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Effect of Modified Atmosphere Packaging to Post-Storage Quality of White Flesh Dragon Fruit (*Hylocereus undatus* (Haw.) Britton & Rose)

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ABSTRACT

Dragon fruits (Hylocereus undatus (Haw.) Britton & Rose) under selected suitable Modified Atmosphere Packaging (MAP) with 50.8μm polyethylene plastic film) and control samples (dragon fruits without MAP) were exposed to ambient condition after being stored for 5, 10, 15, 20, 25, and 30 days at 5°C and 10°C temperature, respectively. To validate if the selected MAP has significant effect in reducing the quality degradation rate of the dragon fruits during post-storage condition, different physico-chemical properties were measured. Data obtained for control samples were only from 5 and 10 days since samples were already considered inedible (with at least 80% peel decay) for days 15, 20, 25, and 30. On the other hand, data for days 5, 10, 15 and 20 were obtained for MAP samples. Highest firmness degradation of 6% was observed for control samples stored at 10°C when compared to day 0. In terms of moisture content (MC), MAP samples obtained the lowest degradation rates (comparing day 5 and day 10 samples) with at most 1.36% decrease in flesh MC and 1.7% decrease in moisture content peel MC. Change in the scale color (from green to yellow) of MAP samples was not drastic and very minimal as compared to controlled samples that have 21-24 difference from the hue value of day 0 sample. On the other hand, titratable acidity and total soluble solid of MAP samples were still acceptable with no significant changes all throughout the storage and post-storage period.

Keywords: *post-storage modified, packaging, dragon fruit, respiration, post-storage, temperature, transmission, polyethylene, optical, moisture, acidity, firmness*

INTRODUCTION

Dragon fruit is a non-climacteric fruit that is usually harvested at 27 to 33 days after flowering (DAF). It is identified as a money crop by the Department of Agriculture-Bureau of Agricultural Research (DA-BAR) due to its high selling price locally and abroad. Its first production/cultivation in the Philippines started in the early 90's which expanded and increased due to the implementation of several strategies and technology (Pascua et al., 2015). According to the Philippine Statistics Authority (2018), as mentioned by Eusebio and Alaban (2018), the total area planted with dragon fruits in the Philippines increased from 182 ha (2012) to 450 ha (2017) which resulted in an increase in yield from 1.41 MT to 3.25 MT. However, along with the increasing production, problems, such as postharvest and transportation losses as well as negative effects on the fruits' shelf life due to unavailability of facilities, were encountered by the producers and retailers.

In the Philippines, dragon fruits are usually delivered to retailers, trading posts, and supermarkets (Tepora, 2019) and are displayed in a fruit stand in bulk under ambient conditions. Fruits that are not sold were normally stored under ambient condition or refrigeration unit and displayed again to be sold the next day. According to Del Carmen et al. (2020), consumers preferred sweet-tasting dragon fruits that are fresh looking with green color bracts/scale and shiny peel. Problems in maintaining these characteristics for a longer period arises as the fruit easily deteriorates during storage under cold and ambient temperature. In a study by Pascual et al. (2017), a change in the appearance of the white flesh dragon fruits such as shriveling of the scales, were observed after 15 days of being stored under 5°C and 10°C. This change is an indication that the fruit is undergoing chilling injury as stated by Nerd et al. (1999). Additionally, Ortiz-Hernandez and Carrillo-Salazar (2012) noticed that dragon fruits are prone to chilling injury and weight loss when being stored under low temperature from 5°C to 10°C, which is the optimum range of storage temperature for the fruit as mentioned by Le et al. (2000). Another study by Jadhav (2018) stated that dragon fruits stored in ordinary conditions had 100% decay incidence and severity after 3.5 days. These potentially lowers the profit of the fruit retailers and sellers and contributes to the postharvest losses which is 35% (about PhP 35.52 billion) of the total fruits and vegetables being harvested in the Philippines per year (Nagpala, 2008).

With these challenges in dragon fruits, supplementary postharvest processing during storage is needed. According to several studies, one of the effective ways to reduce some of the negative effects of cold storage (chilling injury and weight loss) in fruits and vegetables is the application of modified atmosphere packaging (MAP). With this, the study focused on determining whether the application of identified suitable MAP for white flesh dragon fruits can alleviate the rate of degradation of post-storage quality of the fruits.

MATERIALS AND METHODS

This research is a continuation of Pascual et al. (2017) study and determines the effect of MAP to white flesh dragon fruits when exposed under post-storage or ambient condition after cold storage. The procedures used in the determination of the appropriate polyethylene plastic film and physico-chemical properties of the dragon fruits were based on the said study.

Sample Material Preparation

Dragon fruits were obtained and harvested in a farm in Indang, Cavite forty (40) DAF. Samples used were free from visible defects such as discoloration, rots, and decays and were washed with water and dried before the experiment.

Polyethylene Plastic Film Selection

Respiration rate (RR) of the dragon fruit at 5°C and 10°C was determined using static method and was used to compute the required oxygen transmission rate (TrO_2) using the equation below. The computed TrO_2 was compared to the published data in Malilay et al. (2011) to identify the suitable plastic film thickness for modified atmosphere packaging.

$$RR_{o2}W_f = Tr_{O2}A\frac{[O_2]_e - [O_2]_f}{100}$$

where:

W_f = fill weight (kg); Tr_{02} = gas transmission rates (mL/m^2-h); $[O_2]_e$= ambient gas levels (%); $[O_2]_f$= desired gas levels (%) in the package headspace; A = package area (m^2)

Post-storage Physico-Chemical Properties Determination

The samples of approximately 0.4kg to 0.5kg were placed and sealed (using electric sealer) individually into a 7in x 10in low-density polyethylene (LDPE) plastic bags (MAP samples) with 50.8 µm and stored at 5 °C and 10 °C along with the controlled samples.

The fruits were transferred from cold storage to post-storage condition (at ambient temperature of 30°C to 32 °C) for five (5) days. Fruits under MAP were removed from the packaging film. Post-storage physico-chemical properties such as flesh and peel moisture content, firmness, peel and scale color, titratable acidity, and total soluble solid were determined. These were done every 5 days for 30 days.

Moisture Content (MC)

The flesh and peel MC were determined separately. Samples of approximately 2.5g were sliced into small cubes, weighed, and placed in a moisture can with predetermined weight. Following the procedure of Nerd et al. (1999), samples were oven dried at 70 °C for 72 hours. Final weight of the samples was measured, and values of MC were computed.

Firmness

Firmness was determined using a universal testing machine (UTM). Samples were cut axially into two equal halves and the cut surface was made the side in contact with the supporting plate of UTM. The samples were compressed slowly with an 8 mm cylinder probe to a deformation of 10 mm (ASAE Standards, 1998) at a loading rate of 15 mm/min. The firmness was computed as the slope of the force-deformation curve from zero to the bioyield point.

Peel and Scale Optical Properties

Optical properties of the samples' peel and scale which include L* (lightness or luminance component) and two chromatic components a* (from green to red) and b* (from blue to yellow) were measured using a color meter. The color meter was first calibrated using the white standard tile before measuring the optical properties of the sample. The sample measurements were done at five (5) random locations on the samples and the values of L* a* b* were converted to H (hue), S (saturation), and B (brightness) values using the following equations (FAO, 2012):

$$H = tan^{-1}\left(\frac{b^*}{a^*}\right) \quad S = \sqrt{(a^*)^2 + (b^*)^2} \quad ; B = L^*$$

Titratable Acidity (TA) and Total Soluble Solid (TSS)

Distilled water (60mL) was added to 20g of fruit samples (cut into cubed) and the mixture was homogenized using a blender. The homogenized fruit juice was filtered using cotton and the filtrate was used to measure TA through manual titration using 0.1N NaOH and TSS through digital refractometer.

Statistical Analysis

STATA Software (Version 15 licensed to UPLB Institute of Statistics) was used for statistical analysis (F-test ANOVA and pairwise comparison using Bonferroni test) of the data obtained.

RESULTS AND DISCUSSION

Suitable Packaging Film

Table 1 shows the computed required TrO_2 for dragon fruits stored at 5°C and 10°C. Results showed that 50.8µm polyethylene film is the most appropriate packaging for dragon fruits stored at 5°C and 10°C as this has the nearest higher value of TrO_2 (to avoid occurrence of anaerobic respiration).

Physico-Chemical Properties

MAP and controlled samples after being exposed at post-storage condition were shown in **Figures 1** and **2.** Deterioration in scale appearance was evident for control samples at day 5. MAP and control samples were comparable up to ten (10) days. Control samples exhibited about 10% to 20% peel decays on day 5 and were completely spoiled on day 15. MAP samples, on the other hand, only started to show peel decays (above 80%) on day 25 and 30 samples. This delay in deterioration in terms of presence of decay was also observed in plums (Smith et al., 2006), green bell peppers (Singh et al., 2014), and figs (Bouzo et al., 2012). According to Zheng et al. (2005), changes in physiological and biochemical properties increases the fruits' susceptibility to pathogen infection and reduces its resistance to diseases. The use of MAP delays these changes; thereby, also delaying the onset of decays.

Table 1. Required oxygen transmission rate at 5°C and 10°C

Temp (°C)	O_2 (%)	CO_2 (%)	Time (h)	RRO_2 (ml/kg-h)	W_f (kg)	TrO_2 of 50.8 µm PE film* (mL/m^2 – day)	TrO_2 Required (mL/m^2– day)
5	3.0	7.5	234.1	1.08	0.450	1907	1432
10	3.0	9.9	132.5	1.38	0.450	2226	1838

Source: *Malilay et al. (2011)*

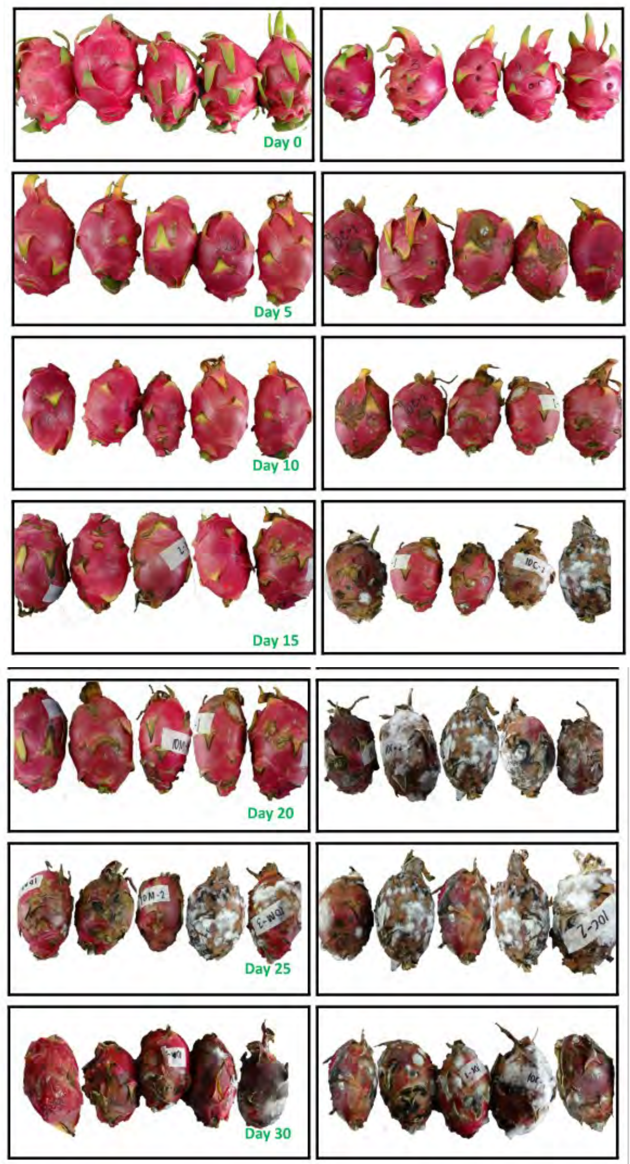


Figure 1. MAP (left) and control (right) samples stored at 10 °C after 5 days in post-storage condition

Moisture Content (MC)

Decrease in MC or water content results in a decrease in the weight of the fruits or vegetables. **Figure 3** illustrates the behavior of peel and flesh MC of dragon fruits at post-storage condition. F-test ANOVA determined that MAP has significant ($p<0.05$) effect on flesh MC and change in flesh MC. On the other hand, both MAP and storage temperature significantly ($p<0.05$) affect the peel MC and change in peel MC. MAP samples were observed to have higher peel and flesh MC compared to control samples as evident in day 20 MAP samples which have higher flesh and peel MC when compared to day 10 control samples. Peel and flesh MC of control samples started to decrease significantly ($p<0.05$) on day 5 samples. MAP samples flesh started to significantly ($p<0.05$) change on day 15 samples. All the MAP samples' peel MC did not show any significant difference ($p>0.05$) with day 0. These results showed that MAP was able to delay the decrease in MC of dragon fruits during post-storage condition.

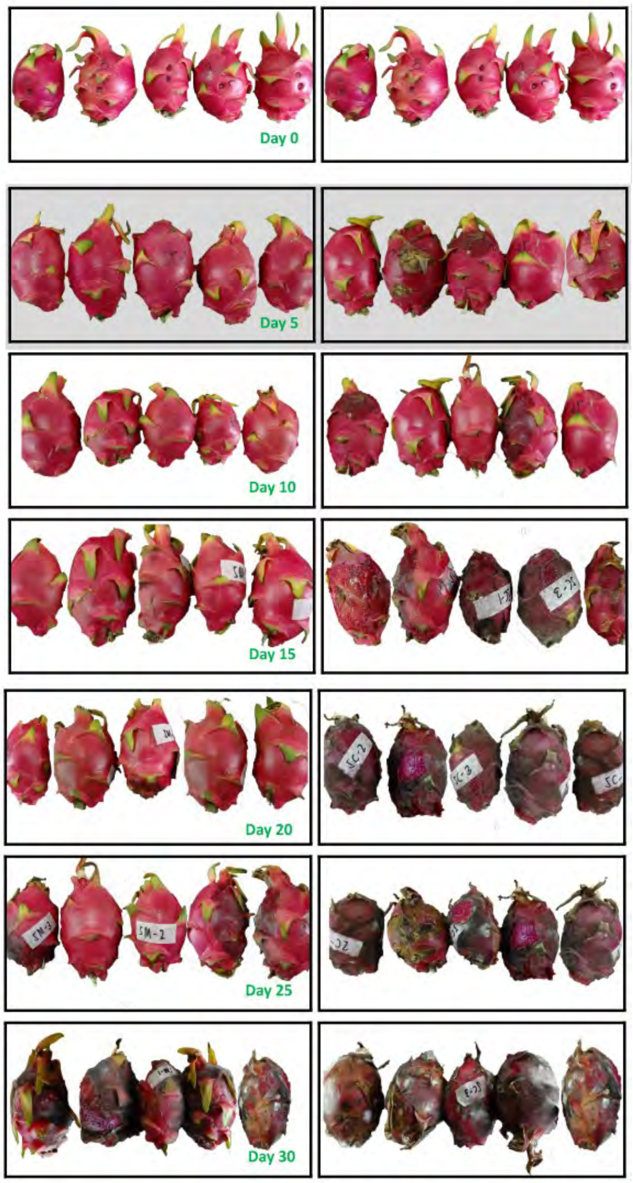


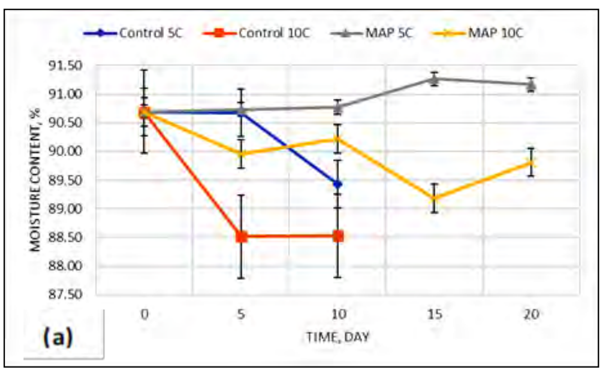
Figure 2. MAP (left) and control (right) samples stored at 5°C after 5 days in post–storage condition

Frans et al. (2021) mentioned that fruits and vegetables under MAP suffered less shriveling due to high relative humidity (RH) inside the packaging film therefore reducing or maintaining the MC of the produce. Moreover, Maguire et al. (2000) explained that high RH will result in decrease in the vapor pressure differences between the produce and the atmosphere within the packaging; thus, enhancing the resistance of the produce to water loss during storage.

Firmness

Firmness is one of the properties that determines whether fruits or vegetables are still acceptable for consumers. **Figure 4** shows the firmness of the samples stored at 5°C and 10°C. Results suggest that firmness of control samples under 10°C degrade faster (decreased by up to 6% after 10 days in storage and 5 days at ambient condition) than 5°C control and 10°C and 5°C MAP samples. According to Dziedzic et al. (2020), reduction in firmness can be due to the increase in the weight loss during storage. Samples that lose moisture content faster will also experience faster firmness loss (Chitravathi et al., 2015). This means that since 10°C control samples have the lowest peel MC then it will have the fastest rate of firmness degradation. Further investigation on this matter through conducting a pairwise comparison through Bonferroni test suggested, though it may seem otherwise, that the mean firmness of control samples (day 5 and day 10) for both temperatures did not decrease significantly when compared with day 0 sample.

Firmness of MAP samples did not change significantly (p>0.05) for day 5, 10, and 15 samples when compared to day 0. These results imply that MAP samples were still acceptable in terms of firmness until 15 days in storage and 5 days in ambient condition. On the other hand, day 20 MAP samples decreased significantly (p<0.05) by at most 20% but as discussed previously, its peel MC did not change significantly. This occurred because during this period, wherein the fruits were removed from the packaging and exposed to atmospheric condition, the generation rate of radicals during respiration increases causing the decrease in firmness of the fruits (Nohl, 1994). The cell wall organization loosens making the wall pectins accessible to pectinases. In addition, firmness also decreases, as commodity maturity progresses, since cell wall components such as pectin substances, hemicellulose and cellulose are broken down (Wang et al., 2015) and there is also a decrease in turgor pressure in the cell (Mannozzi et al., 2018).



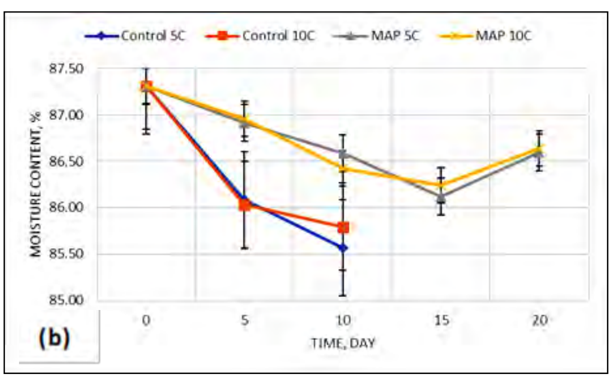


Figure 3. Peel MC (a) and flesh MC (b) after 5 days in post-storage condition

Optical Properties

One of the first characteristics that affect consumers' preference in fresh produce is color. For this reason, it is crucial that that color should have minimal change during storage. **Figure 5** illustrates the behavior of dragon fruits' peel and scale optical properties during post-storage condition. Peel hue values for day 5 and 10 for both control and MAP samples were observed to have no remarkable changes when compared to initial peel hue. Slight increase by 2-4 degrees in the peel hue were observed for days 15 to 20 for both MAP samples. This means that the actual peel color is changing from red to reddish orange. Scale hue for day 5 and 10 samples decreased faster (21% - 24%) for control samples compared to (15% - 18%) MAP samples. This means that the scale of control samples turned into yellow is faster than MAP samples. Peel saturation for all the samples ranges from 32 to 37 with decreasing and increasing trend throughout the experiment period. Scale saturation, on the other hand, was observed to have an increasing (earlier period of experiment) then decreasing (end of post-storage period) trend for control and MAP samples. In terms of brightness, peel values for control samples started to decrease at day 10, while MAP samples did not have any remarkable changes.

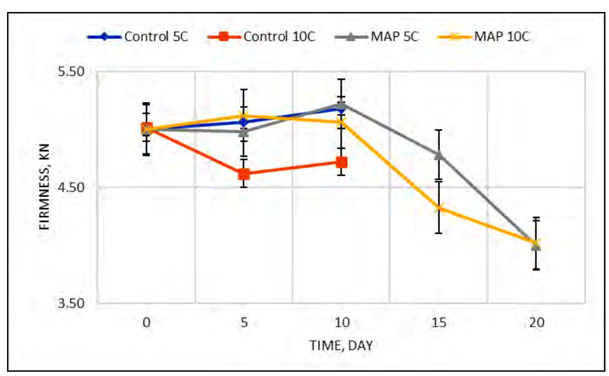


Figure 4. Firmness (kN) of dragon fruits after 5 days in post-storage condition

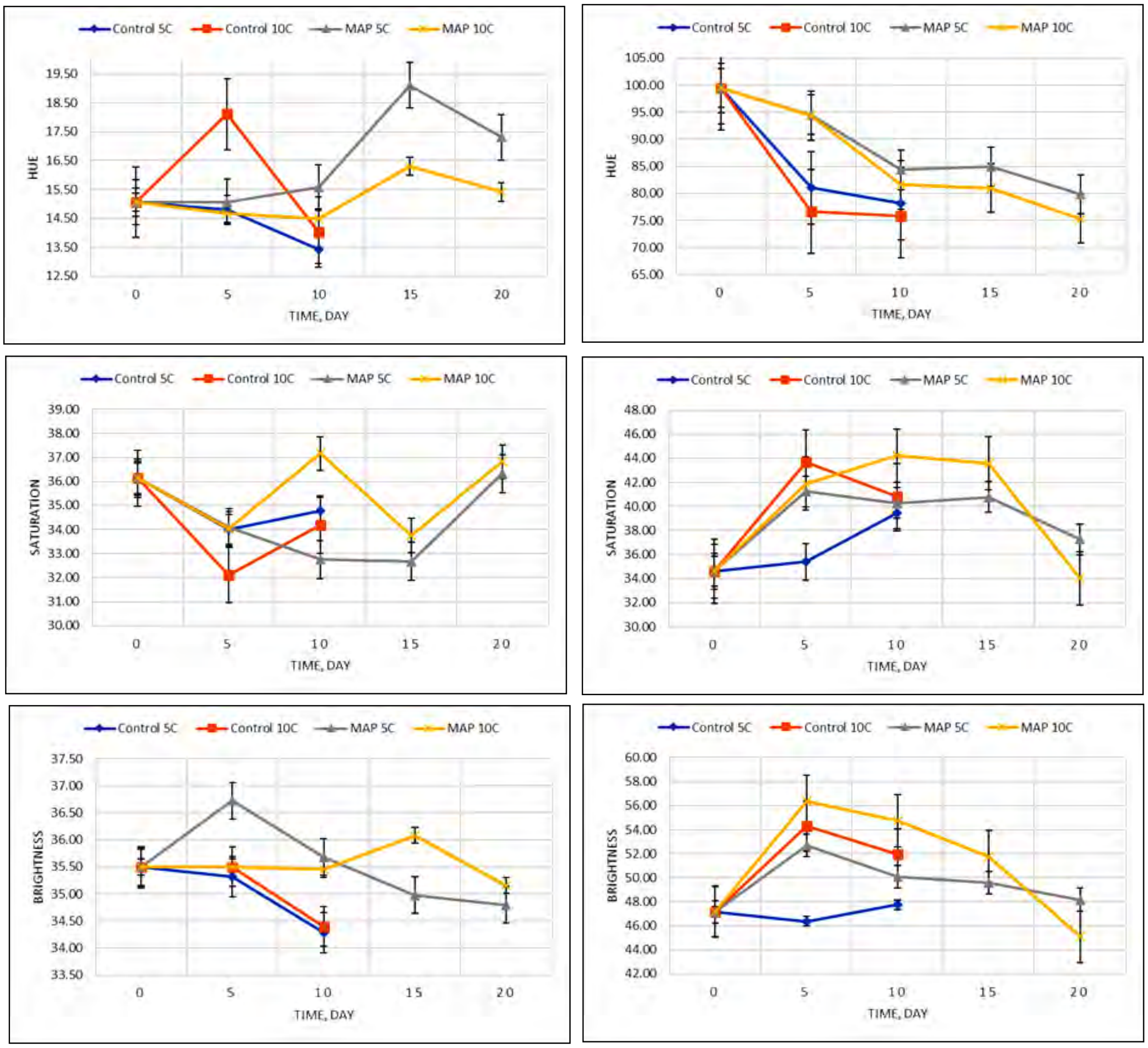


Figure 5. Optical properties (HSB) of peel (left) and scale (right) of dragon fruits after 5 days on post– storage condition

F-test ANOVA resulted in a significant ($p<0.05$) effect of the interaction between MAP and storage temperature to peel hue and peel saturation. It also showed that both temperature and MAP had significant ($p<0.05$) effect with the scale hue, saturation, and brightness. Through pairwise comparison (Bonferroni test), mean peel hue value of control samples for day 15 was found to have significant ($p<0.05$) difference with day 0 while all the values of MAP samples did not change significantly ($p>0.05$). Scale hue values for control samples (days 5 and 10) have significant ($p<0.05$) difference with fresh value while MAP sample started to change significantly ($p<0.05$) on day 10. This means that the rate of change in peel and scale color of dragon fruits under MAP was delayed during post-storage condition.

Studies of He and Xiao (2018), Paulsen et al. (2019), Torales et al. (2020), Perumal et al. (2021), Frans et al. (2021), and Islam et al. (2022) arrived in the same outcome wherein fruits and vegetables that were under MAP were able to preserve or maintain its color and appearance. MAP lowers the oxygen of the commodity's surroundings, causing the metabolic activity to slow down, leading to rate reduction of respiration, chlorophyll degradation, and peel browning (Kader, 1986; Sandhya, 2010) which occur during ripening and senescence.

Titratable Acidity (TA)

According to Islam et al. (2022), titratable acidity (TA) is one of the most significant properties that affect the eating quality of the fresh produce, and this tends to decrease as the storage period increases (Abd El-Gawad et al., 2019). **Figure 6** shows the data obtained for TA. Results showed that the TA decreased for both control and MAP samples all throughout the experiment period.

F-test ANOVA showed that MAP and storage temperature had significant ($p<0.05$) effects to TA of white flesh dragon fruits. Results also suggest that control samples at 10°C decreased faster (53%) as compared to control at 5°C (18%) and MAP for both temperatures (12%-29%). Pairwise comparison through the Bonferroni test showed that mean TA of day 5-10 control samples were significantly ($p<0.05$) different when compared to day 0. On the other hand, TA of MAP samples did not change significantly ($p>0.05$) across days. Changes in TA of control (day 5 and day 10) and MAP (day 5 to day 20) did not show any significant ($p>0.05$) difference with day 0. Having these results, MAP can be an effective treatment to fresh produce to delay the decrease of TA and to maintain an acceptable TA which is comparable to fresh value during post-storage condition. This is because MAP decreases the respiration rate; therefore, slowing down the rate of major organic acid being used as substrate and reducing the rate of decrease in TA (Githiga et al., 2014). Similar trends and results were reported by Techavuthiporn and Boonyaritthongchaib (2016), Islam et al. (2022), and Bi et al. (2022), for some fruits and vegetables.

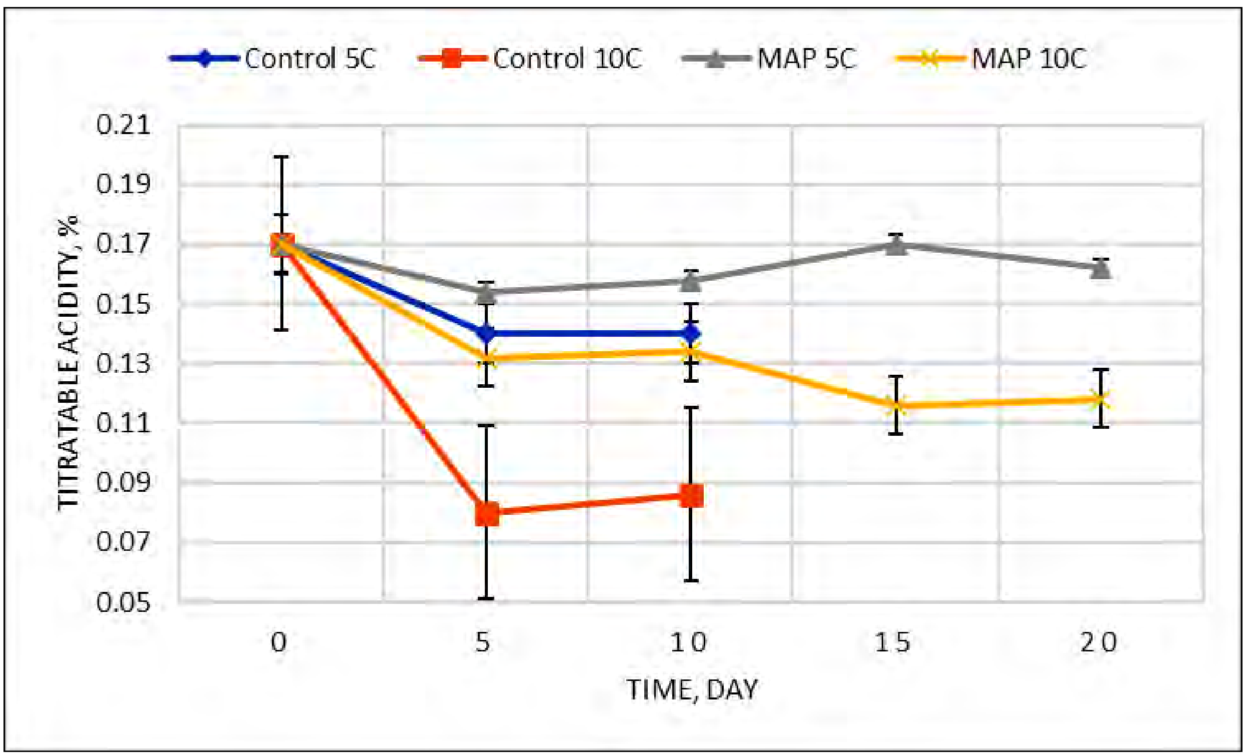


Figure 6. Titratable acidity of dragon fruits after 5 days in post-storage condition

Total Soluble Solid (TSS)

Total soluble solid (TSS) is one of the most important parameters affecting consumers' acceptance (Grierson & Kader, 1986). Results on TSS are shown in **Table 2**. It can be observed that the TSS of both control and MAP samples did not change significantly (p>0.05) throughout the experiment period. Day 5 and 10 control samples did not have significant (p>0.05) difference with day 0. The same can be observed for MAP samples until day 20. These results suggested that even after 20 days in storage and 5 days in post-storage condition, samples under MAP are still acceptable in terms of TSS. The same results were also obtained in Tommy Atkins Mango (Githiga et al., 2014), green asparagus (Techavuthiporn and Boonyaritthongchaib, 2016), mango (Perumal et al., 2021), and plum (Bi et al., 2022). Low temperature, according to Punitha et al. (2010), is also responsible for TSS retention of fruits. This is because MAP and low temperature both lower the rate of respiration rate. The same result was obtained after conducting F-test ANOVA, wherein it was found that both MAP and storage temperature had significant (p<0.05) effect with TSS.

CONCLUSION

Using the proper polyethylene for dragon fruits, the storage plus post-storage life of white flesh dragon fruits was prolonged by up to 25 days as compared to control samples of 15 days. The beneficial effects of MAP during storage resulted in a good start-up condition (freshest condition that is comparable to freshly harvested) of the fruits during post-storage. This slows down the degradation rate or changes in several physico-chemical properties of dragon fruits at post-storage condition which include optical, flesh, and peel MC, TA, and TSS. On the other hand, it was found out that the firmness of the fruits was not affected by MAP. Results also showed that MAP at 5°C is better than MAP at 10°C since 60% of day 25 samples at 5°C are still acceptable in appearance (no decay is visible) while decays in all day 25 samples at 10°C can be observed.

Table 2. TSS of dragon fruits after 5 days in post– storage condition

Day	Control 5°C	Control 10°C	MAP 5°C	MAP 10°C
Initial	9.52	9.52	9.52	9.52
5	9.94	9.63	9.33	9.39
10	10.46	9.62	10.08	9.23
15	-	-	9.89	9.68
20	-	-	10.14	9.89

RECOMMENDATIONS

1. Daily measurement of optical properties and weight change should be done to determine the maximum number of days that the fruit remains edible/acceptable when transferred to post-storage or ambient condition.

2. Measurement of the actual area of decay portion in peel using image analysis (Image J, etc.).

3. Application of MAP for bulk storage of dragon fruits.

4. Sensory evaluation should be conducted to determine the acceptability to consumers.

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