Postharvest Handling and Storage of Fresh Cranberries

Charles F. Forney[1]

ADDITIONAL INDEX WORDS. *Vaccinium macrocarpon*, decay, physiological breakdown, bruising, cultural practices, harvest method, storage

SUMMARY. High-quality cranberry (*Vaccinium macrocarpon*) fruit are required to fulfil the growing markets for fresh fruit. Storage losses of fresh cranberries are primarily the result of decay and physiological breakdown. Maximizing quality and storage life of fresh cranberries starts in the field with good cultural practices. Proper fertility, pest management, pruning, and sanitation all contribute to the quality and longevity of the fruit. Mechanical damage in the form of bruising must be minimized during harvesting and postharvest handling, including storage, grading, and packaging. In addition, water-harvested fruit should be removed promptly from the bog water. Following harvest, fruit should be cooled quickly to an optimum storage temperature of between 2 and 5 °C (35.6 and 41.0 °F). The development of improved handling, refined storage conditions, and new postharvest treatments hold promise to extend the storage life of fresh cranberries.

Over the years, most cranberry production has been destined for the juice and processing markets, comprising about 95% of the fruit produced (Roper and Vorsa, 1997). Fresh fruit has been primarily targeted for the Thanksgiving and Christmas markets. However, with increasing demand for a larger and more consistent supply of fresh fruit and vegetables throughout the year, there is an increasing interest in extending the avail-

ability of fresh cranberries. In today's competitive markets, buyers are looking for high quality and consistent supplies of fresh fruit, thus pushing the demand for fresh cranberries beyond Christmas and into the spring. To meet these growing market demands, more care and attention must be paid to factors affecting fruit quality and storage life. This review discusses the effects of pre- and postharvest practices on the storage life of fresh cranberries in an attempt to identify recommendations to optimize fresh cranberry use.

Fruit quality

Fresh cranberry fruit quality is based on color, size, and texture. Fruit should have intense red color, surface shine, uniform size, good firmness, and freedom from defects. The flesh should be creamy white. Fruit are stored in bulk storage containers normally comprised of wood flats or pallet-sized storage containers with depths of about 15.2 cm (6 inches). After storage, fruit are graded and sorted to remove defective fruit before packaging (Hancock, 1995). Fruit are normally marketed in perforated polyethylene bags of various sizes. Less frequently, fruit may be put into plastic clamshells or fruit baskets. Bags or containers of fruit are placed into corrugated cardboard cartons for shipment and marketing.

The main causes of fruit loss during storage are decay, physiological breakdown, and physical damage. Decay of fruit in storage is caused by a complex of fungal organisms including *Allantophomopsis lycopodina* (black rot), *Allantophomopsis cytisporea* (black rot), *Strasseria geniculata* (black rot), *Coleophoma empetri* (ripe rot), *Fusicoccum putrefaciens* (end rot), *Phyllosticta elongata* (berry speckle), *Physalospora vaccinii* (blotch rot), and *Botrytis* spp. (yellow rot) (Boone, 1995a, 1995b; Carris, 1995; Caruso, 1995; Oudemans et al., 1998; Pepin and Boone, 1995). Infection of the fruit is believed to occur during bloom or wet harvest in the case of fungi causing black rot. Decay normally is characterized by discoloration and softening of the fruit. Rotted cranberries generally have external lesions and often only part of the internal flesh is red, while the unaffected flesh remains white. Unlike many postharvest decays in other crops, there is little spread of disease from infected to healthy fruit in storage (Oudemans et al., 1998).

Physiological breakdown has also been referred to as sterile breakdown because there is no association with a fungal pathogen (Bristow and Patten, 1995). Physiological breakdown is characterized by a dull appearance, rubbery texture, and diffusion of red pigment throughout the fruit flesh. Physiological breakdown can be a result of chilling injury (low temperature breakdown), induced by storage at cold nonfreezing temperatures. The development of physiological breakdown also is associated with over-mature fruit, impact bruising, extended water immersion, and storage in anaerobic conditions.

Physical damage is seen as bruised, ruptured, or cut fruit and can result in both physiological breakdown, decay, shriveling, and/or softening. Cranberries spoiled by either decay or physiological breakdown fail to bounce, in contrast to healthy berries. This property is used to separate good from bad berries in commercial cranberry separators that use a series of 7 bouncing boards with 10.2 cm (4 inches) high hurdles (Hancock, 1995).

Preharvest factors

The storage life of fresh cranberries is dependent on many factors in addition to the environment in which they are stored. Environmental and cultural factors in the field can predispose fruit to early breakdown or decay during postharvest handling and storage.

CULTURAL FACTORS. The proper application and timing of fungicides, particularly around the time of bloom can reduce latent infections and reduce fruit decay during storage (Bristow and Patten, 1995). Oudemans et al. (1998) suggest that many of the fungal organisms responsible for decay of cranberries take several years to complete an infection cycle and therefore the build up of inoculum and infection in the field may take years to develop. Fruit rot increases progressively following the elimination of fungicide use, reaching about 50% after 3 years compared with incidence of 2% to 10% in treated plots (Oudemans et al., 1998) . However, the effectiveness of fungicides applied around the time of bloom is dependent on proper timing and may have no effect on reducing storage rots if applied improperly or if target pathogens are not present (Jeffers, 1991).

A variety of cultural practices can also reduce fruit decay in storage (Oudemans et al., 1998). General sani-

tation and the removal of plant debris from bog areas are advised. Management of water used for flooding has been reported to reduce decay. In Massachusetts, draining bogs in early March for 4 weeks and then reflooding for 4 additional weeks (adding late water) is beneficial, but this practice has not been beneficial in other growing areas. The practice of sanding entails the even distribution of 1.3 to 2.5 cm (0.5 to 1 inch) of sand over the bog during the winter. This procedure is conducted every 2 to 5 years to improve vine vigor by burying runners and stimulating new root growth. Sanding may also reduce fruit decay by burying inoculum sources and thus reducing the amount of pathogen inoculum present. Cultural practices that reduce vine overgrowth and increase air circulation and solar penetration in the cranberry canopy also can reduce fruit rot.

Fertilization practices affect fruit quality and storage life. Increasing nitrogen fertility reduces storage life by increasing storage rots. In an extensive multiple year study across North America, fruit from cranberry bogs fertilized with 0, 22.0, or 44.0 kg·ha^{-1} (0, 19.6, or 39.3 lb/acre) of nitrogen (N) developed more storage rots with increasing N application following storage at 4 °C (39.2 °F) (Davenport, 1996). However, Swanson and Weckel (1975) found that ammonium sulfate rates of 89.2 to 178.4 kg·ha^{-1} (100 to 200 lb/acre), which are equivalent to 18.7 to 37.5 kg·ha^{-1} (21 to 42 lb/acre) of N do not affect the storage life of cranberry fruit at 4 °C or 20 °C (68.0 °F). Enhanced vegetative growth resulting from increased N fertility may reduce air movement and solar penetration in the plant canopy causing increases in decay incidence.

The growing environment also affects the storage potential of the fruit. Some attempts have been made to correlate environmental factors to fruit storage potential. Factors such as hours of sunlight, temperature, and rainfall are used. A predictive model based on these factors was developed by Franklin and Cross (1948) and is still used in Massachusetts to predict the keeping quality of the current year's cranberry crop.

CULTIVARS. Some comparisons have been made between the storage life of different cultivars. When a selection of cultivars grown in Wisconsin are stored at 4 °C, 'Stevens' and 'McFarlin' have the greatest storage life compared with 'Howes', 'Searles', 'Black Veil', and 'Metallic Belle' (Swanson and Weckel, 1975). Similarly, when New Jersey-grown cranberries are stored for 12 weeks at 3 °C (37.4 °F) with a 4-d holding period at 21 °C (69.8 °F), 'Franklin' and 'Pilgram' are superior to 'Early Black', while 'Ben Lear', 'Wilcox', and 'Stevens' are intermediate (Fig. 1) (Stretch and Ceponis, 1986).

Harvest

MATURITY. Fruit maturity at harvest can affect fruit storage life. 'McFarlin' fruit grown in Washington state store better when harvested 2 weeks before commercial maturity (11 weeks past full bloom) than fruit harvested at commercial maturity (13 weeks past full bloom) (Doughty et al., 1967). Commercial harvest maturity is based on optimum color development. The less mature fruit harvested 2 weeks before the commercial maturity are less susceptible to physiological breakdown and pathological rot, and lose less weight during storage. When fruit are sampled from storage in mid-February, 60% of the less mature fruit are sound compared with less than 10% of the fruit harvested at commercial maturity. However, it is not reported if the same method of harvest was used for both fruit maturities. Harvest method could be an overriding factor determining storage life. Ceponis and Stretch (1981, 1983) found that 'Early Black' fruit harvested late, with more intensely developed color, also developed more physiological breakdown in storage than less mature fruit, but rates of decay were not affected. However, they noted that physiological breakdown tends to be less in fully colored dark red fruit than in less highly colored fruit within a harvest. They suggested that there may be a subtle distinction between color and maturity and that higher concentrations of fruit soluble solids may be associated with reduced physiological breakdown. Swanson and Weckel (1975) indicated that green and white immature 'McFarlin' fruit break down more rapidly than mature fruit during storage at 4 °C. However, differences in harvest method (machine harvest vs. hand raking) may have been responsible for these differences.

HARVEST METHOD. The method of fruit harvest and handling also has large effects on the long-term storage life of fresh fruit (Norton, 1982). Fruit are normally harvested wet, where the bog is flooded and fruit are removed from the plants using a water reel harvesting machine or a wet rake. The water reel beats the fruit off the plant resulting in the fruit floating in the water. The fruit is then corralled onto conveyers, transferred to waiting trucks, and taken to receiving stations or packing houses. Fruit harvested in this manner tend to suffer excessive bruising and may not store well. In the wet rake harvest, fruit are removed from the plant using a comb-like devise and conveyed out of the water into holding containers. This method is less damaging to the fruit than the water reels. Some fruit, particularly for the fresh market, are harvested dry. This is done with dry raking machines similar to the wet rakes or by hand raking.

Studies have documented the effects of harvest method on fruit storage life. Swanson and Weckel (1975) found that wet machine harvested 'McFarlin' cranberries, presumably using a water reel, have several fold greater rates of spoilage during storage than fruit harvested by wet or dry raking. Fruit losses during storage of 'Ben Lear', 'Early Black', 'Franklin', 'Wilcox', 'Stevens', and 'Pilgram' harvested with a water reel picker are 2- to 4.6-fold greater than with fruit that are hand picked (Fig. 1) (Stretch and Ceponis, 1986). Hand picked fruit have less decay and physiological breakdown than water picked fruit. The incidence of black rot and total fungal decays is greater in wet than dry harvested fruit (Stretch and Ceponis, 1983, 1986). Decay incidence

Fig. 1. The effect of harvest method on the spoilage of six cultivars of fresh cranberries stored for 12 weeks at 3 °C (37.4 °F) followed by 4 d at 21 °C (69.8 °F). Data from Stretch and Ceponis (1986).
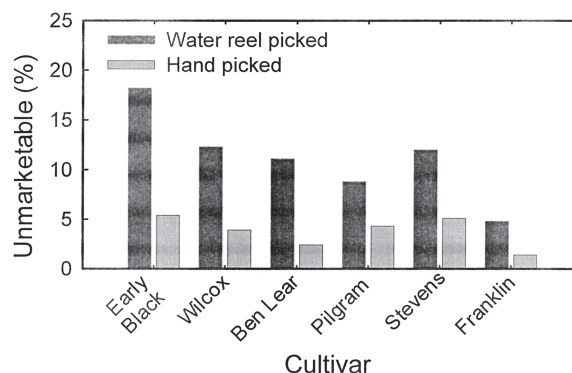
increases as time in water increases indicating that fruit may be inoculated by spores in the water. However, physiological breakdown in storage increases more as a result of water immersion time than does rot. Water immersion times of more than 8 h increase physiological breakdown of fruit that were both water and dry hand-harvested (Ceponis and Stretch, 1981).

MECHANICAL DAMAGE. Physiological softening and breakdown can be induced by impact bruising, which occurs during harvesting and postharvest handling. Graham et al. (1967) found that bruising dry-harvested 'McFarlin' cranberries by dropping a 100 g (3.5 oz) weight onto individual berries from a height of 23 cm (9.1 inches) greatly accelerates both physiological breakdown and fungal decay (Fig. 2). They found over 90% of bruised berries softened during 60 d of storage at both 2 or 20 °C, whereas only 7% and 15% of unbruised berries softened, respectively. Massey et al. (1981) also found that bruising increased breakdown in storage and was dependent on the severity of the bruise. Visible damage from impacts may take up to 8 h to develop and is dependent on the severity of the bruising (Massey et al., 1981). Immediately following bruising by a 1 m (3.3 ft) drop, damage is visually apparent on less than 10% of the fruit, but after 8 h at 18.3 °C (65 °F) about 80% of the fruit appears bruised. Pigment in the bruised areas is lost when fruit are stored at 7.2 °C (45 °F) or 20.0 °C but not at 0 °C (32.0 °F) (Patterson et al., 1967). Impact bruising is cumulative and repeated small impacts are detrimental to storage life. Therefore, minimizing handling of fruit can result in improved storage life. This brings into question the use of bouncing as the method to separate good from bad fruit. An improved method for grading fruit that does not require this physical stress could improve fruit shelf life.

Prestorage treatments

PRECOOLING. Precooling is the rapid removal of heat from freshly harvested produce before shipping, storage, or processing. Because warm fruit have a high rate of respiration, which continues to generate additional heat after harvest, rapid removal of this heat helps to retain fruit quality and freshness and slows decay development. Precooling should be done immediately after harvest, since any delay is detrimental to the

storage life and quality of the fruit. Precooling cranberries can be performed using cold air (forced-air) or water (hydrocooling). If significant field heat is present at the time of harvest, fruit may benefit from its rapid removal. Since cranberries are harvested late in the year when field temperatures are normally low, precooling is normally not done. However, when fruit are warm at time of harvest and are not precooled, fruit may take days or even weeks to cool, resulting in high rates of decay and physiological breakdown (Kaufman et al., 1958). If good air circulation is maintained through and around the fruit, room cooling can cool fruit to room temperature in 24 to 48 h. However, proper forced-air or hydrocooling can rapidly cool the fruit in a few hours or less, which may provide benefit. Methods for proper forced aircooling and hydrocooling are described by Thompson (1996) and Stewart and Couey (1976).

HEAT TREATMENTS. In some fresh commodities short heat treatments using hot water or air can reduce decay and spoilage during storage by killing pathogens or altering the physiology of the product. Hot water treatments of 43.3, 46.1, 48.8, or 51.7 °C (110, 115, 120, or 125 °F) for 20, 10, 5, or 2.5 min, respectively, were tested on cranberries (Anderson and Smith, 1971). Treatments reduced the number of pathogens on the fruit and sometimes reduced the total spoilage of berries. More effective treatments included 48.8 °C for 2.5 or 5 min and 51.7 °C for 2.5 min when stored at 21.1 °C (70 °F). Hot water treatments were more effective on early harvested fruit than on late harvested fruit. Treatment of late harvested fruit increased physiological breakdown. Whether heat treatments can alter the chilling sensitivity of cranberries or reduce physiological breakdown is not known.

COATINGS. Cranberry fruit are normally not subjected to wax or other coatings before storage or marketing. However, coatings of carnauba wax with or without Biosave (EcoScience Produce Systems Division, Orlando, Fla.), a biological fungicide comprised of two different *Pseudomonas syringae* strains, may reduce decay of cranberries stored for 16 weeks at 13 °C (55.4

°F) (Chen et al., 1999). After 16 weeks, carnauba wax alone reduces decay by 25%, while in combination with Biosave 110, decay is reduced by about 35%.

Storage conditions

TEMPERATURE. The use of refrigeration and proper temperature control is the primary postharvest technology used to extend the storage life of fresh fruit and vegetables. All other technologies are supplemental to good temperature management. With many fresh products, the recommended storage temperature is 0 °C or the coldest temperature possible without risking freezing the product. However, cranberries are a chilling sensitive fruit and develop physiological breakdown (chilling injury) when stored for prolonged times at 0 °C. At warmer temperatures, losses resulting from decay increase. Therefore, the optimum long term storage temperature is a compromise between minimizing low temperature breakdown and reducing decay.

The recommended storage temperature for fresh cranberries reported in various handbooks ranges from 2 to 7 °C (44.6 °F) (Hardenburg et al., 1986; Kader, 1997; Kasmire and Thompson, 1992; Lidster et al., 1988; Spayd et al., 1990). This is because many factors can affect chilling sensitivity and the expression of damage to the fruit. These factors include growing conditions, cultural practices, and fruit maturity. In addition, the expression of physiological breakdown is dependent on storage duration. As a result, different lots of fruit may vary in chilling sensitivity or expression of injury and thus have different optimum storage temperatures.

In an early study conducted by Wright et al. (1937), 'Early Black' and

Fig. 2. The effect of bruising on the spoilage of 'McFarlin' cranberries during storage at 2 or 20 °C (35.6 or 68.0 °F). Data from Graham et al.

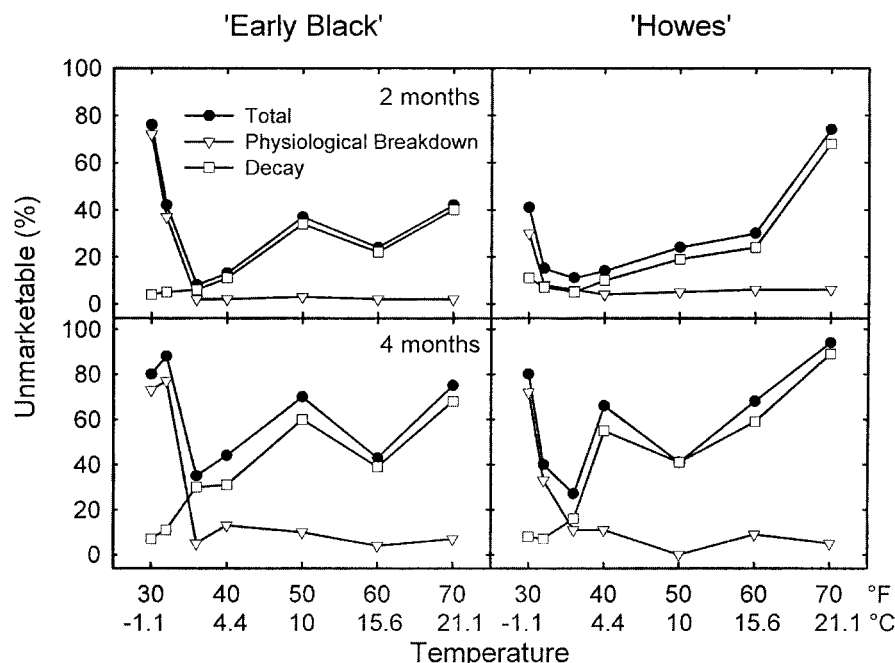(1967).
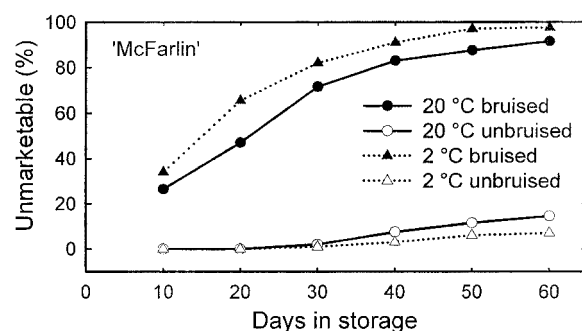
'Early Black'   'Howes'

Fig. 3. The effects of storage temperature on total spoilage, physiological breakdown, and decay of fresh 'Early Black' and 'Howes' cranberry fruit. Data from Wright et al. (1937).

'Howes' fruit from New Jersey were stored for 2 or 4 months at temperatures of –1.1, 0, 2.2, 4.4, 10.0, 15.6, and 21.1 °C (30, 32, 36, 40, 50, 60, and 70 °F) with 90% to 95% relative humidity (Fig. 3). A storage temperature of 2.2 °C was the best temperature for both cultivars. At this temperature, 8% and 35% of the 'Early Black' fruit were unmarketable after 2 and 4 months of storage, respectively, while similarly, 11% and 27% of 'Howes' fruit were unmarketable. The main causes of loss were physiological breakdown (sterile breakdown) at temperatures below 2.2 °C and decay at temperatures above 2.2 °C. At –1.1 and 0 °C losses from physiological breakdown were as high as 80%. At 21.1 °C *Penicillium* was the dominant decay organism, while at lower temperatures late rot (*Godronia*) was the primary cause of loss.

To maximize the effectiveness of cold storage, good refrigeration that provides a tight temperature control is needed. When 'Howes' cranberries are stored at 4.4 °C in refrigeration compared to a simulated common storage, which is held at 15.6 °C for 4 weeks, followed by 10.0 °C for 5 weeks and 4.4 °C for 10 weeks; 96% of unscreened cranberries are good after 6 weeks, 95% after 12 weeks, and 88% after 19 weeks compared with 93%, 89%, and 76% , respectively, in the common storage (Ringel et al., 1959).

In addition to the effect of temperature on breakdown and decay, temperature also affects fruit color. At 2.2 °C and above color tends to darken. At 10.0 °C and above berries become a solid red color, which may be darker than some markets desire (Wright et al., 1937). Color can be improved in early harvested fruit, which tend to be pale in color by storing at 7.2 to 10.0 °C (45 to 50 °F) for several weeks (Levine et al., 1941).

INTERMITTENT WARMING. Some efforts have been made to reduce physiological breakdown caused by chilling through the use of intermittent warming (IW). Intermittent warming is the periodic warming of fruit being held at chilling temperatures. This treatment is effective in reducing chilling-induced breakdown in a variety of fruit (Hatton, 1990). Cranberry fruit that are stored at 0.6 °C (33 °F) or 3.3 °C (38 °F) and warmed to 21.1 °C for 1 d every 4 weeks have less physiological breakdown than those that are not warmed (Hruschka, 1970). Total spoilage of 'Early Black' cranberries after 20 weeks of storage at 0.6 °C was 66%, but was reduced to 27% when fruit were subjected to IW. The main cause of spoilage at 0.6 °C was physiological breakdown, accounting for

60% of the fruit, which is reduced to 18% by the IW treatment. Physiological breakdown began to develop after 8 weeks of storage at 0.6 °C and increased during continued storage. Fruit held at 3.3 °C had less physiological breakdown than fruit held at 0.6 °C. After 20 weeks, total spoilage in the 3.3 °C stored fruit was about 29%, which was similar to the spoilage rates of fruit held at 0.6 °C with IW. However, when fruit were held for an additional week at 21.1 °C, physiological breakdown tripled in fruit held at the constant 3.3 °C, resulting in total spoilage of 59% compared with 41% and 44% for the fruit held at 0.6 °C and 3.3 °C with IW, respectively.

HUMIDITY. As with temperature, the level of relative humidity (RH) recommended for storage of cranberries varies widely. Recommendations include 65% to 70% (Stark et al., 1974); 70% to 75% (Wright et al., 1937); 80% to 90% (Lidster et al., 1988); and 90% to 95% (Hardenburg et al., 1986; Kader, 1997; Spayd et al., 1990). At 4.4 and 10.0 °C high RH (90% to 95%) tends to enhance fruit decay when compared to lower RH of 70% to 75% although results are variable (Wright et al., 1937). High RH reduces weight loss, softening, and shriveling. The effects of RH are very dependent on air movement (circulation). With good air circulation around stored fruit, high storage humidities will likely be beneficial.

CONTROLLED ATMOSPHERES. Controlled atmosphere (CA) storage is the storage of fresh produce in reduced concentrations of oxygen (O_2) and/or

Fig. 4. The effects of controlled atmospheres on the spoilage of fresh 'Howes' cranberries stored at 3.3 °C (38 °F) for 10, 15, 20, or 30 weeks. Fruit were stored in atmospheres comprised of 1%, 3%, 10%, or 21% oxygen (O_2) in combination with 0, 5, or 10% carbon dioxide (CO_2). Values are the means of all four storage times. Data from Anderson et al. (1963).
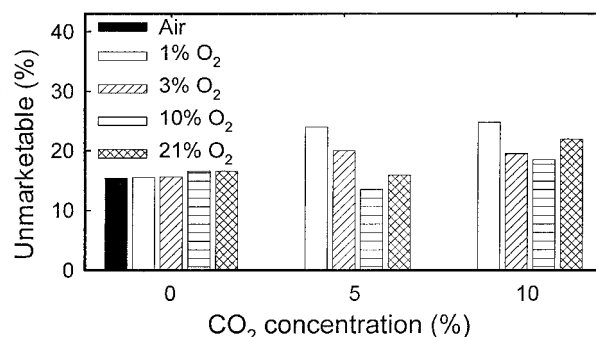
elevated concentrations of carbon dioxide (CO_2). These atmospheres can slow physiological deterioration and decay in some commodities (Hardenburg et al., 1986). Controlled atmosphere storage is used commercially to extend the storage life of a variety of crops including apples (*Malus×domestica*), pears *(Pyrus communis)*, and blueberries (*Vaccinium* spp.). Little work has been conducted on the CA storage of cranberries. In one of the few studies reported, CA storage of 'Howes' cranberries was conducted using combinations of 0%, 5%, and 10% CO_2 with 3%, 10%, and 21% O_2 at 0 and 3.3 °C (Anderson et al., 1963). The least storage losses were found in the 3.3 °C air treatment. If humidity was lowered in the CA chambers, some atmospheres gave results similar to the air controls, but no benefits were found (Fig. 4). Doughty et al. (1967) cited unpublished work by Patterson in Washington state that confirmed these results. Similarly, Stark et al. (1969) found that cranberries stored at 22.2 °C (72 °F) for 3 weeks in atmospheres of 5% or 10% CO_2 with 3% O_2 had the same levels of rot as air stored fruit. Berries held in 100% N_2 became dull and water soaked in appearance and had a fermented odor (Lockhart et al., 1971; Stark et al., 1969).

ETHYLENE. Ethylene, known as the ripening hormone, stimulates ripening in many climacteric fruit. However, cranberries are considered nonclimacteric fruit and show a minimal response to postharvest applications of ethylene. Cranberry fruit gassed with ethylene following harvest had no change in sugar, acid, or red anthocyanin pigment content and only a slight increase in respiration (Fudge, 1930). However, Craker (1971) treated under ripe 'Early Black' cranberries with $10 \mu L \cdot L^{-1}$ (ppm) ethylene at 26 to 30 °C (78.8 to 86.0 °F) for 4 d in the light and observed a 400% to 900% increase in anthocyanin content. The anthocyanin concentration of fruit treated in the dark only doubled. Therefore, a combination of ethylene and light at warm temperatures may be effective to improve the color of poorly colored cranberries.

Literature cited

Anderson, R.E., R.E. Hardenburg, and H.C. Vaught. 1963. Controlled-atmosphere storage studies with cranberries. Proc. Amer. Soc. Hort. Sci. 83:416–422.

Anderson, R.E. and W.L. Smith, Jr. 1971. Effect of postharvest hot-water treatments on spoilage of cranberries in storage. USDA Market Res. Rpt. 928.

Boone, D.M. 1995a. Blotch rot, p. 32. In: F.L. Caruso and D.C. Ramsdell (eds.). Compendium of blueberry and cranberry diseases. ASP Press, St. Paul, Minn.

Boone, D.M. 1995b. Yellow rot, p. 42. In: F.L. Caruso and D.C. Ramsdell (eds.). Compendium of blueberry and cranberry diseases. ASP Press, St. Paul, Minn.

Bristow, P.R. and K.D. Patten. 1995. Physiological (sterile) breakdown, p. 68–69. In: F.L. Caruso and D.C. Ramsdell (eds.). Compendium of blueberry and cranberry diseases. ASP Press, St. Paul, Minn.

Carris, L.M. 1995. Black rot, p. 31–32. In: F.L. Caruso and D.C. Ramsdell (eds.). Compendium of blueberry and cranberry diseases. ASP Press, St. Paul, Minn.

Caruso, F.L. 1995. Botryosphaeria fruit rot and berry speckle, p. 32–33. In: F.L. Caruso and D.C. Ramsdell (eds.). Compendium of blueberry and cranberry diseases. ASP Press, St. Paul, Minn.

Ceponis, M.J. and A.W. Stretch. 1981. The influence of water immersion times at harvest on physiological breakdown of 'Early Black' cranberries in storage. HortScience 16:60–61.

Ceponis, M.J. and A.W. Stretch. 1983. Berry color, water-immersion time, rot, and physiological breakdown of cold-stored cranberry fruits. HortScience 18:484–485.

Chen, X., L.A. Grant, and F. Caruso. 1999. Effect of Biosave and carnauba wax on decay of cranberry. Proc. Fla. State Hort. Soc. 112:116–117.

Craker, L.E. 1971. Postharvest color promotion in cranberry with ethylene. HortScience 6:137–139.

Davenport, J.R. 1996. The effect of nitrogen fertilizer rates and timing on cranberry yield and fruit quality. J. Amer. Soc. Hort. Sci. 121:1089–1094.

Doughty, C.C., M.E. Patterson, and A.Y. Shawa. 1967. Storage longevity of the 'McFarlin' cranberry as influenced by certain growth retardants and stage of maturity. Proc. Amer. Soc. Hort. Sci. 91:192–204.

Franklin, H.J. and C.E. Cross. 1948. Weather in relation to cranberry production and condition. Univ. Mass. Bul. 450.

Fudge, B.R. 1930. Increasing the color of cranberries after removal from the vines. N.J. Agr. Expt. Sta. Bul. 504.

Graham, S.O., M.E. Patterson, and B. Allen. 1967. Bruising as a predisposing factor in the decay of stored cranberries. Phytopathology 57:497–501.

Hancock, J.F. 1995. Introduction: The taxonomy, botany, and culture of *Vaccinium*, p. 1–5. In: F.L. Caruso and D.C. Ramsdell (eds.). Compendium of blueberry and cranberry diseases. ASP Press, St. Paul, Minn.

Hardenburg, R.E., A.E. Watada, and C.Y. Wang. 1986. The commercial storage of fruits, vegetables, and florist and nursery stocks. USDA Agr. Hdbk. 66.

Hatton, T.T. 1990. Reduction of chilling injury with temperature manipulation, p. 269–280. In: C.Y. Wang (ed.). Chilling injury of horticultural crops. CRC Press, Boca Raton, Fla.

Hruschka, H.W. 1970. Physiological breakdown in cranberries—Inhibition by intermittent warming during cold storage. Plant Dis. Rpt. 54:219–222.

Jeffers, S.N. 1991. Effects of fungicides applied during bloom on yield, yield components, and storage rots of cranberries. Plant Dis. 75:244–250.

Kader, A.A. 1997. A summary of CA requirements and recommendations for fruits other than apples and pears. Proc. 7th Intl. Controlled Atmos. Conf., Davis, Calif. 3:1–34.

Kasmire, R.F. and J.F. Thompson. 1992. Selecting a cooling method, p. 63–68. In: A.A. Kader (ed.). Postharvest technology of horticultural crops. Univ. Calif. Div. Agr. Natural Res. Publ. 3311.

Kaufman, J., S.M. Ringel, A.A. Hamer, E.P. Atrops, and G.B. Ramsey. 1958. Effect of precooling on market quality of cranberries shipped by rail or truck. USDA Mktg. Res. Rpt. 287.

Levine, A.S., C.R. Fellers, and C.I. Gunness. 1941. Carbon dioxide–oxygen and storage relationships in cranberries. Proc. Amer. Soc. Hort. Sci. 38:239–242.

Lidster, P.D., P.D. Hildebrand, L.S. Bérard, and S.W. Porritt. 1988. Commercial storage of fruits and vegetables. Agr. Agri-Food Canada (Ottawa, Ontario, Canada) Publ. 1532/E.

Lockhart, C.L., F.R. Forsyth, R. Stark, and I.V. Hall. 1971. Nitrogen gas suppresses microorganisms on cranberries in short term storage. Phytopathology 61:335.

Massey, Jr., L.M., B.R. Chase, and M.S. Starr. 1981. Impact-induced breakdown in commercially screened 'Howes' cranberries. J. Amer. Soc. Hort. Sci. 106:200–203.

Norton, J.S. 1982. Harvesting and handling cranberries, p. 104–116. In: Modern cranberry cultivation. Univ. Mass., Amherst, Coop. Ext. Serv.

Oudemans, P.V., F.L. Caruso, and A.W. Stretch. 1998. Cranberry fruit rot in the Northeast: A complex disease. Plant Dis. 82:1176–1184.

Patterson, M.E., C.C. Doughty, S.O. Graham, and B. Allan. 1967. Effect of bruising on postharvest softening, color changes and detection of polygalacturonase enzyme in cranberries. Proc. Amer. Soc. Hort. Sci. 90:498–505.

Pepin, H.S. and D.M. Boone. 1995. End rot, p. 36–37. In: F.L. Caruso and D.C. Ramsdell (eds.). Compendium of blueberry and cranberry diseases. ASP Press, St. Paul, Minn.

Ringel, S.M., J. Kaufman, and M.J. Jaffe. 1959. Refrigerated storage of cranberries. USDA Mktg. Res. Rpt. 312.

Roper, T.R. and N. Vorsa. 1997. Cranberries: Botany and horticulture. Hort. Rev. 21:215–249.

Spayd, S.E., J.R. Morris, W.E. Ballinger, and D.G. Himelrick. 1990. Maturity standards, harvesting, postharvest handling, and storage, p. 504–531. In: G.J. Galleta and D.G. Himelrick (eds.). Small fruit crop management. Prentice Hall, Upper Saddle River, N.J.

Stark, R., F.R. Forsyth, C.L. Lockhart, and I.V. Hall. 1974. Processing quality of cranberries after extended storage in N_2 atmosphere with low and high relative humidities. Can. Inst. Food Sci. Technol. J. 7:9–10.

Stark, R., I.V. Hall, F.R. Forsyth, and P.R. Dean. 1969. Cranberries, evaluated for fresh fruit and processing quality, after reduced oxygen storage. Cranberries 37(6):14,16 and 37(7):14,16.

Stewart, J.K. and H.M. Couey. 1976. Hydrocooling vegetables. A practical guide to predicting final temperatures and cooling times. USDA Mktg. Res. Rpt. 637.

Stretch, A.W. and M.J. Ceponis. 1983. Influence of water immersion time and storage period on black rot development in cold-stored, water harvested cranberries. Plant Dis. 67:21–23.

Stretch, A.W. and M.J. Ceponis. 1986. Fungal and physiological breakdown in six cranberry cultivars following water harvesting and cold storage. HortScience 21:265–267.

Swanson, B.G. and K.G. Weckel. 1975. Refrigerated storage of fresh cranberries. J. Food Sci. 40:259–261.

Thompson, J.F. 1996. Forced air cooling. Perishable Handling Nwslt. 88:2–11.

Wright, R.C., J.B. Demaree, and M.S. Wilcox. 1937. Some effects of different storage temperatures on the keeping of cranberries. Proc. Amer. Soc. Hort. Sci. 34:397–401.