# GAS ABSORBENT BASED MODIFIED ATMOSPHERE PACKAGING TO OPTIMIZE DRAGON FRUIT SHELF LIFE

*Satria* Primatama[1], *Fahrizal Yusuf* Affandi[2], *Anisa* Kistanti[1], *Musyrifah* Kurniawati[1], *Bayu* Nugraha[1*]

[1]Agricultural and Biosystem Engineering Department, Faculty of Agricultural Technology, Universitas Gadjah Mada, Indonesia
[2]Biological Technology and Veterinary Department, Vocational College, Universitas Gadjah Mada, Indonesia
*Corresponding author: bayu.nugraha@mail.ugm.ac.id

**Abstract.** Dragon fruit is a promising export commodity for Indonesia. But its short shelf-life is a big challenge for an international shipping by sea. This study aims to prolong the dragon fruit shelf life by implementing gas absorbent based Modified Atmosphere Packaging (MAP) in combination with cold storage. This technique decreases the fruit physiological processes by lowering $O_2$ concentration (%) inside the MAP. The selected dragon fruit was packed with gas absorbent-based MAP with different $O_2$ absorber capacities (30 cc; 60 cc; and 120 cc) and plastic types (biodegradable plastic and LDPE). Each treatment was also varied with the use of $H_2O$ absorbent and perforation. Then, the dragon fruit in MAP was stored at 5°C and 90% RH for 6 weeks as shipping simulation. After storage, the dragon fruit was transferred to 27°C room temperature without MAP. The results showed that the application of gas absorbent-based MAP, additional treatments, and low temperature were generally able to maintain the quality of dragon fruit up to 6 weeks in cold storage. However, dragon fruit developed signs of chilling injury, increased water loss, increased weight loss, decreased hardness, skin damage, fin withering, and mold growth after transfer at 27°C room temperature without MAP.

## 1 Introduction

The short shelf life of Indonesian dragon fruit during export via sea transportation poses a significant challenge. The decision to optimize for sea-based export distribution is primarily driven by its cost-effectiveness in comparison to air transportation. The shelf life of dragon fruit is intricately linked to its ability to retain freshness over time. Preservation of dragon fruit's freshness typically involves the application of specific methods. One viable technique for extending the shelf life of dragon fruit involves implementing cold temperature storage and carefully controlled high humidity levels.

Preservation of dragon fruit through cold temperature storage and controlled humidity can effectively uphold its quality and prolong its shelf life. Precise temperature and humidity regulation serve to mitigate adverse effects, including discoloration, flesh quality deterioration, mold growth, shrinkage, and structural damage to the dragon fruit. Furthermore, maintaining optimal cold temperatures and humidity levels can also help retain the moisture content of dragon fruit. Moisture loss in fresh fruit can lead to a decline in taste quality, nutritional value, and overall size reduction. [1].

Drawing upon previous research, it has been determined that the optimal storage temperature for dragon fruit is 5°C. This specific temperature is conducive to preserving the fruit's green hue and firm texture. Furthermore, maintaining a low temperature of 5°C has demonstrated the capability to mitigate the occurrence and severity of decay, as well as reduce weight loss in dragon fruit. Remarkably, this temperature setting can extend the shelf life of dragon fruit for a period of up to 20 days. Nonetheless, it is important to note that while the 5°C storage environment enhances the shelf life of dragon fruit, empirical observations reveal that this condition may induce chilling injury and lead to rapid deterioration when the fruit is subsequently exposed to room temperature. [2].

In addition to maintaining a low temperature of 5°C, employing Modified Atmosphere Packaging (MAP) with oxygen-absorbing properties also holds the potential to effectively preserve the quality and freshness of dragon fruit during the export distribution process. A reduced oxygen ($O_2$) environment has been demonstrated to significantly delay the ripening of dragon fruit, owing to the role of $O_2$ in the respiration process and its substantial impact on the proliferation of microorganisms, which are known contributors to food spoilage. Consequently, this study focuses on determining the optimal combination of MAP and cold storage conditions (5°C and 90% relative humidity). The MAP will be configured with various oxygen absorber capacities (30 cc, 60 cc, and 120 cc) to precisely control the $O_2$ levels within the packaging and will explore the suitability of different types of plastic materials (biodegradable plastic and LDPE plastic) to mitigate environmental contamination. Each MAP configuration

will also be subjected to a range of additional treatments, such as moisture absorbents and perforations, to maximize the shelf life of dragon fruit during sea-based export distribution. The study will monitor the physical attributes of dragon fruit as indicators of its quality.

## 2 Materials and methods

### 2.1 Sample preparation

The dragon fruit samples utilized in this study were obtained from freshly harvested dragon fruit originating from a local farm situated on Kaliurang Road, Km. 18.5, Kertodadi, Pekembinangun, Pakem, Sleman Regency, Special Region of Yogyakarta Province. A total of 54 dragon fruit samples were employed for this research. The specific dragon fruit variety selected for the research was *Selenicereus costaricencis*. Subsequently, these dragon fruit samples were transported to the Laboratory at the Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta, Indonesia, where the samples underwent the prescribed treatments.

### 2.2 MAP & treatments preparation

The modified atmosphere packaging (MAP) system employing gas absorbents underwent variations utilizing LDPE plastic packaging materials and biodegradable plastics, each with identical thicknesses of 0.04mm or 40µm. The selected gas absorbent for the MAP packaging was the O-Buster oxygen absorber containing iron dust. Different quantities of oxygen absorbers, specifically 30 cc, 60 cc, and 120 cc, were applied to control the oxygen concentration within the MAP. Additionally, each MAP configuration was subject to variations involving the incorporation of a water vapor ($H_2O$) absorbent and perforations to regulate the relative humidity within the packaging. The primary objective of these adjustments was to effectively manage the relative humidity in the MAP packaging. Subsequently, the dragon fruit enclosed within the MAPs was subjected to storage conditions simulating international shipping, involving a temperature of 5°C and relative humidity of 90% for a duration of 6 weeks. Following the storage period, the dragon fruit was subsequently transferred to an ambient room temperature of 27°C without the use of MAP for a shelf-life observation period of 7 days.

### 2.3 Moisture content

The moisture content (MC) of each dragon fruit sample was determined under various MAP conditions using the gravimetric method at two time points: at week 0 and week 6 during cold storage. Subsequently, on week 7, after cold storage, the MC of each dragon fruit was measured following transfer to a room temperature environment of 27°C without the application of MAP. Each dragon fruit sample within different MAP conditions was initially weighed. Following this, the dragon fruit samples were subjected to drying in an oven at 110°C for a duration of 24 hours to obtain desiccated samples. These dried dragon fruit samples were then reweighed to determine the weight of the fruit samples without moisture content. The percentage of MC in the dragon fruit samples was calculated using **Formula 1**.

$$\% \text{ MC} = \frac{(W^{ti} - W^{tf})}{W^{ti}} \text{ x } 100\ \% \quad (1)$$

Where:
$W^{ti}$ = initial dragon fruit weight (gram)
$W^{tf}$ = final dragon fruit weight after drying (gram)

### 2.4 Weight loss

Weight loss was measured for each dragon fruit sample under varying Modified Atmosphere Packaging (MAP) conditions every week, starting from week 0 and continuing until week 6 during cold storage. Additionally, on week 7, after storage, the weight loss was measured for dragon fruit samples that had been transferred to room temperature at 27°C without the application of MAP. To minimize data measurement deviations, weight loss measurements were conducted in triplicate. The percentage of weight loss in the dragon fruit samples was calculated using **Formula 2.**

$$\% \text{ weight loss} = \frac{(W^{ti} - W^{tf})}{W^{ti}} \text{ x } 100\ \% \quad (2)$$

Where:
$W$ = dragon fruit weight (gram)
$ti$ = initial time (week)
$tf$ = final time (week)

### 2.5 Firmness

Firmness was assessed in multiple MAP conditions for each dragon fruit sample using a penetrometer. Measurements were taken at week 0 and after six weeks of cold storage. Subsequently, following a week after cold storage without MAP at a room temperature of 27°C, the firmness of dragon fruit samples was also evaluated. The penetrometer recorded data in kilograms (kg), and to obtain a firmness value per unit area ($kg/m^2$), additional calculations were performed. This firmness value was determined using **Formula 3**.

$$\text{P} = \frac{F_r}{A_s} \quad (3)$$

Where:
P = Firmness value ($kg/m^2$)
Fr = value displayed on penetrometer (kg)
$A_S$ = Area of penetrometer probe (0,00209 $m^2$)

### 2.6 pH acidity

The pH acidity values were measured for each dragon fruit sample under varying MAP conditions at weeks 0 and 6 during cold storage. After 6 weeks of cold storage, pH acidity values were also measured for dragon fruit samples that were transferred to room temperature

(27°C) without the use of MAP. The pH acidity values for each dragon fruit sample indicate the percentage of the most dominant type of acid present in the dragon fruit. Furthermore, these pH acidity values serve as indicators of potential fermentation occurring in the dragon fruit samples during the various treatments, including MAP, cold storage, and exposure to room temperature.

### 2.7 Total soluble solids (°Brix)

The measurement of Total Soluble Solids (TSS) was executed on each dragon fruit sample in varied MAP using refractometer (MASTER-53; ATAGO; Japan). The measurement time of dragon fruit samples were on week 0 & week 6 in cold storage. After cold storage on 7$^{th}$ week, pH acidity value was also measured for each dragon fruit sample transferred to 27°C room temperature without MAP. TSS displays the °Brix value that shows the sweetness and maturation level of dragon fruit sample during the treatments of MAP, cold storage, and room temperature.

### 2.8 Respiration rate

The respiration rate was assessed using a gas analyzer ($O_2$ & $CO_2$ headspace analyzer; The Quantek Model 902D; Proprietary Electrochemical sensor for $O_2$; Solid-state Infrared sensor for $CO_2$; 2 – 12 second Timing Pump; USA) for each dragon fruit sample under varying Modified Atmosphere Packaging (MAP) conditions every week, commencing from week 0 and continuing until week 6 during cold storage. On week 7, following cold storage, the respiration rate was also measured for dragon fruit samples transferred to a room temperature of 27°C without the application of MAP. The measurement of respiration rate focused on the $CO_2$ production of dragon fruit samples during MAP treatments, cold storage, and exposure to room temperature. Each week, dragon fruit samples were removed from various gas-absorbent-based MAP environments and placed in specific 1 L volume packaging for respiration rate measurements over a 2-hour period. The available free volume within the packaging for respiration rate measurement depended on the size of the dragon fruit sample. Larger dragon fruit samples placed in the packaging resulted in a smaller free volume within the packaging. Subsequently, respiration rate data were calculated to obtain the average values for each weekly measurement. All respiration rate data from each week were then compiled to determine the trend in the respiration rate of dragon fruit samples under varying MAP conditions. The respiration rate data were calculated using **Formula 4**.

$$RCO_2 = \frac{\left(Y_{CO_2}^{ti} - Y_{CO_2}^{tf}\right) x\, V_f}{100\, x\, M\, x\, (t_f - t_i)} \quad (4)$$

Where:
$RCO_2$ = $CO_2$ production rate (ml$O_2$/kg.h)
$Y$ = gas concentration (%)
$Vf$ = free volume (ml)
$M$ = weight of dragon fruit (kg)
$ti$ = initial time measurement (hour)
$tf$ = final time measurement (hour)

### 2.9 Shelf life

The shelf life of dragon fruit samples subjected to various Modified Atmosphere Packaging (MAP) conditions is indicative of the fruit's ability to maintain freshness during storage. Shelf life, in this context, is determined by monitoring the occurrence of physical damage to the dragon fruit samples during storage. These observations were conducted weekly, commencing from week 0 and concluding at week 6, while the samples were stored in a cold environment. Additionally, a follow-up assessment was performed on dragon fruit samples without MAP at week 7. Physical damage was assessed based on the incidence percentage of fin wilt, the presence of mold, skin damage, and fruit skin cracking. The results of this damage assessment were systematically collected and subjected to analysis. The week at which physical damage incidents occurred served as a key determinant of the dragon fruit's shelf life.

### 2.10 Statistical analysis

Data collected in this study encompassed various parameters, including measurements of weight loss, percentage of water loss, pH acidity, total soluble solids value, firmness value, and respiration rate. To assess the impact of varying oxygen absorber capacities (30 cc, 60 cc, & 120 cc), types of plastic materials (LDPE plastic & biodegradable plastics), and additional treatments ($H_2O$ absorbent and perforation), a three-way Analysis of Variance (ANOVA) was employed. The statistical analysis was conducted using IBM SPSS software, version 25, on the transformed data to ensure normal distribution. Subsequently, the parameter data was examined to discern the influence of treatment variations and interactions among treatments on the tested parameter values. This analysis was conducted using a three-way ANOVA with a significance threshold of $P \leq 0.05$. The goal was to identify the most effective treatment strategy for preserving the quality and extending the shelf life of dragon fruit.

## 3 Result and discussion

### 3.1 Moisture content

The moisture content (MC) of each dragon fruit sample in various Modified Atmosphere Packaging (MAP) conditions showed insignificant changes during weeks 0 and 6 of cold storage. The most substantial decrease in dragon fruit flesh MC, observed during week 6 of cold

storage, occurred in the dragon fruit stored in gas-absorbent-based MAP with biodegradable plastic and perforation, equipped with a 60 cc $O_2$ absorber capacity, resulting in a decrease of up to 4.22% ± 0.42% in MC. Upon transitioning the dragon fruit samples to room temperature (27°C) on week 7, a drastic alteration in MC was observed, particularly in samples lacking gas-absorbent-based MAP. All dragon fruit samples exhibited a decrease in MC, ranging from a minimum of 2.23% ± 1.9% in the case of gas-absorbent MAP with LDPE plastic alone to a maximum of 12.22% ± 3.63% in MAP with biodegradable plastic and perforation. The percentage decrease in flesh MC of dragon fruit samples during week 7 at room temperature (27°C) without MAP was notably significant when compared to the percentage decrease observed during week 6. This decline in water content was accompanied by a visible deterioration in the physical appearance of the dragon fruit samples during week 7. This deterioration was characterized by the rupture of the dragon fruit skin, resulting in the release of water from the fruit, ultimately contributing to the loss of water content. This phenomenon is likely attributed to chilling injury experienced by the dragon fruits during their cold storage at 5°C with 90% relative humidity (RH). However, the effects of chilling injury became evident only after the dragon fruits were transferred to a room temperature environment (approximately 27°C) without the protective benefits of MAP [4].

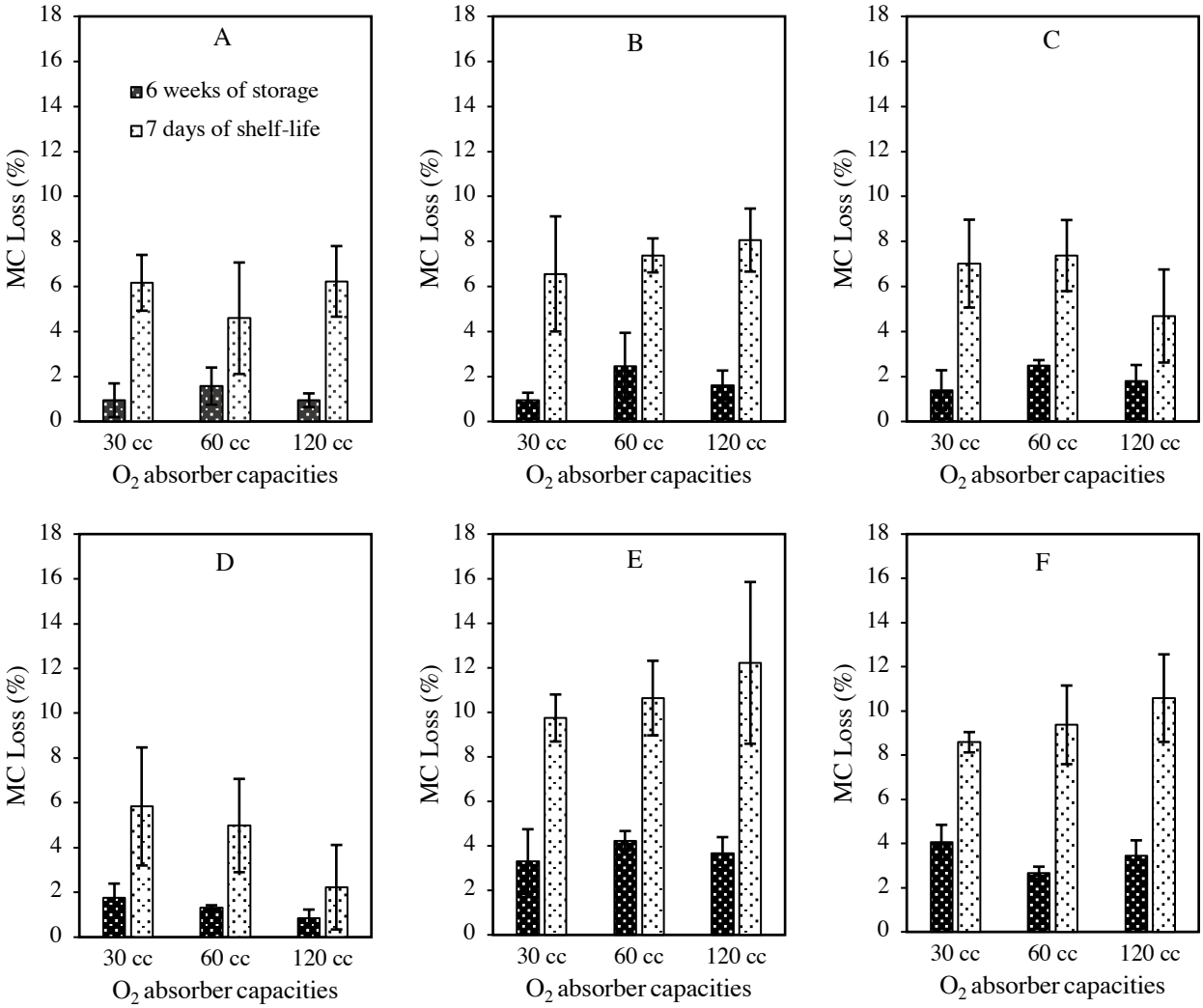


**Figure 1.** The loss of moisture content in dragon fruit under MAP conditions for 6 different packaging scenarios: (A) biodegradable plastic with a water absorbent, (B) LDPE plastic with a water absorbent, (C) biodegradable plastic only, (D) LDPE plastic only, (E) biodegradable plastic with perforations, and (F) LDPE plastic with perforations.

In accordance with the results of the three-way ANOVA statistical test, the variation in the percentage of MC reduction among the different samples of dragon fruit is influenced by the interactions involving various MAP materials, namely biodegradable plastic & LDPE plastic, in conjunction with additional treatments such as the use of $H_2O$ absorbents and the application of perforation holes ($P \leq 0.05$). This phenomenon occurs

due to transpiration events in dragon fruit that trigger water loss due to the difference in water vapor pressure between the surface area of the fruit and the atmosphere. MAP packaging without perforation tends to maintain higher humidity in the MAP, thereby hindering transpiration in dragon fruit samples and subsequently impacting MC preservation [4][5].

### 3.2 Weight loss

The weight loss of each dragon fruit sample across all MAP variations, considering varying $O_2$ absorber capacities (30 cc, 60 cc, 120 cc), diverse packaging materials (biodegradable plastic and LDPE plastic), and additional treatment variations ($H_2O$ absorbent and perforation), exhibits negligible differences, tending to remain constant during cold storage at 5°C and 90% relative humidity (RH). Significant changes in dragon fruit weight loss became evident when the dragon fruit was transferred to room temperature (27°C) without gas-absorbent-based MAP for one week. The weight loss data for dragon fruit is comprehensively presented in **Figure 2** and **Figure 3**. The highest recorded weight loss, at 36.4%, occurred during week 7 after storage at room temperature (27°C) without gas-absorbent-based MAP for dragon fruit samples that had been packaged using a 60 cc $O_2$ absorber capacity, LDPE plastic, and perforation during cold storage. Conversely, the lowest weight loss, at 18.4%, was observed during week 7 at room temperature (27°C) without gas-absorbent-based MAP for dragon fruit samples packaged with a 120 cc $O_2$ absorber capacity and LDPE plastic during cold storage.

Based on the three-way ANOVA statistical test, diverse MAP plastic materials (biodegradable plastic and LDPE), oxygen absorber capacities (30 cc, 60 cc, and 120 cc), and additional treatments ($H_2O$ absorbent and perforation holes) demonstrated no significant effect ($P \geq 0.05$) on weight loss during storage, both in cold storage and at room temperature without gas-absorbent-based MAP. These results also underscore the substantial influence of varied MAP on the maintenance of dragon fruit's physical condition. The findings of this study align with prior research on red dragon fruit in the Philippines, which applied MAP and low temperatures, revealing only a 0.12% weight loss in LDPE-packaged MAP, increasing to just 1.4% by week 6 at a low temperature of 5°C [6].

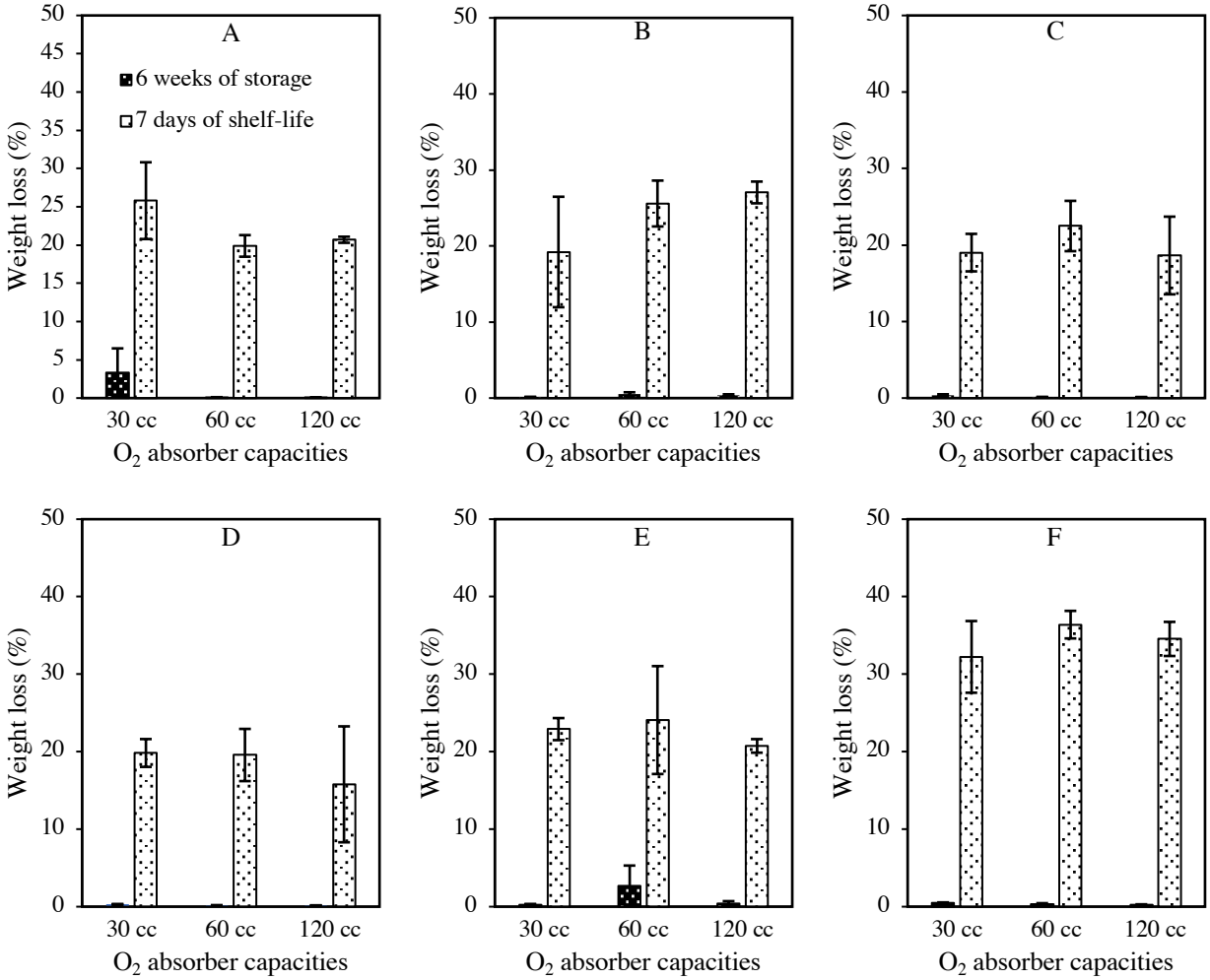


**Figure 2.** The loss of weight in dragon fruit under MAP conditions for 6 different packaging scenarios: (A) biodegradable plastic with a water absorbent, (B) LDPE plastic with a water absorbent, (C) biodegradable plastic only, (D) LDPE plastic only, (E) biodegradable plastic with perforations, and (F) LDPE plastic with perforations

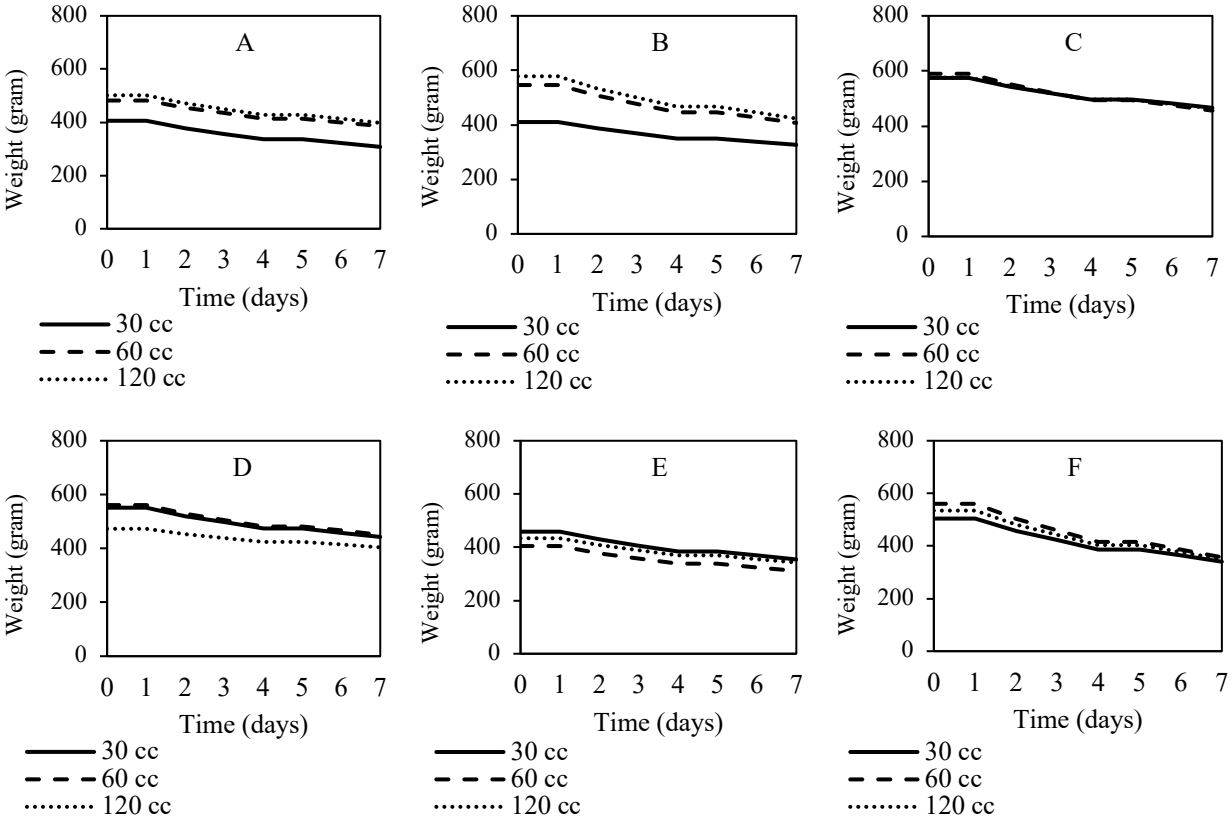


**Figure 3.** Trend of weight loss on dragon fruits of 7 days after storage which have been under MAP conditions for 6 packaging scenarios(A) biodegradable plastic with a water absorbent, (B) LDPE plastic with a water absorbent, (C) biodegradable plastic only, (D) LDPE plastic only, (E) biodegradable plastic with perforations, and (F) LDPE plastic with perforations

### 3.3 Firmness

The firmness of dragon fruit samples under varying Modified Atmosphere Packaging (MAP) conditions was measured, and the results are presented in **Figure 4**. It was observed that the firmness of all sample variations was not significantly affected ($P \geq 0.05$) by changes in MAP parameters, including the type of plastic materials used (biodegradable plastic and LDPE plastic), $O_2$ absorber capacities (30 cc, 60 cc, 120 cc), and additional treatments ($H_2O$ absorbent and perforation).

Over the course of 6 weeks, the firmness of dragon fruit samples in different MAP conditions exhibited a reduction ranging from 0.5% in MAP P1 (biodegradable plastic and $H_2O$ absorbent) to 2.48% in MAP P6 (LDPE plastic and perforation). Subsequently, when these dragon fruit samples were stored at room temperature (27°C) without gas absorbent-based MAP after cold storage, their firmness began to decline. This reduction in firmness ranged from 41.8% in MAP P1 (biodegradable plastic and $H_2O$ absorbent) to 68.1% in MAP P5 (biodegradable plastic and perforation).

These findings align with a previous study, which demonstrated that MAP-wrapped cherry tomato samples experienced only a slight reduction in firmness, whereas MAP-unwrapped samples exhibited a significant decrease in hardness due to elevated $O_2$ exposure [7]. Notably, the hardness of wrapped samples remained higher compared to unwrapped samples. Additionally, prior research has consistently shown that MAP is effective in mitigating the rate of softening during the storage of various fruit types, such as green chili peppers [8], Eva apple [9], and Tommy Atkins mango [10].

The mechanism behind this phenomenon lies in the fact that aerobic respiration can lead to the loosening of cell wall organization [11]. Consequently, this makes pectin from the cell wall more susceptible to enzymatic breakdown by pectinase, resulting in a loss of firmness in dragon fruit samples during the postharvest period. Furthermore, under conditions of high $CO_2$ and low $O_2$ concentrations, the activity of cell wall-degrading enzymes, such as polygalacturonate, is also reduced [12]. MAP systems designed to maintain low $O_2$ atmospheric conditions play a crucial role in suppressing the rate of respiration, thus contributing to a reduced softening rate in fruit samples [13].

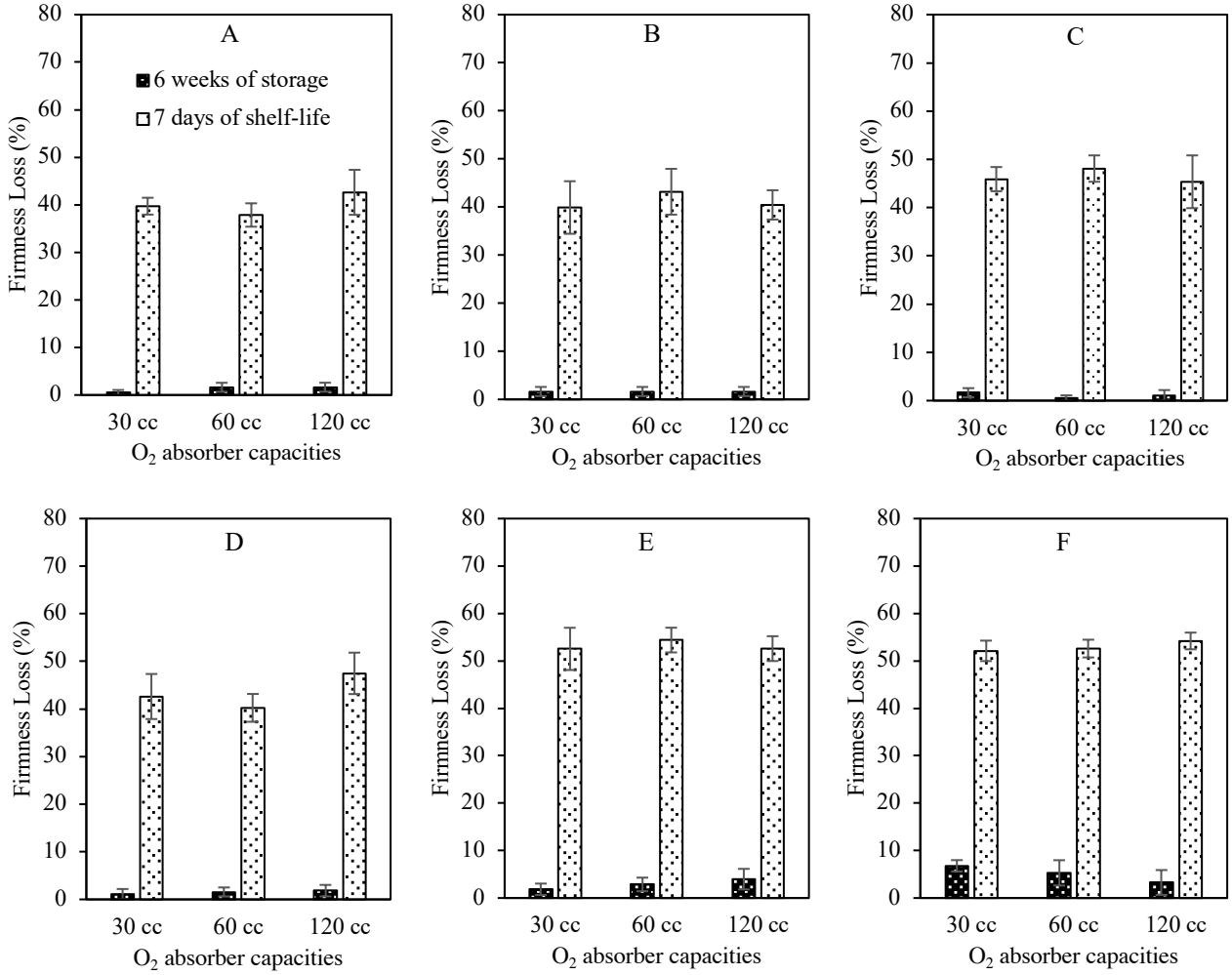


**Figure 4.** The loss of firmness in dragon fruit under MAP conditions was investigated for 6 different packaging scenarios : (A) biodegradable plastic with a water absorbent, (B) LDPE plastic with a water absorbent, (C) biodegradable plastic only, (D) LDPE plastic only, (E) biodegradable plastic with perforations, and (F) LDPE plastic with perforations.

### 3.4 pH acidity

The pH acidity data obtained reveals that the pH acidity values tend to fluctuate within the range of 0.68% ± 1.2% to 3.96% ± 1.1% during the six-week cold storage period. However, the pH acidity value of dragon fruit at week 7, stored at a room temperature of 27°C without MAP, exhibited a decrease from the range of 6.9% ± 5% in MAP P1 (biodegradable plastic & $H_2O$ absorbent) to 11.2% ± 4.4% in MAP P6 (LDPE plastic & perforation). This observation indicates that the pH acidity value of dragon fruit samples with various MAP configurations at 5°C became slightly more acidic after transitioning to room temperature of 27°C without gas absorbent-based MAP. Nevertheless, the dragon fruit samples at week 7 did not exhibit any signs of fermentation. This phenomenon can be attributed to the fact that the $O_2$ concentrations (%) within all utilized MAPs remained within acceptable limits to prevent fermentation. A previous study has indicated that the fermentation threshold begins at an $O_2$ concentration of 1.5% [14].

The results of the three-way ANOVA statistical test conducted on dragon fruit at week 7, stored at room temperature (27°C) without MAP following six weeks of cold storage, demonstrated that variations in oxygen absorber capacity (30 cc, 60 cc, and 120 cc) had a significant impact ($P \leq 0.05$) on reducing the pH acidity value of dragon fruit. This phenomenon is attributed to the fact that the acids present in fruits and other fresh produce primarily serve as substrates during respiration. Therefore, reducing the $O_2$ levels and temperature slows down the consumption of this substrate, leading to a reduced rate of Total Titrable Acidity (TTA) decrease and the maintenance of pH acidity values until the end of the storage period. This consistent pH acidity data holds substantial implications for the advancement of dragon fruit storage techniques, demonstrating that the acidity levels of dragon fruit can be effectively stabilized. The findings of this study provide support for the potential utility of gas absorbent-based MAP methods and low-temperature storage in optimizing the shelf life of dragon fruit [15].

### 3.5 Total soluble solids (°Brix)

In the results of this study, the measured Total Soluble Solids (TSS) values, expressed in °Brix. The °Brix values in all sample variations exhibited no significant change ($P \leq 0.05$). Dragon fruit samples subjected to Modified Atmosphere Packaging (MAP) treatments displayed a gradual decline in °Brix values approaching zero during cold storage. However, at week 7, when maintained at room temperature (27°C) without MAP, the °Brix value of dragon fruit demonstrated a range from 1.37% ± 1.06% in MAP P1 to 5.48% ± 0.4% in MAP P6. This observation highlights that the reduction in °Brix values for dragon fruit samples only occurred after exposure to room temperature (27°C) without MAP. It is noteworthy that lower storage temperatures were found to be conducive to preserving the TSS content in the fruit.

### 3.6 Respiration rate

In this study, the respiration rate of dragon fruit was examined by monitoring changes in $CO_2$ gas concentration within specific packaging designed solely for respiration rate tests. This concentration alteration was observed over a duration of 2 hours. This 2-hour observation period, or 120 minutes, was chosen to minimize environmental exposure dissimilarity from the conditions within gas absorbent-based Modified Atmosphere Packaging (MAP). The $CO_2$ gas concentration data were then subjected to analysis using a respiration rate formula.

The findings indicate that the respiration rate of dragon fruit, following storage under various MAP conditions and cold storage at 5°C with a relative humidity of 90%, exhibited a progressive decrease from week 0 to week 6. The lowest respiration rate was observed at week 6. However, in week 7, the respiration rate of dragon fruit samples stored at room temperature (27°C) without gas absorbent-based MAP increased significantly, illustrating this fluctuation in the dragon fruit's respiration rate, as illustrated in **Figure 5**. Low temperatures decrease cellular respiration in living tissues. As the temperature rises, the kinetic energy required to carry out chemical reactions such as cellular respiration decreases. Therefore, warmer temperatures usually result in more cellular respiration. The rate of respiration decreases with the low storage temperature of the fruit.

Statistical analysis, specifically a three-way ANOVA test, revealed a significant difference in respiration rate values at week 3 ($P \leq 0.05$) among dragon fruit samples within various MAP conditions that had different oxygen absorber capacities (30 cc, 60 cc, and 120 cc). Furthermore, interactions between the types of plastic material (biodegradable plastic & LDPE plastic) and additional treatments ($H_2O$ absorbent & perforation) were found to influence the respiration rate of dragon fruit. At week 6, statistical tests did not reveal any differences in respiration rates between samples subjected to various treatments. Nevertheless, at week 7, the respiration rate of dragon fruit samples exhibited distinct values based on variations in oxygen absorber capacity (30 cc, 60 cc, 120 cc), plastic material type (biodegradable plastic & LDPE plastic), and additional treatments ($H_2O$ absorbent & perforation). This statistical analysis underscores the significant impact ($P \leq 0.05$) of MAP with different oxygen absorber capacities, plastic material types, and additional treatments on the respiration rate.

### 3.7 Shelf life

During cold storage, physical damage to dragon fruit was observed, including wilting of fruit fins, mold growth, damage to the outer skin, and skin cracking. The fin wilt became apparent around week 4 or after 30 days in dragon fruit samples treated with P5 (biodegradable plastic with perforation) and P6 (LDPE with Perforation), both of which had $O_2$ levels of approximately 18-19%. In contrast, for other treatments such as P1 (biodegradable plastic with $H_2O$ absorbent), P2 (LDPE plastic with $H_2O$ absorbent), P3 (biodegradable plastics only), and P4 (LDPE plastic only), symptoms only appeared at the beginning of week 5.

Another indicator of physical damage was the emergence of mold on dragon fruit skin samples in MAP P5 (biodegradable plastic & perforation) at week 5. By week 6, new mold growth occurred in fruit samples subjected to P3 (biodegradable plastic only), P5 (biodegradable plastic with perforation), and P6 (LDPE plastic with perforation) treatments. This highlights that MAP with perforations, such as P5 and P6, can promote mold growth on dragon fruit due to increased air circulation within the packaging, fostering fungal contamination. The high $O_2$ levels (18%-19%) in MAP P5 and P6 further exacerbated this fungal growth. These physical damage manifestations are thoroughly illustrated in **Figure 6**.

Perforated plastic bags were found to effectively reduce the weight shrinkage of dragon fruit during storage. However, they also increased the percentage and severity of fruit spoilage. Dragon fruit stored at 5ºC without perforated plastic bags remained unspoiled even after 25 days of storage. The utilization of perforated plastic bags amplified the percentage of fruits exhibiting spoilage events during storage at 7ºC and 10ºC, as well as the severity of spoilage at 10ºC.

Upon removal of dragon fruit to a room temperature of approximately ±27°C without MAP following storage, approximately 80% of the fruits stored at 5ºC with perforated plastic bags experienced spoilage, while fruits stored at 5ºC without perforated bags remained unaffected. At 7ºC and 10ºC, both with and without perforated plastic bags, all fruits exhibited 100% spoilage within five days at room temperature ±27°C without MAP. Therefore, the storage of dragon fruit in perforated MAP resulted in increased severity of spoilage during shelf life at room temperature ±27°C, even when the bags were removed at the time of storage discontinuation [16].

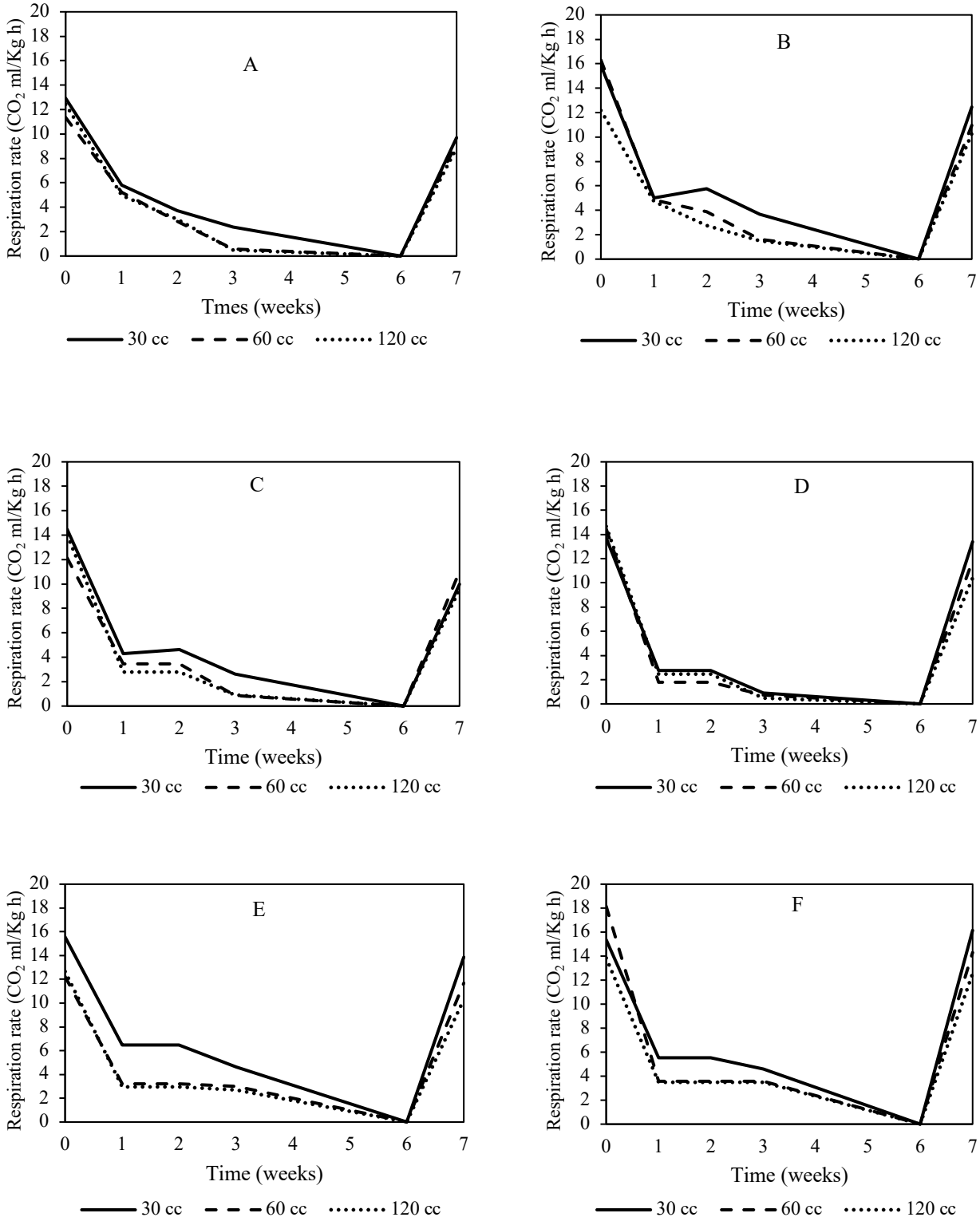


**Figure 5.** Weekly trend of respiration rate on dragon in MAP of (A) biodegradable plastic & $H_2O$ absorbent, (B) LDPE plastic & $H_2O$ absorbent, (C) biodegradable plastic only, (D) LDPE plastic only, (E) biodegradable plastic & perforation, and (F) LDPE plastic & perforation. This respiration rate of dragon fruits is affected under circumstance of $O_2$ concentration (%) in MAP without perforation in range of 3.3% - 12% & MAP with perforation in range of 17.7% - 19.2% in 6 weeks of storage.

A B C D

**Figure 6.** Deterioration of dragon fruit quality by the incident of (A) fin wilt, (B) damage fruit skin, (C) cracking, (D) growth mold

Dragon fruit stored at 5ºC and 7ºC has a better visual appearance after being stored for 20 days compared to fruit stored at 10ºC. Storage at 5ºC and 7ºC retains a greener fin colour and reduces the incidence and severity of spoilage compared to fruit stored at 10ºC. Best visual appearance after 20 days of storage and after five storage days at a temperature of 20ºC are observed in fruits stored at a temperature of 5ºC without plastic bags with holes. However, storage of dragon fruit at 5ºC results in a low chilling injury rate characterized by a thin layer of outer flesh tissue under the skin showing symptoms of being submerged in water, an effect not ameliorated by the application of perforated plastic bags. Following 6 weeks in cold storage, dragon fruit subjected to a transition to room temperature at 27ºC without the presence of MAP shows exacerbated physical damage across all samples. Indicators of fin wilting, skin damage, cracking, and mold growth manifest upon removal of dragon fruit samples to room temperature in the absence of gas-absorbent-based MAP. These findings also suggest the potential occurrence of chilling injury during cold storage with the utilization of MAP. However, the signs of chilling injury begin to manifest upon transitioning to room temperature.

The manifestation of mild chilling injury becomes evident in dragon fruit when stored at 5ºC for a duration of 20 days. It is worth noting that the chilling injury levels observed in this study were considerably lower than those previously reported for the same species cultivated in Israel and subjected to a storage period of two weeks at 6°C. These findings substantiate the proposition that environmental conditions during cultivation significantly influence fruit quality, thereby influencing the optimal harvest time, the fruit's susceptibility to chilling injury, and its potential for storage at low temperatures. Moreover, subjecting dragon fruit to a conditioning process at 25ºC for 24 hours prior to cold storage at 2ºC serves to diminish its susceptibility to chilling injury, thereby facilitating the storage of dragon fruit at low temperatures [17].

The recommended storage temperature for red dragon fruit (*Selenicereus costaricensis*) is 10°C and for the yellow dragon (*Selenicereus megalanthus*) is 6°C with air humidity of 85-90%. Storage periods at 10°C and 5°C with 90% RH were reported for 14 and 17 days respectively. with air humidity of 85-90%. Storage periods at 10°C and 5°C with 90% RH were reported for 14 and 17 days respectively. Dragon fruit quality is still acceptable for 25-30 days if stored in perforated plastic bags at 4.5°C, however, when stored at room temperature, the shelf life is less than 10 days [18][19].

## 4 Conclusions

The results showed that the application of gas absorbent-based MAP, additional treatments, and low temperature were generally able to maintain the quality of dragon fruit up to 6 weeks in cold storage. However, dragon fruit showed signs of chilling injury, increased water loss, increased weight loss, decreased firmness, skin damage, fin withering, and mold growth after transfer at 27°C room temperature without MAP. The application of perforation is not recommended because it affects the high oxygen concentration in MAP so that mold growth and loss of moisture content in dragon fruit increase during storage in cold storage. Cold storage at 5°C is also not recommended to avoid chilling injury. The use of a temperature of 10°C and gas absorbent-based MAP with biodegradable plastic or LDPE plastic without perforation is highly recommended.

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