Effect of passive evaporative cooler on physio -chemical properties of hot water treated *Solanum melongena* L.

Md. Parvez Islam, Tetsuo Morimoto, Kenji Hatou

(*Department of Biomechanical Systems, Ehime University, 3-5-7 Tarumi, Matsuyama 790-8566, Ehime, Japan*)

Abstract: This study was conducted to investigate the effect of passive evaporative cooler on storage behavior - that is visual appearance, physiological loss in weight (PLW), color development, firmness, total soluble solids (TSS) and pH level of hot water treated eggplant fruit (*Solanum melongena* L.). Fresh harvested fruits were treated with hot water at 45°C for 1 h. The highest percentage of PLW (2.39%) was the fruit stored at ambient temperature of 25°C for nine days whereas the lowest percentage of weight loss (2.27%) was the fruit stored inside the passive evaporative cooler. In all cases, the decreasing rate of lightness ($L*$ value) and increasing rate of greenness ($a*$ value) and yellowness (b* *value*) of the hot water treated fruits were almost negligible. Firmness value of the fruits stored inside the passive evaporative cooler was found almost constant, while it reduced in fruits which stored at ambient temperature. Furthermore, higher TSS and lower pH value were observed in those fruits which were stored inside the passive evaporative cooler. In conclusion, the shelf life and quality of eggplant fruits can be extended using passive evaporative cooler.

Keywords: fruit storage, fruit postharvest, freshness quality, shelf life

Citation: Islam, Md. P., T. Morimoto, and K, Hatou. 2014. Effect of passive evaporative cooler on physico - chemical properties of hot water treated *Solanum melongena L.*. Agric Eng Int: CIGR Journal, 16(2): 181－186.

1 Introduction

Passive evaporative cooler is an eco friendly new storage technique which do not require electricity to operate it. The lower inside temperature and higher relative humidity of the passive evaporative cooler could be maintained by passive evaporative cooling mechanism. Eggplant (*Solanum melongena* L.) is an important vegetable worldwide. The sensitivity of eggplant is associated with storage environment and post-harvest processing. One of these symptoms is the darkening of seeds and pulp tissue. More severe symptoms include pitting and browning of skin or surface scald (Cantwell and Suslow, 2012). Biochemical and nutritional characteristics of fruits may change after mechanical or physiological injury during harvest, processing or cold storage, which affect consumer acceptability and palatability because of unpleasant appearance and concomitant off-flavor development (Das et al., 1997; Valero *and* Garcia-Carmona., 1998). According to USDA (2004), eggplant is often affected by some common fungal pathogens such as alternaria (black mold rot), botrytis (gray mold rot), rhizopus (hairy rot), etc. Some of these organisms that cause decay are repressed by high temperature hot water treatment. Moreover, the variety of crops, pre-harvest agronomic practices in the field, and climactic regions of crop growth could vary with hot water treatment efficiency (De Costa and Erabadupitiya, 2005). There has been growing interest in the use of hot water treatment to control insect pests, prevent fungal rot, or retard or minimize commodity response to extreme temperatures (Lu et al., 2007). The aim of the present study was to analyze the changes of physio-chemical quality of eggplant fruits (*Solanum melongena* L.) by passive evaporative cooler.

Received date: 2014-04-23 **Accepted date:** 2014-05-29

Corresponding author: Md. Parvez Islam, Department of Biomechanical Systems, Ehime University, Japan. Email: engr_parvezfpm@agr.ehime-u.ac.jp.

2 Materials and Methods

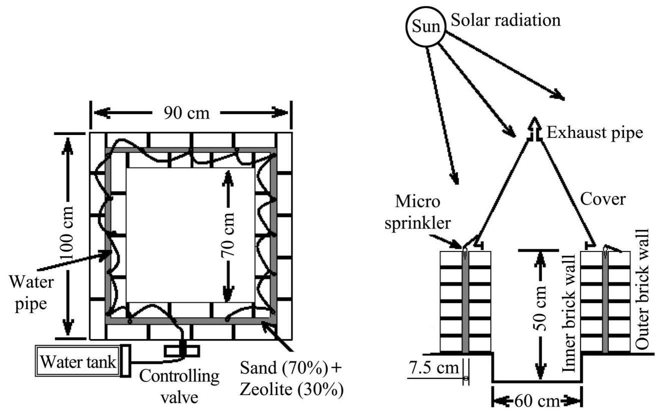
2.1 Site and plant material

The experiments were conducted during summer 2013 and 2014 (from the end of May till the end of August) at Ehime University, Japan. Japanese eggplants (*Solanum melongena* L. *cv.* Millionaire) were harvested at the accurate stage of maturity age (elongated, slender, light to dark purple, very perishable). Undamaged fruits were used within 2 h of harvest. They were washed to remove dirt, drained to remove the excess water, and finally dried. Eggplant fruits were treated with hot water at 45°C temperature for 1 h by using a F-002DN (Tokyo Glass Instruments, Japan) and then distributed in two groups as CHT1 (control – stored at ambient temperature outside the zecc system) and HT2 (stored inside the ZEEC system). Determinations were also made at one day interval until decay. Total 32 fruits of each storage condition were visually observed and the qualitative evaluation was conducted. The daily average ambient temperature of 25°C was maintained during the study period.

2.2 Setup

The passive evaporative cooler with cone shape covering platform made from thermal insulating PVC ply board material was used for this experiment. This system is capable to maintain a uniform low temperature and higher relative humidity, compared with ambient temperature and relative humidity, respectively (Figure 1). The dimensions of the outer and inner brick walls were 100 cm length × 90 cm width × 50 cm height and 80 cm length × 70 cm width × 50 cm height, respectively. The 7.5 cm gap between the outer and inner wall was filled with a mixture of sands (70%) and zeolites (30%). These porous mixtures acted as a passive type of evaporative cooler to reduce the inside temperature of the passive evaporative cooler.

Overhead water tank supplied water by using the gravity force to the sand and zeolite filler through low pressure micro sprinklers with a dimension of 9.7 cm width × 2.5 cm depth × 18.8 cm height. 45 L/d of water was applied by programmable electronic timer. The temperatures at all places were simultaneously measured by using a 4-channel data logger (model 47SD, Sato Shouji Inc., Japan). Three thermocouples were placed in the middle layers of the passive evaporative cooler; another one was placed outside the passive evaporative cooler for measuring the ambient temperature. The average temperature at the middle layer was used as the inside temperature. The relative humidity was measured simultaneously using a 2-channel data logger (model HT-SD, Sato Shouji inc., Japan). The data were recorded at 1 min intervals for 24 h. Thus, about 1440 points of data per day were obtained.



a. Top view b. Front view

Figure 1 Different view of a passive evaporative cooler

2.3 Qualitative evaluation

2.3.1 Measurement of the physiological loss in weight of fruits

Physiological loss in weight (PLW) is one of the main factors in determining the quality of stored fruits (Equation (1)). Storage temperature and relative humidity influences the physiological changes of fresh fruits through physiological weight loss. High relative humidity is therefore desirable for reducing physiological weight loss during storage of fruits. Observation of PLW was monitored using a digital electronic balance (model BL-320S, Shimadzu Corporation, Japan). The shelf-life of fruits and vegetables was determined on the basis of 5% PLW (Tarutani and Kitagawa, 1982).

$$\text{Physiological loss in weight}, \% = \left[\frac{(X1 - X2)}{X2}\right] \times 100 \quad (1)$$

where, *X*1= Weight (g) before the storage; *X*2= Weight (g) after the storage.

2.4 The changes of color

Color of four eggplants was measured every 3rd days by a portable colorimeter (model CR-400, Konica Minolta, Japan) until decay. The colorimeter was calibrated with a standard white ceramic plate (L*=96; a*=0.14*; b*=1.63), where L* describes between light (L*=100) and dark (L*=0), a* describes between green (a*<0) and red (a*>0), b* describes between blue (b*<0) and yellow (b*>0).

2.4.1 Identifying the firmness of fruits

The firmness of fruit depends on maturity and ripeness. The determination of firmness of fruit by means of the penetrometer is based on the pressure necessary to push a plunger of specified size in to the pulp of the fruit up to a specific depth. The value of firmness was determined by hand operated penetrometer (model KM-1, Fujiwara, Japan) fitted with a cone tip plunger. The measurement for each fruit was carried out on four equidistant points. The average force value was computed on 4 eggplants per combination and expressed in N/cm^2.

2.4.2 Measuring the brix value of fruits

During ripening process, starch transformed into sugar which leads to increasing sugar levels. Fresh eggplants were blended in a blender for total soluble solids (TSS). TSS content was measured using a digital refractometer (model PR-101α, Atago Co. Ltd, Japan) with automatic compensation of temperature and three replicates of TSS value of four eggplants were taken. The average value of TSS was then computed and expressed as percentage.

2.4.3 Measuring the pH value of fruits

A portable digital pH meter (model D-51, Horiba, Japan) was used for taking pH through the direct immersion of the electrode in the fruit juice (4 g juice mixed with 20 mL distilled water). Three replicates of pH value were taken and the average value of pH was then recorded.

3 Results and discussions

3.1 Storage environment inside a passive evaporative cooler

Figure 2 illustrates the daily changes in the average value of inside temperature and relative humidity of the passive evaporative cooler over seven days. During this duration the recorded average value of inside temperature and relative humidity were 19°C and 84%, respectively.

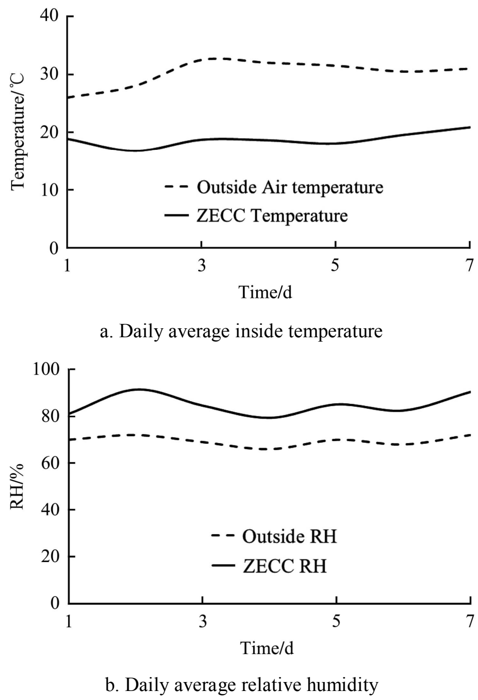
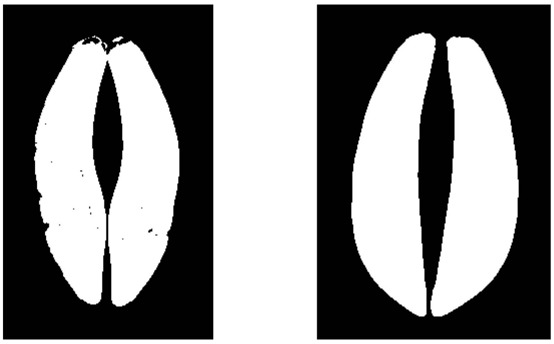


Figure 2 Storage environment inside a passive evaporative cooler

3.2 Evaluation of fruit quality

Figure 3 show photograph of CHT1 after the storage which was found to decay with dark color and spots after nine days of storage. This is because higher outside temperature increased ethylene production causes the fruits to ripen faster. In contrast, HT2 stored inside the passive evaporative cooler was found to be bright in color. This is because low inside temperature slows down color development and the ripening process. Works of Lu et al. (2007) claimed that fruits subject to hot water treatment have lower levels of acidity and a higher content of soluble solids, glucose and sucrose, thereby achieving higher quality for consumption. For instance, mild-temperature hot water treatment increased the thermo tolerance of plant cells and sterilizes many types of bacteria. Many researchers have demonstrated that hot water treatment between 35°C and 60°C effectively inhibits ethylene production, delays ripening, and reduces the water loss of fruits during storage (Klein and Lurie, 1992; Fallik et al., 1996; Porat et al., 2000). It is thus logical to assume that hot water treatment reduces PLW even its storage outside at ambient temperature.

According to Figure 4, the PLW of CHT1 decreased at higher rate after the 3rd day of storage at ambient temperature. The decreasing rate of PLW of HT2 reached to 2.27% after 15 days inside passive evaporative cooler. This is because that hot water treatment could increase the transcript levels of heat shock proteins and protect other proteins from breaking down and thus maintain the integrity of cells (Wang et al., 2001). Thus, it is found that the decreasing rate of PLW of eggplants inside the passive evaporative cooler were lower than those stored at ambient temperature.



a. CHT1 after 9 days stored at ambient temperature b. HT2 after 15 days of storage stored inside a passive evaporative cooler

Figure 3 Visual appearances of presence of spots inside fruit

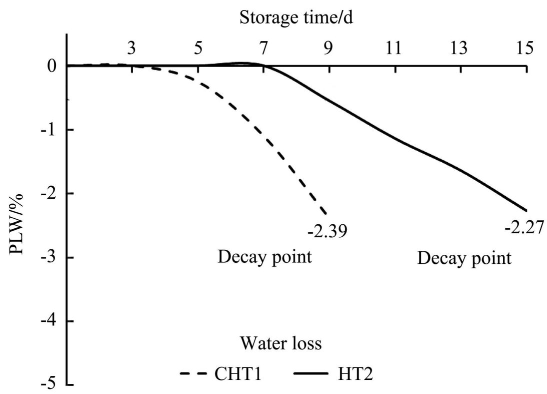


Figure 4 PLW of eggplant fruit stored at ambient temperature and inside passive evaporative cooler

The L* value of eggplant fruits in the control sample (CHT1) decreased at an increasing rate from 25.81 to 24.52. While in HT2, L* value was slightly reduced after 15 days of storage inside the passive evaporative cooler (Figure 5). But a* value in CHT1 was slightly increased from 3.51 to 3.60 until 9 days of storage. Furthermore, the value of HT2 was almost same until 15th day of storage (Figure 5). Nothmann and Spigelman, (1976) described that the eggplant (*Solanum melongena* L.) fruit is the darkest purple fruit with high levels of chlorophyll and anthocyanins. Moreover, some studies have suggested that hot water immersion is a potential alternative method to reduce the loss of green color in vegetables by maintaining the chlorophyll content (Wang, 2000; Dong *et al.,* 2004; Koukounaras *et al.,* 2009). On the other hand, skin yellowness (b*) slightly decreased from the 3rd day of storage with values from -0.71 to -0.63 after nine days of storage (Figure 5). But HT2 demonstrated almost no changes in skin yellowness after 15 days of storage. This is because color development in egg plant is sensitive to temperature, having a better plastid conversion when temperature is above 12°C and below 30°C and postharvest hot water treatment is also effective to inhibit ripening process (Valeria *et al.,* 2012). For why ＊ changes when exposed with high ambient temperature (Lurie, 1998).

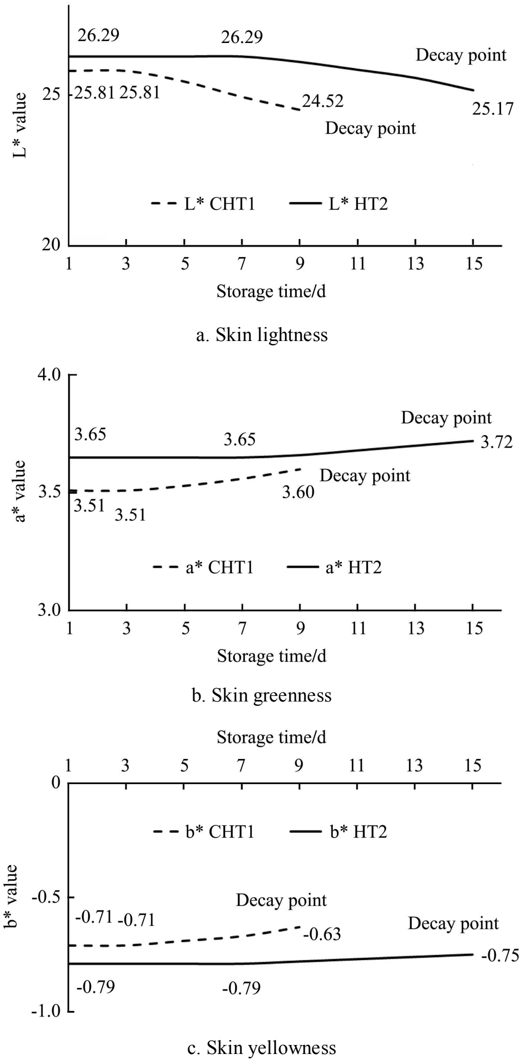
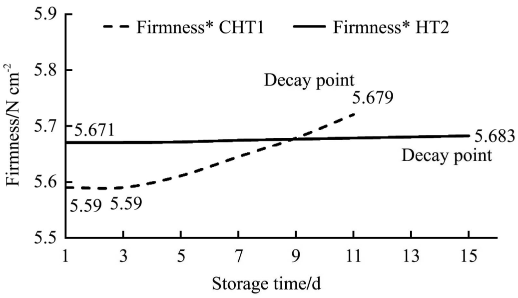
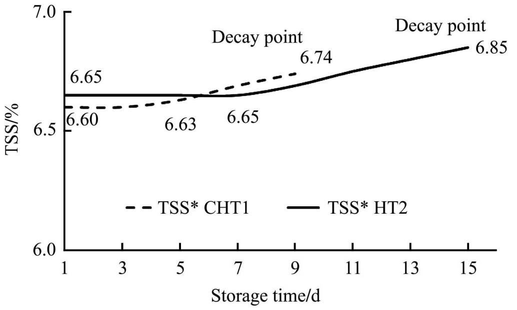


Figure 5 Color changes of eggplant fruit stored at ambient temperature and inside the passive evaporative cooler

Fruit firmness is usually affected by storage time and temperature. As shown by the results in Figure 6, the firmness of CHT1 increased at higher rate after the 3rd day of storage at ambient temperature. Water loss from the surface of the eggplant caused its skin harder during the storage period. While the firmness value of HT2 almost constant during the whole storage time. Hot water treatment could induce polyamine levels which might be a reason for its firmness maintenance (Mirdehghan et al., 2007; Lelievre et al., 1997). These results revealed that hot water treatment and low inside temperature of the passive evaporative cooler maintained the firmness of the eggplant.



a. Changes in firmness



b. TSS of eggplant fruit stored at ambient temperature and inside a passive evaporative cooler

Figure 6 Quality changes of eggplant fruit

The TSS content depends on the maturity stage of the fruit, and it generally increases progressively during the ripening process due to the hydrolysis of polysaccharides to maintain the respiration rate (Azzolini, 2002). There was a gradual increasing trend in the TSS eggplant after storage (Figure 6). The TSS value for CHT1 showed no changes from the beginning of storage to 3rd day and then gradually increased up to 6.74% after nine days of storage. While there was no change of TSS value of HT2 up to seven days of storage and then increased at slow rate up to 6.85% after 15 days of storage. Heat treatment with mild temperature caused the lower decreasing rate of TSS value of CHT1 and HT2. Because hot water treatment and lower inside temperature of the passive evaporative cooler delayed the increase of soluble solids by alternating the cell wall structure and break down the complex carbohydrates into simple sugar and this hydrolytic changes to starch (Aina, 1990).

The neutral pH level of eggplant is very sensitive during the storage. Figure 7 illustrates that the pH was influenced by storage time and conditions. It was found that the control sample CHT1 presented a tendency for rapid increase in the pH value from the 3rd day of storage. But pH value remained constant for HT2 up to 7th day of storage and then slowly increased ranging from pH 5.52 to pH 5.60. Prolong hot water treatment of fruits (45°C for 1 h) and storage time caused the respiration rate inside the fruit descending and increase in pH value (Lurie, 1998; Wills et al., 1989). Furthermore according to Linton (1996), a pH value of 2.5 to 5.5 was considered as favorable level for eggplant during storage time.

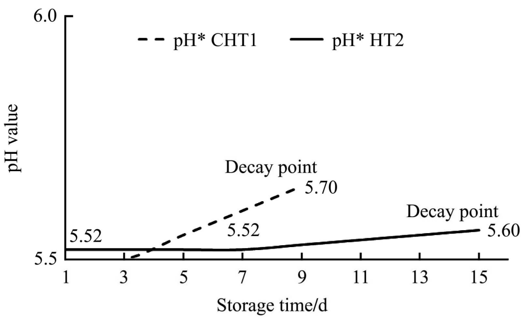


Figure 7 Changes in pH of eggplant fruit stored at ambient temperature and inside a passive evaporative cooler

4 Conclusions

Physical and chemical changes during storage of eggplant are influenced by low storage temperature, hot water treatment and storage time. The passive evaporative cooler maintained the lightness ($L*$ value) and greenness ($a*$ value) which prevented fruits skin darkening. Moreover, low inside temperature and high relative humidity inside the passive evaporative cooler also lowered the reducing rate of PLW and maintained the firmness of eggplant fruits. The temperature inside the passive evaporative cooler reduced through the process of an evaporative cooling mechanism. Hot water treatment could be used as a disinfectant for eggplant prior to storage at passive evaporative cooler in order to reduce decay and microbial growth. It is concluded that a combination of hot water treatment and passive evaporative cooler extend the shelf-life and preserve the quality of eggplant fruits.

Acknowledgments

This work was supported by the Grants-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (No. 26450354).

References

Aina, J. O. 1990. Physico-chemical changes in African Mango (*Irvingia gabonensis*) during normal storage ripening. *Food Chemistry,* 36(3): 205-212.

Azzolini, M. 2012. Physiology of maturity and conservation post-harvest mangaba (*Hancornia speciosa*). *University of Paraiba, Brazil* (In Portuguese).

Cantwell, M., and T. Suslow. 2012. Eggplant: Recommendations for maintaining postharvest quality. Available at: http://postharvest.ucdavis.edu/pfvegetable/Eggplant/ (accessed 20 December 2012).

Das, J. R., S. G. Bhat, and L. R. Gowda. 1997. Purification and characterization of a polyphenol oxidase from the Kew cultivar of Indian pineapple fruit. *Journal of Agricultural and Food Chemistry,* 45(6): 2031-2035.

De Costa, D. M. and H. R. U. T. Erabadupitiya. 2005. An integrated method to control postharvest diseases of banana using a member of the Burkholderia cepacia complex. *Postharvest Biology and Technology* , 36(1): 31-39.

Dong, H., Y. Jiang, Y. Wang, R. Liu, and H. Guan. 2004. Effect of hot water immersion on storage quality of broccoli heads. FTB, 42(2): 135–139.

Fallik, E., S. Grinverg, S. Alkarai, and S. Lurie. 1996. The effectiveness of postharvest hot water dipping on the control of gray and black molds in sweet red pepper (*Capsicum annuum*). *Plant Pathology,* 45(4): 644-649.

Klein, J. D. and S. Lurie. 1992. Improved postharvest quality of horticultural crops. *Horticultural Technology,* 2(3): 316-320.

Koukounaras, A., A. S. Siomos, and E. Sfakiotakis. 2009. Impact of heat treatment on ethylene production and yellowing of modified atmosphere packaged rocket leaves. *Postharvest Biology and Technology,* 54(3): 172-176.

Lelievre, J. M., A. Latche, B. Jones, M. Bouzayen, and J. C. Pech. 1997. Ethylene and fruit ripening. *Physiologia Plantarum,* 101(4): 727-739.

Linton, R. 1996. Food safety hazards in foodservice and food retail establishments. Available at https://www.extension.purdue.edu/extmedia/FS/FS-2.pdf (accessed 30 December 2012).

Lu, J., C. Vigneault, M. T. Charles, and G. S. V. Raghavan. 2007. Heat treatment application to increase fruit and vegetable quality. *Stewart Postharvest Review,* 3(4): 41–47.

Lurie, S. 1998. Postharvest heat treatments of horticultural crops. *Horticultural Review,* 22(1): 91-121.

Mirdehghan, S. H., M. Rahemi, D. Martínez-Romero, F. Guillén, J. M. Valverde, P. J. Zapata, M. Serrano, and D. Valero. 2007. Reduction of pomegranate chilling injury during storage after heat treatment: Role of polyamines. *Postharvest Biology and Technology,* 44(1): 19–25.

Nothmann, J., I. Rylski, and M. Spigelman. 1976. Color and variations in color intensity of fruit of eggplant cultivars. *Scientia Horticulturae,* 4(2): 191-197.

Porat, R., A. Daus, B. Weiss, L. Cohen, and E. Fallik. 2000. Reduction of postharvest decay in organic citrus fruit by a short hot water brushing treatment. *Postharvest Biology and Technology*, 18(2): 151-157.

Valeria, M., G. D. Pía, M. S. Ana, W. R. Noemi, C. Fernando, and G. Gabriela. 2012. Tomato quality during short-term storage assessed by colour and electronic nose. *International Journal of Electrochemistry*, 2012(2012): 1-7.

Valero, E., and F. Garcia-Carmona. 1998. pH-dependent effect of sodium chloride on latent grape polyphenol oxidase. *Journal of Agricultural Food Chemistry,* 46(7): 2447–2451.

Tarutani, T., and H. Kitagawa. 1982. Distribution, storage and processing of horticultural foods. Yokendo Co., Japan.

USDA. 2004. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. Available at http://www.ba.ars.usda.gov/hb66/contents.html (accessed 29 December 2012).

Wang, C. Y. 2000. Effect of heat treatment on postharvest quality of kale, collard and brussels sprouts. *Acta Horticulturae (ISHS),* 518 (1): 71-78.

Wang, C.Y., J.H. Bowen, I.E. Weir, A.C. Allan, and I.B. Ferguson. 2001. Heat-induced protection against death of suspension-cultured apple fruit cells exposed to low temperature. *Plant Cell Environment,* 24(11): 1199-1207.

Wills, R. B., T. H. Lee, D. Graham, W. B. McGalsson, and E. G. Hall. 1989 *Postharvest*: an introduction to the physiology and handling of fruits and vegetables. New South Wales University Press, Australia.