Control of Postharvest Decays of Blueberries by Carbon Dioxide-Enriched Atmospheres

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ABSTRACT

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Freshly harvested blueberry fruits were cooled to 2 C in 2, 48, and 72 hr, and provided with a CO_2-enriched atmosphere averaging 12–15% during 2 wk of storage at 2 C. Rapidly cooled berries had less decay when removed from cold storage and during 3 additional days at 21 C than berries that had been cooled more slowly. Berries subjected to the CO_2-enriched atmosphere had about 50% less decay than their counterparts stored in air. The CO_2 atmosphere was more effective in retarding decays in the rapidly cooled berries than in berries cooled to 2 C in 48 or 72 hr.

Additional key words: precooling, *Vaccinium corymbosum*

In recent years, our studies have concentrated on extending the shelf life of fresh blueberries (*Vaccinium corymbosum* L.) sufficiently to warrant transoceanic surface shipments to Europe. A large marketing potential for this product exists if quality can be maintained for the 12–14 days required to move the berries from field to destination.

Disease, principally gray mold rot (*Botrytis cinerea* Pers. ex Fr.), alternaria rot (*Alternaria* sp.), and anthracnose (*Colletotrichum* sp.), is the major factor limiting fresh blueberry shelf life (2,4). The principal locus of infection is the stem scar (1). Early in our studies, very good disease control was obtained with a combination of rapid precooling, a fungicidal dip, and modified atmospheres in 10-day cold storage of blueberries (3). An objection to fungicidal dips, however, is the cost of extra handling and drying of the berries. Satisfactory disease control was also achieved with rapid precooling and a carbon dioxide (CO_2)-enriched atmosphere. At present, however, no rapid precooling facility exists in the major blueberry-growing areas of New Jersey. In view of this, the present study was made to determine if CO_2 atmospheres, in conjunction with current transit cooling practices, can effectively control decay of nonprecooled fresh blueberries in simulated shipments to distant markets.

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MATERIALS AND METHODS

Ten storage tests were conducted in 1981 with the highbush blueberry cultivar Bluecrop. Three cooling rates were employed to bring down the fruit pulp temperatures, from 23 to 29 C, initially, to 2 C in 2, 48, and 72 hr. The slower cooling rates were patterned after those recorded in USDA shipping tests of fresh produce to distant markets.

Field trays of commercially hand-picked or commercial mixtures of hand-picked and machine-harvested blueberries were obtained from New Jersey growers. Each field tray held 12 uncapped 1-pint (473 ml) pulpboard containers of berries. Pints were capped with a plastic film, and randomized before cooling in each test. Cooling was begun 5–6 hr after the berries were harvested.

Blueberries were cooled to 2 C in 2 hr with forced cold air before composing 12-pint test packages. Other berries were similarly packaged before their temperatures were dropped, incrementally, every

4 hr, to 2 C in either 48 or 72 hr. Some test packages were tightly enclosed within a 4-mil (0.1-mm)-thick polyethylene film and provided with a CO_2-enriched atmosphere.

The CO_2 gas was introduced into each film-covered package through a plastic port attached to the film after the initial package atmosphere was partially withdrawn by a vacuum pump. Atmospheres of 15–20% CO_2 were initially attained within packages of the rapidly cooled berries. The packages subjected to slower cooling rates were provided with initial CO_2 atmospheres of 5–10%. The lower initial CO_2 concentrations were used because of the higher berry metabolism and more rapid buildup of CO_2 under these conditions. To avoid suboxidation or excessive buildup of CO_2, one or two 0.5-mm holes were made in each film-covered package cooled at the slower rates.

After the berries were cooled to 2 C, they were held at that temperature until 14 days had elapsed from the start of each test. Monitoring of CO_2 and O_2 atmospheres within the film-covered packages was carried out periodically during the cold storage period by gas chromatography (Gow-Mac Series 550, Gow-Mac Instrument Co., Bound Brook, NJ). After the berries were removed from cold storage, 3 pints from each test package were examined for decay. The remaining 9 pints in each test package were subsequently stored at 21 C and 3 pints each were examined after 1, 2, and 3 days.

RESULTS

Adding CO_2-enriched atmospheres to blueberries cooled at the three rates reduced decay for all tests by about 50% during subsequent holding at 21 C (Table 1). CO_2 atmospheres averaged 15, 13, and 12% for packaged berries cooled to 2 C in 2 hr (2-CO_2), 48 hr (48-CO_2), and 72 hr (72-CO_2), respectively. Mean CO_2 concentrations for the storage period in a test ranged from 10.1 to 21.3%, from 9.7 to 17.0%, and from 9.1 to 14.4%, respectively, in 2-CO_2, 48-CO_2, and 72-CO_2 berry packages. Rapid cooling combined with the CO_2-enriched atmosphere during cold storage was the best treatment for arresting decay and extending the marketability of fresh blueberries. Decay incidence was delayed 1 day in rapidly cooled berries, when held at 21 C, compared with the decay that developed in berries cooled at the slower rates. A similar benefit occurred with the CO_2 application to berries at all three cooling rates. The CO_2 application was most effective during the first 2 days of the 21 C holding period. The advantage of the CO_2 treatment for 2-CO_2 berries was maintained for 3 days at 21 C but was diminished for 48-CO_2 and 72-CO_2 berries (Table 1).

Package atmospheres were continuously modified by the fruit's metabolism. Improper seals and tiny film tears also affected the internal atmospheres of a few packages. CO_2 or air was added periodically when the CO_2 level dropped below 8% or rose above 20%. Excessive CO_2 levels in a few airtight packages caused some softening and a slight off-flavor of the berries in the first three tests; O_2 levels fell below 2% in these packages. More frequent monitoring of CO_2 levels and film perforations eliminated the problem in subsequent tests.

Table 1. Decay incidence in blueberries after 14 days in cold storage and after 1, 2, and 3 additional days at 21 C

Cooling time to 2 C (hr)	CO_2[v] (%)	14 days at 2 C[w]	Percent decay[x] after additional holding at 1 day (21 C)	2 days (21 C)	3 days (21 C)	Total[y]
2	0	0.8 a[z]	2.0 a	6.8 b	17.2 bc	6.7 b
2	15	0.7 a	1.0 a	2.2 a	5.6 a	2.4 a
48	0	2.7 b	6.9 b	14.1 c	20.7 bc	10.1 c
48	13	0.9 a	2.2 a	5.3 ab	16.3 bc	6.2 b
72	0	3.7 b	10.8 c	20.6 d	24.8 c	15.1 d
72	12	1.1 a	3.0 a	9.6 b	16.0 b	7.3 b

[v] Includes some soft and leaky berries. Mean of 10 tests.
[w] Mean for all tests during cold storage.
[x] Includes cooling time to 2 C.
[y] Comprised of decay incidence for all examinations.
[z] Mean separation within a column by Duncan's multiple range test at the 5% level.

DISCUSSION

Fresh blueberries are not precooled in New Jersey except for an occasional overnight stay in a cold room. Rarely are fresh blueberries shipped to distant markets at transit temperatures much below 10 C, despite reports recommending 0 C as the best temperature to maintain quality (6–8,12). The common practice is to load freshly harvested, nonprecooled blueberries into refrigerated trailers destined for markets 2–4 days distant. Growers and shippers are reluctant to refrigerate blueberries to low temperatures because they believe the condensate formed on the berries when removed from the cold erodes the bloom on the fruit and enhances excessive decay development. Our preliminary studies do not support the premise than an increase in postharvest decay will result when blueberries "sweat" (10).

Carbon dioxide, released from dry ice, has been used to maintain quality in rail shipments of western sweet cherries for years (9). More recently, CO_2-enriched atmospheres have controlled postharvest decays in the marketing of strawberries (5) and in the storage of melons (11). The easy application of CO_2, its nontoxic nature, and the absence of residues, makes this gas an attractive alternative to fungicidal dips.

The most effective treatments in our tests required rapid precooling. Under current marketing operations, rapid precooling is necessary for the quality of fresh blueberries to be maintained during extended storage periods. The lack of a rapid precooling facility poses an obstacle to the shipper who wishes to exploit potentially lucrative European markets. Although air transport is readily available, the high freight costs limit fresh blueberry exports to a relatively miniscule level. On the other hand, surface transport by container ship to European markets is substantially more economical. If quality could be maintained during the 10- to 12-day overseas trip, there would be a multifold increase in the volume of fresh blueberries exported to Europe.

Our tests demonstrate that postharvest disease control and marketable quality can be achieved in nonprecooled fresh blueberrry surface shipments to distant markets if there is adequate refrigeration and a CO_2 atmosphere of about 15% is provided during transit. In our tests, the CO_2-enriched atmosphere compensated for the lack of precooling by suppressing postharvest decays during the time required to cool the blueberries to cold temperatures. Under these circumstances, therefore, the CO_2-enriched atmosphere presents a viable alternative to rapid precooling but, for best results, the CO_2 atmosphere should be a supplement to rapid precooling.

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