Influence of Temperature during Transport on Shelf-life Quality of Highbush Blueberries (Vaccinium corymbosum L. cvs. Bluetta, Duke)

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Abstract. Quality changes of highbush blueberry cultivars (Vaccinium corymbosum L. cvs. Bluetta, Duke) were evaluated as influenced by transport temperature. Neither cultivar remained marketable after 6 days or 16 days at room temperature or 10°C. The ‘Duke’ cultivar had slightly lower weight loss than ‘Bluetta,’ but difference between the cultivars was not significant after 12 days of storage. Decrease of fruit firmness was delayed by storage at 10°C for both cultivars, with ‘Duke’ blueberries being firmer than ‘Bluetta’. Soluble solids content was 9.9 ± 0.3 °Brix for both cultivars, which was lower than previous reports, probably as a result of weather conditions before harvest. Organic acid content declined in both cultivars during storage. Hue value of the ‘Bluetta’ cultivar was higher (more purple-blue) than the ‘Duke’ cultivar, but Hunter L and hue angle did not change during storage. Fruit characteristics at harvest and postharvest maintenance of low temperature are clearly important factors affecting the post-harvest fruit quality during transportation and storage.

Additional key words: fruit quality, storage temperature, vented PET container, weather condition

Introduction

Highbush blueberries contain several bioactive compounds including anthocyanins, flavonoids, polyphenols, and vitamins, and are thus known as a health-promoting food (Faria et al., 2005; Sinelli et al., 2008). In South Korea, cultivation area of blueberries was about 1,082 ha in 2011, and this area is increasing along with public awareness of the potential benefit of blueberries against human pathogens. However, they are highly perishable, the final quality of fresh blueberries critically dependent on the innate firmness and resistance to pathogen attack (Ehlenfeldt and Martin, 2002; Schotsmans et al., 2007). Another major factor responsible for the short shelf life of blueberries is high weight loss that causes shriveling and loss of brightness. Fresh fruit weight loss is mainly caused by water loss that results from a difference in vapor pressure between the fruit and surrounding air and is affected by the area/volume ratio, mechanical damage of the surface area, and storage temperature (Kays, 1997). Small fruit such as blueberries have a high area/volume ratio, which leads to increased dehydration (Wills et al., 1998).

To reduce weight loss during transportation, blueberries are usually packaged in a polyethylene terephthalate (PET) container and then repackaged in a corrugated cardboard box for transport to each wholesale retail market in South Korea. PET is a petroleum-based material that is commonly and widely used for retail and wholesale packaging containers for fresh produce.

In general, harvested highbush blueberries have a storage life of two or three weeks in air at 0°C or up to five or six weeks in a controlled atmosphere environment (DeLong et al., 2003). Blueberries exposed to concentrations of CO₂ above 15% have a prolonged shelf life (Harb and Streif, 2004; Kim et al., 1995), and shelf life can be extended by a combination of elevated CO₂ and reduced O₂ during storage (Ceponis and Cappellini, 1985; Chiabrando and Giacalone, 2011; Rosenfeld et al., 1999). However, CO₂ concentrations higher than 12% have very different effects on flavor, firmness,
and acidity, depending on the cultivar (Harb and Streif, 2004). Storage temperature is an important factor than packaging materials and atmosphere modification. Cultivar is also an important factor in affecting quality of blueberries (Miller et al., 1993). Rosenfeld et al. (1999) showed that important sensory variables for blueberries stored at low temperature were acidic taste and blueberry flavor, while at a high storage temperature, a bitter taste was noted (Ceponis and Cappellini, 1985).

This study examined the shelf life of two cultivars of blueberry for commercial distribution using a vented PET package with four 0.7 cm diameter holes, and evaluated the effect of modified atmosphere (MA) packaging of blueberries on fruit firmness, weight loss, soluble solid and organic acid contents, and surface color during storage at room temperature and 10°C.

**Materials and Methods**

**Plant Materials and Fruit Packaging**

Berries from two highbush blueberry cultivars, ‘Bluetta’ and ‘Duke’ were hand-harvested at full maturity (100% blue) at the end of July in 2007 in Sangju, Kyoungbuk Province, South Korea, and graded based on uniform size and color. Approximately 100 g of blueberries were weighed using a common scale and then placed inside PET containers (10 × 12.5 × 4.5 cm) vented with four 0.7 cm diameter holes that were then placed in corrugated cardboard boxes and stored at room temperature (20-25°C) or 10°C for 6 days and 16 days, respectively.

**Evaluation of Quality**

**Weight loss:** Each punnet of blueberries was weighed on day 0 and on each sampling day using a precision balance (AX 200, Shimadzu, Kyoto, Japan). Results are reported as percent weight loss relative to initial fruit weight.

**Total soluble solids content determination:** Total soluble solids content (SSC) were determined using a hand refractometer (PAL-1, Atago, Tokyo, Japan) with juice obtained from squeezing the berries. Three measurements were taken for each sample and results are expressed as °Brix.

**Firmness:** Fruit flesh firmness was measured with a texture analyzer (EZ Test/CE-500N, Shimadzu, Kyoto, Japan). A 4 mm diameter cylindrical probe was used at a drive forward speed of 120 mm·min⁻¹. Results are expressed in Newtons [N].

**Color:** Fruit color was measured on the surface of each fruit along the equatorial axis using a colorimeter (CR-400, Minolta, Osaka, Japan) calibrated to a white plate, which provided Hunter L, a, and b values. These values were then used to calculate the hue angle (h° = arctangent [b/a]), where 0° = red-purple; 90° = yellow; 180° = bluish green; and 270° = blue, and chroma (C = [a² + b²]¹/²), which indicates the intensity or color saturation.

**Organic acids:** Analysis of organic acids was performed in triplicate using samples from different storage temperatures and expressed as g per 100 g fresh weight. About 4 g of each sample was homogenized and adjusted to 40 mL with 90% MeOH containing 5 mM butylated hydroxy toluene. The homogenates were centrifuged at 6,000 rpm for 10 min at 4°C. The supernatant (1 mL) was passed through a 0.45 μm Millipore syringe filter and then injected into a high performance liquid chromatography (HPLC) system (YL 9100, Young Lin, Anyang, Korea). Samples were eluted with 5 mM sulfuric acid at a flow rate of 0.7 mL·min⁻¹. Organic acids were separated on an Alltech IOA-100 organic acids column (30 cm × 7.8 mm i.d., Alltech, NY, USA) and detected by absorbance at 210 nm.

**Results and Discussion**

**Fruit Quality at Harvest**

‘Bluetta’ and ‘Duke’ are early-season cultivars harvested in late June in Sangju, Gyeongbuk province. Fruit of the ‘Duke’ cultivar were heavier and larger than those from ‘Bluetta’, but other quality indicators such as firmness and SSC were similar (Table 1). ‘Bluetta’ fruit were lighter blue than ‘Duke’ fruit, which had a more desirable waxy bloom, indicating a higher L value. Blueberry color is an important quality factor influencing fresh-market value and the acceptability of berries (Duarte et al., 2009; Faria et al., 2005; Sinelli et al., 2008). Their intense blue color and high pigment content make them a good candidate as a food colorant ingredient. Hue angle is a good measure of blueberry

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bluetta</th>
<th>Duke</th>
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<tbody>
<tr>
<td>Weight (g)</td>
<td>1.72 ± 0.1</td>
<td>2.67 ± 0.1</td>
</tr>
<tr>
<td>Firmness (N)</td>
<td>2.88 ± 0.3</td>
<td>2.78 ± 0.1</td>
</tr>
<tr>
<td>SSC (°Brix)</td>
<td>10.1 ± 0.3</td>
<td>9.7 ± 0.3</td>
</tr>
<tr>
<td>Hunter L</td>
<td>26.92 ± 0.3</td>
<td>24.5 ± 0.4</td>
</tr>
<tr>
<td>Chroma</td>
<td>3.84 ± 0.1</td>
<td>2.86 ± 0.4</td>
</tr>
<tr>
<td>Hue angle</td>
<td>290.0 ± 1.3</td>
<td>302.2 ± 4.2</td>
</tr>
</tbody>
</table>

Values represent Mean ± SE (n = 6).

Table 1. Quality characteristics at harvest time of fruit from ‘Bluetta’ and ‘Duke’ blueberry cultivars.