Quality of fresh tomato fruit stored inside a solar adsorption cooling storage system as function of low pressure treatment

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Abstract: This paper assessed the physiological loss in weight, total color development and total soluble solids of stored fresh tomato inside solar adsorption cooling storage system. Fresh and treated tomato stored inside solar adsorption cooling storage system at the temperature range of 10℃ to 12℃ with an average relative humidity level of 80%. The results showed that tomato stored at ambient condition lost weight 5% after seven days of storage then 0.008 MPa treated tomato for 15 minutes, which lost 4.6% after 25 days of storage inside a solar adsorption cooling system. Soluble solids decreased slightly from 7.1% to 6.6% after 25 days storage. The skin brightness L* values of stored tomato at ambient condition increased from 46.1 to 47.9 after seven days of storage at ambient condition and tomato treated with 0.008 MPa treatment for 15 min stored inside solar adsorption cooling storage system decreased from 44.7 to 35.5 after 25 days of storage. The skin redness a* values of stored tomato at ambient condition increased from 18.8 to 20.5 after seven days of storage but tomato treated with 0.008 MPa treatment for 15 min stored inside solar adsorption cooling storage system showed a* values increased from 20.4 to 21.4 after 25 days of storage. The skin yellowness b* value of stored tomato at ambient condition decreased from 10.2 to 7.6 after seven days of storage and tomato treated with 0.008 MPa treatment for 15 min stored inside solar adsorption cooling system decreased from 8.9 to 8.6 after 25 days of storage. These results suggest that the low-cost and energy-saving solar adsorption cooling storage system with low pressure treatment method is useful to keep the fresh tomato fruit quality.

Keywords: low pressure treatment, solar adsorption cooling storage system, vacuum chamber, tomato

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1 Introduction

Reducing of postharvest loss is a challenging task. Post-harvest fruit spoilage is now growing concerns in the developing world. Storage temperature for tomato fruit is usually maintained constant at low level (from 0℃ to 15℃). Recently solar adsorption refrigerators have been receiving much attention as a replacement for conventional type vapor compression refrigeration cycles driven by electricity. The solar energy is safe, environmentally friendly and abundant. Therefore, a solar-driven adsorption refrigerator is eco-friendly, low-cost and simple in structure. Several solar refrigeration systems such as liquid/vapor, solid/vapor absorption, adsorption, vapor compression and photovoltaic-vapor/compression systems have been developed (Pons and Guilleminot, 1986; Sakoda and Suzuki, 1986; Pons and Grenier, 1987; Exell et al., 1987; Headley et al., 1994; Lin et al., 1994; Khattab, 2004; Wang et al., 2005; Mesquita et al., 2006; Leite et al., 2007; Islam and Morimoto, 2014).

It has been reported that physical treatments, such as cooling, controlled atmosphere and heat are effective in fruit and vegetable quality maintenance by inhibiting ethylene production and delaying the ripening of fruit. Salunkhe and Wu (1973) and Burg (2004) reported that storage under pressure poses an alternative to refrigeration storage and atmosphere storage methods. Pressure storage systems can protect stored fruits against ethylene-independent deterioration, including desiccation, decay and insect infestation (Zapotoczny and Markowski,

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2014). Patterson (2005) also described that low pressure treatment is one of the techniques that can be used to meet consumer demand for high quality fresh fruits with microbiologically safe and an extended shelf-life. Pressure treatment consists of applying to the low atmospheric pressure (0-1 MPa) and offers homogeneity as it acts uniformly around each single produce or throughout an entire mass of fruits, independently of its size, shape or composition (Goyette et al., 2007; Patterson, 2005). Apelbaum et al. (1977) reported that mango fruits subjected to 0.013 and 0.01 MPa had an extended shelf-life of 25 and 35 days, respectively. Fresh green asparagus subjected to a hypobaric pressure of 0.035-0.045 MPa had their storage life extended by up to 50 days compared with 25 days under refrigerated storage and six days at room temperature (Wenxiang et al., 2006). The aim of this study is to investigate the changes of physio-chemical quality of tomato stored inside solar adsorption cooling storage system after various low pressure treatment (0.002, 0.004, 0.008 MPa) with different time duration (15, 30 min). The findings of this research will help farmers from the developing countries to reduce the spoilage of freshly harvested fruits and also improve the food security situation of the developing countries.

2 Materials and methods

The fruit used for the experiment was tomato (*Lycopersicon esculentum* Mill. cv. Momotaro) with almost the uniform shape and size (by visual and weight) and free from fungal infection. Five kilograms of tomatoes at the ripening stage (light red) were harvested manually from plants grown in the Ehime University greenhouse.

2.1 Structure of the solar adsorptions cooling system

A solar adsorption cooling storage system was set up at the Faculty of Agriculture, Ehime University, as is shown in Figure 1 (Islam and Morimoto, 2014). The storage chamber consists of a double wall (inner and outer walls) made with 10 mm thick polystyrene (expanded type) heat insulation board, an evaporating pipe and a storage space for tomato. The storage space was 700 mm long × 700 mm wide × 700 mm high. Field testing of the solar adsorption cooling storage system was done continuously from 1 to 30, June 2014 during summer. The experimental prototype was positioned north-south, which was the average frequent air direction at the location during the experiment period. The average total solar radiation was 18 MJ/m^2 during the experiment period.

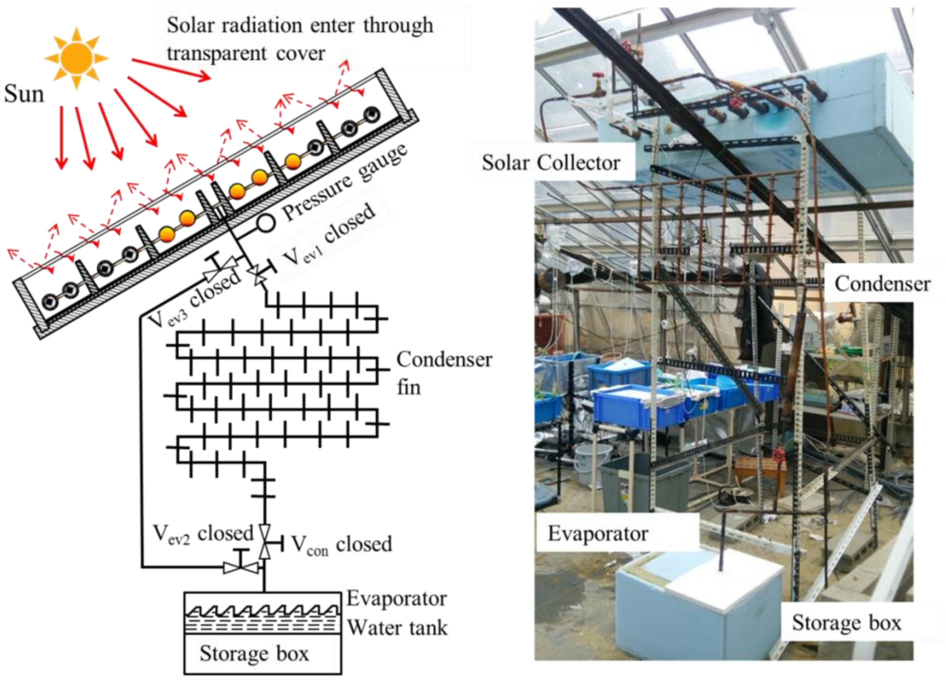


Figure 1 A solar adsorption cooling storage system

2.2 Qualitative evaluation of stored tomato

2.2.1 Physiological loss in weight (PLW)

Physiological loss in weight (PLW) is one factor in determining the quality of stored fruit (Equation 1). PLW and the shelf-life of tomato were monitored every day using a digital electronic balance (BL-320S; Shimadzu Corporation, Japan). The readings were made at 2-day intervals during the experiment period. The shelf life of fruit and vegetables was based on 5% PLW. A decrease of only 5% in PLW often results in a loss of freshness and a wilted appearance (Tarutani and Kitagawa, 1982; Ben-Yehoshua, 1987; Sondi and Salopek-Sondi, 2004).

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

where *X1* is initial weight, g; *X* is final weight, g.

2.2.2 Color measurement

Color is the best criterion for determining quality in tomato fruits and this change is associated with chlorophyll degradation and biosynthesis of diverse pigments or lycopene (Clément et al., 2008; Niño-Medina et al., 2013). A portable colorimeter (CR-400; Minolta Co., Ltd, Japan) is used to measure the color changes during storage time. Before the color measurement, the colorimeter was calibrated with a standard white ceramic plate (L*=96; a*=0.14*; b*=1.63). L* describes lightness (L*=0 for black, L*=100 for white), a* describes red-green intensity (a*>0 for red, a*<0 for green), and b* describes blue-yellow intensity (b*>0 for yellow, b*<0 for blue). The mean value of the two tests was used for a single fruit and three replicate samples were taken each day until decay.

2.2.3 Total soluble solids measurement

During the development of the flesh of a fruit, in many species nutrients are deposited as starch, which during the ripening process is transformed into sugar. The progression of the ripening process leads to increasing sugar levels (**Ross et al., 2010**). A portable NIR type K-BA100 fruit selector (Kubota, Japan) measures TSS (total soluble solids). Three replicates of TSS samples were taken each day until decay.

2.3 Treatment trial and storage study

Five different low pressure treatments, each with two different time durations were experimented for evaluating the qualitative performance of stored tomato fruits inside the solar adsorption system, as shown in Table 1. A vacuum-sling-vane pump (TAI50XA, Tasco Japan Co., Ltd) that produced the low atmospheric pressure inside the vacuum chamber is shown in Figure 2.

Table 1 Low pressure treatment under different time duration

Control	Treatment methods					
Without treatment	0.002 MPa for 15 min	0.002 MPa for 30 min	0.004 MPa for 15 min	0.04 MPa for 30 min	0.008 MPa for 15 min	0.08 MPa for 30 min

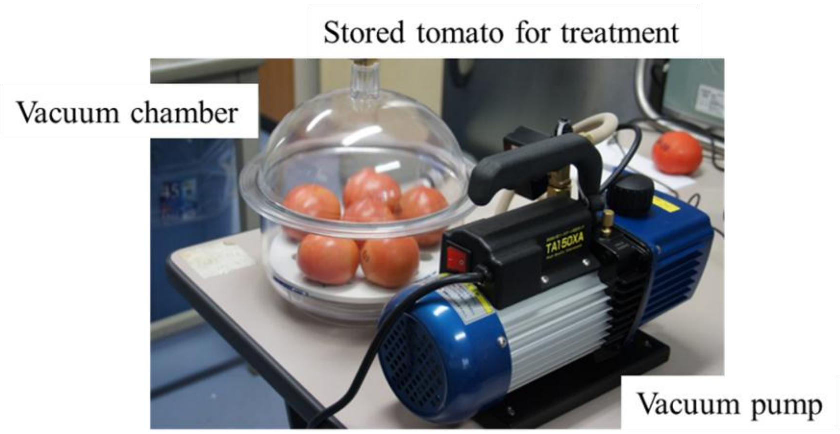


Figure 2 A low pressure treatment process

3 Results and discussions

3.1 Physiological loss in weight (PLW) of tomato

Figure 3 shows that tomato stored at ambient temperature (control) spoiled after seven days with a physiological loss in weight (PLW) of 5% (Wills and Ku, 2001). However, the shelf life of tomato treated with 0.002 MPA treatment for 15 min, 0.002 MPA treatment for 30 min, 0.004 MPA treatment for 15 min, 0.04 low pressure treatment for 30 min, 0.008 MPA treatment for 15 min and 0.08 low pressure treatment for 30 min stored inside solar adsorption cooling storage system prolonged to 17, 19, 19, 13, 25 and 19 days with physiological loss in weight (PLW) of 4.2%, 4.9%, 4.8%, 4.8%, 4.9% and 4.6%, respectively. The weight loss of tomatoes was almost linear both at ambient and cooling storage condition. The continuous lower inside temperature of the solar adsorption cooling storage system and low pressure treatment of tomato before storing, offers a unique advantage in lowering ethylene production and thus decreases physiological loss in weight (PLW) and other metabolic processes (Lauring et al., 2005).

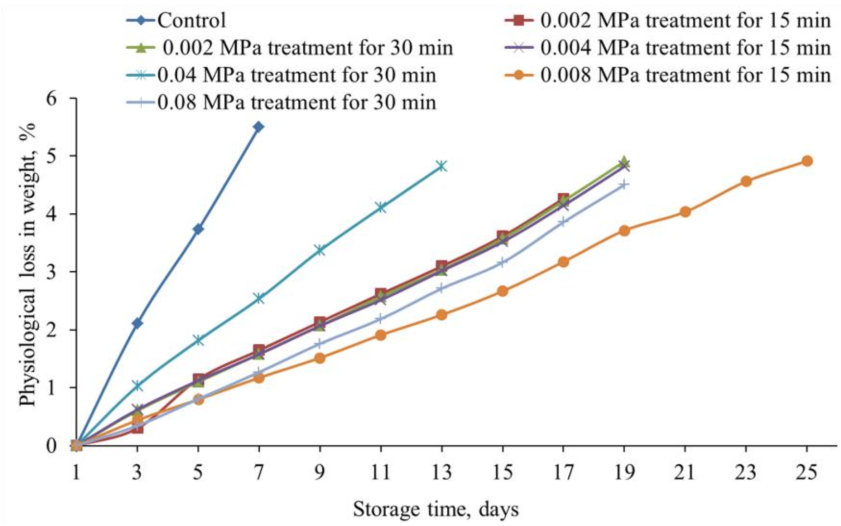
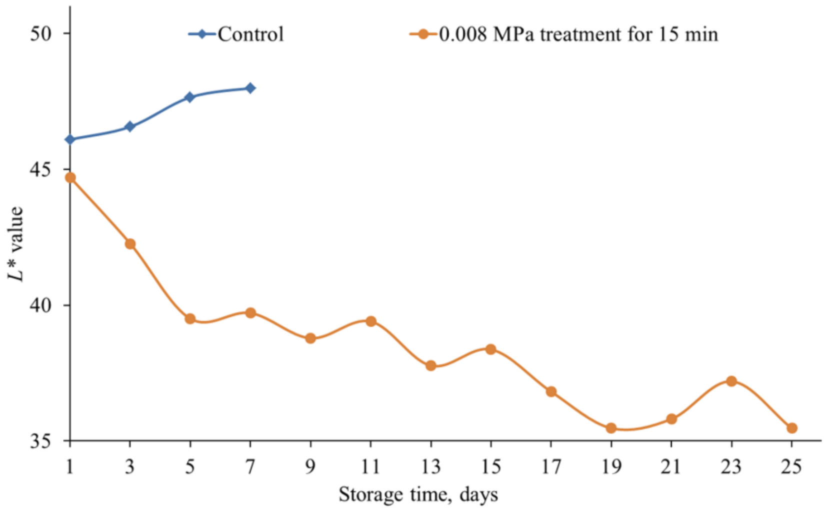


Figure 3 Physiological loss in weight of tomato stored outside in ambient temperature (control) and inside solar adsorption cooling storage system

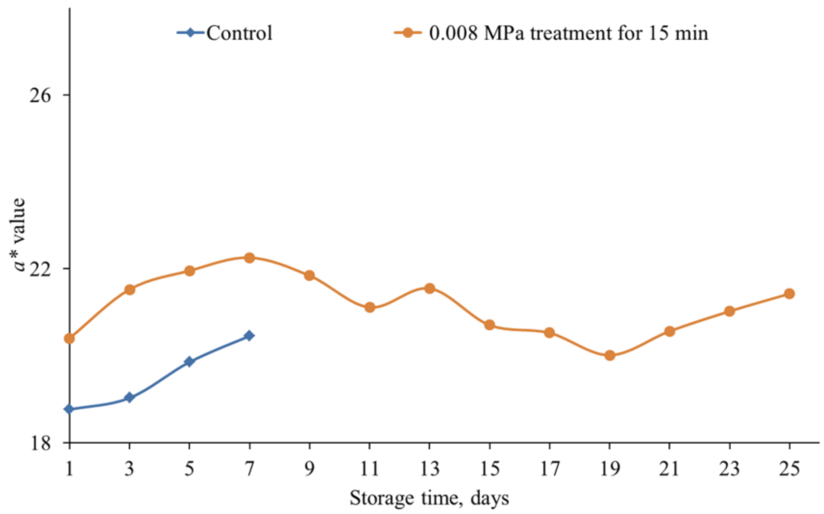
3.2 Skin color of tomato

Tomatoes in the control sample stored at ambient temperature tended to have increasing *L** values (control) from the beginning with values of 46.1 to 47.9 until seven days of storage (Figure 4(a)). However, tomato treated with 0.008 MPa treatment for 15 min stored inside solar adsorption cooling storage system showed *L** values decreasing from 44.7 to 35.5 after 25 days of storage. Figure 4(b) shows that tomatoes in the control sample stored at ambient temperature tended to have increasing *a** values (control) from the beginning with values of 18.8 to 20.5 until seven days of storage. But tomato treated with 0.008 MPa treatment for 15 min stored inside solar adsorption cooling storage system showed *a** values increased from 20.4 to 21.4 after 25 days of storage.

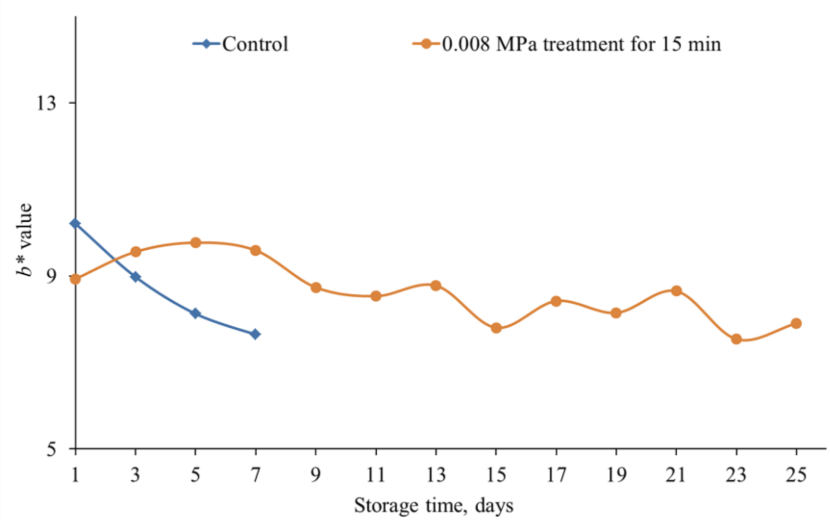
Tomatoes in the control sample stored at ambient temperature (control) tended to have decreasing skin yellowness (*b** value) from the beginning with values of 10.2 to 7.6 until seven days of storage (Figure 4(c)). Tomato treated with 0.008 MPa treatment for 15 min stored inside solar adsorption cooling storage system showed *b** values decreasing from 8.9 to 8.6 after 25 days of storage. For tomato stored inside solar adsorption cooling storage system, *L** and *b** (Figures 4(a), (c)) decreased but *a** increased (Figure 4(b)). If tomatoes ripened at high temperature (from 12℃ to 30℃), causing a better plastids conversion, and yellowing takes place due to inhibiting lycopene synthesis and accumulating yellow/orange carotenoids, then *b** undergoes large changes (López and Gómez, 2004; Tijskens and Evelo, 1994). When red pigments start to synthesize, a decreasing value indicates the darkening of the red color (Messina et al., 2012). This behavior was observed in all samples.



(a) Storage time vs L^* value of stored tomato



(b) Storage time vs a^* value of stored tomato



(c) Storage time vs b^* value of stored tomato

Figure 4 Color changes in tomato stored at ambient temperature and inside solar adsorption cooling storage system

3.3 Total soluble solids (TSS) content

Soluble solids are a large fraction of the total solids in tomato, which is widely used to determine the sweetness. From Figure 5, it is visible that the total soluble solids of the tomato in control increases progressively due to the hydrolysis of polysaccharides to control the respiration rate of tomato under ambient condition (Islam and Morimoto, 2015). As is shown in Figure 5, TSS value of tomato treated with 0.008 MPa treatment for 15 min stored inside solar adsorption cooling storage system decreased slowly from 7.1 to 6.9 after five days of storage, then increased to 7.1 after seven days of storage and decreased gradually to 6.6 until 17 days of storage and then again increased to 6.6 after 25 days of storage (Medina, 2013; Bartz et al., 2003). This could be due to the fact that during storage condition (storage temperature varied from 10℃ to 12℃) inside the solar adsorption cooling chamber when the fruit temperature reduced to the storage temperature 10℃, enzymatic activities also reduced and less starch converted to sugar. But when the storage temperature increased to 12℃, the enzymatic activities also increased and thus increase the TSS level. This is due to the combine effect of cooling temperature of the solar adsorption cooling chamber and low pressure treatment on enzymatic activities of tomato (Islam and Morimoto, 2014; Ahmed and Ramaswamy, 2006).

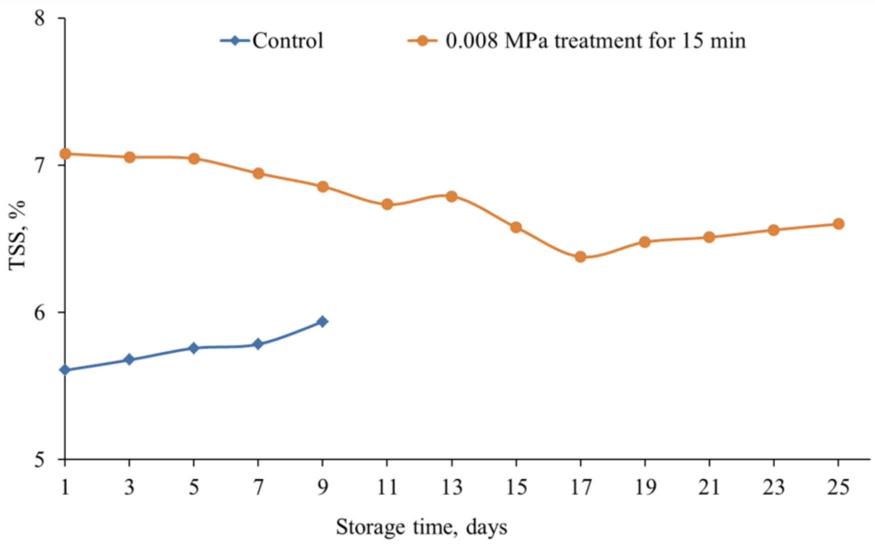


Figure 5 Total soluble solids (TSS) changes in tomato stored at ambient temperature and inside solar adsorption cooling storage system

4 Conclusion

The lack of infrastructure facility and knowledge cause a significant amount of harvested fruits decaying from farmers' field to market. To overcome this problem, a low-cost, ecofriendly solar adsorption cooling storage system was developed. From experiment, it has been found that the shelf-life of tomato treated with 0.008 MPa for 15 minutes prolonged from seven days to 25 days with PLW of 4.9% inside the solar adsorption cooling storage system. During the experiment period the storage temperature varied from 10℃ to 12℃. As a result, both the cold temperature inside the storage and low pressure treatment are inhibiting ethylene production through reducing the enzymatic activities of tomato fruit and thus prolonged the shelf life of stored tomato.

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References

Ahmed, J., and H. S. Ramaswamy. 2006. High pressure processing of fruits and vegetables. *Stewart Postharvest Review*, 1(8): 1-10.

Apelbaum, A., G. Zauberman, and Y. Fuchs. 1977. Subatmospheric pressure storage of mango fruits. *Scientia Horticulturae*, 7(2): 153-160.

Bartz, J. A., and J. K. Brecht. 2003. Postharvest physiology and pathology of vegetables. Taylor & Francis, Second edition, New York, p. 297-669.

Ben-Yehoshua, S. 1987. Transpiration, water stress, and gas exchange. In: Weichmann J, editor. Proceedings of the postharvest physiology of vegetables. New York: Marcel Dekker, p. 113-170.

Clément, A., M. Dorais, and M. Vernon. 2008. Multivariate approach to the measurement of tomato maturity and gustatory attributes and their rapid assessment by Vis-NIR spectroscopy. *Journal of Agricultural and Food Chemistry*, 56(5): 1538-1544.

Exell, R. H. B., S. C. Bhattacharya, and Y. R. Upadhyaya. 1987. Research and development of solar-powered desiccant refrigeration for cold-storage application. Asian Institute of Technology, Bangkok, Thailand, p. 1-67.

Goyette, B., M. T. Charles, C. Vigneault, and V. G. S. Raghavan. 2007. Pressure treatment for increasing fruit and vegetable qualities. *Stewart Postharvest Review*, 3(3): 1-6.

Headley, O. S., A. F. Kothdiwala, and I. A. Mcdoom. 1994. Charcoal-methanol adsorption refrigerator powered by a compound parabolic concentrating solar collector. *Solar Energy*, 53(2): 191-197.

Islam, M. P., and T. Morimoto. 2014. A new zero energy cool chamber with a solar-driven adsorption refrigerator. *Renewable Energy*, 72(2014): 367-376.

Khattab, N. M. 2004. A novel solar-powered adsorption refrigeration module. *Applied Thermal Engineering*, 24(2004): 2747-2760.

Laurin, E., M. C. N. Nunes, J. P. Emond, and J. K. Brecht. 2005. Residual effect of low-pressure stress during simulated air transport on beit alpha-type cucumbers: stomata behavior. *Postharvest Biology and Technology*, 41(2): 121-127.

Leite, A. P. F., M. B. Grilo, R. R. D. Andrade, F. A. Belo, and F. Meunier. 2007. Experimental thermodynamic cycles and performance analysis of a solar-powered adsorptive icemaker in hot humid climate. *Renewable Energy*, 32(4): 697-712.

Lin, G. P., X. G. Yuan, and Z. G. Mei. 1994. A new type solar-powered solid-absorption icemaker. *Acta Energiae Solaris Sinica*, 15: 297-299.

López, C. A. F., and P. A. Gómez. 2004. Comparison of color indexes for tomato ripening. *Horticultura Brasileira*, 22(3): 534-537.

Medina, G. N., J. C. R. Castro, J. A. V. Contreras, H. R. F. Fuentes, and A. I. L. Maldonado. 2013. Physicochemical Parameters for Obtaining Prediction Models in the Postharvest Quality of Tomatoes (*Solanum lycopersicum* L.). *Transactions on Machine Learning and Data Mining*, 6(2): 81-91.

Messina, V., P. G. Dominguez, A. M. Sancho, W. N. de Reca, F. Carrari, and G. Grigioni. 2012. Tomato quality during short-term storage assessed by colour and electronic nose. *International Journal of Electrochemistry*, 1-7. Hindawi Publishing Corporation, USA. http://dx.doi.org/10.1155/2012/687429.

Mesquita, L. C., S. J. Harrison, and D. Thomey. 2006. Modeling of heat and mass transfer in parallel plate liquid-desiccant dehumidifiers. *Solar Energy*, 80(11): 1472-1482.

Niño-Medina, G., J. C. Rivera-Castro, J. A. Vidales-Contreras, H. Rodriguez-Fuentes, and A. I. Luna- Maldonado. 2013. Physicochemical parameters for obtaining prediction models in the postharvest quality of tomatoes (*Solanum lycopersicum* L.). *Transactions on Machine Learning and Data Mining*, 6(2): 81-91.

Patterson, M. F. 2005. Microbiology of pressure-treated foods. *Journal of Applied Microbiology*, 98(6): 1400-1409.

Pons, M., and P. H. Grenier. 1987. Experimental data on a solar-powered ice maker using activated carbon and methanol adsorption pair. *Journal of Solar Energy Engineering*, 109(4): 303-310.

Pons, M., and J. J. Guilleminot. 1986. Design of an experimental solar-powered, solid adsorption ice maker. *Journal of Solar Energy Engineering*, 108(4): 332-337.

Ross, G. A., A. B. David, N. B. Jeremy, J. P. Kevin, and J. S. Robert. 2010. Plants in Action. Ed. David A. Brummell, Edition 2. Plant & Food Research, Palmerston North; Auckland.

Sakoda, A., and M. Suzuki. 1986. Simultaneous transportation of heat and adsorbate in closed type adsorption cooling system utilizing solar heat. *Journal of Solar Energy Engineering*, 108(3): 239-245.

Sondi, I., and B. Salopek-Sondi. 2004. Silver nano-particles as antimicrobial agent: a case study on E. Coli as a model for gram-negative bacteria. *Journal of Colloid and Interface Science*, 275(1): 177-182.

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

Tijskens, L. M. M., and R. G. Evelo. 1994. Modelling colour of tomatoes during postharvest storage. *Postharvest Biology and Technology*, 4(1-2): 85-98.

Wang, S. G., R. Z. Wang, and X. R. Li. 2005. Research and development of consolidated adsorbent for adsorption systems. *Renewable Energy*, 30(9): 1425-1441.

Wenxiang, L., M. Zhang, and Y. Han-qing. 2006. Study on hypobaric storage of green asparagus. *Journal of Food Engineering*, 73(3): 225-230.

Wills, R. B. H., and V. V. V. Ku. 2001. Use of 1-MCP to extend the time to ripen of green tomatoes and postharvest life of ripe tomatoes. *Postharvest Biology and Technology*, 26(1): 85-90.

Zapotoczny, P., and M. Markowski. 2014. Influence of hypobaric storage on the quality of greenhouse cucumbers. *Bulgarian Journal of Agricultural Science*, 20(6): 1406-1412.