

# HANDLING STRAWBERRIES

*for Fresh Market*



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*Did you know that . . .*

- the strawberry is one of the most perishable of all fruits?
- strawberry deterioration comes from three main sources: (1) physical injuries from harvesting and handling, (2) decay, and (3) self-destruction (natural senescence after harvest)?
- reducing strawberry losses must start with picker training and supervision?
- careful grading at harvest to prevent packing of overripe, injured, or diseased berries is essential to prevent spread of disease to healthy berries?
- good temperature management is the single most important factor in minimizing deterioration and maximizing strawberry shelf life?
- berries exposed to the sun after picking will quickly reach temperatures considerably above air temperatures?
- even a breeze of 5 miles per hour will warm fruit nearly to air temperature within 20 to 30 minutes?
- cooling delays of longer than 1 hour will reduce the percentage of marketable strawberries?

# HANDLING STRAWBERRIES *for Fresh Market*

E. GORDON MITCHELL

*Extension Pomologist, Emeritus*

*Department of Pomology*

*University of California, Davis*

ELIZABETH MITCHAM

*Postharvest Pomologist*

*Department of Pomology*

*University of California, Davis*

JAMES F. THOMPSON

*Agricultural Engineer*

*Department of Biological and Agricultural Engineering*

*University of California, Davis*

NORMAN WELCH

*Farm Advisor*

*University of California Cooperative Extension*

*Santa Cruz County*

*Photographs by Jack Kelly Clark*

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# Handling Strawberries for Fresh Market

Despite their high perishability, fresh strawberries are successfully marketed in large volumes over great distances. This success is possible only if careful attention is given to all details of fruit selection, handling, and protection. Since consumer acceptance of strawberries is based on past experiences combined with the visual appearance of fruit in retail displays, it is vital that all berry handlers (growers, shippers, transporters, and distributors) carefully select for high quality and then provide the protection needed to maintain that quality and minimize berry deterioration. Fruit quality is a combination of appearance (especially color and gloss), texture, flavor, apparent freshness, freedom from injury and decay, and nutritional value (strawberries are a good source of fiber and vitamin C and are fat free; see Appendix A). Handling practices during and after harvest influence all of these.

## Overview of Postharvest Handling Considerations

Strawberries are one of the most perishable fruits. Unlike many other fruits that are picked “mature-green” and ripened later, strawberries are essentially fully ripe at harvest. They have a high rate of metabolism and will destroy themselves in a relatively short time, even without the presence of decay-causing organisms. As living organisms, they must be kept healthy, for their health determines the quality of fruit that the consumer receives.

The structure of the strawberry makes it vulnerable to spoilage. It has a thin, tender skin that is easily broken. The seeds are easily torn away, and the flesh of the fruit is soft, making it vulnerable to crushing and bruising. Any injury may invite an attack by decay organisms to which this fruit is very susceptible.

Because of their high rate of metabolism and susceptibility to injury and decay, strawberries require careful handling to maintain postharvest quality. When the sun rises on a field of strawberries, deterioration of the ripe fruit is enhanced through high fruit temperature, which hastens decay development and internal breakdown of the fruit. This deterioration continues until the fruit are eaten. The quality of the fruit when the consumer receives them, or whether the fruit ever reach the consumer, depends on the care taken by the various handlers.

Each handler of strawberries, from the grower to the retailer, may do damage that is not seen until later in the marketing system. Such damage, which results in loss of fruit or fruit quality, ultimately affects the monetary returns to all handlers of strawberries.

## Importance of Temperature

The most important way to slow the spoilage and deterioration of strawberries is to remove field heat and to maintain the fruit at a low temperature. For maximum life, keep strawberries as near 0°C (32°F) as is practical.

Strawberry fruit will deteriorate quickly even if they are free of disease organisms. When the temperature of a strawberry is raised from 0° to 10°C (32° to 50°F), its deterioration rate increases two- to fourfold. This means that fruit at 10°C (50°F) have a life expectancy of only one-fourth to one-half that of fruit at 0°C (32°F). If the fruit are held near 30°C (86°F), as may happen in harvested berries left unshaded in the field, high respiratory activity (fig. 1) will reduce the market life of the fruit to only a few hours.

Other environmental factors that may be manipulated to benefit strawberry handling are the level of relative humidity and the carbon dioxide concentration of the atmosphere during holding and transportation. High relative humidity (90 to 95%) and high carbon dioxide (15%) may

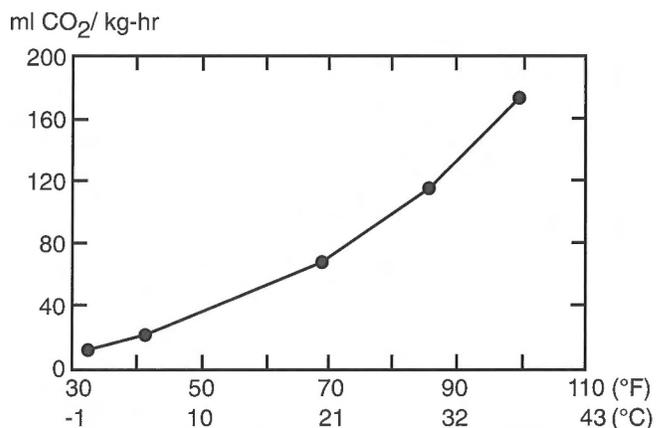


Figure 1. Temperature and respiration. Strawberries have a high rate of physiological activity as represented here by their respiratory rate. High temperatures raise this rate and thus limit postharvest life.

prolong shelf life, but these are only supplements to good temperature management.

### **Importance of Quality-Control Procedures**

A vital factor in the successful marketing of strawberries is the development and effective use of a good quality-control program, which must start in the field and extend throughout the marketing system. It must include field supervision to ensure selection of high-quality fruit, handling to avoid injuries, and avoidance of delays in achieving desired temperature management. Careful records should be kept of quality and condition (from sample grading), time delays in the system, temperatures, and relative humidity measurements.

### **Fruit Rots**

Fruit-rotting organisms are an important cause of strawberry fruit losses. Gray mold or *Botrytis* rot, caused by the fungus *Botrytis cinerea*, is the greatest single cause of fresh strawberry loss. This organism can invade flower blossoms and remain dormant in the fruit until ripening begins, and it can also enter wounds that occur during harvesting or handling. The organism causing the disease is always present in every strawberry field. Gray mold is most serious during rainy or foggy periods. Surface mycelia from infected berries can also directly penetrate adjacent sound fruit to produce an ever-enlarging "nest" of rotting berries, which may spread throughout the basket or crate of fruit. The organism grows rapidly at warm temperatures and continues to grow at 0°C (32°F) but at a very slow rate.

Other fruit-rotting organisms can also cause losses. One of these, *Rhizopus* rot, caused by *Rhizopus* spp., can result in severe losses at warm temperatures, but it does not grow below 5°C (41°F). The advent of good temperature management has made it a less severe problem during marketing, but it may cause severe losses in the field. Infected fruit are soft and watery, giving rise to the name "leak." Under high-humidity conditions, the fungus produces a long, whiskery growth on infected fruit and, like gray mold, the fungus can spread from infected fruit to adjacent healthy fruit, producing a nesting effect.

Field sanitation and disease control, avoidance of berry contact with wet soil, avoidance of fruit injuries, grading to remove rotted and injured berries, and good temperature and humidity management are all important. Under some conditions, high-carbon dioxide treatment during transport can also help to reduce decay incidence and severity.

### **Fruit Bruising**

Strawberries are susceptible to serious bruising injury during harvest and postharvest handling. Studies of strawberry losses have shown that most injuries occur in the field during picking and packing and that differences in magnitude of mechanical injuries caused during picking could be so great as to mask other causes of fruit deterioration.

Often berries may be damaged by the basket edges as a result of being packed over the tops of baskets within the crate. Some overpacked fruit may also be injured by abrasion against the corrugated board of the crate. Such injuries may result in direct berry loss, and injured fruit are more susceptible to gray mold. Proper crate packing and good picker supervision help reduce berry injuries and subsequent fruit-rot problems.

Transit vibration (or "roller") bruising, which causes severe losses in many fruits, also damages strawberries. Varieties differ in their level of susceptibility, and new varieties can be evaluated for relative susceptibility to the injury through simple tests. Selection of transport vehicles that limit the vibration potential (such as those with air-suspension systems) may also help to minimize transport injury. Because the tractors of long-haul trucks usually have air-suspension systems, partial loads of strawberries should be placed near the front of the trucks to benefit from such equipment. When vibration damage occurs, it will normally be most severe in crates on the top of the load.

### **Fruit Water Loss and Shriveling**

Strawberries are subject to rapid water loss, causing them to shrivel and appear old and deteriorated and causing the berry calyx (the green cap) to wilt or dry. These symptoms will affect fruit appearance before they affect actual eating quality. Avoidance of delays between harvest and cooling, rapid and thorough cooling, low holding temperatures, and 90 to 95 percent relative humidity during holding, all help to reduce fruit shriveling potential.

### **Overripeness and Senescence**

Because of their high rate of physiological activity, strawberries quickly pass from a ripe to an overripe or senescent state if held at warm temperatures. Proper maturity selection and good temperature management are important in minimizing the losses resulting from the development of senescent breakdown of overripe strawberries.

## **Strawberry Harvesting and Field Handling**

Strawberry growers and harvesters play a key role in determining fruit quality and deterioration throughout marketing and distribution. Important factors in the field include preharvest disease control and field sanitation; maturity selection; avoiding fruit injuries while harvesting and packing fruit into crates; grading to eliminate injured, diseased, and defective fruit; protection from warming; and prompt movement from field to cooler.

Field disease control may include use of fungicides, removal of all diseased fruit from the plants at each harvest, and avoiding fruit contact with damp soil. In using fungicides, one should follow label instructions on proper use of the material.

## Strawberry Harvest and Grading

Berries are picked with the caps (calyxes) attached. The picker holds the fruit gently between thumb and fingers and, with a sharp upward or forward twist of the wrist, snaps the berry free from the stem (fig. 2). Some special stem-grade fruit are picked by pinching the stem about 5 cm (2 in) from the calyx.

The fruit must be loosely held in the hand without squeezing. Any squeezing of the fruit will cause bruising injury and discoloration. The strawberries must be handled gently. They should be placed into the crate, not dropped into it. To avoid fruit injury, only a few fruit should be held in the hand at any one time. Although crates need to be well filled for marketing, they should not be filled so full that berries are crushed when crates are stacked.

Harvest should be as frequent as needed to avoid over-mature fruit, and any overripe berries should be diverted to processing or discarded. Fruit color should be within a fairly narrow range when harvested (normally at least three-fourths of the surface showing red color) so that all berries will respond to handling conditions in a similar manner. Fruit should be sorted carefully to remove even small fungal lesions and injuries (cuts, finger bruises, torn or removed calyxes, etc.), and care should be taken to avoid wounding the fruit during harvest and packing operations. Harvesting, grading, and packing are done simultaneously by the pickers in the field (fig. 3). The crates are usually placed onto a picking cart or stand, which keeps the crate off the ground and facilitates easy packing by the picker during harvest (fig. 4). Pickers must be careful that their feet and knees do not injure blossoms or green fruit that are hanging down along the sides of the furrow because this can reduce the quantity and quality of later harvests.

Any berries that show rot, sunburn, insect feeding, severe deformity, softness, or overripeness should be removed from the plant but not placed in the shipping container. Fruit should also be discarded if the calyx has been accidentally removed during picking.

### Avoiding Picker Damage

Picker damage can nullify all other attempts to maintain fruit quality. Picking and packing into the crates can cause substantial fruit injury. Because picker performance can be extremely variable, training and careful supervision are needed to minimize physical injuries to the berries. In a series of tests, fruit injury was measured following picking and packing. Four pickers were used, each of whom picked the same number of crates (usually four). These measurements were taken from the fields of five different growers at different times during the season. There was a moderate range in the scores of the best pickers (1.1 to 1.6), but a large difference in fruit injury between the best and the worst pickers for all five grower locations (average

**Table 1. Strawberry injury scores related to pickers**

Grower no.	Best picker score	Worst picker score
1	1.1	1.6
2	1.2	2.2
3	1.4	1.8
4	1.4	2.5
5	1.6	2.6
Average	1.3	2.1

Score: 0 = no damage; 1 = slight; 2 = moderate; 3 = severe.

1.3 to 2.1) (table 1). Good field supervision and training pickers to handle berries carefully are both extremely important in reducing these injury problems.

### Field-Inspection Program

Of great importance is a field-inspection program designed to ensure that grade standards and product quality—including uniformity and level of maturity, freedom from defects, avoidance of injuries, and overall uniformity of pack—are being maintained. Written inspection records should be routinely available to supervisors to guide them in maintaining an acceptable level of fruit quality.

### Packing Fruit into Trays

Strawberries in California are frequently shipped in corrugated fiberboard trays holding twelve 1-dry-pint baskets. Open mesh plastic baskets are most commonly used. The plastic baskets are often not capped, and the crate is not lidded for subsequent handling. The California industry began shifting to several new package systems in 1993. All of them are compatible with 120 × 100 cm (48 × 40 in) pallets, which are standard in the grocery industry. This allows the fruit to be handled in the wholesale distribution chain without restacking. This size pallet is also reusable and is the size used by pallet pool organizations.

The corrugated fiberboard trays hold 4 to 5 kilograms (9 to 11 lb) of fruit, usually in 1-dry-pint or 1-dry-quart capacity polypropylene mesh baskets (fig. 5). Clear lids are sometimes used with the baskets. One of the new designs uses a 1-pound basket made of clear thermoformed plastic with a hinged lid (fig. 6). The basket can be placed directly on the retail display without repacking or adding a cover.

Trays are grouped together in a two-tray stack with wires at both ends of the trays. The wires protrude above the tray top and fit into slots in the tray stacked above (fig. 7). Fiberboard tie sheets are placed on top of the sixth, tenth, and top tray layers. Wires and tie sheets stabilize the pallet load and protect the fruit so that pallet wraps or strapping are not used.

### Protection from Warming and Prompt Movement to Cooler

Berries should be protected from warming while they remain in the field. Because of their dark color, strawberries



Figure 2. Proper holding and twisting of the fruit with the attached cap (calyx) allows the fruit to be snapped free of the stem.



Figure 3. A strawberry harvest operation. Picking from only half the bed on each side of the picker eliminates excessive reaching and simplifies selection of ripe berries.



Figure 4. The small, wheeled cart keeps the crate clean and at a convenient height for packing the fruit.



Figure 5. Newer package design holding 4 to 5 kilograms (9 to 11 lb) of fruit in twelve 1-dry-pint polypropylene mesh baskets.



Figure 6. Newer package design holding eight 0.45-kilogram (1-lb) baskets made of clear thermofomed plastic with hinged lids.



Figure 7. Packed crates are loaded onto shipping pallets directly on small delivery trucks in the field. Note the plastic liner over the wooden pallet, which may be used later with sealed pallet bags for carbon dioxide treatment before transport to market.

in direct sun exposure absorb heat and can quickly warm to above air temperature. With prolonged delays after picking, such exposed fruit can warm many degrees above air temperature (fig. 8). Shading can help to keep pulp temperatures of harvested berries below air temperature, but the amount of fruit warming depends on the temperature difference between fruit and air, the duration of exposure, and the amount of air flow over the fruit (breezes). If other shade is not available, then inverting empty crates over stacks of harvested fruit can help to avoid warming, even during very short delays in transporting the fruit. Enough trucks should be available so that fruit can be sent from the field to the cooler every hour.

Severe deterioration occurs if strawberries are held in the field for prolonged periods, as indicated by the relationship among time, berry temperature, rate of physiological activity, and deterioration (figs. 1 and 9). Obviously, prolonged delays at extremely high temperatures result in reduced market life of the fruit. When berries are picked under cool conditions and properly shaded in the field, the rate of spoilage occurs at a somewhat slower pace. If the berries are harvested when cool,

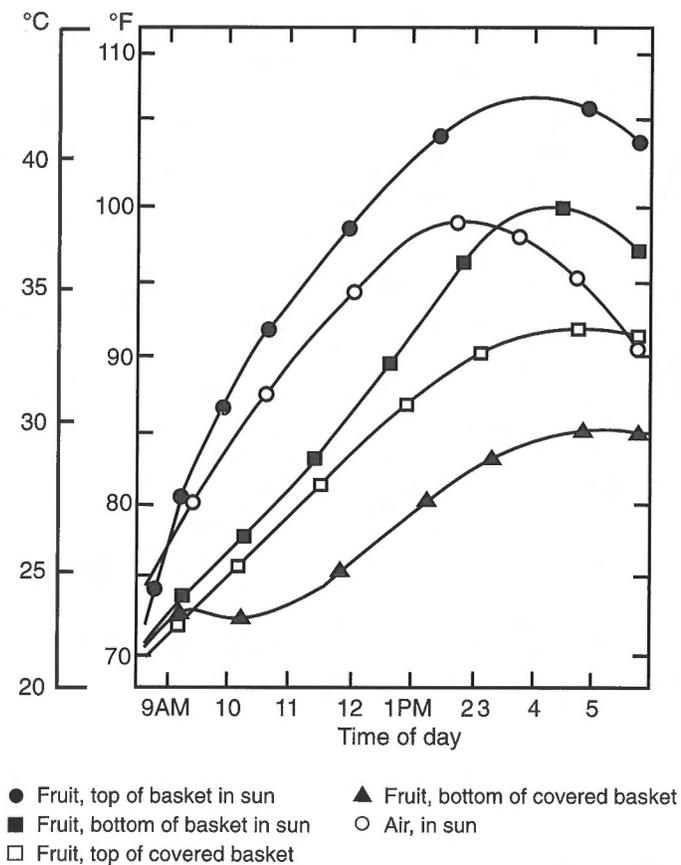


Figure 8. Simulated tests show that strawberries crated in the field should not remain exposed to the sun. Temperature is ambient air temperature.

but held in the field until air temperatures have warmed, then rapid fruit warming occurs during transport. Tests on the effect of air speed on strawberry warming showed that even a mild breeze of 5 miles per hour over the fruit results in warming nearly to air temperature within 20 to 30 minutes. Some evaporative cooling occurs as water is removed from the fruit, and thus berries in the center of the basket—which are somewhat protected from the air—are not warmed to air temperature. This water loss, however, causes further reduction in fruit quality.

## Preparing Harvested Strawberries for Market

Handlers can influence the ultimate quality of fresh strawberries by assuring that their fruit meet the desired quality standards, by properly protecting the fruit under their control, by properly preparing the fruit for transport, and by ensuring that reasonable loading procedures are used.

### Temperature Management

Good temperature management, including rapid cooling and maintenance of low pulp temperatures, is the single most important factor in minimizing strawberry deterioration and maximizing postharvest life. Constant circulation of delivery trucks to and from the field is required, and frequent, small loads must be delivered to the cooler. Arriving fruit should be moved promptly to the cooler without delays for inspection or other processing.

Because of the harmful effects of delays in cooling, it is recommended that cooling begin within approximately 1 hour of picking (fig. 9). All strawberries in California are forced-air cooled to remove field heat and cool the fruit to storage temperature as soon as possible. Forced-air cooling is a specific method of cold-air management in which pal-

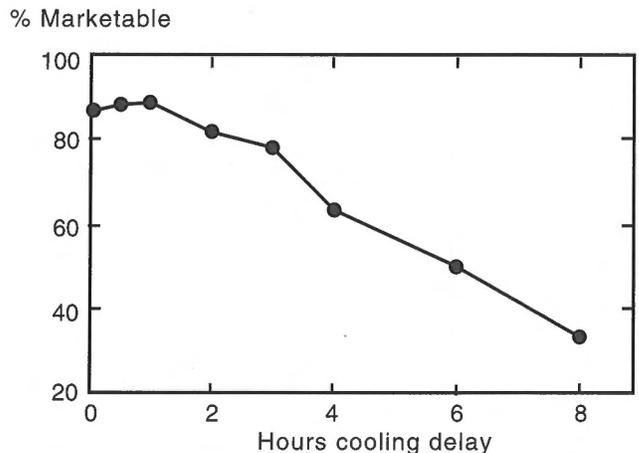


Figure 9. Cooling and deterioration. Strawberries should be cooled as soon as possible after harvest; delays beyond 1 hour reduce the percentage of marketable fruit.

lets of fruit are positioned so that cold air must pass through package openings and around individual berries. In the most common design, a tunnel is formed by leaving space between two rows of loaded pallets and then covering the opening with a tarp, except where an exhaust fan is located (figs. 10 and 11). With the exhaust fan operating, air is removed from the tunnel, creating a slightly negative air pressure within the tunnel. Cold air from the room then flows through package openings and around the warm fruit to reach the low-pressure area. The design of the strawberry crate commonly used in California, with its large side-ventilation openings, allows large volumes of air to move across packed berries with only modest air-pressure differences, and berry cooling can be quite rapid. Approximate air-flow characteristics needed for cooling strawberries in standard corrugated crates used in California are shown in table 2.

Seven-eighths cooling time is the time required to cool the berries seven-eighths of the difference between their initial temperature and the temperature of the cold air. A 24°C (75°F) strawberry in -1°C (30°F) air is 7/8 cool when it reaches 2°C (about 36°F). Under these conditions, more than 7/8 cooling would be needed to achieve a desired holding temperature. If a 2-hour 7/8 cooling period were used, fruit that reached 2°C in 2 hours, would reach about 0.5°C (33°F) within 3 hours. All of these values are based on the warmest fruit in the pallet (on the downstream position, inside the tunnel). The static pressure can vary significantly along the length of the tunnel cooler, with the greatest pressure near the fan. For this reason, the pallet farthest from the fan usually contains the warmest fruit. As every system is somewhat different, fruit temperatures should be monitored during several tests to determine where the warm spots are in the system, and then those spots should be routinely monitored. A guide to troubleshooting slow-cooling problems can be found in Appendix B.

**Refrigerated Holding**

Because of their extreme perishability, strawberries should be marketed as rapidly as possible after harvest. Depending on their handling and harvest maturity, strawberries may have a market life of 1 to 2 weeks. Strawberry coolers and holding facilities should be maintained as close to 0°C (32°F) as possible with minimum temperature fluctuation. The highest freezing point that has been reported for strawberries is -0.8°C (30.6°F), but the freezing point depends on the soluble solids concentration—higher soluble solids result in a lower freezing point.

Strawberries and their calyxes are quite subject to shriveling and wilting as a result of water loss. Water is lost as water vapor that moves from open intercellular spaces within the fruit to the outside. The “skin” of the strawberry offers little protection against this water-vapor movement. Water vapor moves from areas of high concentration (high water-vapor pressure) inside the fruit, to areas of lower concentration in the air surrounding the fruit. The

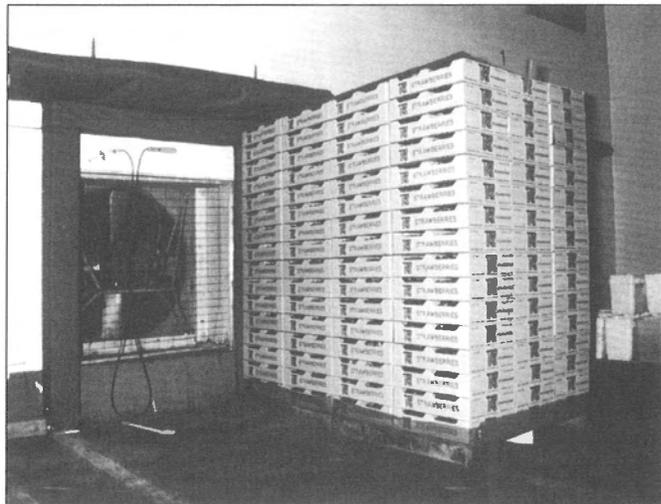


Figure 10. Strawberry pallets arriving from the field are placed in forced-air cooling; pallets are stacked on either side of an exhaust fan to create a forced-air cooling tunnel.

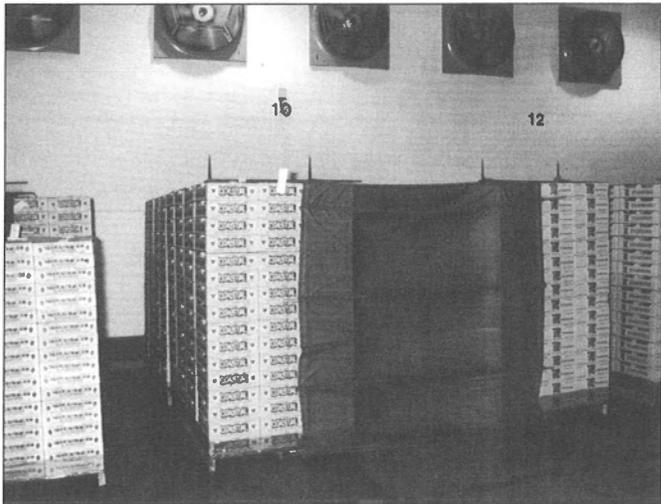


Figure 11. A completed forced-air cooling tunnel in operation. With the space between the pallet rows covered and the exhaust fan operating, air is drawn from the tunnel. This creates a slight vacuum that causes cold room air to be pulled through vent holes in the crates, quickly cooling the fruit.

**Table 2. Air-flow characteristics and time to cool strawberries**

Hours to 7/8 cool warmest fruit	1.5	2	3	4
Air flow (cfm/lb berries)	2.0	1.4	0.8	0.5
Static air pressure across pallet (inches of water)	0.40	0.20	0.08	0.04

rate of water-vapor movement is directly related to the vapor-pressure differences within the system. Because warm fruit in cold air lose moisture rapidly, maintaining 90 to 95 percent relative humidity in storage areas is necessary to minimize water loss.

Some temporary holding of strawberries is often essential to achieve orderly marketing of the fruit. The duration of such holding should be kept as short as possible in order to minimize deterioration before transportation. It may be difficult to maintain the fruit temperature near 0°C (32°F) in a holding room if considerable in-and-out traffic occurs. Only cold fruit should be added to the holding room, and warm fruit should not have to pass through a holding room to be placed on the forced-air cooler. If constant in-and-out operations occur, it may be desirable to provide for some barrier, such as air curtains, to minimize heat leakage into the system.

Anyone handling strawberries in holding-room conditions should consider the use of electric forklifts rather than petroleum-fueled forklifts. In operation, a petroleum-fueled forklift can generate more heat than the strawberries that are being held in the room. There are also serious concerns about worker safety if carbon monoxide produced by the petroleum-fueled forklifts is allowed to accumulate in the room.

### Carbon Dioxide Treatment

Some California and Florida strawberries are shipped under elevated carbon dioxide, sometimes called modified-atmosphere transport. This treatment may be useful in slowing the physiological activity of the berries, thus slowing their rate of deterioration. It can also reduce the spread and development of rots (especially gray mold). This effect on gray mold development is measurable at transport temperatures above about 2°C (36°F), when growth and spread of the rot are more active. The value of carbon dioxide treatment depends on the transport time and temperature and on the decay potential of the fruit. The greatest benefit would be expected in periods of cool, moist, or foggy weather, when free water might collect on berries in the field, and when gray mold spread would be expected to be most severe.

The standard method of carbon dioxide treatment is to enclose pallet loads of cold berries in sealed plastic bags (fig. 12), remove a predetermined amount of air, and replace it with carbon dioxide to create a 12 to 15 percent carbon dioxide atmosphere within the pallet bag and around the fruit (fig. 13). With proper selection of the bag materials and proper sealing, atmospheres can be kept near this 12 to 15 percent carbon dioxide level during transport. Leakage from the bag must approximately balance the amount of carbon dioxide produced by the berries through respiration. In preparing pallets for carbon dioxide treatment, it is important that the fruit be thoroughly cold, since the plastic pallet cover will impede further cooling. All preparation and treatment should occur inside the refrigerated holding rooms, and pallet covers should be applied immediately before truck loading. This carbon dioxide treatment is normally provided as a commercial service using patented application procedures.

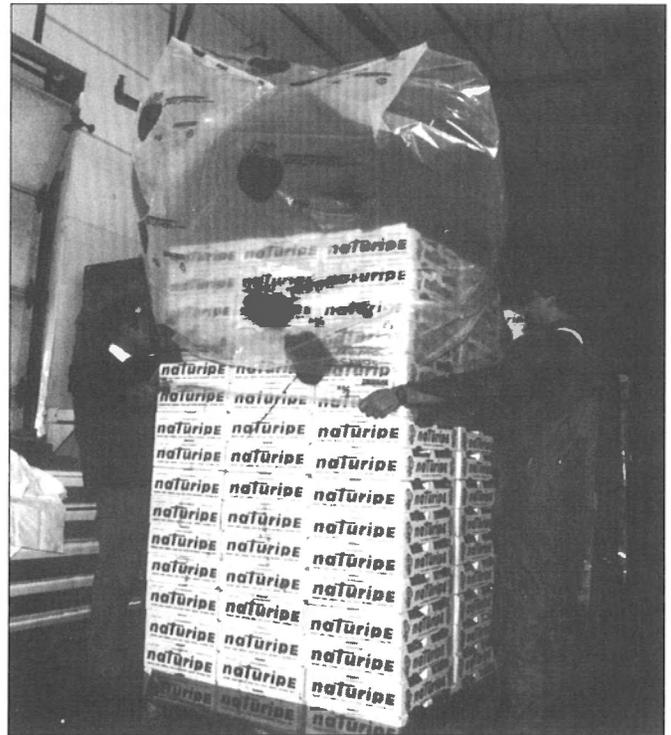


Figure 12. A pallet bag is placed over a pallet of thoroughly cooled strawberries; the bag will be sealed to the plastic pallet liner under the fruit.

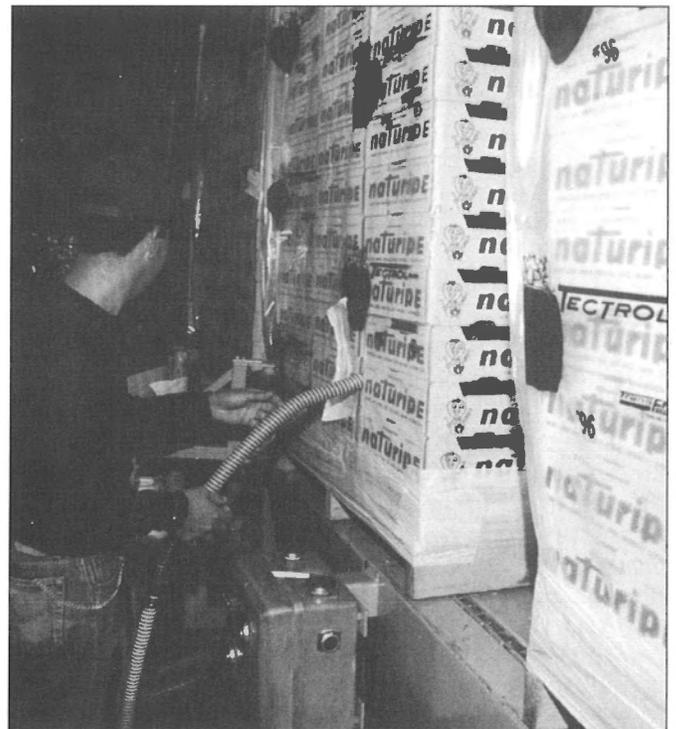


Figure 13. With the plastic bag and pallet liner carefully taped together, a nozzle pierces the bag to exhaust some air and then replace it with carbon dioxide. Tape will cover the point of injection in order to maintain the gas seal.

“Sweating” (water condensation) may occur on the plastic pallet bag after carbon dioxide treatment when the pallet bag is colder than the fruit or other surfaces inside the bag. The moisture that condenses on the inside surface of the bag is water vapor that has been released by the berries. If the berries are warmer than the air in the storage room at the time of bagging, this condensate problem may become severe. In addition, when fruit are held in bags for an extended period, they will warm as a result of their respiration, and “sweating” will increase. These are additional reasons to bag only thoroughly cooled fruit and to apply the bags just before market transport begins. Sweating can weaken crates and allow transport damage to occur, and the free moisture on the fruit may increase decay.

## Transporting Fresh Strawberries to Market

The time period during which fresh strawberries are in transport is a major portion of their total postharvest life. Thus, assuring good conditions, including maintenance of low fruit temperatures during loading and transport, is critical to the successful marketing of fresh strawberries. The shipper, the transporter, and the receiver can all exercise considerable influence on the successful movement of fresh strawberries to market.

### Refrigerated Loading

Refrigerated holding rooms or loading docks for strawberries should be equipped with sealed loading doors that allow berries to remain under refrigeration while they are loaded into transport vehicles (fig. 14). This avoids the potential for fruit warming that can occur with outside, ambient-air loading operations. Loading doors should remain closed except when vehicles are in place, and vehicles should be thoroughly cooled before they are positioned for loading.

Most fresh strawberries are now transported across the United States and Canada in mixed truck loads with other horticultural commodities. Thus, successful transport depends on the compatibility, condition, and temperature management of the other commodities in the load; the procedures used in separating commodities within the load from each other; and delays and conditions encountered during the loading of other commodities; as well as the condition and handling of the strawberries and the condition and proper operation of the transport equipment.

Any produce to be loaded with strawberries should be compatible—capable of transport under high (at least 90%) relative humidity, and temperatures near 0°C (32°F). Compatible produce is free of fumigants or natural volatiles that could cause injury or off-flavor development in strawberries. All of the produce, including the strawberries, should be thoroughly cooled with pulp temperatures near 0°C (32°F) when loading. Any additional produce

items to be subsequently loaded must also be near 0°C (32°F) since their temperature will affect the temperature of the strawberries in the load.

### Checking the Transport Vehicle

The transport vehicle should be thoroughly inspected to ensure that the refrigeration and air-flow systems are operating properly and that the vehicle and any contents have been completely cooled before strawberry loading begins. The vehicle—including the floors—should be clean, because blockage of air channels could compromise temperature management. All doors should be well sealed, and the entire vehicle should be free of damage that could result in heat leakage. If overhead air ducts are used to distribute cold air over the load, they should be in good condition. When possible, it is desirable that transport vehicles be equipped with air-ride suspension on every axle so as to minimize vibration of the fruit.

### Loading the Vehicle

Just as it is desirable for strawberries to be loaded through a refrigerated loading dock, it is also preferable that any subse-

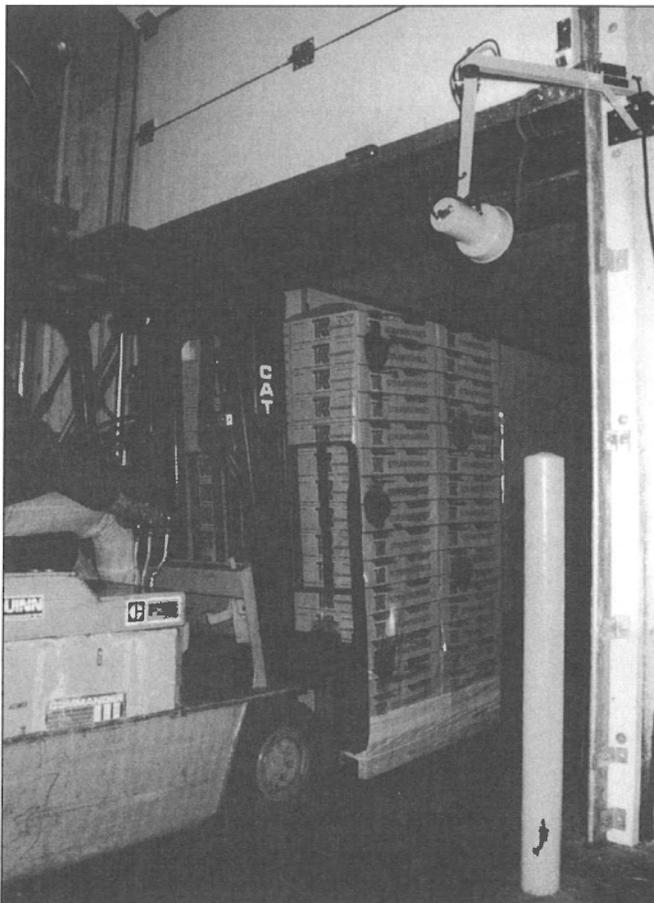


Figure 14. Strawberries are loaded into a refrigerated van; complete sealing between the van and the cold room prevents any fruit warming during the loading operation.

quent loading of the vehicle be through refrigerated docks, with the cold vehicle sealed to the dock during the loading operation. When this is not possible, the vehicle doors should remain open for the shortest time possible to achieve loading (of thoroughly cold product), and the air-distribution system should be turned off only while doors are open.

Experience suggests that damage to strawberries during transport is least when fruit are placed near the front and center of the vehicle. The tractor axle under the load is often equipped with air-ride suspension (for driver comfort), whereas the rear trailer axles most commonly have normal spring suspension. In mixed loads, strawberries and crates must be protected from water dripping from iced products (such as broccoli) with divider sheets. For top-air-delivery vehicles with back-to-front air flow through the load, all load dividers must be installed so they do not impede the normal back-to front pattern of air flow. This means providing opportunities for air flow under pallets and around the sides of pallets as needed. Bottom-air-delivery vehicles with bottom-to-top air flow have fewer restrictions related to use of load dividers.

**Center loading.** Past studies have shown that considerable heating of fruit can occur through trailer walls, and strawberries loaded against side walls may warm substantially during cross-country transport. This warming is especially severe with a southern exposure (the right side of the vehicle traveling east), which puts the truck in greater contact with the sun. The problem is most acute in trailers with smooth inside walls, where the cold air cannot flow between the fruit and the insulated side wall. Ribbed side walls, which allow considerable air flow, can minimize this heating problem.

To prevent warming during transport, the California strawberry industry pioneered the use of "center loading" of pallets, using dunnage blocks along the sides (between walls and pallets) to stabilize the load (fig. 15). This assures space for air flow between the trailer wall and the pallets. With wide trailers, a modification of center loading may be used to retain some space in the center as well as along the sides of the load. The latter spacing can be useful with mixed loads in back-to-front air-flow trailers, where maintenance of center air-flow spacing may be desirable for other palletized commodities.

**Loading bagged pallets.** Bagged strawberry pallets (with the high-carbon dioxide treatment) can be handled and loaded as other palletized produce. Care must be taken to avoid puncturing the bag. The bag will restrain air flow to the open spaces around the pallet surfaces, and this restriction must be accommodated in the loading pattern and installation of load dividers. As noted earlier, all strawberries must be thoroughly cooled to near 0°C (32°F) before bagging, and bagging should occur close to the

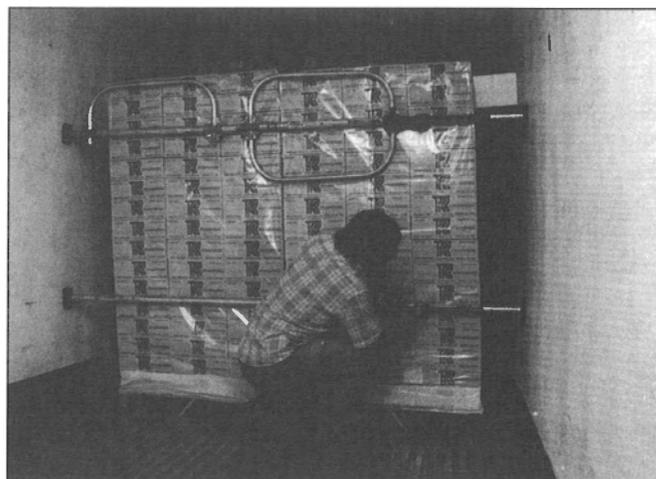


Figure 15. Strawberries have been "center-loaded" into this van. Air flow between the smooth van walls and the fruit minimizes fruit warming, and wooden braces at the floor and loading blocks (here foam plastic) near the top maintain load stability.

time of loading so that the fruit will not have warmed substantially as a result of respiratory heat.

### Setting the Thermostat

The vehicle thermostat should be set at as low a temperature as possible without danger of freezing the strawberries. If the freezing point is near  $-0.8^{\circ}\text{C}$  ( $30.6^{\circ}\text{F}$ ) and if the accuracy of the thermostatic control equipment of the vehicle is  $\pm 1.5^{\circ}\text{C}$  ( $\pm 3^{\circ}\text{F}$ ), then a  $1^{\circ}\text{C}$  ( $34^{\circ}\text{F}$ ) setting may be possible. Because of the heat produced by the respiration of the strawberries, and the limited air flow through the load, strawberries in the center of a pallet or load may be several degrees warmer than the thermostat setting by the time the load arrives in the market. The refrigeration should remain operational throughout transport, except during brief periods when doors must be temporarily opened to warmer outside temperatures for loading or unloading.

Although transport vehicles are normally equipped with recorders to monitor the temperature of the air leaving the refrigeration equipment, it is common for the shipper to install a portable recorder at time of loading. This will give the shipper information on the temperature of the air available to the load. When mounted over the load in a top-air-delivery van, these recorders monitor the temperature of the air before it passes through the load. This can be useful in determining how well air-temperature requirements have been met during transport. It does not tell the temperature of the berries, which may also be affected by the loading patterns and temperatures of other produce in mixed loads.

### Air Transport

Strawberries for air transport should receive the same preparation and protection as strawberries for surface

transport. Typically, small refrigerated trucks are used to transport the strawberries to airports. Berries should be cooled and loaded as discussed above, and the fruit should be kept cold as long as possible before being staged for air-cargo handling. Although some refrigerated facilities do exist at airports, they are generally limited in refrigeration capacity and air flow and are often inconvenient to the receiving and staging operations. Efforts should be made to minimize exposure of strawberries (pallets or air-freight containers) to sunlight, especially on hot tarmac staging areas. Upon arrival at the destination, the fruit should be promptly returned to refrigeration and re-cooled with the use of forced air to near 0°C (32°F) as quickly as possible.

There has been some concern that strawberries for air transport or for local marketing should not be cooled, because rewarming would exaggerate fruit deterioration (as a result of moisture condensation on cold fruit, which might expedite the development of fruit-rot organisms). Extensive studies have shown that the amount of deterioration is directly related to the duration of strawberry exposure to warm temperatures, with only limited influence of the pattern of warming and cooling cycles during that exposure (table 3). Strawberries should thus be thoroughly cooled and then re-cooled as needed to protect their quality and condition and to minimize deterioration. Although keeping the fruit constantly cold is best, any cooling is beneficial.

**Table 3. Effect of handling temperatures on strawberry deterioration**

Treatment (48-hour period)	Fruit condition (%)		
	Sound	Soft	Rotted
1. 48 hr at 5°C (41°F)	95	4	1
2. 24 hr each at 5° and 20°C (41° and 68°F)	76	10	14
3. 12 hr each: 5° to 20°C to 5° to 20°C (41° to 68° to 41° to 68°F) (equivalent to 24 hr each, as in 2)	70	7	23
4. 48 hr at 20°C (68°F)	44	1	55

## Care of Strawberries in Distribution and Retailing

Success in handling fresh strawberries in the distribution market and retail stores depends on the efforts made throughout the handling system to avoid deterioration. By the time the strawberries have reached the point of sale, they have been handled through the entire chain from grower to shipper to carrier to the distribution warehouse. This handling should have included careful grading and quality control, avoidance of injuries, rapid and thorough cooling, low-temperature maintenance, and possibly other special services such as high-carbon dioxide treatment before transport. Because strawberries are highly perish-

able and have a short postharvest life, it is vital that this protection continues in the market place.

### Receiving

Berries arriving in the distribution warehouse should be carefully monitored for fruit condition and temperature. Cold fruit in refrigerated vehicles should be unloaded directly into the 0°C (32°F) cold warehouse whenever possible. If the fruit are warmer than about 2°C (36°F), they will benefit by being re-cooled and held at 0°C (32°F). If they are cold, they should be protected from warming during the unloading operation. If reconditioning is required because inspection indicates the presence of decay, the fruit should still be placed at cold temperature, and small lots removed for sorting and returned to refrigerated space as soon as possible.

### Handling Bagged Pallets

Strawberries in pallets that have been bagged and treated with carbon dioxide will warm somewhat during transport as a result of their own respiration. The bags do not allow cold air to flow through the pallets to remove this respiratory heat. Because of handling abuses to the pallets during loading and unloading, it is likely that some of the plastic pallet covers will have been punctured and the high-carbon dioxide atmosphere will have been lost. It is thus important that these plastic bags be removed and the berries thoroughly re-cooled before final distribution.

### Recooling

Fruit that have been transported by air, or fruit that have not been well protected during surface transport, may be quite warm on arrival and should be quickly re-cooled. For small amounts of fruit, it may be possible to spread crates in a cold room with good air flow and achieve reasonable cooling.

To handle a few pallets of strawberries, a practical small forced-air cooler can be constructed. A square box the length and height of a pallet of strawberries can be fitted with a small exhaust fan on the top, and each side of the cooling box constructed with a removable cover. Single pallets of berries should be placed tightly against all four sides of such a box with the open, vented sides of the strawberry crates against the box opening. With the covers removed and the fan operating, cold air from the room can pass over the strawberries and quickly re-cool them. Air-flow data for forced-air cooling are presented in the earlier discussion of strawberry cooling.

### Refrigerated Holding

Strawberries in distribution should be held between 0° and 2°C (32° and 36°F) under high (90 to 95%) relative humidity. Berries not refrigerated become almost completely unmarketable after 2 or 3 days (fig. 16). The requirements for strawberries are compatible with those of many other

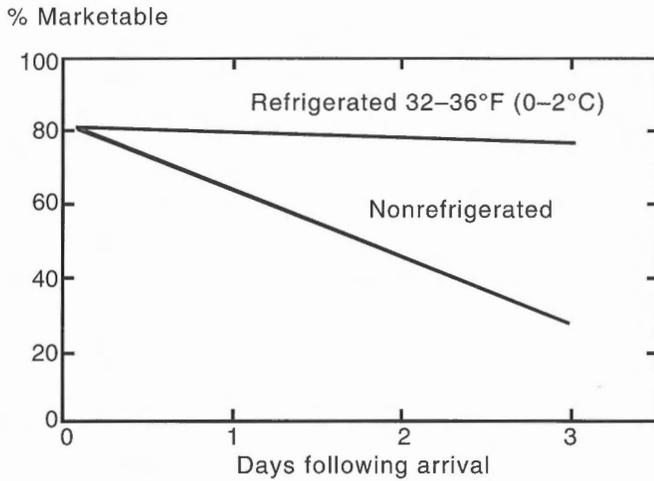


Figure 16. Berries not refrigerated after transport (during handling at wholesale and retail) become almost completely unmarketable after 2 or 3 days.

temperate fruits and vegetables. They can be held near wet produce such as leafy vegetables as long as they are not in direct contact with the water or ice that may be used with those products. Although strawberries are not highly sensitive to ethylene gas that is produced in quantity by some fruits, high concentrations (above 10 ppm) of ethylene may speed the growth of fruit-rot organisms and may cause some twisting or curvature of the calyx on the strawberry.

Under low relative humidity (below 90%) the fruit will readily lose water, causing them to shrivel and appear old quite quickly. Because shriveling results from cumulative water loss, fruit that appear sound may be approaching the shriveling stage at the time of arrival in the distribution market.

By their nature, strawberries have a very short postharvest life, and their longevity depends largely on time and

temperature. Therefore, refrigerated holding time should be the minimum needed to achieve orderly distribution and sales. Fruit should be kept cold whenever possible throughout distribution and recooled if warming occurs.

### Loading for Retail-Store Distribution

Because of their high perishability, strawberries should receive special handling in their final distribution. They should not be allowed to accumulate in warm staging areas where individual store orders may be assembled, and they should not be loaded into warm distribution vehicles awaiting assembly of other products to complete the load. Whenever possible, strawberries should be kept cold until the delivery trucks are ready to depart and only then placed into the load for final movement to retail outlets.

### Handling at Retail

At the final stop before the fresh strawberries reach the consumer, all of the care discussed previously should be continued. Fruit awaiting retail display should be kept in refrigeration, as near 0°C (32°F) as possible. Whenever possible the fruit should be displayed in a refrigerated produce display counter. Although strawberry baskets are often not covered at the point of origin, capping of the baskets before sale may minimize handling damage and avoid spillage of the fruit.

### Consumer Satisfaction

Ultimately the success of strawberry marketing depends on the consumers' pleasure with the fruit after purchase. This means that each handler, from grower through retailer, must do everything possible to protect the quality and condition of the fruit while it is under his care. Consumer satisfaction is the only basis for repeat strawberry purchases and thus is vital to the health of the strawberry industry.

# Appendix A

## Nutrition Labeling for Strawberries

<b>NUTRITION FACTS</b>			
Serving Size: 8 medium berries (147g)			
<b>Amount Per Serving</b>			
<b>Calories</b>	70	Calories from Fat	0
% Daily Value*			
<b>Total Fat</b>	0.5g		1%
Saturated Fat	0g		0%
<b>Cholesterol</b>	0mg		0%
<b>Sodium</b>	0mg		0%
<b>Total Carbohydrate</b>	17g		6%
Dietary Fiber	3g		13%
Sugars	8g		
<b>Protein</b>	1g		
Vitamin A	0%	Vitamin C	130%
Calcium	2%	Iron	2%
*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.			
	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Saturated Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g
Calories per gram			
Fat	9	Carbohydrate	4
		Protein	4

### Voluntary Data

Potassium	220mg; 6% DV
Soluble Fiber	2g
Insoluble Fiber	1g

### Nutrient Content Descriptors Allowed

Fat free (must state that strawberries contain less than 0.5g of fat per 140g strawberries)  
 Saturated fat free  
 Sodium free  
 Cholesterol free  
 Good source of fiber  
 High in vitamin C  
 High in folate (add 20% folate to label)

### Health Claims Allowed

Fiber-containing fruits, vegetables, and grain products and cancer  
 Fruits and vegetables and cancer  
 Fruits, vegetables and grain products that contain fiber and the risk of coronary heart disease  
 Fat and cancer  
 Saturated fat and cholesterol and coronary heart disease  
 Sodium and hypertension

SOURCE: PMA LABELING FACTS, 1994

# Appendix B

## Slow-Cooling Problems in Strawberry Coolers

Slow cooling in tunnel-type forced-air coolers is caused by inadequate air flow through containers or by a cooler that does not consistently maintain set-point air temperatures.

### Inadequate Refrigeration

**Symptom:** Cooling air temperatures rise during periods when large amounts of product are being cooled.

**Cause:** Refrigeration capacity is probably inadequate.

Undersized refrigeration equipment or poor maintenance may allow air temperatures to rise. Work with a refrigeration engineer to determine the best and least expensive way to increase refrigeration capacity.

In tunnel-type coolers, a large batch of warm product may cause a temporary increase in air temperature (fig. B1; see also figs. 10 and 11). This will cause slow cooling or even warming of product that is nearing completion on a neighboring cooling position. Instead of buying extra refrigeration capacity for occasional peak loads, divide the cooler into separate air spaces (fig. B2), thereby preventing the air in one cooling position from affecting the cooling in neighboring positions. If each cooling position in a large room has its own evaporator coil, then each position can be set up as a separate air space. If several positions are cooled with the same evaporator, then it may be best to have one air space per evaporator. Uninsulated walls or even curtains can be used to divide the cooler.

### Inadequate Air Flow

If temperature records show that cooling air temperature is consistently at the set point during cooling, then inadequate air flow may be causing slow cooling.

**Symptom:** All outside boxes on pallets—those that get first contact with the cold air—cool slowly.

**Cause:** Not enough air is flowing through the boxes because

1. boxes are not adequately vented; 3 to 5 percent carton-wall venting is needed, and vents must align when boxes are palletized
2. packing materials are blocking air flow
3. fan has too little air-flow capacity; 1.0 to 2.0 cubic feet

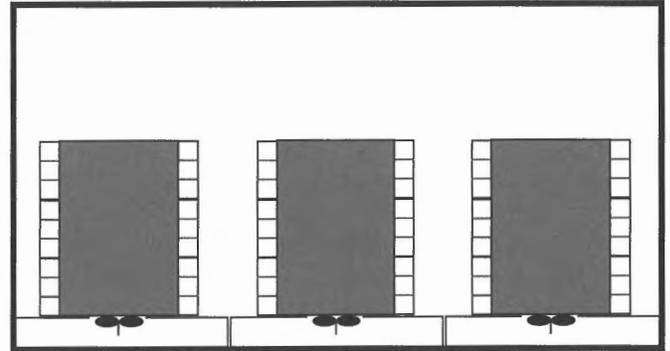


Figure B1. Air from one cooling position can mix with air from other positions.

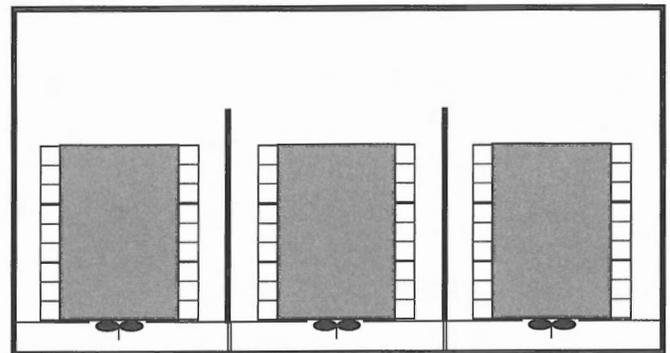


Figure B2. Separate air space for each cooling position prevents air from mixing.

4. too many boxes are being placed on the cooler, each pound of product needs 1.0 to 2.0 cubic feet per minute for rapid cooling

### Fan Capacity

Fan capacity, measured in cubic feet per minute (cfm), can be estimated by measuring the static air-pressure difference between the air-return channel and the general room. For palletized strawberries in standard trays, a pressure difference of 0.1 inch of water column equals an air flow of 1 cubic feet per minute per pound, and 0.4 inch of water column equals 2 cubic feet per minute per pound. A more accurate way to determine fan capacity is to measure the static-pressure difference between the fan inlet and outlet and the fan's rotational speed and then use the fan manufacturer's performance data to estimate air-flow capacity.

**Symptom:** Some outside boxes—those that get first contact with the cold air—cool fast but others cool slowly.

**Cause:** Air-supply and air-return channels are not wide enough (fig. B3):

1. a narrow air-supply channel causes slow cooling of boxes near the floor
2. a narrow air-return channel causes slow cooling of pallets farthest from the fan

Channels should be wide enough so that air speed in them does not exceed a maximum of 1,500 feet per minute. High air speeds cause uneven air distribution and large static-pressure variations in the air-supply or air-return channels. Highest air speeds are near the top of the pallets in the air-supply channel and near the fan in the air-return channel. A hot-wire anemometer or vane anemometer can be used to measure air speeds in air channels. A pressure gauge can be used to check for air-pressure variation in the channels.

Proper duct width can be estimated with the following equations or by using figure B4, if the fan capacity and pallet dimensions are known. The width of the air-supply channel ( $W^S$ ) is

$$W^S = \frac{Q}{L \times 3000},$$

where  $Q$  is the fan air volume (cfm),  $L$  is the length of pallets on cooler (ft), and  $W^S$  is the air-supply channel width (ft). The width of the air-return channel ( $W^R$ ) is

$$W^R = \frac{Q}{H \times 1500},$$

where  $Q$  is the fan air volume (cfm),  $H$  is the height of pallets on the cooler (ft), and  $W^R$  is the air-return channel width (ft).

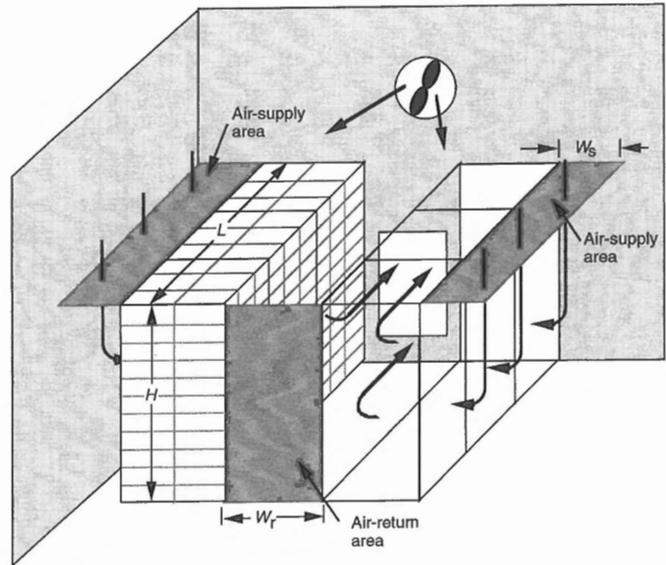


Figure B3. Schematic of a typical tunnel-type forced-air cooler, showing important dimensions.

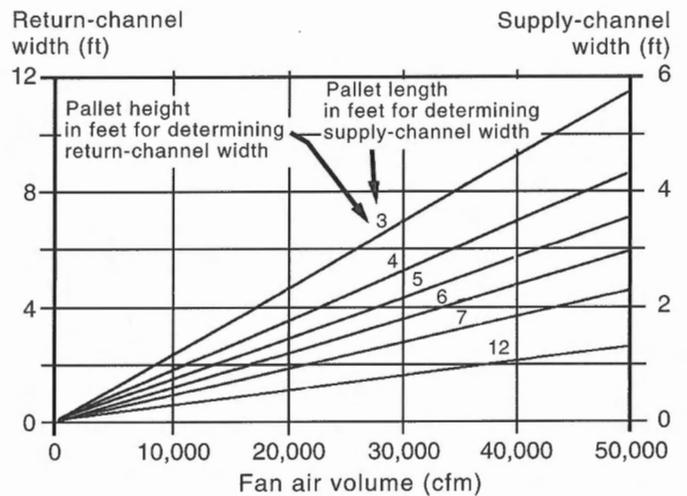


Figure B4. This chart can be used to determine the width of air-supply and air-return channels in tunnel-type forced-air coolers.

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