TEMPERATURE PRECONDITIONING TECHNIQUE INCREASES CHILLING TOLERANCE IN PAPAYA

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ABSTRACT

The most effective postharvest tool to extend storage life and maintain the quality of fruits is low-temperature storage. However, storing fruits below the optimum level caused a chilling injury. Papaya is prone to chilling injuries characterised by scald, pitting of the skin, hard lumps in the pulp around the vascular bundles, abnormal ripening with blotchy discolouration and water soaking of the flesh, all these increased susceptibility to decay. The study aimed to evaluate the effectiveness of temperature preconditioning treatment in developing chilling tolerance of papaya cv. 'Sekaki' during storage at suboptimum temperature. The study was carried out by manipulating temperature preconditioning and storage at sub-optimum temperature (7°C). No chilling injury symptom was observed in samples stored at a sub-optimum temperature of 7 °C throughout the storage period. Quality parameters like pH, total titratable acidity (TTA), total soluble solids (TSS) and ascorbic acid content showed no significant differences between treatments. Higher firmness value was recorded in fruits subjected to temperature conditioning, associated with delayed ripening. The temperature preconditioning technique preserves the papaya quality under storage at sub-optimum temperatures as low as 7 °C without chilling injury symptoms, with a longer shelf life (4 weeks) than only three weeks for conventional handling techniques. The fruits can be ripened by being exposed to ethylene when they are ready to be marketed.

Keywords: *chilling injury, fruit quality, postharvest treatment, sub-optimum temperature, temperature manipulation*

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' 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 & Maharaj, 1997). The papaya's optimum storage temperature has been recommended between 10 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., 2013). Below 10 °C, chilling injury (CI) will limit the storage life with symptoms such as scald, pitting of the skin, hard lumps in the pulp around the vascular bundles, abnormal ripening with blotchy discolouration and water soaking of the flesh, all these increased susceptibility to decay (Ali et al., 1993; Chan et al., 1985; El-Tomi et al., 1974; Thompson & Lee, 1971), while above 10 °C, ripening will slowly occur (Chen & Paull, 1986). The CI symptoms appeared sooner and became more serious with lower storage temperature (Pan et al., 2017).

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.

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 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; Liu et al. 2012).

A preliminary study on temperature preconditioning treatment on papaya var. 'Sekaki' has been reported by Razali (2013). Treatments involved were control stored directly at 12°C, temperature preconditioning 15°C (1 day), temperature preconditioning 15°C (1 day) + 10°C (3 days) and 15°C (1 day) + 10°C (1 day). Temperature preconditioning was applied by step-wise temperature reduction before storage at sub-optimal temperature (7°C). Results showed that preconditioned papaya (15°C (1 day) + 10°C (3 days)) could be stored up to 4-5 weeks at a sub-optimum storage temperature of 7°C, while the control samples can only be stored for 2-3 weeks. Therefore, this study was conducted to validate the effectiveness of the temperature preconditioning treatment in developing the chilling tolerance of papaya cv. 'Sekaki' during storage at suboptimum temperature, hence extending papaya's storage life.

MATERIALS AND METHODS

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 before storage according to the treatments. Samples were subjected to temperature preconditioning and MAP treatments as followed:

i. Treatment 1: Control (stored at optimum temperate of 12 °C)
ii. Treatment 2: Temperature preconditioning [15 °C (1 day) + 10 °C (3 days)] and stored at a sub-optimum temperature of 7 °C

Samples were stored for four weeks to evaluate the postharvest quality during storage.

Fruit quality assessment
The samples were evaluated at weekly intervals for 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).

The peel colour was measured using a colourimeter (Konica Minolta Sensing Model CR-400; Tokyo, Japan) with D65 illuminant, obtaining CIE L*, a*, and b* values; the a* and b* values were converted into hue angle (h*) and chroma value (C*) as described by McGuire (1992). 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/sec. 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 (TTA) 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.

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

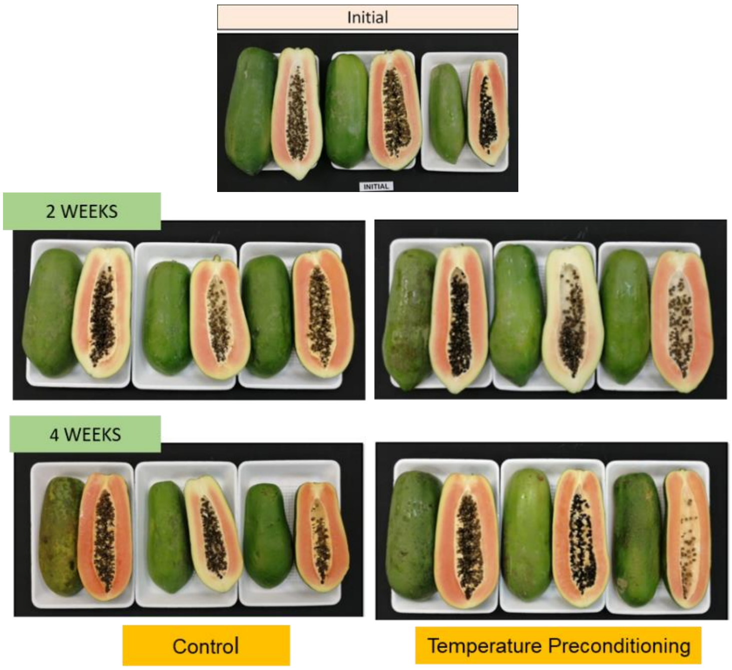
Statistical analysis
The experimental setup was a completely randomised design and performed for each variable. Statistical analyses of the treatment responses were conducted using analysis of variance (ANOVA). The analysis is used to identify the relationship between parameters and treatments. Experimental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

RESULTS AND DISCUSSION

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, scald and hard lumps in the pulp around the vascular bundles (Chen & Paull, 1986). The visual appearance of papaya after treatment and subsequent storage for two and four weeks was demonstrated in Figure 1. No chilling injury symptom was observed in both treatments. The temperature preconditioning successfully prevented CI in papaya stored at sub-optimum 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). No chilling injury in control was expected because they were store at the optimum storage temperature.

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



Freckles incidence was obvious on control, while slightly on temperature preconditioning fruits (Table 2). The lower storage temperature 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 detected in control as early as 3-weeks storage, while in temperature preconditioning samples, it was detected at 4-weeks of storage. At week-4, control fruit was scored as poor, while fruit treated with temperature preconditioning was acceptable. Without this treatment, papaya could last only three weeks in the cold storage of 12 °C. The temperature preconditioning maintains 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 four weeks at 5 °C (Nur Azlin et al., 2014).

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

Treatments	Chilling injury	Skin freckle	Anthracnose disease	Flesh colour	Overall Appearance
Control	none	moderate	moderate	Orange-yellow	Poor
Temperature preconditioning	none	slight	slight	Orange-yellow	Acceptable

Fruit quality assessment
Data analysis revealed no effect of temperature conditioning on skin and flesh colour during storage (Table 3). Papaya fruit firmness declined gradually with the ripening of the fruit. Fruit firmness for the temperature preconditioning samples recorded higher data indicating the ripening process was slower in lower storage temperature (Table 4). 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 (data not shown).

Quality assessment data showed no significant differences recorded on the parameters of pH, TSS and TTA (Table 4). The TSS was between 8-9%, depending on the maturity stage (Santamaría Basulto et al., 2009). The TTA of papaya fruit was 0.9% in both treatments. No significant difference in TTA treated with temperature conditioning compared to control was similar to the report by Ongom & Pranamornkith (2019), who experimented on papaya cv. Holland grew in Thailand. The ascorbic acid content was recorded between 48-52mg 100 g^{-1} FW at four weeks of storage. The ascorbic acid of Holland papaya grown in Thailand reported that this cultivar was 45 mg 100 g^{-1} FW (Supapvanich and Promyou, 2017).

Table 3. Skin and flesh colour of papaya stored for four weeks of storage.

Treatments	Peel colour			Flesh colour		
	L	Hue	Chroma	L	Hue	Chroma
Control (T1)	53.96a	105.31b	43.08a	58.35a	62.09a	40.39a
Temperature conditioning (T2)	5.1.98b	110.90a	40.16b	59.33a	62.97a	40.31a

In each column with the same letter, Means are not significantly different separated using Duncan's Multiple Range Test.

Table 4. Flesh firmness and quality parameter of papaya stored for four weeks of storage.

Treatments	pH	Total Soluble Solids (%)	Total Titratable Acidity (%)	Ascorbic acid (mg/100g)	Firmness (N)
Control (T1)	5.71a	8.63a	0.09a	48.56a	16.08b
Temperature conditioning (T2)	5.73a	8.25a	0.09a	51.36a	26.02a

In each column with the same letter, Means are not significantly different separated using Duncan's Multiple Range Test.

CONCLUSION

From the experiment carried out, it can be concluded that papaya preconditions at 15°C (1 day) + 10°C (3 days) before storage at a suboptimum temperature of 7°C was validated as the best temperature preconditioning technique that can be applied to developed chilling tolerance. Lower temperature storage at 7°C was able to maintain firmness and delay the ripening of papaya fruit without chilling injury symptoms. Thus, the storage life of papaya fruits undergoes this temperature precondition treatment extended to four weeks storage compared to pitaya fruits without temperature preconditioning treatment, only two weeks storage. This technique can be included in the postharvest handling value chain of papaya for the export market so that the storage life can be extended for market distribution and expansion.

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