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# Physiological Responses to Low Temperature Conditioning and Chitosan Coating of Red-Fleshed Dragon Fruit [*Hylocereus polyrhizus* (Weber) Britton & Rose]

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**The effect of the combination treatment of 1% chitosan coating and 3-d low temperature conditioning (LTC) at 10 °C was evaluated in maintaining the quality of red-fleshed dragon fruit during storage at 8 °C. Fruit subjected to LTC and chitosan coating treatments had slower respiration rate than the control. Ascorbic acid (AAC) and total phenolic contents (TPC) of the fruit subjected to the treatments were unaffected during storage. However, the decline in AAC after transfer to 20 °C was slower in treated fruit. Furthermore, the increase in flesh concentration of 1-aminocyclopropane-1-carboxylic acid (ACC) during storage at 8 °C was due to the inhibition of ethylene biosynthesis. The increase in electrolyte leakage, on the other hand, was a manifestation of cell breakdown as a result of chilling injury.**

Key Words: antioxidant activity, chitosan coating, *Hylocereus polyrhizus*, low temperature conditioning

Abbreviations: AAC – ascorbic acid content, ACC – 1-aminocyclopropane-1-carboxylic acid, CI – chilling injury, CRD – completely randomized design, DAF – days after flowering, DPPH – 2,2-diphenyl-1-picrylhydrazyl, FID – flame ionization detector, GAE – gallic acid equivalent, HSD – Tukey's honest significance test, LTC – low temperature conditioning, PHTRC – Postharvest Horticulture Training and Research Center, ROS – reactive oxygen species, SAM – S -adenosyl-l-methionine, TCD – thermal conductivity detector, TPC – total phenolic content, UPLB – University of the Philippines Los Baños

## INTRODUCTION

Dragon fruit or pitaya (*Hylocereus* spp.) is an emerging crop in the Philippine market because of its attractive peculiar appearance and shape, supplemented with its high nutritional benefits (Le Bellec et al. 2006). The promise of profitability in the dragon fruit industry has some drawbacks due to the fruit's short shelf-life even at low temperatures. Dragon fruit stored at 10°C and 20°C at 90% relative humidity has a shelf life of 14 and 7 d, respectively (Nerd et al. 1999). Physiological disorders such as chilling injury (CI) lower the fruit quality, marketability and the potential storage life. Moreover, dragon fruit is a seasonal crop, thus extending its availability during off-season months is a challenge. While its storage life can be extended for more than 4 wk at 5 °C, chilling injury can occur (Nerd et al. 1999). It is therefore the objective of this study to determine the effect of low temperature conditioning (LTC) (Wang 2013) and chitosan coating (Ali et al. 2013) in maintaining the quality of red-fleshed dragon fruit at suboptimal temperature, thereby increasing the potential storage life.

## MATERIALS AND METHODS

### Fruit Material

Red-fleshed dragon fruits [*Hylocereus polyrhizus* (Weber) Britton & Rose], with commercial maturity of 25 d after flowering (DAF), were harvested from Silan's Agri Farm in Barangay Tambo Kulit, lndang Cavite, Philippines. The fruits selected were defect-free, with uniform full red peel, green and firm bracts, and of regular size (300–380

g). Fruits were then placed in polyethylene film-lined perforated crates and transported to the Postharvest Horticulture Training and Research Center (PHTRC), University of the Philippines Los Baños (UPLB), College, Laguna, Philippines.

### Postharvest Treatments

Dragon fruits were subjected to combination of 1% chitosan coating and 3-d conditioning at 10 °C then stored at 8 °C for 6 wk. Single chitosan coating and low temperature conditioning treatments were also included for comparison. Dragon fruits were withdrawn weekly from storage and transferred to 20 °C (post-storage) to simulate retail temperature in supermarkets until the limit of marketability (fair quality with moderate defects) was reached.

Weekly monitoring of the respiration rate and ethylene production was done during storage for 6 wk. Immediately after withdrawal, 1-aminocyclopropane-1-carboxylic acid (ACC), ascorbic acid and total phenolic content, electrolyte leakage and antioxidant activity of the flesh were determined.

### Respiration and Ethylene Production

The rates of carbon dioxide ($CO_2$) and ethylene ($C_2H_4$) production were determined by analyzing the head space gas of the respiration jar containing the fruit using a gas chromatograph. One milliliter (1 mL) of gas was sampled and injected in Shimadzu GC-8A fitted with thermal conductivity detector (TCD) and Shimadzu GC-2014 fitted with flame ionization detector (FID) to determine the concentrations of $CO_2$ and $C_2H_4$ produced, respectively. Analyses were done in three (3) replicates with two trials per replicate.

### 1-aminocyclopropane-1-carboxylic acid (ACC) Flesh Concentration

Assay procedure was adapted from the method of Lizada and Yang (1979). Five (5) grams of dragon fruit flesh were blended and homogenized. The resulting mixture was centrifuged (10,000 rpm, 15 min) and the collected supernatant was partitioned into 4 aliquots, each equivalent to 0.1 g of fruit tissue. The aliquots were air dried and one (1) drop of 0.1 M $HgCl_2$ was then added to each tube and shaken until the residue was dissolved. In tubes 1 and 2, 0.85 mL of distilled water was added. On the other hand, 0.1 mL of $10^{-5}$ M ACC and 0.75 mL distilled water was added in tubes 3 and 4. Additional vacutainer tubes labelled as tubes 5 and 6 were treated as blanks which contained 0.1 mL of $10^{-5}$ M ACC, one (1) drop 0.1 M $HgCl_2$ and 0.75 mL distilled water. All the prepared test tubes were stoppered and agitated using a vortex mixer for five seconds (5 s) followed by cooling in ice bath. Ten (10) drops of freshly prepared NaOCl-NaOH (2:1) were injected in the tubes using 1-mL syringe. Tubes were agitated again using vortex mixer to increase ethylene diffusion. One (1) mL gas samples were withdrawn from the tubes after 2.5 min. Gas samples were injected into GC fitted with FID for $C_2H_4$ measurement. Results were expressed in nmol ACC per gram of flesh.

### Total Phenolic Content

The method of determining the phenolic content was adapted from that of Bae and Suh (2007). Folin-Ciocalteau reagent (0.25 N, 2.0 mL) was added to dragon fruit ethanolic extracts (0.1 mL). After letting it stand for 5 min in the dark, 2.0 mL saturated $Na_2CO_3$ was added and allowed to stand for 1 h. Absorbance was measured at 640 nm using Secomam UV-Vis spectrophotometer against a blank sample containing only ethanol. A calibration curve was prepared using several concentrations of gallic acid standard (0, 80, 100, 120, 140, 160, and 180 ppm gallic acid solutions). Results were expressed as gallic acid equivalent (GAE) per 100 g of fruit flesh.

### Electrolyte Leakage

The procedure was modified from the method of Suwapanich and Haesungchareon (2007). Ten (10) grams of disc-shaped flesh was obtained for each fruit and rinsed twice with deionized water and blotted dry. The fruit flesh was placed in an E-flask containing 20 mL of deionized water and agitated using a mechanical shaker for 1 h. Electrical conductivity of the resulting mixture was measured using the Horiba Laquatwin portable conductivity meter. Samples were then placed in a boiling water bath (Thelco model 83) for 20 min. Conductivity was again measured after the mixture cooled down to room temperature. Electrolyte leakage was calculated using the equation

$$EL(\%)=\varsigma_o/\varsigma_t \times 100$$

where EL = electrolyte leakage expressed in percent, $\varsigma_o$ = electrical conductivity of extract before heating, and $\varsigma_t$ = electrical conductivity of extract after heating.

### Antioxidant Activity Assay

The free radical scavenging activity of each sample was measured using the modified procedure described by

Khamsah et al. (2006). One (1) mL of fruit ethanolic extract was mixed with 0.1 mM ethanolic 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution. After letting it stand for 30 min in the dark at room temperature, absorbance of the mixture was measured at 517 nm against an ethanol blank using Secomam UV-Vis spectrophotometer. Antioxidant activity of the extract was calculated using the equation

$$AA(\%)= (A_{ctrl}-A_{smpl})/A_{ctrl} \times 100$$

where AA = antioxidant activity in percent, $A_{ctrl}$ = Absorbance of control, and $A_{smpl}$ = Absorbance of sample.

### Statistical Analysis

The experiment was laid out in Completely Randomized Design (CRD) with four treatments and data was subjected to ANOVA at $\alpha$ = 0.05. Tukey's Honest Significant Difference (HSD) was performed to determine difference among treatments.

## RESULTS AND DISCUSSION

### Respiration Rate

Red-fleshed dragon fruit, a non-climacteric fruit (Novita 2008)), has a low rate of respiration of 75–100 mg $CO_2$ $kg^{-1}$ $h^{-1}$ at 23 °C (Le et al. 2000) when harvested at full maturity. Storage at 8 °C reduced respiration rate from 68 to 18–28 mg $CO_2$ $kg^{-1}$ $h^{-1}$ in all treatments during the first 2 wk (Fig. 1). The decline in respiration rate at 8 °C was due to the inactivation of enzymes at this temperature which slowed down the utilization of substrates thus preserving fruit quality (Silva 2008).

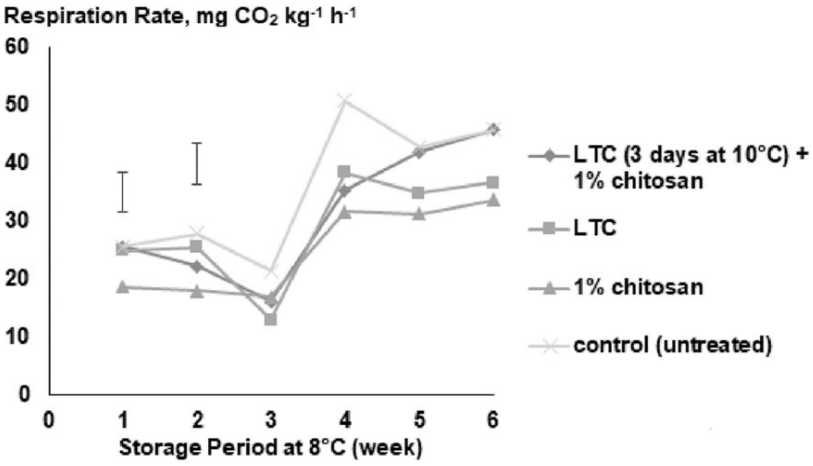


**Fig. 1**. Respiration rate of red-fleshed dragon fruits during storage at 8 ° C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C for 6 wk. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bars indicate HSD values.

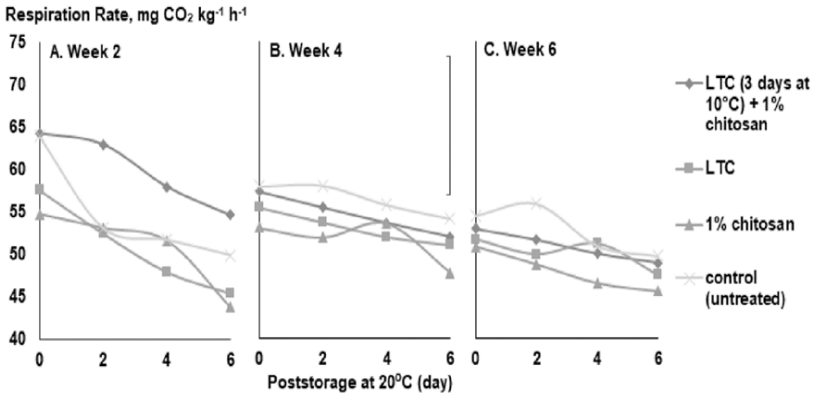


**Fig. 2**. Respiration rate of red-fleshed dragon fruits during post storage at 20 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C and withdrawn every 2 wk for 6 wk. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bar indicates HSD value.

A dramatic increase in respiration rate on the fourth week was observed in all treatments followed by a slight decline except for LTC with 1% chitosan coating, which exhibited a continuous increase until the sixth week. Throughout storage, 1% chitosan coating exhibited the lowest rate of respiration, indicating the direct effects of chitosan coating in regulating gas diffusion wherein internal $O_2$ levels decreased while that of internal $CO_2$ increased, thus retarding the rate of respiration (El Ghaouth et al. 1992).

Immediately after transfer to 20 °C, respiration rate increased to 55–64, 53–58 and 51–54 mg $CO_2$ $kg^{-1}$ $h^{-1}$ for fruits withdrawn at the second, fourth and sixth week, respectively (Fig. 2). The increase in respiration rate was a result of the resumed activity of enzymes at 20 °C. This increase in respiration was temporary as substrates became depleted, so the rate of respiration also slowed down. Chitosan (1%) coating was effective in keeping the respiration rate at minimum even at post storage (20 °C) due to its ability to modify internal gas concentration in the fruit (El Ghaouth et al. 1992). Compared to that of the second week, the decline in respiration rate was slower in fruits

withdrawn on the fourth and sixth weeks, which could be attributed to the onset of CI during prolonged storage at 8°C that led to its gradual deterioration at 20°C.

### Ethylene Production

Production of ethylene was at minimum for the first 2 wk of storage. However, a dramatic increase in the rate of ethylene production was observed on the fourth week followed by a sharp decline on the fifth until the sixth week (Fig. 3). The increase in the rate of ethylene production could be an early symptom of chilling injury in fruits during prolonged storage at 8°C although physical manifestations of the injury had not yet appeared.

Chilling temperatures induce the synthesis of the immediate ethylene precursor, ACC, which leads to its enhanced production (Gonzalez-Aguilar et al. 2000). Chilling injury results in the degradation of cell membranes, leading to leakage of cell contents (Leshem et al. 1986), which become exposed to enzymes, thus metabolic activities such as respiration proceeds faster. Throughout storage, fruit coated with 1% chitosan and then subjected to LTC exhibited the lowest ethylene production. On the other hand, fruit acclimatization through LTC may have reduced the inherent effects of temperature changes by augmenting S-adenosylmethionine (SAM) decarboxylase activities which reduce the availability of SAM for production of ethylene (Wang 1995).

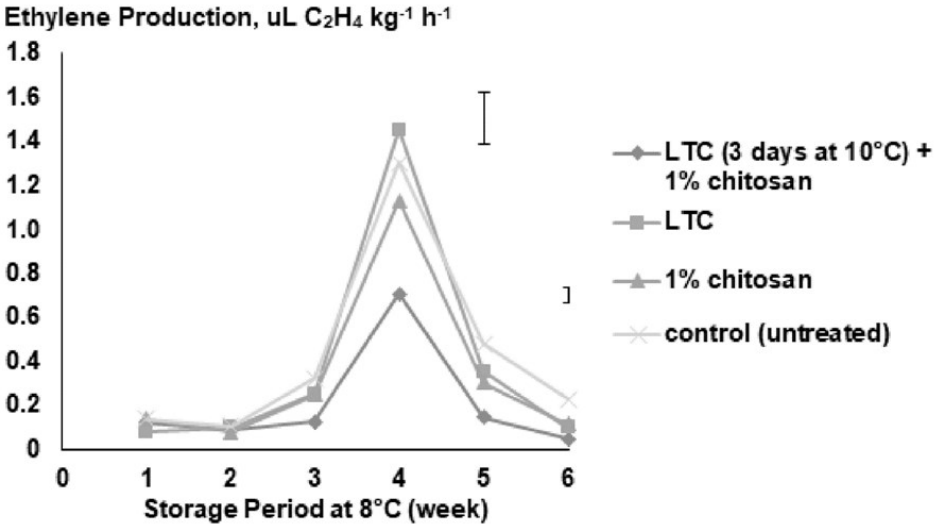


**Fig. 3**. Ethylene production of red-fleshed dragon fruits during storage at 8 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C for 6 wk. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bars indicate HSD values.

Immediate transfer to 20 °C led to an increase in ethylene production (0.46–0.73, 0.37–0.53 and 0.28–0.35 μL $kg^{-1}$ $h^{-1}$) of the fruits withdrawn on the second, fourth and sixth week, respectively (Fig. 4). The increase in ethylene production is a general response of the fruit to increase in temperature.

Post storage ethylene production of fruit, regardless of the duration of storage, generally declined until the sixth day with the lowest rate of ethylene production observed for the sixth-week withdrawn fruit. Control fruit, regardless of

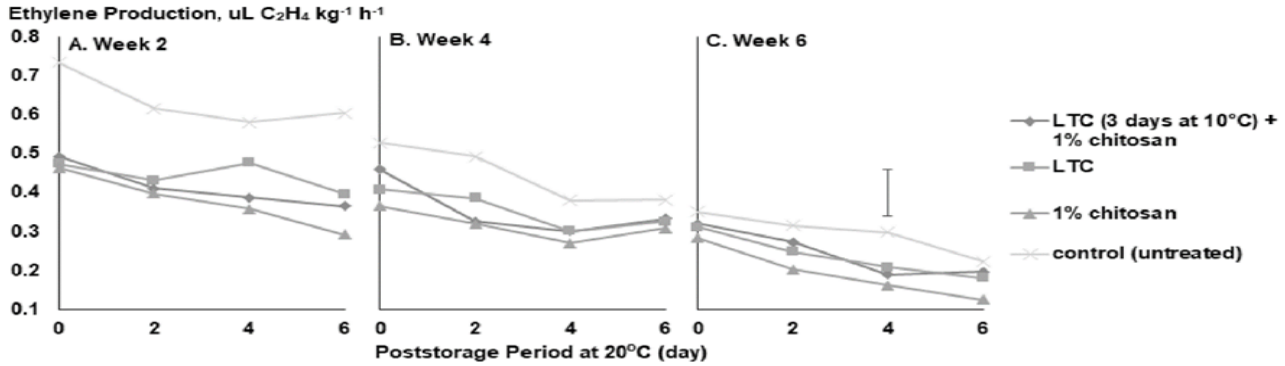


**Fig. 4**. Ethylene production of red-fleshed dragon fruits during post storage at 20 °C. Dragon fruits were coated with 1% chitosan or, subjected to LTC at 10 °C for 3 d and combination of the two then stored at 8 °C and withdrawn every 2 wk for 6 wk. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bar indicates HSD value.

the duration of storage, exhibited the highest production of ethylene for 6 d. The progression of fruit deterioration at 20 °C resulted in the decline of ethylene production. Fruit deterioration was the consequence of CI gauged as the increase in respiration and ethylene production on the third week of storage at 8 °C that led to structural degradation. In a similar study, white-fleshed dragon fruit showed first CI symptoms on the third week of storage with shelf life of 5 d at 20°C (De Freitas and Mitcham 2013).

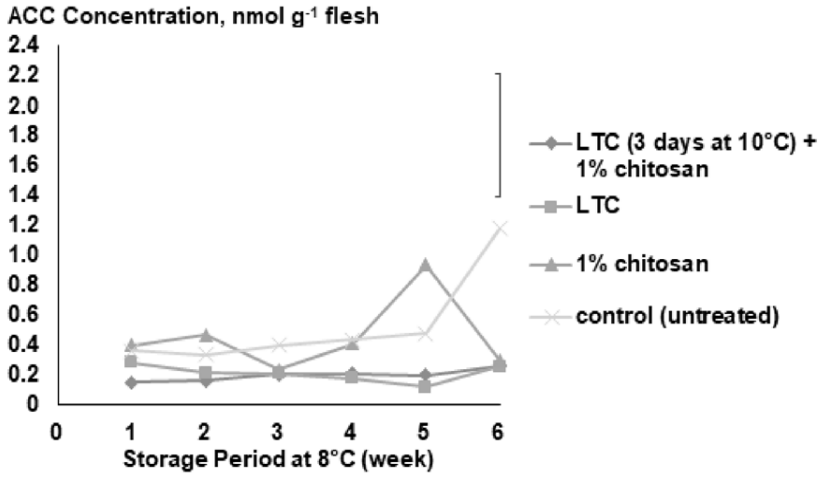


**Fig. 5**. ACC concentration levels of red-fleshed dragon fruits during storage at 8 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C for 6 wk. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bar indicates HSD value.

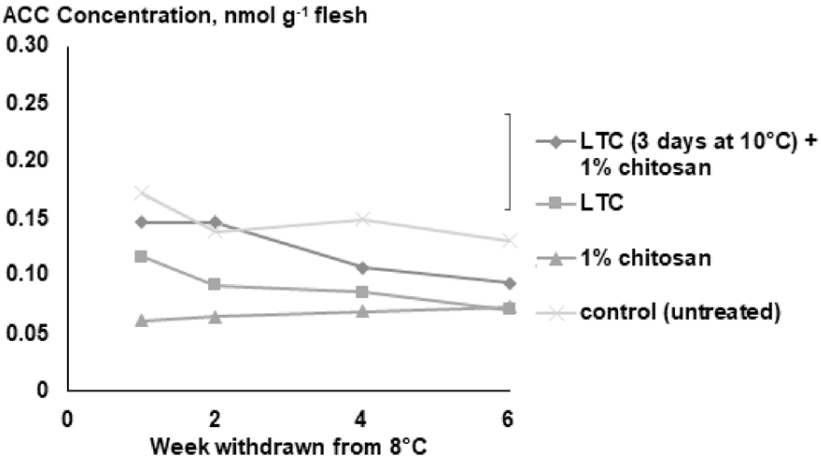


**Fig. 6**. ACC concentration levels of red-fleshed dragon fruits at limit of marketability during post storage at 20 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C and withdrawn every 2 wk for 6 wk and monitored until VQR 5 was reached. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bar indicates HSD value.

## 1-aminocyclopropane-1-carboxylic acid (ACC) Concentration

ACC, the immediate precursor of ethylene, is converted to ethylene through its oxidation by ACC oxidase, which is one of the key regulatory points in the ethylene biosynthetic pathway (Paliyath et al. 2008). Exposure to suboptimal temperatures such as 8 °C can reduce the activity of ACC oxidase, which resulted in accumulation of ACC and decreased the production of ethylene. This reduction in the synthesis of ethylene will delay any ethylene-induced deteriorative changes in the fruit. Dragon fruit, which is a non-climacteric fruit, is expected to have very low levels of ACC.

Physiological disorders such as chilling injury could occur during storage at suboptimal temperatures. However, its manifestation especially in red-fleshed dragon fruits is hard to detect. Since suboptimal temperatures could result in impairment of the ethylene biosynthetic pathway, accumulation of ACC could also be a gauge of the occurrence of chilling injury.

LTC, with or without 1% chitosan coating treatments, both resulted in lower ACC concentration levels throughout the 6-wk storage at 8 °C (Fig. 5). The observed decline in ACC concentration only suggests the inherent effect of LTC in regulating ACC concentration by augmenting the SAM decarboxylase activity (Wang 2013). Fruit coated with 1% chitosan alone exhibited fluctuating concentration of ACC until the fourth week with an abrupt increase on the fifth, followed by immediate decline on the sixth week. The relatively higher ACC concentration in 1% chitosan-coated fruits could be attributed to the reduction of internal oxygen, which is a requirement for the oxidation of ACC to ethylene (Leshem et al. 1986). The control fruits exhibited sustained increase in ACC concentration with an abrupt increase on the sixth week.

ACC levels in all treatments exhibited a slow decline at the limit of

marketability that is dependent on the week the fruit was withdrawn from storage (Fig. 6). Control fruits had the highest ACC concentration while 1% chitosan treated fruits exhibited the lowest at their limit of marketability regardless of the week withdrawn from cold storage. ACC concentration at 20 °C was relatively lower in all treatments than in those stored at 8 °C because of resumed activity of ACC synthase which reduced the concentration of ACC in the flesh.

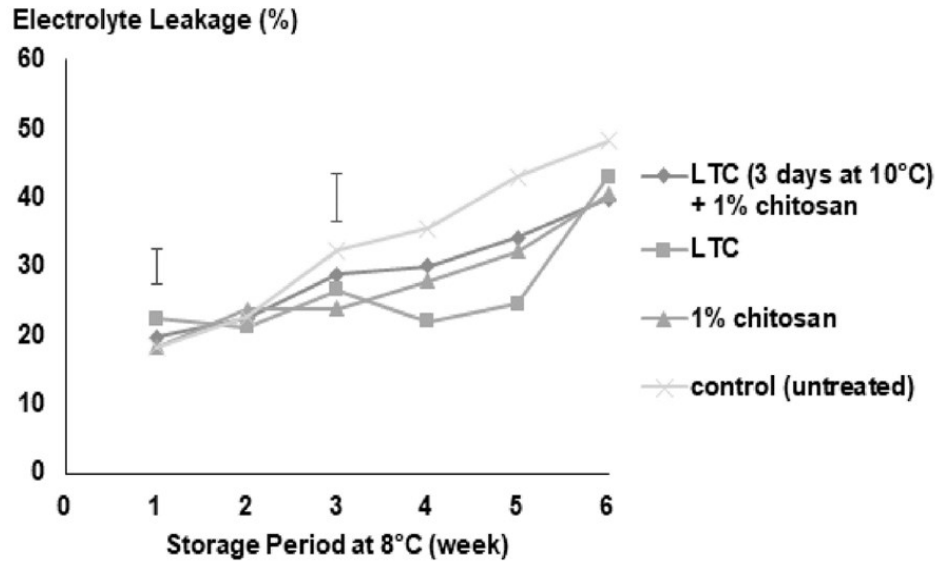


**Fig. 7**. Electrolyte leakage in red-fleshed dragon fruits during storage at 8 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C for 6 wk. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bars indicate HSD values.

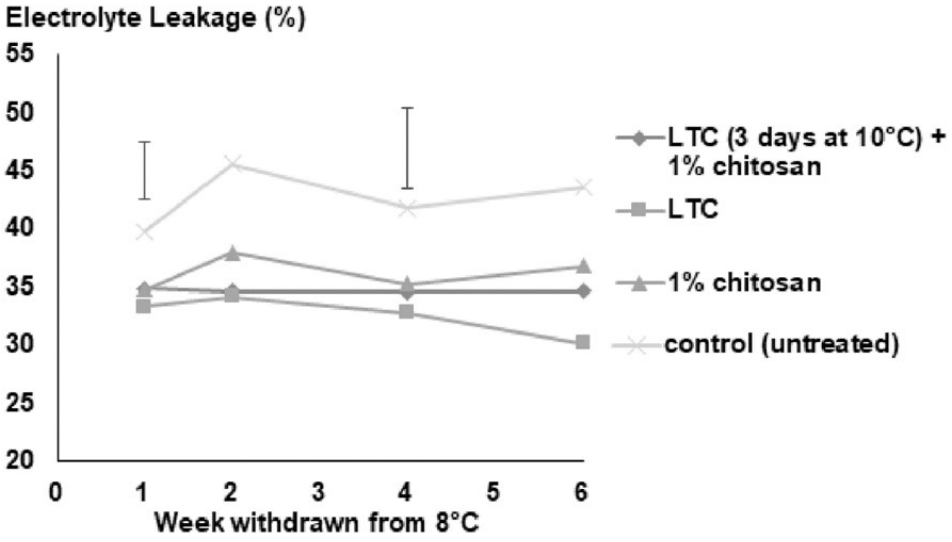


**Fig. 8**. Electrolyte leakage in red-fleshed dragon fruits at limit of marketability during post storage at 20 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C and withdrawn every 2 wk for 6 wk and monitored until VQR 5 was reached. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bars indicate HSD values.

## Electrolyte Leakage

Electrolytes are contained within the cell membrane. However, exposure to suboptimal temperatures result in the membrane's increased permeability and loss of integrity, thus it is a reliable gauge of the early onset of chilling injury (Wilson and Jacobs 2004). Cell contents leak out of the cell which is detected as an increase in conductivity of the fruit leachate.

An increase in electrolyte leakage was observed in all treatments throughout the storage period. The control exhibited the highest electrolyte leakage followed by LTC with 1% chitosan coating, and chitosan treatment alone (Fig. 7). High electrolyte leakage in the control was the result of the onset of chilling injury that led to membrane deterioration thus leakage of cellular contents. These results suggest that LTC and 1% chitosan improved cell membrane integrity, thus preventing the leakage of cell contents.

At fruit's limit of marketability, LTC with or without 1% chitosan coating, and chitosan coating treatment alone had lower electrolyte leakage than the control (Fig. 8). The control exhibited the highest electrolyte leakage while LTC exhibited the lowest

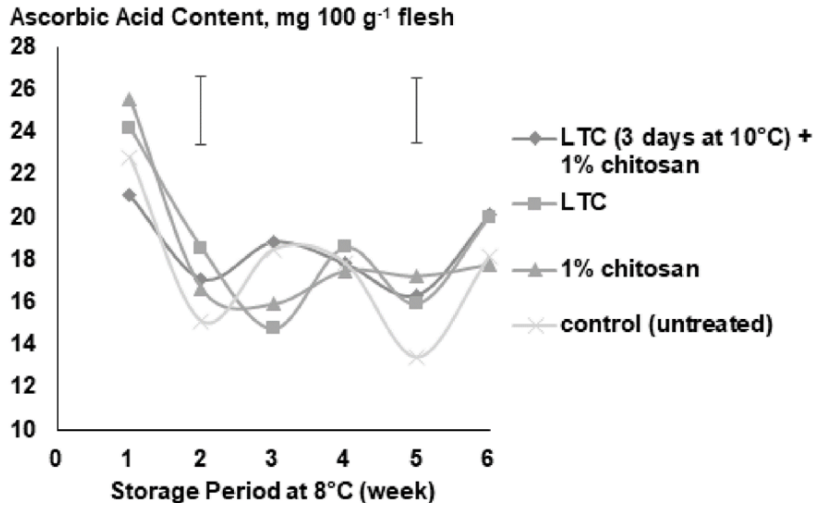


**Fig. 9**. Ascorbic acid content of red-fleshed dragon fruits during storage at 8 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C for 6 wk. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bars indicate HSD values.

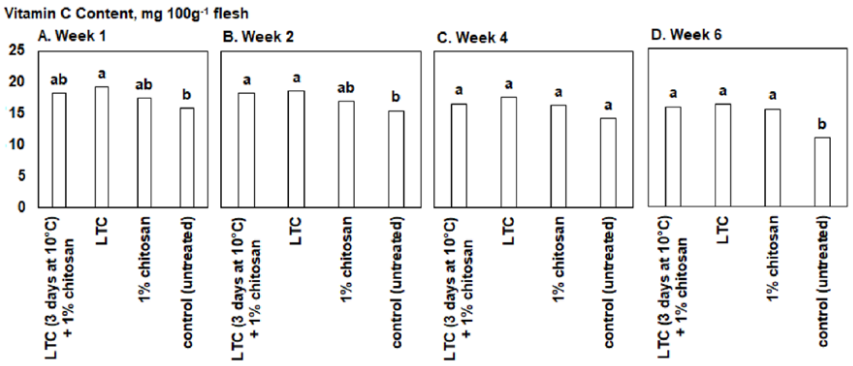


**Fig. 10**. Ascorbic acid content of red-fleshed dragon fruits at limit of marketability during post storage at 20 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C and withdrawn every 2 wk for 6 wk and monitored until VQR 5 was reached. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Treatments with common letter labels are not significantly different.

regardless of the duration of cold storage. This implies that LTC + 1% chitosan coating combination treatment, and LTC and 1% chitosan single treatments were both effective in delaying cell membrane degradation that could lead to enhanced leakage of cellular substrate as observed in the control.

## Ascorbic Acid Content

There was no significant difference in ascorbic acid content (AAC) among treatments during the six-week storage (Fig. 9). It could be implied that LTC + 1% chitosan coating and single treatment of LTC and chitosan single treatments had no effect in delaying the decline of ascorbic acid levels in fruits during storage at 8 ° C.

The decline in ascorbic acid content was minimal in all treatments except for the control at the limit of marketability regardless of the week of withdrawal from storage (Fig. 10). AAC of the control withdrawn on the first week dropped from 16 to 11 mg per 100 g flesh when withdrawn from storage on the sixth week. This shows that combination treatment of LTC + 1% chitosan and single treatments of LTC and 1% chitosan were effective in delaying the decline of AAC at 20 °C.

## Total Phenolic Content

Polyphenolic compounds are plant secondary metabolites naturally present in fruits which are known to have antioxidant activity. Polyphenols neutralize the free radicals, quench singlet oxygen and decompose peroxides (Pandey and Rizvi 2009). Total phenolic content of red-fleshed dragon fruit obtained in this experiment ranged from 0.3 to 0.7 mg GAE $g^{-1}$ flesh weight, which was almost similar with the reported range of 0.18–0.86 mg GAE $g^{-1}$ flesh weight (Mahattanatawee et al. 2006). Gallic acid is a well-known natural oxidant that is widely occurring in plants (Aruoma et al. 1993) and constitutes the main phenolic compound in dragon fruit (Esquivel et al. 2007).

An abrupt increase in total phenolic content in all treatments was observed during the first 2 wk of storage (Fig. 11). From then on, the phenolic content remained fairly constant in all treatments and did not vary significantly among treatments.

There was a decline in total phenolic content of fruits at limit of marketability during post storage (20 °C). The decline was gradual in all treatments except for the

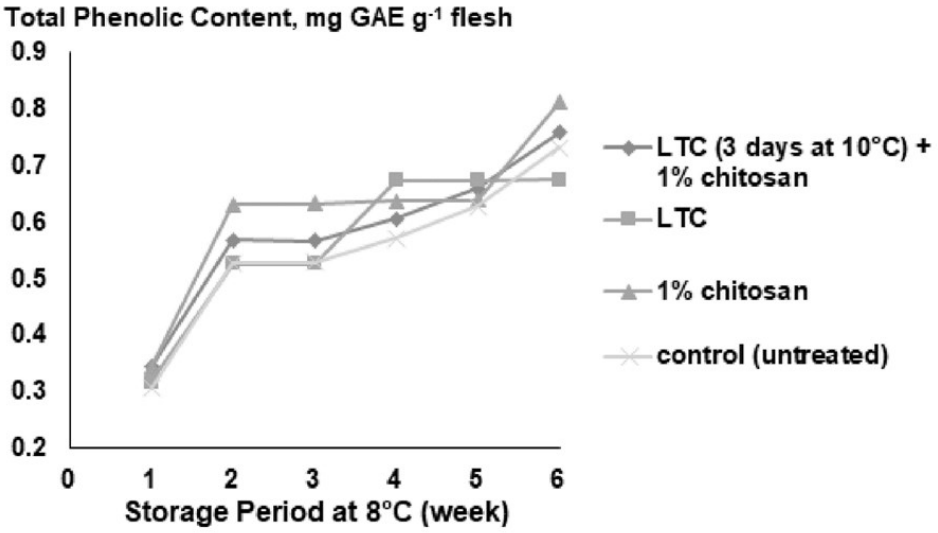


**Fig. 11**. Changes in total phenolic content of red-fleshed dragon fruit during 6-week storage at 8 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C for 6 wk. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate.

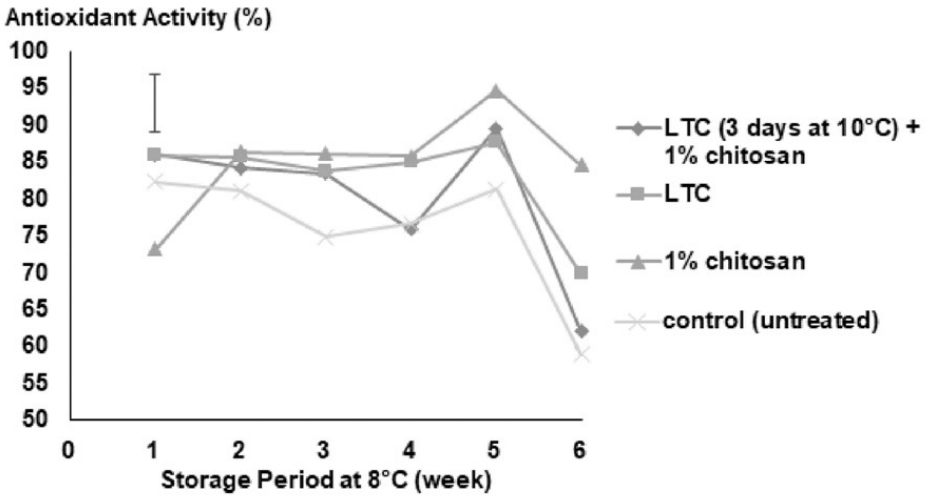


**Fig. 12**. Changes in antioxidant activity of red-fleshed dragon fruits during storage at 8 °C. Dragon fruits were coated with 1% chitosan, subjected to low temperature conditioning at 10 °C for 3 d and combination of the two then stored at 8 °C for 6 wk. Each point represents the mean of 3 replicates consisting of 1 fruit per replicate. Vertical bar indicates HSD value.

control which exhibited the fastest regardless of the week of withdrawal from cold storage. The decline in total phenolic content resulted from the utilization of some phenolic compounds hastened by breakdown of cell structure because of chilling injury during storage at 8 °C (Macheix et al. 1990). Phenolic compounds are involved in stress response in many horticultural crops by acting as antioxidants to protect cellular structures from free radical attack that leads to cell deterioration (Artes-Hernandez et al. 2007).

### Antioxidant Activity

A tropical fruit like dragon fruit undergoes stress when exposed to suboptimal temperatures, in this case 8 ° C. Stress can induce the generation of reactive oxygen species (ROS), such as singlet oxygen, hydroxyl and peroxy radicals and superoxide anion, which result in cellular deterioration including lipid deterioration, enzyme inactivation, and mutation (Halliwell 2006). Plant cells are protected from ROS by an antioxidant system that works as scavenger.

There was an abrupt increase in the antioxidant activity of 1% chitosan-coated fruit for the first two weeks of storage at 8 °C where it maintained its activity until the fourth week (Fig. 12). LTC-treated fruits exhibited a gradual decline in antioxidant activity until the third week and then a gradual increase until the fifth week followed by a sudden decline on the sixth week. Fruits coated with 1% chitosan and subjected to LTC exhibited a gradual decline until the fourth week and then an abrupt rise on the fifth followed by a dramatic decline on the sixth week. The continued decline in antioxidant activity, especially at week 6, was due to the breakdown of cell structure because of chilling injury during storage (Ghasemnezhad et al. 2010). Fruits subjected to LTC and 1% chitosan had the highest antioxidant activity while the control had the lowest throughout the storage period. The effectivity of LTC was corroborated by the report of Wang (2013) that low temperature acclimatization of zucchini squash enhanced its antioxidant content and antioxidant enzyme activities. On the other hand, Ali et al. (2013) reported a retention of antioxidant activities of 1%

chitosan-coated white-fleshed dragon fruits by acting as free radical scavengers to protect cellular membrane degradation that could hasten fruit deterioration.

## SUMMARY AND CONCLUSION

Early onset of chilling injury was pronounced in control fruit as manifested by its higher respiration rate, ethylene production and electrolyte leakage during storage at 8 °C. Chitosan (1%) coating single treatment was more effective than LTC (3 d at 10 °C) with or without 1% chitosan in alleviating CI as exhibited by lower respiration rate and ethylene production during storage (8 °C) and post storage (20 °C). On the other hand, electrolyte leakage was lower in chitosan and LTC single and combination treatments, which suggest their effectivity in alleviating chilling injury as well. Although treatments had no effect on the total phenolic content, 1% chitosan-coated fruits showed enhanced antioxidant activity.

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