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# Lowbush Blueberry Quality Changes in Response to Mechanical Damage and Storage Temperature

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***Abstract.*** **Postharvest response of wild lowbush blueberry *(Vaccinium angustifolium* Ait. and *V. myrtilloides* Michx.) to mechanical damage and storage temperature was studied during 2 years. Fruit weight loss and the incidence of shriveled or split berries were major components that contributed to the loss of marketable yield resulting from mechanical damage and storage temperature. Decay of berries resulted in only 1% to 2% of the total marketable fruit loss. In general, the major quality attributes (firmness, microbial growth, hue, bloom, split, and unblemished berries) deteriorated with increasing damage levels and increasing storage temperature without significant interaction. Temperature had consistent effects in both years on moisture content, soluble solids concentration, titratable acids, weight loss, shriveled and decayed berries, Hunter L values, and anthocyanin leakage, while damage level had inconsistent or no significant effect.**

The susceptibility of blueberries to mechanical injury, particularly during machine harvesting, has been reported by several authors. Compared with hand harvesting, Mainland et al. (1975) noted a reduction in marketable yields of up to 44% for machine-harvested highbush blueberries *(Vaccinium corymbosum* L.) after storage for 7 days at 21C. The loss was attributed to softening and increased decay, mainly a consequence of bruising. Similar observations were made by Austin and Williamson (1977) and Miller and Smittle (1987) for rabbiteye blueberries (V. *ashei* Reade).

Additional injury may be incurred during primary processing (cleaning, grading, packaging). Pneumatic winnowing operations (Mainland et al., 1975) or dropping berries from various heights onto a hard surface (Ballinger et al., 1973; Hamann et al., 1973) resulted in further immediate softening and 5% to 10% more decay after nonrefrigerated storage for 1 week. Several short drops, a situation more likely encountered in primary processing, softened the berries as much as a single long drop for the same total distance. A single long drop, however, led to more decay due to opening of the "picking wound".

Lower storage temperature has been shown to delay quality losses. As early as 1959, Woodruff and Dewey (1959) described the deterioration events for the highbush blueberry and concluded that breakdown was mainly physiological, with mold infection and growth occurring adventitiously on the debilitated tissues. They also observed that the changes could be slowed effectively by a reduction in storage temperature. Subsequently, Kender et al. (1966), working with lowbush blueberries (V. *angustifolium),* and Cappellini et al. (1972) and Ballinger et al. (1978), working with *V. corymbosum,* demonstrated incremental benefits in the retention of fruit quality and marketable yield as the storage temperature was decreased. Ballinger et al. (1978) concluded that blueberries for the fresh market should not be exposed to temperatures exceeding 10C and preferably should be held at or near lC.

Most of this previous work studied the effects of damage or storage temperature on quality in isolation and generally were confined to limited experimental material from a single cultivar of highbush blueberry. Texture and percent decay have been the primary determinants of quality and marketability. The present study assessed the combined effects of mechanical damage and storage temperature on various quality and marketability attributes of lowbush blueberries, representing the diverse cultural conditions in the Atlantic region of Canada.

## Materials and Methods

### Prestorage treatment

Ten individual sources of wild lowbush blueberries were selected from diverse cultural locations throughout Nova Scotia and New Brunswick, Canada, in each of the 1987 and 1988 crop years. Berries were harvested by raking, precleaned either mechanically or by hand, and transported under refrigeration at 0C to the research processing facility. Within 24 hr of harvest, fruit from each lot was allowed to warm to 20C before treatment. To induce impact damage, berries were dropped onto a moving smooth conveyor belt from a height of 40, 80, 120, or 160 cm (0, 53, 106, and 159 cm in 1988 study.) Twelve 300-g samples were collected from each damage treatment for each lot, placed in 500-ml molded pulp cartons, weighed, and three samples stored at each of 0, 5, 10, or 20C for 14 days. Fruit was stored at ambient relative humidity, which varied from 80% to 50670 for the range of temperatures from 0 to 20C.

### Post-storage analyses

*Weight loss.* After 14 days of storage, each of the three samples from each damage–storage treatment combination was reweighed to determine weight loss (% w/w) during storage.

*Defective berries.* In 1987, a 300-g sample was segregated according to categories of split, shriveled, and decayed berries. The remaining berries and the less shrivelled berries were classified as unblemished. In 1988, the method was improved by taking a 50-g weighed sample and segregating it according to categories of split, shriveled, decayed, or unblemished berries. In both studies, the weight of fruit in each class was determined and converted to percent of the total weight. The attributes were defined as follows: 1) Split–any berry that displayed a visible

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fracture in its outer skin; 2) shrivelled–any berry that exhibited a wrinkled outer skin; 3) decayed—any berry that exhibited visible mold; 4) unblemished—none of the above.

*Microbial growth.* For each experimental treatment, a 25-g sample of blueberries was aseptically withdrawn and blended for 2 min in 225 g of 0.1 % (w/v) sterile peptone water in a Colworth 400 Stomacher (Seward Laboratory, London) to prepare a $10^{-1}$ dilution. A further $10^{-1}$ dilution was subsequently prepared and both dilutions individually surface-plated on duplicate plates of appropriate agar media using a Spiral Plater (Spiral Systems, Bethesda, Md.). General microbial numbers were estimated on TSY agar [tryptic soy broth (Difco Laboratories, Detroit), 30 g; yeast extract, 5 g; agar, 20 $g{\cdot}liter^{-1}$], incubated aerobically at 30C for 48 hr; lactic acid bacteria on lactobacilli MRS agar (Difco), adjusted to pH 5.6, and incubated anaerobically at 30C for 48 hr; and yeast/molds on oxytetracycline gentamicin yeast extract (OGY) agar (ICMSF, 1978), incubated aerobically at 25C for 5 days. The microbial counts reported for each sample represented the highest count obtained on any one of the agar media used.

*Fruit* firmness. Two methods were used: 1) A sensory assessment of fruit firmness, whereby 15 berries were individually rolled between the thumb and index finger and rated for firmness on a 0 to 5 scale (0 = berry rupture on touch; 2.5 = berry surface depressed on touch; 5 = berry firm, not yielding to touch). 2) Use of a modified compression head attached to a Accuforce II model AF-100 digital force gage (Ametek, Hunter Spring Division, Hatfield, Pa.). A 30-g sample of berries was placed in a 36.4-mm-diameter plastic cylinder and the berries compressed to a depth of 30 mm using a solid plastic piston.

*Soluble solids concentration (SSC,) and titratable acids.* About 200 g of berries were squeezed through cheesecloth and the resulting juice measured for SSC using a hand-held refractometer (Atago, Japan) and for titratable acidity by titrating a 2-ml sample against 0.1 N NaOH using a semiautomatic Multi-Dosimat E-415 titrator (Metrohm AG, Herisau, Switzerland). The endpoint was indicated with phenolphthalein and results expressed as milligrams of citric acid per 100 ml of blueberry juice.

*Moisture content.* A 10 ± 2-g sample of berries was dried at 60C in a vacuum oven to a constant weight.

*Bloom (epicuticular wax).* Bloom was rated on a *0* to 5 scale (0 = no bloom, 5 = high bloom) using a full box of berries carefully poured onto a standard-sized white plastic tray.

*Color.* A single box of berries from each experimental treatment was used to determine fruit color on a D25-L Hunterlab Tristimulis Calorimeter (Hunter Associates, Reston, Va.). The blueberries were carefully poured into a 12.5-cm square optical plastic cell, the sample placed over the viewing port, covered with a black mask to prevent external light interference, and two readings taken of Hunter L, a, and b values; the cell was rotated 90° between readings. During 1987, the sample cell was refilled with the berries and an additional two readings taken. Hunter a and b values were converted to hue in angles by $\cos^{-1}[a/\sqrt{(a^2 + b^2)}]$.

*Anthocyanin leakage.* As a measure of the integrity of the berry skins, the amount of anthocyanin pigment leaking through splits or breaks in the skins was measured using a modification of the method of Sapers and Phillips (1985). For each experimental treatment, berries were carefully poured onto a tray and a 75-g composite sample weighed into the beaker containing, toward its base, a friction-fitting disk of 15-mesh nylon screening. The screen served to physically separate the berries from a 55-mm stir bar in the bottom of the beaker. Potassium hydrogen phthalate buffer (175 ml) at pH3 was added and the mixture slowly stirred under standard conditions for 10 min. A 5-ml aliquot was removed, an additional 5 ml of buffer added, and the diluted sample filtered under suction through 4.25-cm-diameter No. 2 Whatman paper. The optical density (OD) of the sample at 519 nm was measured using a Beckman (Irvine, Calif.) DU-7 spectrophotometer.

*Statistical analysis.* Damage level and storage temperature formed a 4 × 4 factorial experiment arranged in a randomized complete-block design, with grower samples as replicates. Damage and storage effects were estimated through polynomial regression within an analysis of variance for each attribute. A logarithmic transformation was used to stabilize variance of anthocyanin leakage data. Percent shriveled, decayed, split, and marketable berries were transformed to angles to stabilize the variance, and the mean values were back-transformed for the presentation of the means. All data were analyzed statistically using Genstat 5 procedures (Genstat 5 Committee, 1987).

## Results and Discussion

Except for SSC and titratable acids, there was no interaction between the effects of damage level and storage temperature; the effects due to damage or storage temperature add to the effect of the other. Consequently, the results are described in terms of the individual experimental factors, and, where the response trends were similar in both years, the average trend is discussed. The significance level for statistical tests was $P < 0.05$, and statistically significant effects are reported in the positive form without the term ‘significantly’.

Damage had little effect on weight loss, but increasing storage temperature, accompanied by progressively lower RH levels, generally resulted in progressively greater weight loss (Table 1). In 1987, weight loss increased ≈50% when berries were stored at 20C, as compared with 10C or lower. However, in 1988, considerably more weight loss was evident at 10 or 20C than at 0 or 5C, despite humidity-temperature combinations comparable to those in the 1987 study. Storage at 0 or 5C were the only treatments to yield weight losses that we considered to be commercially acceptable.

Averaged over both years, increasing damage level resulted in an overall decline of 13% in the percentage of unblemished berries, while increasing storage temperature resulted in an overall decline of 44% (Table 1). With increasing impact damage, the decrease was mainly attributed to the corresponding increase in the incidence of split berries (Table 1). Decay was unaffected by damage level. The incidence of shriveled berries was significant only in 1987 (Table 1). Increasing storage temperature resulted in higher levels of split, shriveled, and decayed berries (Table 1), although the degree of increase depended on the year. This increase in split berries with increasing storage temperature was most likely related to the general physiological breakdown of the berries. Woodruff and Dewey (1959) described the breakdown of berries as being characterized by complete internal disintegration of the flesh and collapse of the berry when subjected to slight pressure. Increases in skin rupturing and concurrent anthocyanin leakage with soft berries was observed by Sapers and Phillips (1985).

Although microbial counts in 1988 increased with increasing damage level, there was no concomitant rise in visible decay (Table 1). Similarly, as storage temperature was raised, microbial growth increased progressively, while only small increases

Table 1. Effects of mechanical damage and storage temperature on lowbush blueberry weight, fruit loss, and microbial counts in fruit stored for 14 days.

| Source of variation | Wt loss (%) | | Unblemished berries (%) | | Split berries (%) | | Shrivelled berries (%) | | Decayed berries (%) | | Microbial counts (log 10) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1987 | 1988 | 1987 | 1988 | 1987 | 1988 | 1987 | 1988 | 1987 | 1988 | 1988 |
| Location | | | | | | | | | | | |
| Minimum | 17.0 | 8.5 | 21.1 | 15.5 | 19.9 | 14.5 | 12.1 | 15.1 | 0.1 | 0.0 | 5.72 |
| Maximum | 35.4 | 12.7 | 86.0 | 57.3 | 52.9 | 52.0 | 77.4 | 30.2 | 6.3 | 9.5 | 7.09 |
| Damage$^z$ (cm drop height) | | | | | | | | | | | |
| 0 | 22.8 | 10.3 | 50.1 | 47.7 | 34.8 | 21.4 | 45.5 | 23.8 | 1.5 | 0.9 | 6.20 |
| 53 | 22.8 | 10.4 | 46.7 | 41.4 | 40.4 | 30.1 | 49.2 | 22.1 | 1.4 | 0.6 | 6.27 |
| 106 | 22.5 | 10.4 | 41.7 | 35.1 | 44.8 | 36.4 | 52.4 | 21.3 | 2.1 | 0.7 | 6.34 |
| 159 | 23.7 | 11.7 | 39.2 | 32.9 | 48.0 | 43.0 | 54.9 | 18.9 | 1.7 | 0.8 | 6.42 |
| SEM (n = 40, df = 135) | 0.90 | 0.27 | 1.09 | 1.16 | 0.98 | 1.47 | 1.06 | 1.71 | 1.08 | 0.95 | 0.042 |
| Significant effects$^y$ | NS | L, Q | L | L | L | L | L | NS | NS | NS | L |
| Storage temperature (°C) | | | | | | | | | | | |
| 0 | 20.1 | 5.3 | 68.4 | 59.1 | 20.5 | 19.5 | 31.4 | 17.8 | 0.0 | 0.1 | 5.94 |
| 5 | 22.0 | 7.6 | 49.9 | 42.3 | 35.6 | 38.7 | 47.8 | 13.8 | 0.6 | 0.4 | 6.30 |
| 10 | 20.1 | 12.8 | 46.2 | 31.7 | 46.7 | 36.0 | 49.0 | 24.8 | 3.5 | 1.5 | 6.41 |
| 20 | 29.7 | 17.1 | 15.9 | 24.9 | 66.8 | 34.9 | 73.3 | 31.1 | 5.6 | 1.5 | 6.55 |
| SEM (n = 40, df = 135) | 0.90 | 0.27 | 1.09 | 1.16 | 0.98 | 1.47 | 1.06 | 1.71 | 1.08 | 0.95 | 0.042 |
| Significant effects$^y$ | L, Q | L, Q | L | L, Q | L, Q | L, Q | L | L | L | L | L, Q |

$^z$Damage levels for 1987 were 40, 80, 120, and 160 cm.

$^y$L = linear, Q = quadratic, NS = not significant ($P > 0.05$).

in the percentage of decayed berries were recorded (Table 1). Generally, decay accounted for an average fruit loss of only 1% to 2%, with a maximum of 5.6%. This low percentage was accompanied by a low incidence of mold and a predominance of yeast colonies on the TSY and OGY isolation agars.

This evidence on lowbush blueberry is in contrast to previous reports on highbush (Cappellini and Ceponis, 1977; Stretch, 1959) or rabbiteye (Miller and Smittle, 1987) blueberries, reports that indicate that decay was potentially the most critical cause of commercial product loss. The present results suggest, however, that lowbush blueberries, even when damaged or physiologically debilitated, are not as susceptible to adventitious mold growth (decay) as the other commercial species. Despite the consistent presence of a variety of mold on freshly harvested material, yeast growth appears to occur preferentially, at least over the storage humidities studied (80% RH or lower).

This apparent resistance of lowbush blueberries to decay is not easily explained, but may result, in part, from the development of unfavorable growth conditions for molds as the berries age. For instance, Ballinger et al. (1978) have suggested that decay in highbush blueberries maybe inhibited, particularly at high storage temperatures, by increases in titratable acids and SSC. Such a thesis is supported by similar storage trends in lowbush blueberries (Table 2). It is contradicted, however, by the apparent lack of inhibition of yeasts. These microorganisms exhibit many of the nutritional and physiological growth requirements of molds and should, therefore, share a similar response to changes in the stored berries. They did not.

Perhaps the phenomenon of antagonism between specific bacteria or yeasts and decay molds on stored fruits, as recently reviewed by Wilson and Wisniewski (1989), provides a better explanation for the observed results. Although such interactions between the components of the contaminating microflora of either low- or highbush blueberries remain to be affirmed, further examination of their role in the extension of postharvest shelf life appears appropriate.

Increased damage level or storage temperature resulted in loss of fruit firmness, as measured by instrumental and sensory methods (Table 2). In 1988, a large decline in fruit firmness occurred with the first level of impact damage (53-cm drop), after which fruit firmness loss increased with incremental levels of damage. Storage temperature had a greater impact than damage on fruit firmness. Berries held at 0C were the firmest; berries held at 5C showed a disproportional decrease in firmness; and each additional rise in storage temperature resulted in incremental decreases in fruit firmness. Storage of lowbush blueberries at 0C resulted in a substantial retention of firmness, as compared with fruit stored at 5C.

Berry SSC was unaffected by impact damage in both years, but SSC was higher in fruit stored at 5C or higher (Table 2). However, this apparent increase in SSC could be explained simply by lower moisture contents (Table 2).

Titratable acids contents of the berries increased with impact damage and in response to storage temperature (Table 2). Increase in fruit titratable acids content with storage duration was observed previously by Smittle and Miller (1988) on rabbiteye blueberries *(Vaccinium ashei)* stored in air at 5C. Increased titratable acids contents of blueberries cannot be completely explained on the basis of declining moisture content of the berry; titratable acids contents were observed to increase in response

Table 2. Effects of mechanical damage and storage temperature on lowbush blueberry texture and chemical determinations in fruit stored for 14 days.

| Source of variation | Firmness Instrumental (N) | | Firmness Sensory (rating)[z] | | Soluble solids concn (%) | | Titratable acids (mg/100 ml) | | Moisture content (%) |
|---|---|---|---|---|---|---|---|---|---|
| | 1987 | 1988 | 1987 | 1988 | 1987 | 1988 | 1987 | 1988 | 1988 |
| Location | | | | | | | | | |
| Minimum | 8.4 | 7.0 | 0.3 | 0.7 | 14.0 | 9.3 | 446 | 300 | 83.7 |
| Maximum | 19.1 | 27.2 | 2.3 | 2.8 | 17.9 | 11.8 | 939 | 880 | 86.5 |
| Damage[y] (cm) | | | | | | | | | |
| 0 | 13.7 | 20.9 | 2.0 | 2.1 | 16.2 | 11.0[x] | 470 | 578[w] | 84.7 |
| 53 | 13.1 | 16.7 | 1.8 | 1.6 | 16.2 | 10.7 | 525 | 600 | 84.6 |
| 106 | 12.5 | 15.6 | 1.5 | 1.4 | 16.5 | 10.9 | 581 | 634 | 84.3 |
| 159 | 11.6 | 14.2 | 1.5 | 1.2 | 16.5 | 10.8 | 1251 | 657 | 84.5 |
| SEM (n = 40, df = 135) | 0.49 | 0.76 | 0.12 | 0.07 | 0.18 | 0.08 | 29.5 | 21.3 | 0.16 |
| Significant effects[v] | L | L | L | L, Q | NS | NS | L | L | NS |
| Temperature (°C) | | | | | | | | | |
| 0 | 20.1 | 28.9 | 2.8 | 2.0 | 15.6 | 10.6[x] | 669 | 432 | 85.4 |
| 5 | 14.2 | 15.5 | 2.0 | 1.7 | 16.3 | 10.7 | 684 | 538 | 84.9 |
| 10 | 9.7 | 12.0 | 1.0 | 1.4 | 15.7 | 11.1 | 710 | 664 | 84.1 |
| 20 | 6.8 | 11.0 | 0.5 | 1.1 | 17.7 | 11.0 | 764 | 836 | 83.6 |
| SEM (n = 40, df = 135) | 0.49 | 0.76 | 0.12 | 0.07 | 0.17 | 0.08 | 29.5 | 21.3 | 0.16 |
| Significant effects[v] | L, Q | L, Q | L, Q | L | L, Q | L | L, Q | L | L |

[z] Rating: 0 = soft, 5 = firm.

[y] Damage levels for 1987 were 40, 80, 120, and 160 cm.

[x] Mean values for soluble solids at each damage level and storage temperature (SEM = 0.16) in 1988 were:

| Damage (cm) | Temp (°C) 0 | 5 | 10 | 20 |
|---|---|---|---|---|
| 0 | 10.7 | 10.7 | 11.3 | 11.1 |
| 53 | 10.6 | 10.7 | 10.7 | 10.8 |
| 106 | 10.8 | 10.7 | 11.2 | 10.9 |
| 159 | 10.5 | 10.6 | 11.0 | 11.2 |

[w] Mean values for titratable acids at each damage level and storage temperature (SEM = 42.6) in 1988 were:

| Damage (cm) | Temp (°C) 0 | 5 | 10 | 20 |
|---|---|---|---|---|
| 0 | 453 | 504 | 605 | 750 |
| 53 | 413 | 524 | 652 | 810 |
| 106 | 445 | 608 | 680 | 804 |
| 159 | 416 | 516 | 719 | 978 |

[v] L = linear, Q = quadratic, NS = nonsignificant ($P > 0.05$).

to impact damage, with no associated change in moisture content. Also, the decline in berry moisture content did not correspond proportionately to the increase in titratable acids with increased storage temperature. The increased titratable acids content may be from the release of additional acids associated with softening and cell wall breakdown (Proctor and Peng, 1989).

In 1987, damage level had no significant effect on the color and appearance attributes of bloom (epicuticular wax), Hunter L value, and anthocyanin leakage (Table 3). In 1988, impact damage resulted in decreased bloom ratings; however, berry darkening was not associated with a significant drop in Hunter L values. When berries were severely damaged by dropping them 159 cm, the major change in color, as measured by hue angle 0, was a significant shift in sample color from blue to blue-red. During both studies, increasing storage temperature significantly affected berry color and appearance, as shown by decreasing Hunter L values (darkening), loss of bloom, increased anthocyanin leakage, and a shift in sample color (hue angle θ) from blue to blue-red (Table 3). Anthocyanin pigments act as color-indicating dyes (Wrolstad, 1976). Since berry hue changes with pH, this shift in color (from blue to blue-red) may be related to the effect of cell breakdown and concurring increases in titratable acids. The general increase in anthocyanin leakage corresponded with the increased incidence of split berries. This result supports the observations of Sapers and Phillips

Table 3. Effects of mechanical damage and storage temperature on lowbush blueberry bloom, calorimetric determinations, and anthocyanin leakage,

| Source of variation | Bloom rating[z] | | Colorimetric determinations | | | | Anthocyanin (OD 519) | |
|---|---|---|---|---|---|---|---|---|
| | | | Hunter L | | Hue | | | |
| | 1987 | 1988 | 1987 | 1988 | 1987 | 1988 | 1987 | 1988 |
| Location | | | | | | | | |
| Minimum | 0.8 | 1.5 | 14.6 | 34.3 | 282 | 258 | 2.22 | 2.44 |
| Maximum | 5.0 | 4.2 | 20.9 | 52.2 | 315 | 303 | 3.10 | 3.40 |
| Damage[y] (cm) | | | | | | | | |
| 0 | 2.8 | 3.0 | 17.9 | 39.8 | 293 | 279 | 2.54 | 2.85 |
| 53 | 2.5 | 2.7 | 17.4 | 39.6 | 296 | 284 | 2.59 | 2.83 |
| 106 | 2.5 | 2.7 | 17.7 | 40.2 | 296 | 282 | 2.58 | 2.89 |
| 159 | 2.5 | 2.5 | 17.4 | 40.2 | 298 | 285 | 2.63 | 2.94 |
| SEM | | | | | | | | |
| (n = 40, df = 135) | 0.13 | 0.08 | 0.15 | 0.27 | 1.3 | 1.5 | 0.030 | 0.024 |
| Significant effects[x] | NS | L | NS | NS | L | L | NS | L |
| Temperature (°C) | | | | | | | | |
| 0 | 3.3 | 2.9 | 18.6 | 40.1 | 286 | 274 | 2.21 | 2.56 |
| 5 | 3.0 | 2.8 | 18.1 | 40.5 | 290 | 277 | 2.55 | 3.08 |
| 10 | 2.3 | 2.8 | 17.4 | 39.8 | 299 | 286 | 2.66 | 3.02 |
| 20 | 1.5 | 2.6 | 16.3 | 39.5 | 308 | 292 | 2.92 | 2.85 |
| SEM | | | | | | | | |
| (n = 40, df = 135) | 0.13 | 0.08 | 0.15 | 0.27 | 1.3 | 1.5 | 0.030 | 0.024 |
| Significant effects[x] | L | L | L | L | L | L | L, Q | L, Q |

[z] Rating: 0 = no bloom, 5 = intact bloom.

[y] Damage levels for 1987 were 40, 80, 120, and 160 cm.

[x] L = linear, Q = quadratic, NS = not significant ($P > 0.05$).

(1985) and Sapers et al. (1985) that suggested that anthocyanin leakage resulted from breaks in the epiderm.

The present study quantified the potential for reducing commercial losses in processing lowbush blueberries from weight loss and split and shriveled berries through the control of storage temperature and care in handling. The major qualitative characteristics that contribute to low commercial yields are loss of firmness, loss of bloom, and loss of the blue anthocyanin coloration either through leakage from the berry, chemical disruption, or expression of the pigment. The improvement in product quality often increased disproportionately with each increment toward the optimal conditions of no impact damage and storage at 0C. Therefore, the economic return to the processor may warrant modifying the handling and storage temperature of the product. Potential losses due to decay were not as great as those reported for highbush or rabbiteye berries (Cappellini and Ceponis, 1977; Miller and Smittle, 1987).

To reduce product losses and optimize product quality during the postharvest handling of lowbush blueberries, berry damage should be minimized and low storage temperatures maintained.

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