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Quality and Shelf-life of Salad Savoy under Different Storage Temperatures

Ji Gang Kim[1]*, Yaguang Luo[2], and Kenneth C. Gross[2]

[1]*National Horticultural Research Institute, Rural Development Administration, Suwon 440-706, Korea*
[2]*Produce Quality and Safety Laboratory, U.S. Department of Agriculture,*
Agricultural Research Service, Beltsville, MD 20705, USA

(*Corresponding author)

Abstract. Two varieties of salad savoy (white and violet) were obtained from a commercial grower and stored at 0, 5, 10, 15, and 20°C with about 95% relative humidity. Quality attributes including color, weight loss, decay, and overall quality, were evaluated every 4 days for up to 40 days. In general, storage temperature had a significant effect on the maintenance of quality of salad savoy. Both white and violet salad savoy leaves exhibited minimum weight loss, decay, and color change when stored at 0°C for 40 days. No chilling injury was noted at this temperature. A storage temperature of 5°C also maintained good overall quality of salad savoy, although there was a rapider change in color of samples as compared to those stored at 0°C. With storage temperatures of 10°C or above, the quality of salad savoy deteriorated rapidly, rendering the product unmarketable after 8 days at both 15 and 20°C. Both white and violet salad savoy had similar responses to storage temperature, although quality maintenance was better in violet salad savoy than in white.

Additional key words: discoloration, overall quality, postharvest technology, quality maintenance

Introduction

Salad savoy is a new vegetable crop of the *Crucifer* family, and is the result of breeding kale (*Brassica oleracea L* var. *acephala*) and cabbage (*B. oleracea L.* var. *capitata*) (Kim et al., 2004). Salad savoy, also known as colored varieties of kale, is typically used as a decorative garnish, but is as edible as the more common kale variety (Sugar, 1999). Although the consumption of fresh salad savoy has increased over the past decade (Kim et al., 2003), little attention has been given to research on the postharvest technology for this new crop.

Storage temperature is an important factor in maintaining quality and shelf-life of fresh produce. Low temperature prolongs storage life by reducing respiration rate and senescence, as well as reducing growth of spoilage microorganisms (Roura et al., 2000; Watada et al., 1996). Optimum storage temperatures vary among commodity types. For fruits and vegetables susceptible to chilling injury, excessively low temperature can also cause chilling injury and result in loss of quality and shelf-life. Improper storage temperatures may adversely affect quality factors such as appearance, flavor, and color. In addition, product deterioration may proceed rapidly. Therefore, it is important to select the optimum storage temperature to maintain quality and extend storage-life of fresh fruits and vegetables.

Little information exists on optimum storage temperature and quality maintenance in salad savoy. The objectives of this study were to evaluate the effect of temperature on quality maintenance and to determine the optimum storage temperature for salad savoy.

Materials and Methods

Salad savoy materials and experimental treatments

Two varieties, white and violet salad savoy formed from heads of cream and violet colored leaves, respectively, were harvested by a commercial grower in Yuma, AZ, USA and shipped overnight to our laboratory in Beltsville, MD, in insolated containers with ice. Samples were sorted immediately upon arrival and stored at 0, 5, 10, 15, and 20°C in ventilated containers within 2 days of harvesting. Plastic liners were placed inside the containers to maintain a relative humidity of about 80% for the first 4 days and then about 95% throughout the storage period to minimize moisture loss.

Respiration rate and ethylene production

White and violet salad savoy samples (1,500 g each) were placed, in triplicate, in gas-tight containers and treated for 24 h with a flow of air at 20 mL·min^{-1} at 5 °C. Respiration rate was measured as CO_2 production using an automatic sampling, flow-through system (Watada and Massie, 1981) equipped with a gas chromatograph (model HP 5890, Hewlett Packard, Rockville, MD, USA) with a Hayesep Q column (2.4 m × 3 mm)

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and a thermal conductivity detector. Ethylene production was measured with the same GC with a GS-Q column (30 m × 0.54 mm) and a flame ionization detector.

Quality evaluation

Quality evaluation was performed every 4 days during storage. Weight loss was calculated based on fresh weight, which was determined at each sampling time. The color of both outer leaves and the cut ends of stems were measured with a Chroma Meter (Model CR-300, Minolta Corp., Japan). The color values of L* (light/dark), a* (green/red), and b* (yellow/red) were converted into hue angle [hue = $\tan^{-1}$ (b/a)] according to Heimdal et al. (1995) and Nunes and Emond (1998). Sensory quality was assessed by a three member trained panel. Each of discoloration and decay was scored on a 0 to 5 scale, where 0 = none, 1 = trace, 2 = slight, 3 = moderate, 4 = strong, and 5 = severe. A score of 1.5 was considered the limit of marketable quality. Overall quality was evaluated at the end of storage with a 9 point hedonic scale, where 9 = like extremely, 5 = neither like nor dislike, and 1 = dislike extremely (Meilgaard et al., 1991); a score of 6 was considered the limit of salability (Loaiza and Cantwell, 1997; Lopez-Galvez et al., 1997).

Experimental design and statistical analysis

The experiment was conducted utilizing a completely randomized design with repeated measures. Five replications were tested per treatment. All quality evaluations were performed at storage temperature conditions that minimized the effect of temperature variation during testing. Data were analyzed as a two-factor linear model using Proc Mixed (SAS Inst., Cary, NC, USA) with storage temperature and salad savoy variety as the two factors.

Results and Discussion

Respiration rate and ethylene production

The respiration rate of white salad savoy stored at 5°C was significantly ($P < 0.001$) higher than that of violet salad savoy; ranging from 0.86 to 1.04 mmol·kg^{-1}·h^{-1} in white salad savoy and 0.61 to 0.75 mmol·kg^{-1}·h^{-1} in violet (Fig. 1A). Respiration rates of cabbage and kale are about 0.23 and 1.14 mmol·kg^{-1}·h^{-1} (Ryall and Lipton, 1978). Thus, salad savoy has an average respiration rate roughly between the related crops.

Ethylene production was also higher in white (10.7 to 21.8 nmol·kg^{-1}·h^{-1}) salad savoy than in violet (8.2 to 12.1 nmol·kg^{-1}·h^{-1}) (Fig. 1B). A significantly larger difference in ethylene production between white and violet salad savoy was observed at the beginning of testing

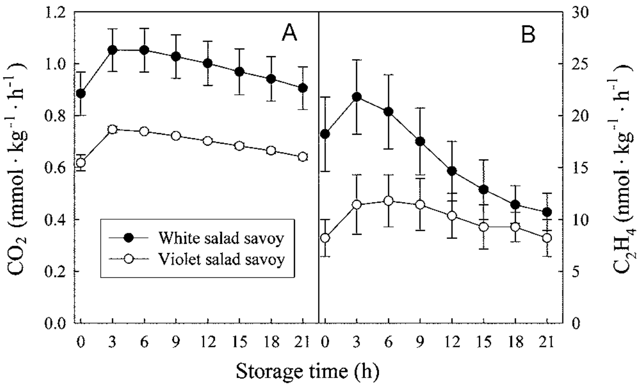

Fig. 1. Respiration rate (A) and ethylene production (B) of salad savoy stored at 5ºC for 21 h. Each line is the mean of three replications measured at 3-h increments during storage. Vertical bars represent standard error of the means. Some bars are not shown when masked by the symbol.

than after 24 h.

Weight loss

Most fresh vegetables contain 85 to 95% water (Ryall and Lipton, 1978). Leafy vegetables with a large surface-to-volume are particularly vulnerable to rapid water loss (Kays, 1991). The loss of moisture results in a reduction in the fresh weight of harvested vegetables, often accompanied by the loss of freshness, appearance, and texture (Roura et al., 2000). Generally, a loss of 5 to 10% moisture result in products that are unmarketable. The maximum acceptable weight loss of a cabbage, which is related to salad savoy, is 7% (Kang et al., 2002; Kays, 1991). In the present study, weight loss of both white and violet salad savoy was minimal and below 7% at storage temperatures of 10°C or below until close to the end of storage (Fig. 2). Excessive weight loss (far

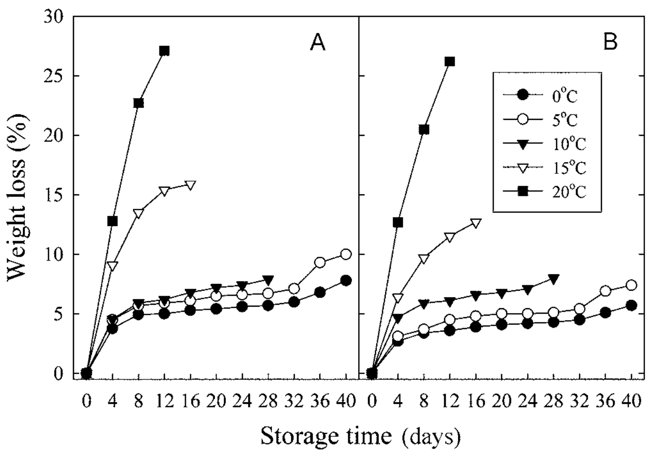

Fig. 2. Weight loss of white (A) and violet salad savoy (B) during storage at different temperatures. Vertical bars represent standard error of the means. Some bars are not shown when masked by the symbol.

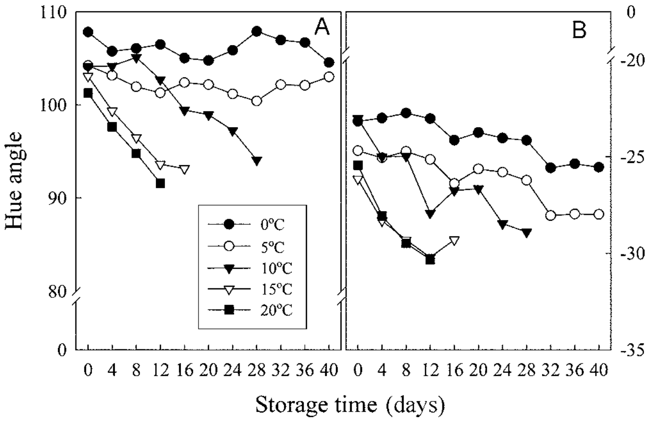

Fig. 3. Hue angles on outer leaves of white (A) and violet salad savoy (B) during storage at different temperatures.

greater than 7%) was found at 15 and 20°C for both white and violet salad savoy within 8 days of storage. Visual observations also noted an appearance of wilting and shriveling on salad savoy stored at 15 and 20°C. Greater weight loss was noted with white salad savoy than than violet one.

Color

The retention of the inherent color of fresh vegetables is often used as a quality indicator and has a substantial impact on consumer acceptance (Roura et al., 2000). As shown in hue angle values (Fig. 3), leaf color changed over time and was significantly influenced by storage temperature. Hue angle values of leaf colors of violet salad savoy decreased rapidly at higher storage temperatures (15 and 20°C) but were relatively stable at 0°C.

There is no apparent information available in the literature regarding the major pigments in violet salad savoy. The green and violet colors of most vegetables are contributed by chlorophyll and anthocyanins (Lazcano et al., 2001; Weichmann, 1987). Therefore, the loss of color in violet salad savoy is most likely related to degradation of chlorophyll and anthocyanins, which often have a higher degradation rate at higher temperatures, compared to lower temperatures. Visual evaluation of color changes (Fig. 4) was consistent with hue angle values.

Discoloration of the cut end of stems is another factor resulting in quality deterioration of shredded cabbage during storage (Pirovani et al., 1997). In the present study, the color of the cut end of stems of both white and violet salad savoy was similar at the beginning of storage, and both discolored gradually over time (Fig. 5). This was most likely due to an enzymatic browning reaction. Storage temperature significantly ($P < 0.001$) affected the discoloration rate and intensity. Samples stored at 15 and 20°C developed severer discoloration than those stored at 0°C. White salad savoy also showed a greater browning reaction than violet at the same temperature. Kim et al. (2004) reported greater discoloration (browning) on the cut surface of fresh-cut white salad savoy compared to fresh-cut violet salad savoy. The difference in browning intensity between white and violet salad savoy samples was probably due to the browning potential of different varieties. Further studies on polyphenoloxidase activities and phenolic compounds may be helpful to explain the difference between these two varieties.

There was a significant difference in hue angle between 0 and 5°C. There was a much larger difference in white salad savoy between 0 and 5°C than in violet.

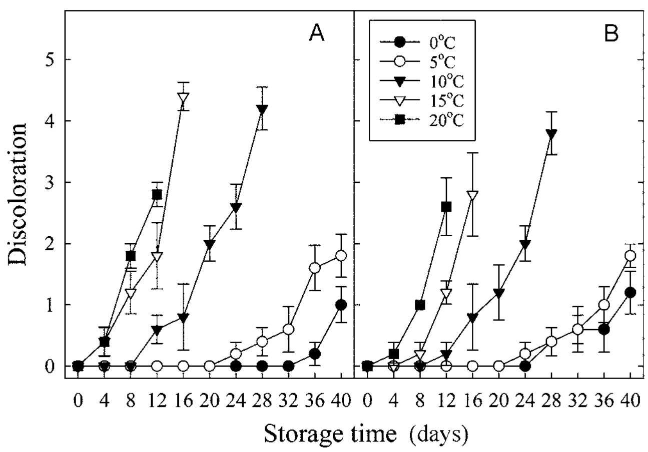

Fig. 4. Discoloration scores of white (A) and violet salad savoy (B) during storage at different temperature. Discoloration was scored by three trained panelists using a 0 to 5 scale where 0 = none; 1 = very slight, 2 = slight; 3 = moderate; 4 = strong; and 5 = severe. Each symbol is the mean of three measurements performed by three trained panelists on each of five replicate samples (n = 15). Vertical bars represent standard error of the means. Some bars are not shown when masked by the symbol.

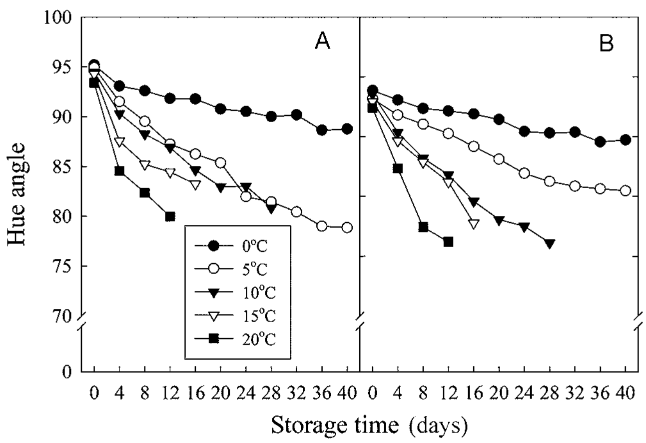

Fig. 5. Hue angles on the cut ends of the stems of white (A) and violet salad savoy (B) during storage at different temperatures.

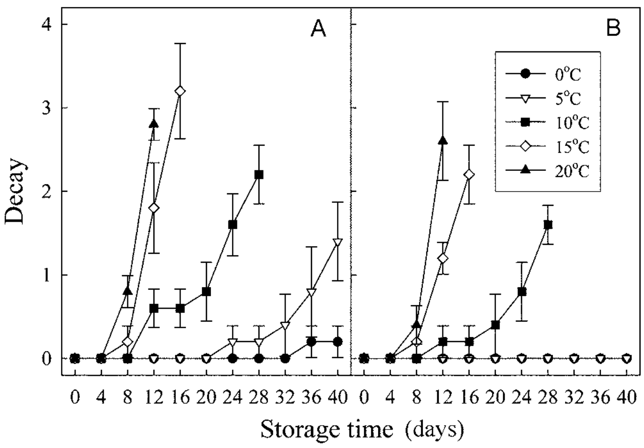

Fig. 6. Decay score of white (A) and violet salad savoy (B) during storage at different temperatures. Decay was scored by three trained panelists using a 0 to 5 scale where 0 = none; 1 = very slight, 2 = slight; 3 = moderate; 4 = strong; and 5 = severe. Each symbol is the mean of five measurements performed by three trained panelists on each of three replicate samples (n = 15). Vertical bars represent standard error of the means. Some bars are not shown when masked by the symbol.

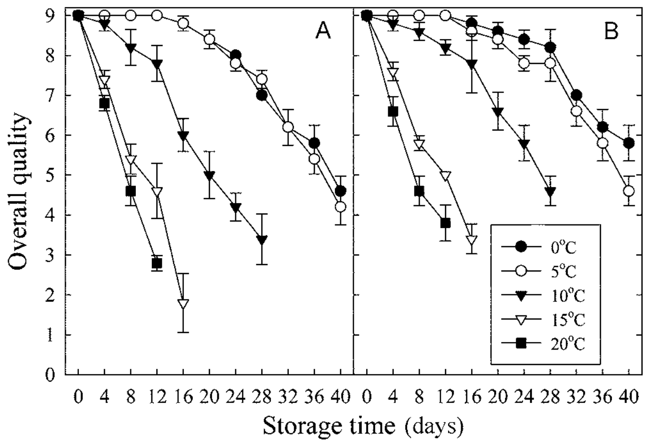

Fig. 7. Overall quality of white (A) and violet salad savoy (B) during storage at different temperatures. Overall quality was scored by three trained panelists using a 1 to 9 hedonic scale where 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; and 9 = like extremely. Each symbol is the mean of three measurements performed by three trained panelists on each of five replicate samples (n = 15). Vertical bars represent standard error of the means. Some bars are not shown when masked by the symbol.

This indicates that it is more important to maintain 0°C for white than violet salad savoy to maintain acceptable color. Visual observations agreed with the color meter measurement.

Chilling injury, decay, and sensory quality

No chilling injury was observed in either white or violet salad savoy at storage temperatures as low as 0°C. This indicates that salad savoy can be stored at 0°C to maintain quality and extend shelf-life. Similar results were reported for cabbage, a parent of salad savoy (Apeland, 1984; Kim and Klieber, 1997). Decay was first observed on both white and violet salad savoy samples stored at 20°C within 8 days in storage (Fig. 6). The severity of decay progressed rapidly at both 15 and 20°C with the product deemed unmarketable within 12 (white) and 16 days (violet) salad savoy. Reducing storage temperature significantly ($P < 0.001$) delayed development of decay. Decay was found in white salad savoy after 24 and 36 days at 0 and 5°C, respectively. No decay was found for violet salad savoy until the end of storage at 0 and 5°C. Comparing these two varieties, the relative decay score for violet salad savoy was less than that of white salad savoy at the same temperature. Since respiration rate is positively correlated with quality deterioration rate (Ryall and Lipton, 1978), the higher decay rate in white compared to violet was most likely related to the higher respiration rate in white than in violet salad savoy.

There was a rapid decline in overall quality of both white and violet salad savoy when stored at 15 and 20°C, with quality deemed unacceptable within 8 days of storage (Fig. 7). At storage temperatures of 0 and 5°C, quality decline was gradual and salad savoy maintained an acceptable quality score of 6.0 until 32 days of storage. Although both white and violet salad savoy showed a similar trend in overall quality scores, violet salad savoy samples had higher scores than white salad savoy at the same storage temperature and sampling time.

In conclusion, storage temperature significantly affects quality and shelf-life of both white and violet salad savoy. However, violet salad savoy retains its inherent quality better than white during cold storage. At storage temperatures of 15°C or above, the quality of both white and violet salad savoy deteriorates rapidly, which is slowed significantly by a reduction in storage temperature. Salad savoy is not sensitive to chilling and should be stored at 0 to 5°C for best quality and shelf-life.

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