Food Research 6 (Suppl. 1) : 89 - 94 (2022)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

A combined technique of temperature preconditioning and modified atmosphere packaging to prolong the storage life of papaya

[1,]*Razali, N.A., [1]Wan Husin, W.M.R.I., [2]Safari, S., [1]Rosly, N.K., [1]Hamzah, F.A. and [1]Abdul Hamid, M.F.

[1]*Horticulture Research Centre, Malaysian Agricultural Research and Development Institute (MARDI), MARDI Headquarters, Persiaran MARDI-UPM, 43400 Serdang, Selangor, Malaysia*
[2]*Socio Economic, Market Intelligence and Agribusiness Research Centre, Malaysian Agricultural Research and Development Institute (MARDI), Persiaran MARDI-UPM, 43400 Serdang, Selangor, Malaysia*

Article history:
Received: 1 September 2021
Received in revised form: 17 November 2021
Accepted: 20 November 2021
Available Online: 29 June 2022

Keywords:
Atmospheric condition,
Chilling injury,
Fruit quality,
Temperature manipulation

DOI:
https://doi.org/10.26656/fr.2017.6(S1).017

Abstract

Papaya is a popular tropical fruit for human consumption over the world. However, it has a relatively short shelf life due to rapid ripening and anthracnose infection after harvest. Generally, papaya is stored at the optimum temperature of 12°C and can last only two weeks. After this period, the fruit will begin to ripen and spoil. Theoretically, fruit stored at lower temperatures will have a longer shelf life. However, papaya is prone to chilling injuries characterised by pitting and inability to ripen if stored at sub-optimum temperature, which may also cause secondary postharvest disease attacks if held for a longer period. The study aimed to evaluate the effectiveness of a combination of temperature preconditioning treatment and modified atmospheric packaging (MAP) in prolonging the storage life of papaya under sub-optimum temperature. In terms of visual appearance, no chilling injury symptoms were observed in samples stored at a sub-optimum temperature of 7°C throughout the storage period. No significant differences were recorded in the parameters of total soluble solids (TSS), total titratable acidity (TTA) and TSS: TTA ratio. Relatively lower ascorbic acid content and higher firmness value were recorded in fruits subjected to the combined technique of temperature conditioning and MAP, which could be associated with delayed ripening. A combination of temperature preconditioning and MAP techniques maintains the papaya quality under storage at sub-optimum temperatures as low as 7°C without chilling injury problems, with a longer shelf life (4 weeks) than only 2 weeks for conventional handling techniques. The fruits can be ripened by being exposed to ethylene when they are ready to be marketed. The technology is helpful for the industry, farmers, wholesalers, and exporters, particularly for the delivery of more extended distribution and periods.

1. Introduction

Papaya (*Carica papaya* L.) is among the most popular fruit in Malaysia, including jackfruit, pineapple, durian and banana. Malaysian production of papaya in 2019 for the domestic and export market achieved 53,000 metric tons (FAOSTAT, 2019). ‘Sekaki’ (*Carica papaya cv. Sekaki)* is a popular papaya variety in Malaysia and also known as Hong Kong papaya (Rahman *et al*., 2008). 'Sekaki' papaya is considered a leading cultivar after Eksotika papaya for export and domestic markets (Sankat and Maharaj, 1997). The papaya's optimum storage temperature has been recommended between 7 to 13°C with 90-95% relative humidity (RH), and the shelf life could be up to 3 weeks (Paull *et al*., 1997; Zhou *et al*., 2014). Below 10°C, chilling injury (CI) will limit the storage life with symptoms such as scald, pitting of the skin, water soaking of the flesh, hard lumps in the pulp around the vascular bundles, abnormal ripening with blotchy discolouration, and increased susceptibility to decay (Thompson and Lee, 1971; El-Tomi *et al*., 1974; Chan *et al*., 1985; Chen and Paull, 1986; Ali *et al*., 1993), while above 10°C, ripening will slowly occur (Chen and Paull, 1986). The CI symptoms appeared sooner and became more serious with lower storage temperature (Pan *et al*., 2017).

Preconditioning involves exposure to temperatures at slightly above optimum storage temperature for a certain period before actual storage at sub-optimum temperatures. Preconditioning treatment significantly

*Corresponding author.
Email: *nurazlin@mardi.gov.my*

eISSN: 2550-2166 / © 2022 The Authors.
Published by Rynnye Lyan Resources

allows the healing process of bruises and cuts, reduced chilling injury and the hazard of rot by preventing the entry of organisms (Abdullah *et al*., 2008; Moran *et al*., 2010). Temperature preconditioning was applied to reduce chilling injury in some products, including avocado, cucumbers, pineapple, loquat, tomatoes and zucchini (Wang, 1996; Woolf *et al.,* 2003; Lee *et al*., 2005; Cai *et al.,* 2006; Abdullah *et al.,* 2008; Liu *et al.,* 2012).

Modified atmosphere packaging (MAP) is a technique of modifying the packaged atmosphere by introducing optimal gas compositions to inhibit the metabolic process and prolong the shelf life (Zhang *et al*., 2015). The MAP technique is done by packing fresh produce in a polymeric film to allow self-modification of the atmosphere in the package. The packaging film with the ability to diffuse certain amounts of oxygen (O_2) and carbon dioxide (CO_2) into or from the package creates an atmosphere of low O_2 and high CO_2 concentrations desired by the fruit. Both low O_2 and high CO_2 concentrations reduce respiration rate, delay ripening, and extend the storage life of fruits. A previous study used MAP for papaya cv. Eksotika was proved to maintain the quality of papaya during the 5 weeks storage at 12°C (Mohd Salleh *et al*., 2007).

Postharvest Technology and strategy need to be consolidated to promote the export market of papaya and maintain good quality. Fruits for long-distance export markets could be transported using either air or sea freight. Airfreight is common due to the short travelling and simple handling techniques; however, the freight cost is quite expensive. Sea freight has the advantages of delivering larger quantity produce and cheaper freight cost, but the storage life of produce should be extended to meet the longer shipping period. A study on temperature preconditioning treatment on papaya var. Sekaki has been reported by Razali (2013). The quality and freshness of the papaya fruits could be further extended during market expansion by combining temperature preconditioning with modified atmosphere packaging (MAP). Therefore, this study was conducted to evaluate the effectiveness of the combined technique of temperature preconditioning and MAP to extend the storage life of papaya.

2. Materials and methods

2.1 Sample preparation of papaya

'Sekaki' papaya with a colour index of two (green with a trace of yellow) or three (more green than yellow) were transported from a farm to Postharvest Laboratory MARDI. The fruit samples used in this study were sorted for uniformity of size, shape and maturity, and free from any form of mechanical injury and insect and pathogen damages. Papaya fruits were then sanitised with propiconazole fungicide (250 ppm) and allowed to dry. The fruit samples were then packed using a corrugated fibreboard (CFB) box, replicating three samples for each box and were weighed prior to storage according to the treatments. Samples were subjected to temperature preconditioning and MAP treatments as followed:

Treatment 1: Control (Without both MAP and temperature preconditioning)

Treatment 2: MAP only (without temperature conditioning)

Treatment 3: Temperature preconditioning [15°C (1 day) + 10°C (3 days)] only (without MAP)

Treatment4: Temperature preconditioning [15°C (1 day) + 10°C (3 days)] with MAP

For MAP treatment, samples were packed and sealed in low-density polyethylene (LDPE) polymeric film with 0.04mm thickness. For temperature preconditioning treatments, samples were stored at 15°C (1 day) followed by 10°C (3 days) before actual storage at 7°C. The samples from treatments 1 and 2 (without temperature preconditioning) were stored at the optimum temperature of 12°C, while treatments 3 and 4 (with temperature preconditioning) were stored at 7°C. The samples were evaluated at weekly intervals for quality assessment.

2.2 Gases in the package

The gases in the package were measured initially and every day for 23 days in which steady-state concentration was achieved. A syringe drew the gas samples (O_2 and CO_2) through a septum in the package. O_2 and CO_2 were detected using a thermal conductivity detector (TCD), with a stainless-steel column packed with Porapak R of 80/100-mesh size. The purified helium gas flow rate was 30 mL/min, and the column oven was operated at 50°C. Three replications were used for each treatment.

2.3 Fruit quality assessment

The fruit qualities were assessed subjectively for their visual appearances. The physical quality of the fruits, which includes chilling injury symptoms, freckles incidence, anthracnose disease and overall acceptability ratings, was analysed according to the visual rating scale (Table 1) modified from Proulx *et al*. (2005). Samples were analysed to determine the changes in quality. The postharvest quality evaluation included firmness and compositional (pH, soluble solids content (SSC), total titratable acidity (TTA) and ascorbic acid content) characteristics.

Table 1. Percentage of chilling injury symptoms, freckles incidence, anthracnose disease and overall acceptability ratings

Chilling injury symptoms, freckles incidence and anthracnose disease (% surface area)	Overall acceptability ratings
0% = No abnormality	5. Excellent
1-15% = Trace symptoms	4. Good
16-25% = Moderate symptoms	3. Acceptable
25-50% = Moderate to severe symptoms	2. Poor
>50% = Severe symptoms	1.Very poor

The texture of the flesh was measured using a texture analyser (TA.xt.Plus, Stable Micro Systems), fitted with a flat stainless-steel cylindrical probe (P2N) and travelled 10 mm of the depth of the cut surface of the sample with a penetration speed of 5 mm/s. Values were expressed as Newton (N). The flesh firmness was determined at three different places on the fruits. The pH value was measured using an Origon digital pH meter (model SA 520). Total titratable acidity was measured by titrating the known volume of homogenates solution with 0.1 N NaOH to an endpoint of pH 8.1 using a digital burette. The total soluble solids (TSS) were determined by a digital refractometer (ATAGO RX-5000, ATAGO, Japan). Finally, ascorbic acid content was determined by titration with 2,6 dichlorophenolindophenol until a faint pink colour persists.

2.4 Statistical analysis

The experimental setup was a completely randomised design and performed for each variable. Statistical analyses of the treatment responses were conducted using analysis of variance (ANOVA). The analysis is used to identify the relationship between parameters and treatments. Experimental data are presented as means, with a discussion of significant differences in the text.

3. Results and discussion

3.1 Chilling injury symptoms, freckles incidence, anthracnose disease and overall acceptability ratings

Tropical fruits such as papaya are susceptible to low temperatures (below 10°C). They may develop chilling injury (CI) symptoms such as pitting of the skin, scalding and hard lumps in the pulp around the vascular bundles (Chen and Paull, 1986). The visual appearance of papaya after treatment and subsequent storage for 4 weeks was demonstrated in Figure 1. No chilling injury symptom was observed in all samples regardless of treatments (Table 2). No chilling injury in control (T1) and MAP only (T2) samples were expected because they were stored at the optimum storage temperature. In this study, the temperature preconditioning successfully prevented CI in papaya stored at low temperature (7°C). Without temperature preconditioning, papaya stored at such lower temperature developed CI symptoms like surface pitting developed on the skin as reported in 'Exp. 15' papayas stored at 5°C (Proulx *et al*., 2005).

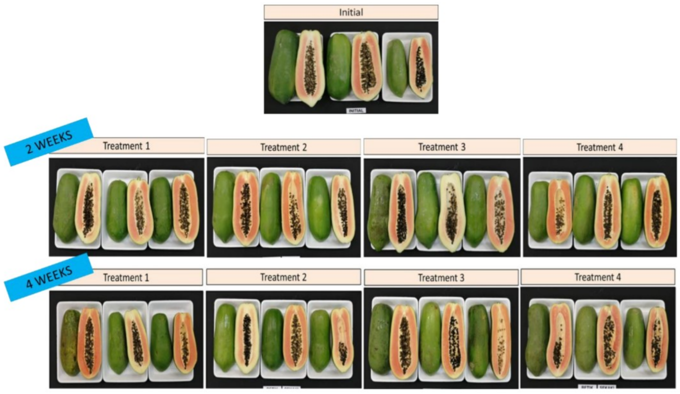

Figure 1. The visual appearance of papaya after storage for 4 weeks

Freckles incidence was obvious on fruit without MAP. The packaging helped reduce the symptoms, probably due to delayed ripening as the freckles were obvious when the fruit matures. Freckles are superficial, do not affect the flesh and are primarily a cosmetic disorder. Anthracnose disease was not detected in all treatments during storage. Mohd Saleh (2007) reported minimum diseases on papaya in MAP during storage at 12°C. At week-4, control fruit was scored as poor while fruit treated with the combination of temperature preconditioning and MAP was scored as good. Without this treatment, papaya could last only two weeks in the cold storage of 12°C. The temperature preconditioning and MAP maintain the fruit quality by slowing down the ripening process (delay the colour advancement) and maintaining the fruit freshness. A previous study on chilli treated with preconditioning treatment also reported that the storage life could be prolonged for 4 weeks at 5°C (Nur Azlin *et al*., 2014).

Table 2. Visual appearance score of papaya after 4 weeks of storage.

Treatments	Chilling injury	Skin freckle	Anthracnose disease	Flesh colour	Overall Appearance
Control (T1)	none	moderate	none	Orange-yellow	Poor
MAP only (T2)	none	slight	none	Orange-yellow	Acceptable
Temperature conditioning only (T3)	none	moderate	none	Orange-yellow	Poor
Combined temperature conditioning and MAP (T4)	none	slight	none	Orange-yellow	Acceptable

eISSN: 2550-2166

3.2 Gases in the Package

The performance of MAP designs for fresh produce is directly associated with the ability of the package to convert the composition of respiratory gases into its optimum composition in the shortest time possible and maintain the composition throughout the storage period. The result showed that LDPE (0.04mm) packaging used in the present study was able to decrease O_2 and increase CO_2 concentrations as compared with 21% O_2 and 0% CO_2 in the control package (without MAP) (Figure 2). The O_2 concentration declined to about 9.0% for papaya packed in MAP, while CO_2 concentration rose to about 6% after about 8 days in storage. Then, the gas concentration changed after day 9 of the storage period, where the O_2 reached steady-state at 10%, and CO_2 decreased to steady-state at 5%.

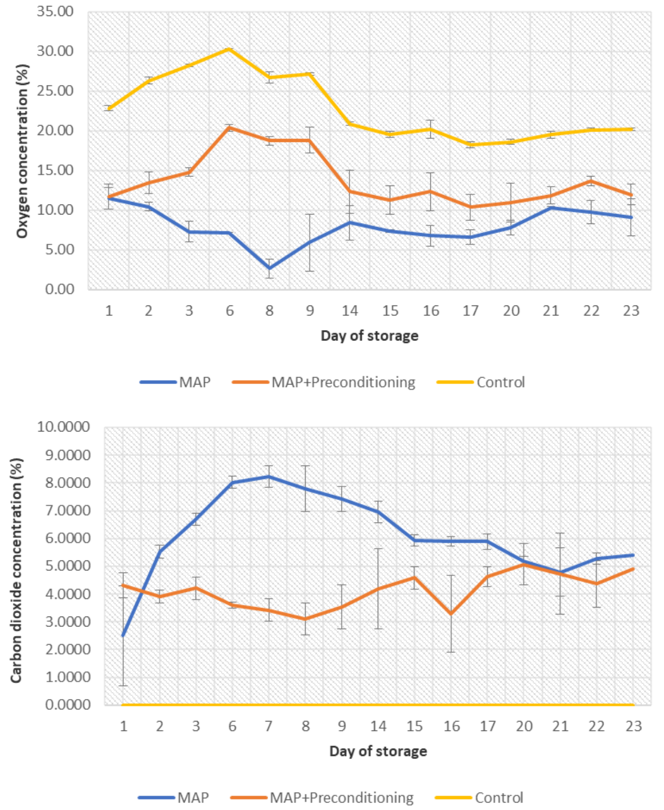

Figure 2. Oxygen and carbon dioxide concentrations inside MA packages during 23 days of storage.

3.3 Fruit quality assessment

Quality assessment data showed no significant differences recorded in the parameters of pH, TSS and TTA (Table 3). The TSS was between 7-9% due to delayed ripening in which the papaya's index was still between 2-3 during storage. The TSS of papaya fruit depended on the stage of maturity (Santamaría Basulto *et al.*, 2009). The TTA of 'Sekaki' papaya fruit ranged between 0.8 and 0.9% in this study. No significant difference in TTA treated with temperature conditioning compared to control was similar to the report by Ongom and Pranamornkith (2019), who experimented on papaya cv. Holland grew in Thailand.

A relatively low ascorbic acid content was recorded in papaya that underwent a combination of temperature conditioning and MAP, possibly due to the fruit still at Index 3 even after 4 weeks of storage. The ascorbic acid of 'Holland' papaya (at 5% yellow) grown in Thailand reported that this cultivar was 45 mg/100 g FW (Supapvanich and Promyou, 2017). Papaya fruit firmness declined gradually with the ripening of the fruit. However, the decrease in firmness was significantly suppressed with the reduced storage temperature. Fruit firmness for the combination treatment also recorded the highest reading indicating the ripening process was slower in low temperatures. A previous report on papaya cv. Zhongbai, the fruit stored at 1°C, did not ripen after being moved to room temperature, indicating that the fruit could suffer from chilling injury (Pan *et al.*, 2017). However, in this study, when the fruits were transferred back to ambient temperature after cold storage, they could ripen perfectly and uniformly with the induction of ethylene gas 150 ppm (Figure 3).

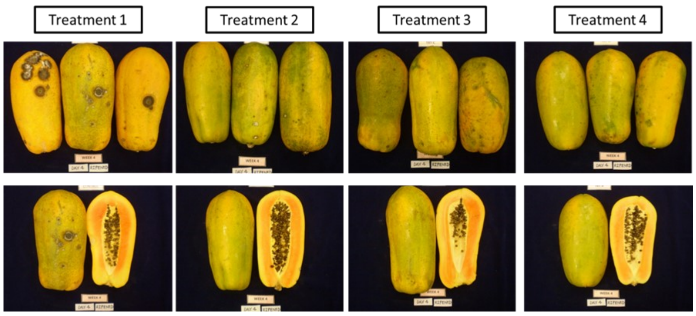

Figure 3. The visual appearance of papaya after storage for 4 weeks and subsequent ripening induction with ethylene gas

4. Conclusion

Being a highly perishable fruit, technology to preserve and prolong the shelf life of papaya is greatly

Table 3. Firmness and quality parameter of papaya stored for 4 weeks of storage.

Treatments	pH	TSS (%)	TTA (%)	Ascorbic acid (mg/100 g)	Firmness (N)
Control (T1)	5.62^{c}	8.37^{a}	0.09^{a}	48.06^{a}	28.56^{bc}
MAP only (T2)	5.75^{b}	7.88^{a}	0.08^{a}	42.65^{ab}	24.98^{c}
Temperature conditioning only (T3)	5.73^{b}	7.89^{a}	0.09^{a}	44.34^{ab}	40.71^{a}
Combined temperature conditioning and MAP (T4)	5.91^{a}	7.71^{a}	0.08^{a}	39.50^{b}	33.72^{ab}

Values are presented as mean. Values with different superscript within the same column are significantly different using Duncan's Multiple Range Test.

eISSN: 2550-2166

needed. By using the combined technique of temperature conditioning and modified atmosphere packaging, papaya can be stored at sub-optimum temperatures as low as 7°C without chilling injury problems, with a longer shelf life (4 weeks) compared to only just 2 weeks for conventional handling techniques (storage kept at an optimum temperature of 12°C). Furthermore, the extended storage life enables distribution to further market and reduce the transportation cost by using sea shipment.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgement

This work was supported by the Rancangan Malaysia Ke-11 Projek Pembangunan [grant numbers P21003004050001]. The authors would like to acknowledge their deepest thanks to MARDI and the team members to give generous support to this research.

References

Abdullah, H., Rohaya, M.A. and Engku Hasmah, E.A. (2008). Increasing pineapple fruit resistance to chilling injury during storage by temperature preconditioning. *Acta Horticulturae,* 768, 217-224. https://doi.org/10.17660/ActaHortic.2008.768.26

Ali, Z.M., Lazan, H., Ishak, S.N. and Selamat, M.K. (1993). The biochemical basis of accelerated softening in papaya following storage at low temperature. *Acta Horticulturae,* 343, 230-232. https://doi.org/10.17660/ActaHortic.1993.343.53

Cai, C., Xu, C.J., Shan, L.L., Li, X., Zhou, C.H., Zhang, W.S., Ferguson, I. and Chan, K.S. (2006). Low temperature conditioning reduced postharvest chilling injury in loquat fruit. *Postharvest Biology and Technology,* 41(3), 252-259. https://doi.org/10.1016/j.postharvbio.2006.04.015

Chan, H.T., Sanxter, S. and Couey, H.M. (1985). Electrolyte leakage and ethylene production induced by chilling injury in papaya. *HortScience,* 20(6), 1070-1072.

Chen, N.M. and Paull, R.E. (1986). Development and prevention of chilling injury in papaya fruit. *Journal of the American Society for Horticultural Science,* 111(4), 639-643.

El-Tomi, A.L., Aziz, A.B.B., Abdel-Kader, A.S. and Abdel-Wahab, F.K. (1974). The effect of chilling and non-chilling temperatures on the quality of papaya fruits. *Egyptian Journal of Horticulture*, 1(2), 179-185.

FAOSTAT. (2019). Crop production. Retrieved on June 20, 2021 from FAOSTAT Website: http://faostat.fao.org/site/567/default.aspx.

Lee, S.H., Chung, G.C. and Steudle, E. (2005). Gating of aquaporins by low temperature in roots of chilling-sensitive cucumber and chilling-tolerant fig leaf gourd. *Journal of Experimental Botany,* 56(413), 985 – 995. https://doi.org/10.1093/jxb/eri092

Liu, C., Jahangir, M.M. and Ying T. (2012). Alleviation of chilling injury in postharvest tomato fruit by preconditioning with ultraviolet irradiation. *Journal of the Science of Food and Agriculture,* 92(15), 3016 – 3022. https://doi.org/10.1002/jsfa.5717

Mohd Salleh, P., Pauziah, M., Ahmad Tarmizi, S. and Zaipun, M.Z. (2007). Quality of papaya in modified atmosphere packages under simulated storage condition for export by sea. *Journal of Tropical Agriculture and Food Science,* 35(1), 71-79.

Moran, E.R., Deell, R.J. and Murr, P.D. (2010). Effects of preconditioning and fruit maturity on the occurrence of soft scald and soggy breakdown in 'Honeycrisp' apples. *Hortscience,* 45(11), 1719-1722. https://doi.org/10.21273/HORTSCI.45.11.1719

Nur Azlin, R., Razali, M., Zaipun, M.Z. and Habsah, M. (2014). Effect of different preconditioning treatments for shelf-life extension of chilli (*Capsicum annuum* L.). *Journal of Tropical Agriculture and Food Science*, 42(2), 135-142.

Ongom, A.B.L. and Pranamornkith, T. (2019). Effects of Intermittent Warming on Quality of Papaya Fruit cv. Holland during Storage. *Journal of Food Science and Agricultural Technology*, 5 (Special Issue), 166-171.

Pan, Y.G., Yuan, M.Q., Zhang, W.M. and Zhang Z.K. (2017). Effect of low temperatures on chilling injury in relation to energy status in papaya fruit during storage. *Postharvest Biology and Technology,* 125, 181–187. https://doi.org/10.1016/j.postharvbio.2016.11.016

Paull, R.E., Nishijima, W., Marcelino, R. and Cavaletto, C. (1997). Postharvest handling and losses during marketing of papaya (*Carica papaya* L.). *Postharvest Biology and Technology,* 11(3), 165-179. https://doi.org/10.1016/S0925-5214(97)00028-8

Proulx, E., Cecilia, M., Nunes, N., Emond, J.P. and Brecht, J.K. (2005). Quality attributes limiting papaya postharvest life at chilling and non-chilling temperatures. *Proceedings of the Florida State Horticultural Society*, 118, 389 - 395.

Rahman, M.A., Mahmud, T.M.M., Kadir, J., Abdul Rahman, R. and Begum, M.M. (2008). Major Postharvest Fungal Diseases of Papaya cv. 'Sekaki' in Selangor, Malaysia. *Journal Tropical Science,* 31 (1), 27-34.

Razali, M., Habsah, M., Nur Azura, H., Zaipun, M.Z., Tham, S.L., Zaulia, O., Azhar M.N. and Siti Nur Raihan, A. (2013). Prolong storage life of `sekaki' papaya by using preconditioning technique for reducing postharvest losses, presented at Proceeding of Postharvest Losses and Food Waste Conference 2013. Malaysia: MARDI

Sankat, C.K. and Maharaj, R. (1997). Postharvest Physiology and Storage of Tropical and Subtropical Fruits. London: CAB International.

Santamaría Basulto, F., Sauri Duch, E., Espadas y Gil, F., Díaz Plaza, R., Larqué Saavedra, A. and Santamaría, J.M. (2009). Postharvest ripening and maturity indices for Maradol papaya. *Interciencia*, 34(8), 583 - 588.

Supapvanich, S. and Promyou, S. (2017). Hot water incorporated with salicylic acid dips maintaining physicochemical quality of 'Holland' papaya fruit stored at room temperature. *Emirates Journal of Food and Agriculture*, 29(1), 18-24. https://doi.org/10.9755/ejfa.2016-07-966

Thompson, A.K. and Lee, G.R. (1971). Factors affecting the storage behaviour of papaya. *Journal of Horticultural Science,* 46(4), 511-516. https://doi.org/10.1080/00221589.1971.11514429

Wang, C.Y. (1996). Temperature preconditioning affects ascorbate antioxidant system in chilled zucchini squash. *Postharvest Biology and Technology,* 8(1), 29-36. https://doi.org/10.1016/0925-5214(95)00061-5

Woolf, A.B., Cox, K.A., Anne, W. and Ferguson I.B. (2003). Low temperature conditioning treatments reduce external chilling injury of 'Hass' avocados. *Postharvest Biology and Technology,* 28(1), 113-122.

Zhang, M., Meng, X., Bhandari, B., Fang, Z. and Chen, H. (2015). Recent application of modified atmosphere packaging (MAP) in fresh and fresh-cut foods. *Food Reviews International,* 31(2), 172–193. https://doi.org/10.1080/87559129.2014.981826

Zhou, L., Paull, R.E. and Chen, N.J. (2014). Papaya: Postharvest quality maintenance guidelines. Fruit, nut and beverage crops. Retrieved on May 21, 2021 from College of Tropical Agriculture and Human Resources (CTAHR) Website: https://www.ctahr.hawaii.edu/oc/freepubs/pdf/F_N-34.pdf

