [67]. Plastic-film box liners can also be used in packages of vacuum-cooled produce as long as they are only folded over the top of the produce or not sealed. In general, any container designed for forced air cooling should meet the requirements of vacuum cooling.

5. Characteristics

5.1 Size and palletization

Pallets are plastic or wood made platforms on which containers of produce are placed for transport and storage. Many sizes are available as there is no official standard size. However, a widely used pallet size in North America and Europe is 1.0 m wide by 1.2 m length and has evolved as the unofficial standard size [8]. This pallet can hold anywhere between 20 to over 100 individual packages, depending on package size [8].

Wider or higher produce stacks increase the resistance to cooling fluid flow in precooling, storage and transport [15]. This usually causes longer precooling times and greater temperature difference among packages in storage. It also increases the total energy used per unit for precooling compared to the same mass of produce palletized in a narrower stack. Cooling systems for horticultural produce packed in containers are usually designed for air to flow across a given type and width of produce. Special care must be taken when modifying any characteristic of the packaged produce; including pallet size, container configuration (size and opening size and distribution) or produce porosity.

Produce containers are generally stacked two- or three-across on a pallet. When container openings are restricted (2 to 5% of total surface area), using the same total opening surface and stacking one box wide would permit more airflow resulting in faster cooling with a lower static pressure loss [10]; but, making a container so large that one dimension is equal to a dimension of the pallet is clearly not commercially feasible for boxes handled by people. However, number of boxes stacked on the same size pallet would not have any effect on required cooling period and static pressure loss if using container of larger total opening (over 25% of the total surface) [15,16].

The container must sized to fit the produce item packed in it. The produce should fit well inside the container, with little wasted space. Small produce items that are spherical or oblong (such as potatoes, onions, and apples) may be packaged efficiently utilizing many package shapes and sizes. However, other produce items such as asparagus, berries, or soft fruits may require containers specially designed for them [8].

Standardization of pallet and container size can reduce pallet inventory, facilitate reuse and reduce cost. RPC footprint design should be based on the commonly used palletizing system and the size of the produce to be packed. The size of RPCs already used by the horticultural industry of North American and many European countries corresponds to 5 containers per layer on a standard 1 m by 1.2 m pallet, resulting in RPC dimensions of 400 mm by 600 mm. RPC height is chosen to suit the weight and size of the produce.

5.2. Container height

One of the most important heights to be considered in the design of any container is the external height of common punnets. By convention, the punnet is a small, light and rectangular basket or container in which small fruits or vegetables such as strawberry, cherry, cherry tomato or small potatoes are packaged. The height of the punnet is more or less standardized at 110 mm and the overall height of the container design for their handling is 127 mm. Three other RPC overall heights are also generally used around the world (182, 203 and 268 mm), but no real standardization exists as of yet [37]. Standardizing the height and footprint of RPCs is critical to avoiding incompatibility, common in mixed load handling.

5.3. Weight

The individual weight of a container plays a relatively important role where and when vehicle weight limitations are applied. A lighter container allows more net produce to be stowed in a vehicle before the limitation is met, resulting in a lower transport cost per unit of produce. A lighter container is also easier to handle at point during the transportation and handling process between the field to the consumer. Net produce weight is usually limited to around 23 kg for worker protection purposes. However, this limitation varies considerably due to worker capacity, the national and local regulations, and working conditions. In North America, net produce weight is limited to 22.7 kg [50].

The ratio of weight to volume varies with different packaging materials. For example, injection molded plastic used for RPC has a density about 33 kg m^{-3} of gross volume, where a lighter plastic such as polystyrene is about 9.7 kg m^{-3} of stored volume. Fiberboard, depending on its thickness, normally is about 22 kg m^{-3} of stored volume [50].

5.4. Container shape

Empty tapered wall containers can be quickly nested to occupy a small volume resulting in a low return cost to the owner or transportation to the next user. Vertical-wall RPC containers can be collapsed, but they require more time for handling than nestable containers. However, filled vertical-wall containers generate a better volumetric efficiency than tapered-wall containers because they have no free space between each other. Free space between container has a negative effect on air circulation and indirectly decreases cooling efficiency [18].

5.5. Ability to interlock

Load shifting, container collapsed and a column of container falling are commonly encountered events. These damage produce, rendering them unmarketable and pose a safety hazard to workers. Interlocked containers stabilizes the load and decrease problems associated with load shifting during transport and handling. Container design must allow boxes to be interlocked [43] unless the containers are used in a system with added unitizing materials.

Corrugated fiberboard boxes have best compression strength when all the boxes are aligned (column stacked). Interlocked stacking (cross-stacked) patterns are popular because they provide more stability than column stacking. In an interlocked pattern, each layer is arranged in opposing directions to the layer below. However, the corners are not aligned, with three or four corners resting on side panels. This reduces compression strength by 45% to 55% [50]. A good compromise for stability and compression strength is to use a mixed pattern where the bottom layers of the load are column stacked and the top layers are cross-stacked [50].

Special container base and top edges have been designed to allow interlocking when containers are either column or cross-stake [43]. Other unitizing methods include application of glue between successive layers of fiberboard containers, utilization of rigid vertical corner device and plastic or metal wire bound, and wrapping with plastic film, perforated film or net.

5.6. Cost

A 2006 survey of California table grape containers showed that RPCs were the least expensive box type. A corrugated fiberboard container cost about 20% more than the cost of leasing an RPC. Expanded polystyrene (EPS) and wood boxes cost about 50% more than RPCs. However a leased RPC by contract must be used quickly and can not be used for long term produce storage. RPCs and corrugated fiberboard also have costs associated with forming or assembling the container before use. EPS boxes are delivered already assembled but have significant storage costs because the EPS forming machinery is used all year but the boxes are generally needed only a few months during the year.

6. Other considerations

6.1. Environment

As environmental awareness increases, container disposal becomes a great concern in many countries. Containers disposed in landfills can take 200 to 400 years to break down [8]. Container material should either be recyclable or reusable. If the container cannot be reused or recycled and must be discarded in a landfill, it should be made out of biodegradable materials. A growing number of North American and European grocery stores, supermarkets and many export markets have waste disposal restrictions or fees for packaging materials that are not recyclable or reusable.

Corrugated fiberboard containers can easily be recycled if they are made of a single material and do not have too much ink [50]. Wax coated corrugated fiberboard containers cannot be recycled. In USA, several states and municipalities have recently taxed wax cartons or have instituted rigid back haul regulations. Due to this, RPC may eventually replace wax cartons or, forced-air cooling may replace package icing and hydrocooling [8].

RPCs can be folded, cleaned and shipped back to the suppliers. Management of RPC includes two types of ownership. The simplest is a single industry or a group of producers who regularly deliver produce to a single market or a group of markets located a fairly close distance. The owner can wash and reuse the containers in a short period. This method is the cheapest but produce is rarely marketed in a small closed system like this.

The second RPC managing system involves a third party between the producer and the fresh produce marketing system. The third party owns the containers and rents them to the producer and collects them after use at the marketing sites. To be viable, this third party system must be based on a very wide region such as Europe or North America as the fresh produce transit often in such wide region. The transportation cost of empty containers can be reduced by always using the closest available container. This triangular managing system utilizes companies specializing in logistics management. Traceability systems are used firstly to manage produce quality but also container statute and localization [37,68]. The traceability system also should account for environmental and bio-chemical conditions to guarantee produce is not contaminated by chemical or biological produces previously shipped in the same container [69,70].

With both systems, the containers must go through a washing process prior to re-use which can mean additional handling although some larger packing houses and retail distribution centres have their own washing plants. The washed containers must be kept clean by wrapping them in plastic sheeting to protect them from dust and contamination. During storage containers should occupy the least amount of volume. For that purpose, the containers should have tapered walls for nested stacking, or they should be collapsible.

6.2. Global system

In order to facilitate reuse of RPCs at minimum cost, standardization must be established. In the U.S. alone, 1,500 different types of packages exist for produce [8]. Standardization of containers is not an easy task because different groups have different criteria for container design. Grocery stores are concerned with the marketing and want containers with colorful labels and graphics to entice the consumers. Shippers and transporters want containers which are easy to handle and transport, while producers may want containers which precool efficiently [8].

Designing an optimal standard container to meet everybody’s needs is nearly impossible as there are too many constraints. Many compromises will have to be made. For now, each commodity has an unofficial standard for packing and each container design is based on a specific commodity or group of commodities. Depending also on the location, there may be regulations that restrict container design [8].

6.3. Energy

Considering the total mass of produce to be handle from the producer to the consumer, and the increase of the energy cost, the design of any container or handling system must consider the energy involving in that hole process. For example, as discussed earlier the total surface of opening on the side wall of a container should be between 8% and 16% of the container [62] for minimizing the energy required during the cooling process. This configuration was calculating the energy requirement while using airflow rate of 0.5 to 3.9 L s^{-1} kg^{-1} and produce respiration rates covering the entire range normally encountered with fresh fruits and vegetables. The minimum calculated energy requirement for any produce could be calculated based on its respiration rate and the percentage of opening [62]. The operating conditions of any precooling process, storage system or transportation method should be calculated or chosen to minimize the total energy required. Important energy saving could be realized by optimizing the operating conditions without decreasing the final quality of the fresh produce, and often even resulting in an increase of the final quality of the fresh produce.

Minimizing the energy use associated with containers is generally difficult to accomplish in commercial practice. The entity who purchases the containers or sets a standard for the containers may have no interest in the energy use associated with cooling the produce. For example, if a chain store prescribes the container design it will likely consider only factors that reduce handling costs and facilitate marketing. An entity independent from the any harvest and postharvest horticultural produce management should be involving in the preparation of any standard concerning the container to avoid bias standard. This independent entity must consider the entire harvest and postharvest horticultural produce handling system and all the environmental, socio economical and energy aspect in the development of such standard.

References

1. Garcia, E., and Barrett, D. 2004, Processing Fruits, Science and technology D. Barrett, L. Somogyi, and H. Ramaswamy (Eds.), 2nd edition. CRC Press, Boca Raton (FL), 53.
2. International Institute of Refrigeration. 1995, Guide to Refrigerated Transport. International Institute of Refrigeration, Paris, France.
3. FAO. 2003, Summary of Food and Agriculture Statistics. Food and Agriculture Organisation of the United Nations. Rome, Italy.
4. Camargo, G., and Perdas, A. 2002, Agrianual, Anuário da Agricultura Brasileira, 41.
5. Anonymous. 2006, Singapore to implement new cold chain standards. ColdStoreDesign.comNewsletter. http://newsletter.coldchainexperts.com/August06/CCEAugust.htm
6. Kader, A.A. 2002, Postharvest Technology of Horticultural Crops, 3rd ed. Coop. Ext. Uni. of Ca. Div. Agric and Nat. Res. Univ. of CA, Davis (CA), Publication no. 3311.
7. Cortez, L.A.B., Honório, S.L., and Moretti, C.L. 2002, Resfriamento de frutas e hortaliças. Embrapa Informação Tecnológica, Brasília, DF, Brasil.

8. Boyette, M.D., Sanders, D.C., and Rutledge, G.A. 1996, Package requirements for fresh fruits and vegetables. The North Carolina Agricultural Extension Service. North Carolina State University, Ralley, NC. USA. Publication no 9/96-3m-TWK-260373-AG-414-8.
9. Tanner, D., and Smale, N. 2005, Stewart Postharvest Rev., 1: 1.1
10. Thompson, J.F., Mitchell, F. G., Rumsey, T.R., Kasmire, R.F., and Crisosto, C.H. 1998, Commercial cooling of fruits, vegetables, and flowers. Univ. Calif. Div. Agric. Nat. Res. Pub., 21567.
11. Boa, W., and Lindsay, R.T. 1976, ARC Res. Rev., 2 (3): 86.
12. Rennie, T., Vigneault, C., DeEll, J.R., and Raghavan, G.S.V. 2003, Cooling and storage. Handbook of Postharvest Technology : Cereals, Fruits, Vegetables, Tea, and Spices, M.A. Chakraverty, G.S.V. Raghavan, and H.S. Ramaswamy (Eds.), Marcel Dekker Inc., New York (NY), 505.
13. Boyette, M.D. 1996, Appl. Eng. Agric., 12(3): 213.
14. Castro, L.R., Vigneault, C., and Cortez, L.A.B. 2004, Int. J. Food Agric. Environ., 2(1): 135.
15. Vigneault, C., and Goyette, B. 2005, Cahiers Agricultures, 14 (4) :383.
16. Vigneault C., Markarian, N.R. da Silva, A., and Goyette, B. 2004, Trans. ASAE, 47 (3): 807.
17. Fraser, H.W. 1991. Forced-air cooling of Fresh Ontario Fruits and Vegetables. Ministry of Agricultural and Food, Toronto, Ontario, Canada. AGDEX 202-736..
18. Vigneault, C., and Goyette, B. 2003, Can. Biosyst. Eng., 45(3) : 23.
19. Bennet, A.H. 1963, USDA Tech. Bull., 1292.
20. Stewart, J.K., and Lipton, W.J. 1960, USDA Market. Res. Rep., 421.
21. Mitchell, F.G., Guillou, R., and Parsons, R.A. 1972. Commercial cooling of fruits and vegetables. Univ. Calif. Agric. Exp. Stn. Ext. Serv. Manual 43.
22. Pentzer, W.T., Perry, R.L., Hanna, G.C., Wiant, J.S., and Asbury, C.E. 1936. Precooling and shipping California asparagus. Univ. Calif. Agric. Exp. Stn. Bull. 600.
23. Perry, R.L., and Perkins, R.M. 1968. Hydrocooling sweet corn. Am. Soc. Agric. Eng. St. Joseph, MI: Paper 68-800.
24. Toussaint, W.D., Hatlow, T.T., and Abshier, G. 1955. Hydrocooling peaches in the North Carolina Sandhills. N.C. Agric. Exp. Stn. Agric. Env. Infor. Ser. 320.
25. Vigneault, C., Goyette, B., Gariépy, Y., Cortbaoui, P., Charles, M.T., and Raghavan, G.S.V. 2007, Postharvest Biol. Technol., 43 (3): 351.
26. Vigneault, C., Gallichand, J., Blouin L., and Jacob, G. 1990, Can. Agric. Eng., 32 (2): 285.
27. Silva F., Goyette, B., Bourgeois, G., and Vigneault, C. 2006, Int. J. Food Agric. Environ., 4(3&4) : 33.
28. Stewart, K.S., and Couey, H.M. 1963, Hydrocooling vegetables – A practical guide to predicting final temperatures and cooling times. USDA-Agricultural Marketing Service, Market. Res. Rep., 637.
29. ASHRAE. 1990. Refrigeration. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), Atlanta (GA).
30. Vigneault, C., Sargent, S.A., and Bartz, J.A. 2000, Plant Dis., 84(12): 1314.

31. DeEll, J. R., Vigneault, C., and Lemerre. S. 2000, Postharvest Biol. Technol., 18: 27.
32. Gaffney, J.J., and Baird, C.D. 1975, Proc. Fl. St. Hortic. Soc., 88:490.
33. Prussia, S.E., and Shewfelt, R.L. 11984, Ice Distribution for Improved Quality of Leafy Greens. ASAE, St-Joseph, MI. No. 84-6014.
34. Boyette, M.D., and Estes, E.A. 1992. Postharvest Technology Series : Crushed and Liquid Ice Cooling. North Carolina Cooperative Extension Service, North Carolina State University, AG-414-5.
35. Kasmire, R.F. 1974, Perishables Handling Newsletter. Univ. Calif. Coop. Ext., University of California, Davis (CA), Publication no. 39.
36. Goyette, B., Vigneault, C., Panneton, B., and Raghavan, G.S.V. 1996, Can. Agric. Eng., 38(4): 291.
37. Vigneault, C. 2006. Stewart Postharvest Rev., 3 : 2.1.
38. Barger, W.R. 1963. Vacuum Cooling. A comparison of cooling different vegetables. USDA Market. Res. Rep., 600.
39. Rennie, T.J., Raghavan, G.S.V., Vigneault, C., and Gariépy, Y. 2001, Trans. ASAE, 44(1): 89.
40. LeBlanc, D.I., and Hui, K.P.C. 2005, Stewart Postharvest Rev., 1 (4): 5.
41. McGregor, B.M. 1987, Tropical Products Transport Handbook, no. 668. Agriculture Handbook, U.S. Department of Agriculture, Washington, DC.
42. Pitchler, E.F. 2004. Embalagens para transporte e exportação. IPT-Instituto de Pesquisas Tecnológicas, http://www.ipt.br/imprensa/noticias/?ID=442.
43. Vigneault, C., and Émond, J.P. 1998. Reusable container for the preservation of fresh fruits and vegetables. United States Patent No. 5,727,711. Washington DC, US Patent Office.
44. Vigneault, C., and Goyette, B. 2002, Appl. Eng. Agric., 18(1):73.
45. Vigneault, C., and Goyette, B. 2002, Can. Biosyst. Eng., 44 (3): 3.7.
46. Vigneault, C., Goyette, B., Markarian, N. R., Hui, C.K.P., Côté, S., Charles, M.T., and Émond, J.P. 2004, Can. Biosyst. Eng., 46: 3.41.
47. Vigneault, C., and Goyette, B. 2001, Can/ Biosyst. Eng., 43: 3.45.
48. Vigneault, C., Goyette, B., and Raghavan, G.S.V. 1995, Can. Agric. Eng., 37(3): 225.
49. Castro, L.R., Vigneault, C., and Cortez, L.A.B. 2004, Trans. ASAE, 47(6) : 2033.
50. Luvisi, D.A., Shorey, H.H., Smilanick, J.L., Thompson, J.F., Gump, B.H., and Knutson, J. 1992, UC ANR bull., 1932.
51. Hanney, S. 2006, Lecturer Writtle College, UK. Personal communication.
52. Stone Container Corporation. 1992. Fiber box handbook. 20th Ed. Fiber Box Association, Rolling Meadows (IL), USA.
53. Thompson, J.F., Brecht, P.E., and Hinsh, T. 2002, Refrigerated trailer transport of perishable products. Agriculture and Natural resources, University of California, Davis (CA), Publication no. 21614.
54. Mitchell, F.G., Parsons, R.A., and Mayer, G. 1971, Calif. Agric., 25(9): 13.
55. Wang, J. K., and Tunpun, K. 1968, Trans. Am. Soc. Agric. Eng., 12(6): 804.
56. Émond, J.P., Mercier, F., Sadfa, S.O., Bourré, M., and Gakwaya, A. 1996, Trans. ASAE, 39(6): 2185.

57. Luvisi, D.A., Shorey, H.H., Thompson, J.F., Hinsch, T., and Slaughter, D.C. 1995, Packaging California table grapes. Univ. Calif. Div. Agric. Nat. Res. Bull., 1934.
58. Castro, L.R., Vigneault, C., and Cortez, L.A.B. 2004, Trans. ASABE, 47(6): 2033.
59. Vigneault, C., Castro, L.R., Goyette, B., Markarian, N.R., Charles, M.T., Bourgeois, G., Tang Line Foot, E., and Cortez, L.A.B. 2007. Can. Biosyst. Eng., 49(3): 13.
60. Vigneault, C., and Castro, L.R. 2005, J. Food Agric. Environ., 3(2): 93.
61. Vigneault, C., and Castro, L.R. 2006, Trans. ASABE, 49(5): 1.
62. Castro, L.R., Vigneault, C., and Cortez, L.A.B. 2005, Can. Biosyst. Eng., 47: 3.1.
63. Castro, L.R., Vigneault, C., and Cortez, L.A.B. 2005, Postharvest Biol. Technol., 38: 254.
64. Maul, F., Vigneault, C., Sargent, S.A., Chau, K.V., and Caron, J. 1997, Sensors for Nondestructive Testing. NRAES, Cooperative Extension Publication, Ithaca (NY), NRAES-97: 351.
65. Goyette, B., Hui, C.K.P., and Vigneault, C. 2000, Appl. Eng. Agric., 16(3): 259.
66. Harvey, J.M. 1963, ASHRAE J., 5(1): 41.
67. Cheyney, C.C., Kasmire, R.F., and Morris, L.L. 1979, Calif. Agric., 33(10): 18.
68. Doyon, G., and Lagimonière, M. 2006, Stewart Postharvest Rev., 3: 3.1.
69. Leblanc, D.L., and Vigneault, C. 2006, Stewart Postharvest Rev., 3: 4.1.
70. Toussaint, V., and Vigneault, C. 2006, Stewart Postharvest Rev., 3: 5.1.