U.S. #1 grade blueberries must be of one variety or with similar varietal characteristics with small dry stem scars, which are firm, not overripe or undeveloped, and which are free from mold or decay and free from damage caused by dirt, moisture, foreign matter, disease, insects, mechanical or other means. Each blueberry should be blue in color with a minimum diameter of 10 mm (7/16 inch) [5]. Other suggested quality attributes include pH (2.25 to 4.25), citric acid (0.3 to 1.3%), soluble solids (greater than 10%), soluble solids to acid ratio (10 to 33) and firmness (greater than 7 grams for 0.01 cm on Instron testing machine) [5].

Moisture loss from the blueberry fruit causes weight loss and shriveling and must be minimized. The whitish waxy covering on the fruit (bloom) is important, both for its effect on the color of the fruit and in preventing moisture loss through the fruit skins. Postharvest steps which removed the bloom should also be avoided [13].

## Cooling requirements

Understanding the cooling requirements of horticultural commodities requires knowledge of their biological responses. Fresh horticultural crops are alive and carry on many biological processes essential to the maintenance of life. They must remain alive and healthy until processed or consumed. Energy that is needed for these life processes comes from the food reserves that accumulated while the commodities were still attached to the plant [8].

Respiration is the process by which food reserves are converted to energy. Through a complex sequence of steps, stored food (sugars and starches) are converted to organic acids and subsequently to simple carbon compounds. Oxygen from the surrounding air is used in the process while carbon dioxide is released. Some of the energy of respiration is used to maintain the life processes and some is released in the form of heat, called "vital heat". Romoval of this heat must be considered in the temperature management program.

The respiration rate varies with commodity, variety, ripeness, injuries, temperature, and other stress related factors. Blueberries have a moderate respiration rate, 2-10 mg $CO_2$/kg-h (440-2,200 Btu per ton per day) at 0°C (32°F) [7]. The major factor affecting respiration rate is the product temperature. Since the final result of respiration activity is productdeterioration and senescence, achieving as low a respiration rate as possible is desirable. For each 10°C (18°F) temperature decreases respiration activity decreases by a factor of 2 to 4 [3]. For example the respiration of blueberries at 10°C (50°F) is 23-35 mg $CO_2$/kg-h (5,100-7,700 Btu per ton per day), over 4 times greater than at 0°C (32°F). Therefore blueberries must be rapidly precooled to slow their metabolism (physiological deterioration) to maximize quality and storage life for shipping and handling operations.

Blueberries are not a chilling sensitive crop (crops which must be stored at temperatures generally above 10°C (50°F) to prevent physiological damage). Therefore, they can be safely cooled to a temperature of -0.5 to 0°C (31 to 32°F) and should be maintained at that temperature throughout the marketing channels. The required rate of cooling during precooling can be expressed in terms of the half cooling time or the 7/8 cooling time (Figure 1). These values remain constant for the particular set of precooling conditions from which they were determined. The half cooling time is the time required to remove one half of the temperature difference between the initial pulp temperature and the cooling medium temperature. For commercial precooling, it is recommended [14] that 7/8 of the difference between the pulp temperature and the cooling medium temperature be removed prior to storage and transport. Under ideal circumstances the 7/8 cooling time is equal to about three times the amount of the half cooling time.

For example, if blueberries are harvested at 30°C (86°F) and cooled in a forced-air cooler with an air temperature of 1.1°C (34°F) the half cooling time would be the time required to remove 14.5°C (26°F)[3] or for the blueberries to cool to 15.5°C (60°F)[4]. For the same situation, the 7/8 cooling

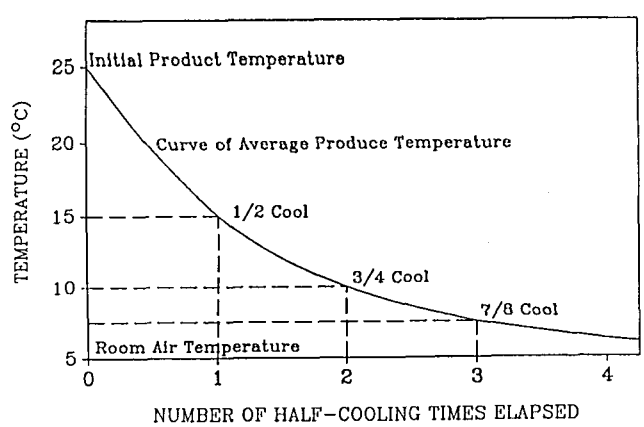


**Figure 1. Cooling curve showing the drop in temperature from the initial product temperature through one (1/2 cool), two (3/4 cool), and three (7/8) cool half-cooling times.**