Research Updates

Ice or an Ice-replacement Agent does Not Improve Refrigerated Broccoli Storage at 1C

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Summary. Broccoli (*Brassica oleracea* L. Italica group) was stored separately with ice and with an ice-replacement agent in polystyrene boxes and without an internal coolant in plastic-lined fiberboard boxes at 1C for 5 weeks and then under simulated marketing conditions at 20C for 2 days. Internal coolants did not improve quality, which was marginally reduced under all handling conditions, and they did increase postharvest costs.

Broccoli is a crop grown commonly for both local and export markets. Marketing of broccoli has to take into account its perishable nature, as it will yellow and decay if not held under the correct

storage conditions (Wang, 1979). Storage life generally is believed to be ≈ 2 to 3 weeks at a low temperature, but some cultivars can be stored for 6 to 8 weeks at 0C (Klieber and Wills, 1991; Morris, 1990). Broccoli is very temperature-sensitive-high storage temperatures lead to accelerated quality loss (Klieber and Wills, 1991). The current practice of icing broccoli in polystyrene or plastic-lined fiberboard boxes results from the need to maintain a low temperature at all times throughout the marketing chain, even if no refrigeration is available (Mitchell, 1992; Simons, 1987). However, transportation and handling costs are increased (Mitchell, 1992) as ≈ 4 kg of ice are added to each box. The risk of rotting is increased after 2 weeks at 0C due to free melt-water (Klieber and Wills, 1991; S.C. Morris, J. Antico, personal communications). Shewfelt et al. (1983) drained melt-water daily and did not find rotting to be a limiting factor, but where it did occur decay spread rapidly throughout a box due to the melt-water. While market acceptance of the ice-boxes is very high in Australia, the United States, and parts of Southeast Asia, this practice is not carried out in some other countries (i.e., the United Kingdom) (A.H. Wearing, personal communication).

This study was conducted to determine the feasibility of storing broccoli without ice or with an ice-replacement agent that does not release water upon thawing. Such an agent is used at present for live seafood export and can be used without increasing costs.

Materials and methods

Three replicates of commercially grown 'Generation' broccoli were harvested in Aug. 1992 at the Univ. of Queensland Gatton College, Australia.

Broccoli was precooled to 0C within 2 h after harvest, similar to commercial practice, and 7 kg was placed in each box. In each replicate, five polystyrene broccoli boxes were top-iced with 4 kg of ice, five polystyrene boxes had placed on top two sheets of F2 ThermaFreeze with 48 cells holding 2 kg of water (Lindgren, Brisbane, Australia) covering the entire top layer of broccoli, and five waxed fiberboard boxes contained broccoli in a loosely folded, low-density polyethylene liner. The ice-replacement sheets consisted of a gel powder sealed in cells between a plastic and a fiber sheet. These were soaked in water to hydrate the gel, frozen at -18C, and placed with the fiber side on the broccoli. The cost of ice per ice-pack was A\$1.00 (Story, 1990) and for two ice-replacement sheets A\$0.95 (G. Little, personal communication). Broccoli was held for 5 weeks-long enough to permit export by sea in a cold room at 0C and then removed for a 2-day marketing period at 20C, similar to commercial practice. Boxes were assessed throughout storage for melt-water and the room and stem temperatures of broccoli were recorded. Broccoli yellowing and rotting in each box was assessed at the end of the marketing period on a rating scale of 1 (no), 2 (trace), 3 (slight), 4 (moderate), and 5 (severe reduction in quality). Results were analyzed by analysis of variance using a Minitab program (Minitab, Valley Forge, Pa.).

Results and discussion

The coldroom temperature averaged 0.9C; broccoli in the fiberboard boxes, 1.1 C; in the polystyrene boxes with ice, 1.0C; and in the polystyrene boxes with the ice-replacement agent, 1.5C. No significant differences in temperatures were observed. While 0C was the targeted storage temperature, temperature fluctuations in the coldroom resulted in the average temperature of 0.9C. Ice started to melt 3 days after storage began. Ice-replacement sachets were fully thawed on the 3rd day, and no free water was found.

After the marketing period, no significant differences in rotting or yellowing were found (Table 1). Quality was reduced marginally in all package types as compared to the original condition.

Broccoli quality did not benefit from icing or an ice-replacement agent in a postharvest and marketing system

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Table 1. *Quality of 'Generation' broccoli after storage for 5 weeks at 1°C and a market period of 2 days at 20°C.*

Treatment	Rotting ^a	Yellowing ^a
Plastic liner/fiberboard box	1.9	1.9
Ice/polystyrene box	2.1	1.7
Ice-replacement/poly-styrene box	2.2	1.9
Significance	NS ^b	NS

^a1 (no), 2 (trace), 3 (slight), 4 (moderate), and 5 (severe quality reduction).

^bNo significant difference for three replicates of five boxes per treatment ($P \leq 0.05$).

where it was precooled and held under refrigeration at 1°C during storage. A significant cost savings of A\$1.00 (US\$0.70) per package could be made by discontinuing the present use of ice. There also would be a saving in labor costs. A precooling system, however, needs to be used that may offset some of the cost savings, if it is not already available. While no significant difference in rotting from the ice treatment was found in this study, previous evidence suggests that melt-water can lead to serious rotting after 1 to 2 weeks of storage (Klieber and Wills, 1991), as decay spreads quickly where it occurs (Shewfelt et al., 1983). There is, therefore, no technical or physiological reason to use ice or an ice-replacement where adequate refrigerated storage and precooling is available; furthermore, ice treatments potentially reduce quality due to promotion of rotting. As no additional protection against temperature increases during handling is available, good management of the cold-chain will be necessary.

The faster completion of thawing in the ice-replacement boxes, compared to ice melting, was due to the lower cooling capacity of the reduced mass of frozen water present. The weight of coolant could have been increased by placing sheets on the bottom of the boxes, but this would have

made the use of the ice-replacement agent twice as expensive as the ice.

Conclusion

Growers, wholesalers, retailers, and importers need to be shown that broccoli marketing with ice or an ice-replacement agent increases costs while not improving quality in the general marketing system where refrigeration is normally available. Icing during refrigerated storage and export is currently the accepted marketing practice in Australia, the United States, and many Southeast Asian countries. Removal of this, in many cases superfluous, practice will benefit the horticultural industry by reducing costs and diminishing the risk of rot development (Klieber and Wills, 1991).

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