

Fig. 1 .... Average Temperatures of Peaches in Packed Lugs, Shipped in Fan-equipped Refrigerator Cars from Colorado to Minnesota[2]

reasonably uniform air velocities, and (3) a container type and load pattern which permit air to circulate freely through the load and to reach a substantial part of the surface of each package.[1]

Temperatures during precooling in rail cars and in the subsequent transit period are illustrated in Fig. 1.[2] Both the non-precooled and car-precooled loads were in rail cars equipped with built-in floor fans for air circulation. Refrigeration was supplied by bunker ice to which 300 lb of salt was added. The built-in fans in car *A* were operated with portable motors for 8 hr before shipment. The non-precooled and the car-precooled loads were shipped together to Minneapolis, Minn., with the car fans in the *on* position. Despite the fact that the 8 hr allowed for precooling only reduced the average load temperature to 46 F, commodity temperatures in car *A* were considerably lower through the third day than those in car *B*. Commodity temperatures in the non-precooled car (car *B*) were reduced rather rapidly in transit as a result of fan operation. If car *A* had been thoroughly precooled (14 to 16 hr), the contrast in subsequent commodity temperatures would have been much greater.

Tunnel cooling was developed prior to 1950 by cooperative effort between industry and U. S. Department of Agriculture research,[3] which resulted from a need for continuous precooling of table grapes that would permit packing, cooling, loading, and shipment of table grapes on the same day they were harvested. Several variations of tunnel cooling have been used. The most effective system has a plenum chamber above a continuous conveyor, with high velocity, refrigerated air directed from slots in the plenum at the face of unlidded lugs of grapes moving in a single layer on the conveyor. Refrigerated air is provided to the plenum from an ice bunker or mechanically refrigerated coils. The best of these systems cools grapes from field temperatures to 45 F or below in 45 min. In order to cool a carload or more of grapes per hour, the tunnel must be quite long. The conveying system is expensive and considerable power is required to provide the high velocity air needed for rapid cooling. However, the equipment has the advantage of very rapid heat removal as well as economies in handling that result from moving the packed lugs directly from the packing house floor into the refrigerator car or van.

A modification of room or car precooling which materially increases the cooling rate of products in adapted containers has been developed at the University of California.[4] The method involves definite stacking patterns and the baffling of

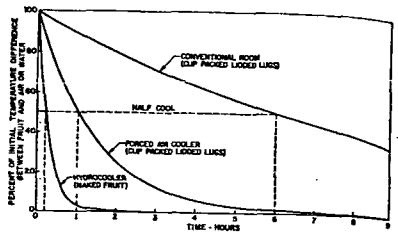


Fig. 2 .... Comparative Cooling of Peaches by Different Methods (Average Fruit Pulp Temperatures)[4]

stacks so that the cooling air is forced through rather than around the individual containers. Successful use of the method requires container ventilation in the direction that the air will move and a minimum of packaging materials that would interfere with free movement of air through the containers. Under these conditions a relatively small pressure differential between the two sides of the containers results in good air movement and excellent heat transfer.

Fig. 2 shows comparative cooling of cup-packed peaches in lidded lugs in a conventional room cooler and in a forced-air cooler with the air moving through the containers. Half-cooling (half of the difference between the original commodity temperature and that of the refrigerating medium) required 1 hr in the forced-air system and 6 hr by conventional room cooling. The third curve of Fig. 2 shows the cooling rate of peaches in a hydrocooler, but since these peaches were loose and the air-cooled peaches were packed, the rates are not comparable.

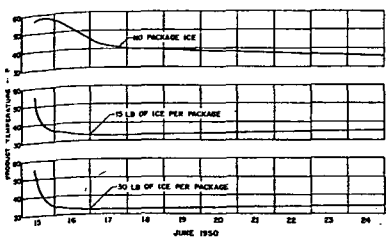
Cooling with Contact Ice

A very effective method of precooling uses crushed ice in direct contact with the product to be cooled. Until the advent of vacuum cooling, most of the leafy vegetables such as lettuce, bunched beets, carrots, radishes, and spinach were cooled by adding crushed ice to the package. The ice is commonly applied so that there is a layer of ice on each side of each layer of produce. After the packaged produce is loaded into the car or van, crushed ice is blown onto the top of the load and sometimes into the load channels to provide additional refrigeration during transit.

Fig. 3 shows temperatures of lettuce in L.A. crates with 15 or 30 lb of crushed ice in each package or without added ice.[4] In commercial practice, at least 30 lb of crushed ice is used per L.A. crate, and 20,000 lb or more of body ice is placed in and on the load. As indicated in the temperature curves, lettuce refrigerated in this manner was cooled to below 35 F within 8 hr. The package ice remaining after field-heat removal and the body ice in the car maintained the lettuce temperatures in a 32 to 34 F range continuously until the car was unloaded in New York City on the tenth day. There is presently no other combination of precooling method and transit protective service which will maintain temperatures as near to ideal for lettuce as the combination of package and body ice.

Cooling with Top Ice

The use of top ice for precooling western cantaloupes originated in 1944 and has been widely used since that time for shipments of cantaloupes packed in wooden crates. Originally,



* *Salinas, Calif. to New York, N.Y. via Sou. Pac., U. Pac., C.N.W., and N.Y.C. 20,000 lbs of body ice at noon on June 15. Initial full-bunker ice at 4:00 p.m. on June 16.*

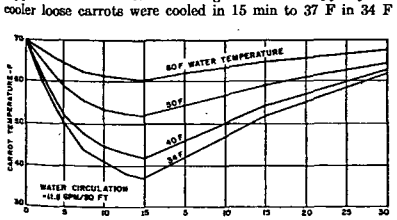
Fig. 3 .... Rate of Cooling and Transit Temperature of Lettuce Packed in L.A. Crates*[4,5]

about 10,000 lb of crushed ice was used on each carload regardless of the melon temperatures at loading. As a result of problems with residual ice and wet melons at destination, research was conducted[6] to relate the amount of top ice needed to the average melon temperature at loading. This research resulted in recommendations for top ice applications which have since been generally used. In a further refinement of this method, car or portable fans are operated for 6 to 8 hr after top icing to melt most of the ice from the load before shipment.

Cooling with Water

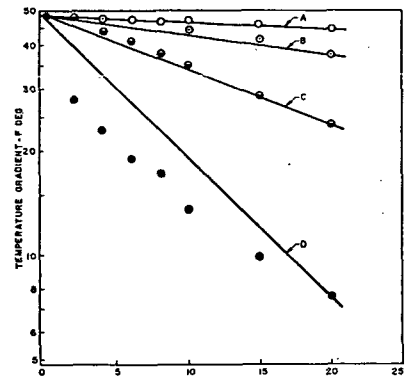
Cooling by flooding, spraying, or immersion in cold water is commonly known as *hydrocooling*. The method has been widely used for many years for precooling vegetables such as celery, sweet corn, and asparagus and in recent years has been used increasingly for topped carrots and freestone peaches. Properly used, it is one of the most rapid and effective cooling methods. Unfortunately, it too often involves a brief dunking or spraying with insufficiently chilled water. The fact that a wet product emerges from the process sometimes seems to be the only justification for declaration on the containers or invoice that the lot has been hydrocooled. The same principles apply to hydrocooling as to air cooling: (1) water temperatures must be low, (2) volume flow over and around the product is essential, (3) there must be maximum surface contact between the water and the product, and (4) sufficient time must be allowed for product cooling.

The relation of water temperature to the cooling rate of topped carrots is illustrated in Fig. 4. In a flood-type hydrocooler loose carrots were cooled in 15 min to 37 F in 34 F



* *With subsequent warming when held at 70 F.*

Fig. 4 .... Cooling Rate of Carrots as Related to Water Temperature in a Flood-type Hydrocooler*[6]



Curve	Measurement Depth, In.	Half-cooling Time, Min
A	2½ (Cavity)	—
B	1¼	61
C	¾	20
D	¼	8

Fig. 5 .... Temperature Gradients (Temperature Difference between Melons and Water) for Indicated Depths During Hydrocooling of Size 36 Cantaloupes[7]

water; to 42 F in 40 F water, and cooled much less in 50 F and 60 F water. Fig. 4 also indicates the importance of rapid handling of the hydrocooled carrots. The rate of warm up of loose carrots at 70 F is such that, unless the product is packaged and refrigerated within 15 or 20 min after cooling, much of the advantage of hydrocooling is lost.

As indicated previously, the cooling rate depends in part upon the surface exposure of the product to the water. Additionally, the size and heat-transfer characteristics of the units will substantially affect cooling rate. Because of the vast difference in mass, a radish will cool in a fraction of the time required to cool a cantaloupe under comparable hydrocooling conditions. Research on cantaloupe hydrocooling[7] showed a substantial difference in half-cooling time for sizes 36 and 45 melons. A weighted average of temperatures taken at different depths showed that 20 min was required to half-cool size 36 melons and only 11 min for size 45.

Temperature readings to determine the extent of cooling obtained with any commodity are misleading if the place at which the temperature is taken is not considered, whether it be an individual fruit or a packed basket of fruits. Fig. 5 illustrates the temperature difference at different depths in size 36 cantaloupes after hydrocooling for different periods. Obviously, temperatures taken either close to the surface or in the seed cavity will not represent the true temperature of the melon.

Table 1 shows the effects of starting fruit temperatures and period of cooling on final temperatures. Peaches in ¾-bushel baskets varied in temperature from 63 to 84 F before cooling. The hydrocooling period varied from 11 to 18 min. The fact that fruit at the higher starting temperatures was not ade-