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Hydrocooling Extends Quality and Shelf Life of Asian Vegetables

Adrian D. Berry*, Steven A. Sargent, and Catherine E. Belisle

University of Florida, Horticultural Sciences Department, P.O. Box 110690, Gainesville, FL 32611

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The objective of these studies was to compare cooling methods and subsequent effects on shelf life and quality maintenance of Indian bitter melon, smooth bitter melon (*Momordica charantia* L.) and long bean [*Vigna unguiculata* (L.) Walp. ssp. *sesquipedalis* (L.) Verdc.]. All three commodities were packed in returnable plastic containers or wax cartons then either pallet hydrocooled to 5 °C or placed directly into the grower's storage room (4 °C) for room cooling and stored 14 days for quality observations. Pulp temperature for the smaller Indian bitter melon decreased 19 °C during 23 minutes of hydrocooling, whereas smooth bitter melons lost 10 °C in 21 minutes. Long beans cooled 17 °C within five minutes. After 14 days, bitter melon held in unwrapped cartons lost 2 to 3% more moisture than those either overwrapped immediately or partially overwrapped. Hydrocooled Indian bitter melon maintained better overall visual quality and less decay after 14 days of storage.

The popularity of Asian vegetables is on the rise, especially in North America. Even researchers in Canada are testing the feasibility of growing some Asian crops like bitter melon (*Momordica charantia* L.) using high tunnels (Kong et al., 2017). Recent demand for crop diversification has led to increased production of Asian vegetables in Florida (Liu et al., 2017). Currently, Florida produces over 45 different Asian vegetable crops on more than 2000 ha (Liu 2018, personal communication). Many of these crops are sensitive to temperatures below 2 to 5 °C. Florida has a favorable climate for growing many types of Asian vegetables and their production can be quite profitable, with some crops generating $40,000 gross income per acre (Liu, 2016). Examples of popular Asian vegetables grown in Florida include bitter melon, long squash [*Lagenaria siceraria* (Molina) Standl.], long bean [*Vigna unguiculata* (L.) Walp. ssp. *sesquipedalis* (L.) Verdc.] , and luffa (*Luffa cylindrical* (L.) Roem) (Liu, 2016).

Bitter melon, a member of Cucurbitaceae, is a tropical and subtropical vegetable with climbing vines. Other common names used for bitter melon are bitter gourd, bitter squash, Goya melon, karela, and balsam pear. Bitter melon is widely cultivated in Asia, Africa, and the Caribbean and has long been grown as a minor vegetable in regions of the United States, including parts of Florida (Stephens, 2012). There are two main types, Chinese bitter melon which has smooth ridges extending the length of the fruit, and Indian bitter melon which has pointed ridges (Liu et al., 2015).The immature fruit is used as a vegetable with a mild bitter flavor, which comes from the alkaloid momordicine (Zong et al., 1995). Various research has shown that bitter melon contains high nutritional (Horax et al., 2005; Behera et al., 2010) and pharmaceutical properties (Basch et al., 2003; Subratty et al., 2005; Nerurkar and Ray, 2010).

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*Corresponding author. Email: adberry@ufl.edu

Long bean is a leguminous vegetable with climbing vines that produce long edible pods. The subspecies name means "one-and-half-foot long" and is also referred to as yard-long bean, asparagus bean, Chinese long bean, long-podded cowpea, bora, bodi, pea bean, and snake bean. Pods should be harvested at an immature stage before the seeds mature. The young leaves can also be eaten as a vegetable. Similar to bitter melon, long bean can be grown in both spring and fall seasons in Florida (Khatri et al., 2015).

Developing postharvest storage recommendations for Asian vegetables can be challenging because they are considered chilling sensitive. Zong et al. (1993) showed that bitter melon and long bean can develop chilling injury below 10 °C. Bitter melon is very perishable due to a high respiration rate and, when stored above 15 °C, rapidly senesces which leads to seed development, tissue softening, yellowing and eventual fruit splitting (Kays et al., 1978; Zong et al. 1992). The ripening process is also accelerated by exposure to low levels of ethylene (Rubatzky and Yamaguchi, 1997). Similarly, long bean has a limited shelf life due to high respiration rate and wilting (Coker et al., 2007). Typical storage time for these crops can be one to two weeks depending on harvest maturity stage and storage temperature.

Hydrocooling is widely used to cool fresh produce. It offers several benefits to growers, such as rapid and thorough cooling, reduced moisture loss, extended shelf life, and a sanitized product. Several preliminary studies were conducted to compare cooling method, shipping container type and storage conditions, and their effects on postharvest quality and shelf life of smooth and Indian bitter melon and long bean.

Materials and Methods

The University of Florida (UF) portable hydrocooler unit was set up at a commercial farm in Elkton, FL, and three separate tests were conducted during July and Aug. 2017. Test 1 involved hydrocooling of smooth bitter melon and long bean to determine the cooling rate as well as the effect of various plastic overwrap treatments on storage quality. Smooth bitter melons were packed in waxed cartons or returnable plastic containers (RPCs); long beans were packed in RPCs. Individual containers were immersed for 3 min. (long beans) to 20 min. (bitter melons). After hydrocooling, each entire container was either wrapped immediately with plastic, wrapped after 24 h, left unwrapped or had a paper top cover, then stored in the farm's commercial cold room set at 4 °C. This process was repeated, with the freshly harvested crops being packed using the same methods and placed directly into the cold room, which was the grower's practice. After 8 and 14 d, samples were assessed on-site for quality then brought to the UF Postharvest Laboratory in Gainesville, FL, and placed at room temperature (21 °C) for 2–3 d to evaluate visual quality and possible chilling injury. Smooth bitter melon moisture content of pulp and peel was determined by drying the tissue at 65 °C for several days.

Test 2 employed the pallet-scale shower hydrocooling of smooth bitter melon and long bean to determine the cooling profile. Single pallets were hydrocooled. Smooth bitter melon was packed in waxed cartons and palletized four layers high with eight cartons per layer. Long beans were packed in open-top RPCs, six layers high with seven containers per layer. A waterproof data logger probe (HiTemp 140-FP, MadgeTech, Warner, NH, USA) was inserted into the blossom end of each of two smooth bitter melons; one fruit was placed under the carton's top vent opening and the other fruit under the top flap. To monitor pulp temperature during hydrocooling of long beans, a probe was placed in the middle of a snapped pod and placed on the top center of the RPC.

Test 3 assessed Indian bitter melon that were packed into waxed cartons (5 layers, 7 cartons per layer) or RPCs (4 layers, 7 cartons per layer) then either hydrocooled using the pallet-scale shower unit or room cooled to about 5 °C. After cooling, samples were returned to the UF Postharvest Laboratory in Gainesville for subsequent storage at 5 and 12 °C for 17 d. Quality evaluations and moisture content measurements were conducted after 8, 14 and 17 d plus transfer to room temperature (21 °C) for 2 d after 14 d storage. All hydrocooling tests were conducted using water maintained at approximately 5 °C with 150 ppm sodium hypochlorite and pH 7.

Results and Discussion

In Test 1, immersion hydrocooling of smooth bitter melon took 12 to 18 min. to reach 10 °C depending on container type (data not shown). It took 6 min. longer to cool product packed in wax cartons as compared to those in the RPCs, since the latter was open-top and had sufficient openings in the sides and base. Long bean immersion hydrocooling took less than 2 min. to reach 4 °C (data not shown). These commodities are typically room cooled which takes hours and contributes to high levels of moisture loss and reduction in quality. Hydrocooling offers the possibility of more efficient cooling, sanitizing, and maintaining hydration of the product.

After 8 d at 4 °C, in the grower's cold room, bitter melons stored in RPCs without overwrap were flaccid due to moisture loss while the overwrap treatments were considered by the grower to be marketable. Room cooled bitter melon subsamples (also stored at 4 °C for 8 d then transferred to 21 °C for 48 h) exhibited extensive shriveling, pitting and some yellowing compared to hydrocooled samples which remained green and turgid without any shriveling. After 14 d at 4 °C, bitter melon hydrocooled and wrapped immediately after cooling were still firmer to the touch than those not wrapped or with delayed wrapped (Fig. 1). However, upon transfer to ambient (21 °C) for 60 h, they were unmarketable due to extreme shriveling, pitting, and decay, regardless of overwrap treatment (Fig. 2). After 14 d at 4 °C, smooth bitter melon moisture content was similar for peel (94%) and pulp (92%) tissue stored with various overwrap treatments (Table 1).

Fig. 1. Hydrocooled, smooth bitter melon visual quality either (a) immediately wrapped, (b) left unwrapped, (c) delayed wrapped, or (d) paper cover after 14 d at 4 °C.

After 8 d at 4 °C, unwrapped long beans were still firm and had acceptable quality. After 14 d at 4 °C, long beans left unwrapped showed minor shriveling and were more flaccid than after 8 d, but were still marketable.

Fig 2. Hydrocooled smooth bitter melon visual quality either (**a**) delayed wrapped, (**b**) paper cover, (**c**) immediately wrapped, and (**d**) unwrapped after 14 d at 4 °C plus 60 h at 21 °C.

Table 1. Moisture content (%, wet weight basis) of hydrocooled smooth bitter melon with various overwrap treatments after 14 d at 4 °C.

Treatment	Pulp	Peel
Unwrapped	90.46 ± 0.28	94.15 ± 0.72
Immediately wrapped	92.01 ± 0.24	93.95 ± 0.09
Paper on top	93.25 ± 0.24	94.53 ± 0.11
Wrapped 24 h after cooling	92.36 ± 1.25	94.31 ± 0.45

Values represent the mean (n = 2) and standard deviation.

In Test 2, pulp temperature profile changed faster and more uniformly when the bitter melon was positioned directly in the water stream under the open slot of the carton lid (10 to 12 °C) compared to being indirectly exposed to the cooling water under the top flap (8 to 26 °C). After 30 min. in the pallet-scale shower hydrocooler, fruit positioned under the lid opening cooled to 11 °C while fruit positioned under the lid was 19 °C (Fig. 3). Long beans packed in RPCs cooled uniformly, in about 3 min., in the shower hydrocooler (Fig. 4). With both the smooth bitter melon and the long beans, the top layer of the pallet cooled the fastest due to direct contact with the water flow, while those located in the middle of the pallet (layer 3) cooled more slowly.

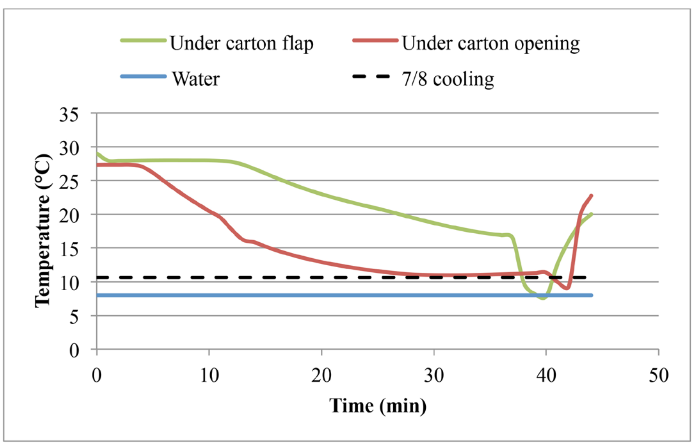

Fig. 3. Smooth bitter melon cooling profile during hydrocooling with probed fruit positioned either under the wax carton lid opening or under the carton flap. Data represent pulp temperature mean from different positions in the pallet (n = 4).

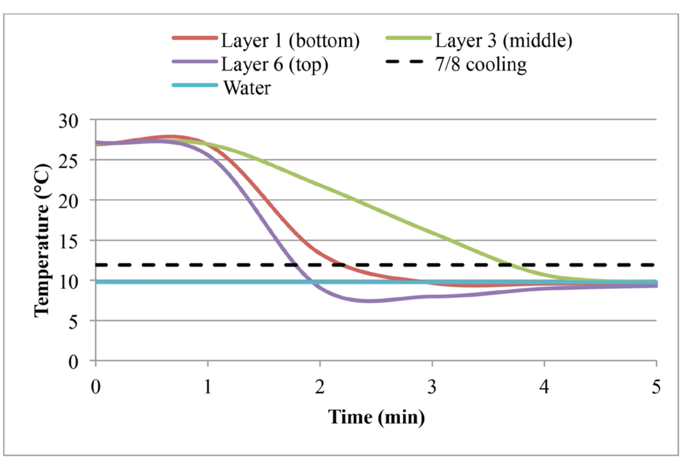

Fig. 4. Long bean cooling profile during hydrocooling at three locations within a pallet.

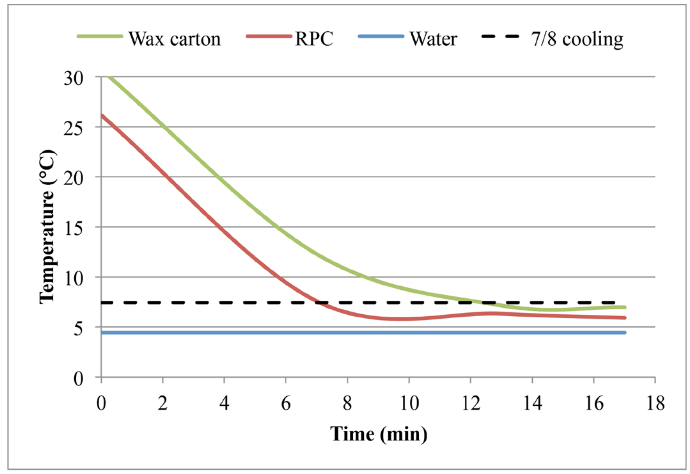

Fig. 5. Cooling profile of Indian bitter melon cooling packed in waxed cartons or RPCs during hydrocooling.

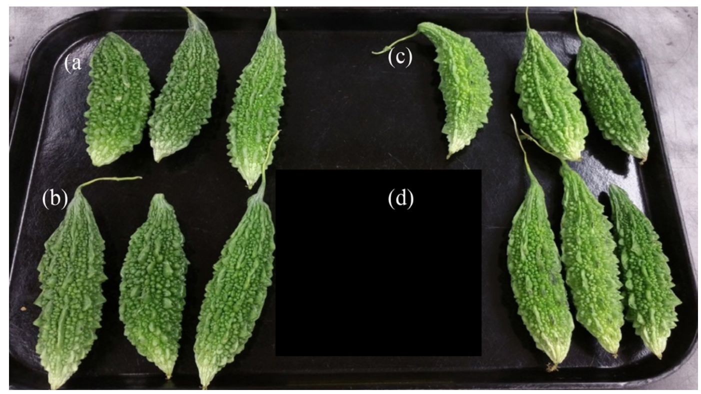

Fig. 6. Indian bitter melon visual quality after hydrocooling and storage at (**a**) 5 or (**b**) 12 °C or room cooling and storage at (**c**) 5 or (**d**) 12 °C for 8 d.

In Test 3, Indian bitter melon was cooled using the pallet-scale shower unit. Again, those fruit packed in the RPC cooled to 10 °C more uniformly and faster (8–9 min.) than those packed in the wax carton (7–12 min.) (Fig. 5). Since Indian bitter melon is typically smaller in size than smooth bitter melon, it cooled slightly faster. After 8 d storage at 5 or 12 °C both room cooled and hydrocooled. Indian bitter melon maintained acceptable quality (Fig. 6). Indian bitter melon that was room cooled started to show symptoms of senescence (yellowing and decay) after 14 d at 12 °C (Fig. 7). Indian bitter melon stored for 14 d at either 5 or 12 °C then transferred to 21 °C for 2 d exhibited extensive shriveling, yellowing and some decay. The room cooled India bitter melon stored at 12 °C split open after 2 d at 21 °C, which is a sign of maturation also reported by various researchers (Mohammed and Wickham, 1993; Zong et al. 1993; Liu et al., 2015). Hydrocooled and room cooled Indian bitter melon stored at either 5 or 12 °C continuously maintained acceptable quality for 17 d (Fig. 8). There was no difference in moisture content between Indian bitter melon hydrocooled or room cooled after 7 d (90.2%) and 14 d (90.3%) storage at 4 and 12 °C (Table 2).

Conclusions

In Test 1, when smooth bitter melon was overwrapped immediately after room cooling or hydrocooling it remained marketable for 8 and 14 d, respectively. Long beans remained

Fig. 7. Indian bitter melon visual quality after hydrocooling and storage at (**a**) 5 or (**b**) 12 °C or room cooling and storage at (**c**) 5 or (**d**) 12 °C for 14 d.

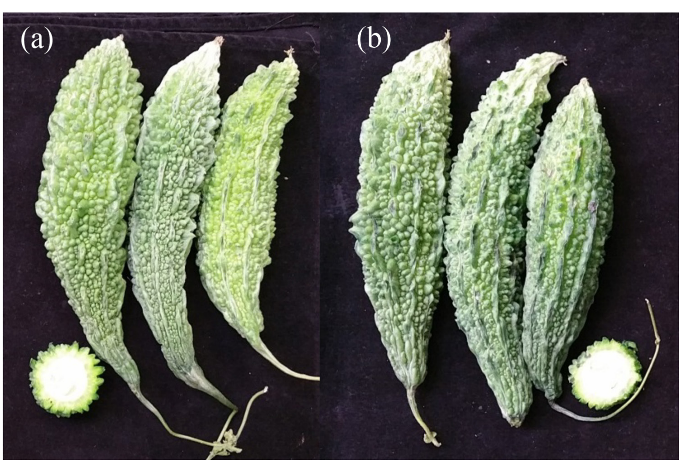

Fig. 8. Indian bitter melon hydrocooled (**a**) or room cooled (**a**) then stored 17 d at 5 °C.

Table 2. Moisture content (%, wet weight basis) of Indian bitter melon hydrocooled or room cooled then stored at 5 or 12 °C for 7 and 14 d.

Treatment	7 d	14 d
Hydrocooled then stored at 5 °C	90.43 ± 1.10	89.87 ± 0.88
Hydrocooled then stored at 12 °C	90.54 ± 1.57	90.33 ± 1.88
Room cooled then stored at 5 °C	88.21 ± 0.57	89.42 ± 0.77
Room cooled then stored at 12 °C	91.48 ± 0.86	91.57 ± 1.21

Moisture content of whole tissue (peel and pulp). Values represent the mean (n = 3) and standard deviation.

marketable for 14 d irrespective of the overwrap treatment, however overwrapping reduced shriveling. Since moisture loss is one of the primary reasons for quality reduction in many Asian vegetables, adoption of hydrocooling along with overwrapping could significantly extend shelf life.

In Test 2, smooth bitter melon cooling rate was slowed 10 to 25 min. by the flaps on waxed carton lids. This demonstrates the importance of container design on hydrocooling efficiency, especially the size and number of vents. The container type not only affects cooling time but also the ability to drain excess water efficiently. Long beans in RPCs cooled in 2–3 min. This is dramatically faster than when room cooled, which took several hours or even overnight.

In Test 3, hydrocooled Indian bitter melon had acceptable quality after 14 d at either 5 or 12° C. As reported in previous research, these studies demonstrated that smooth and Indian bitter melon and long bean can be stored below 12 °C to extend shelf life, however they quickly deteriorate once placed in ambient conditions, which is symptomatic of chilling injury. The commodities evaluated in these tests benefitted from hydrocooling compared to room cooling. Further studies should be conducted to compare rapid cooling method (hydrocooling vs. forced-air cooling), storage temperature, and overwrap treatment for maximum shelf life extension while preventing chilling injury.

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