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Modelling the respiration rate of *dabai* fruit (*Canarium odontophyllum* Miq.) stored in different packaging films

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Abstract

Dabai (*Canarium odontophyllum* Miq.) is a highly nutritious fruit that has a huge potential to be marketed both locally and globally. However, the lack of promotion leads to an oversupply during peak season, thus reducing its market price. Proper handling and packaging are therefore necessary to maintain the quality and extend the shelf life of *dabai*. In the present work, nylon film with an oxygen transmission rate (OTR) of 55 cc/m^2/day and water vapour transmission rate (WVTR) of 334 g/m^2/day; polyethylene terephthalate (PET) film with an OTR of 90 cc/m^2/day and WVTR of 35 g/m^2/day; and low-density polyethylene (LDPE) film with an OTR of 8000 cc/m^2/day and WVTR of 200 g/m^2/day were used to pack *dabai* and stored at 5°C for 14 d. All films had a dimension of 200 × 300 mm, and a thickness of 0.01 µm. It was found that *dabai* maintained its hue angle (h°) values within the dark purple region (299.73° to 338.64°) and its lightness (L^*) values throughout storage. However, the colour intensity (chroma) significantly changed ($p < 0.05$) between different films throughout storage ($p < 0.05$). The control sample had the most significant decrease in firmness and weight ($p < 0.05$) between day 0 and 14, followed by the samples stored in PET, LDPE, and nylon. Whereas the samples in LDPE demonstrated the lowest respiration rate as compared to nylon and PET. The uncompetitive Michaelis-Menten equation model was used to model the respiration rate of *dabai*. Results showed that all films obtained good fit (R^2 of near to 1). Additionally, the mean relative percentage (E%) was less than 10%, thus indicating that the data were suitable for real-time application.

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Introduction

Dabai (*Canarium odontophyllum* Miq.) is a type of fruit that belongs to family Burseraceae and order Sapindales, and mainly originates from Malaysia (Sabah and Sarawak), Indonesia (Sumatra and Kalimantan), the Philippines (Palawan), and Brunei (Ding, 2011). In Malaysia, *dabai* is particularly famous in Sarawak where it is known as the 'Sibu Olive' among the community due to its appearance, texture, and flavour which nearly resemble olives with a stony seed inside (Chua *et al*., 2015). Immature fruit has white-coloured flesh, and will change to blue-black or dark violet when ripens. It has a hard texture, and the locals usually soak it in water at approximately 50°C for 15 to 20 min to soften the flesh. The fruit also has a creamy taste that is similar to ripe avocado, and its kernel and seeds can be eaten (Gadug and Yusup, 1992). Additionally, the combination of salt and sugar enhances the unique flavour of *dabai* (Ding and Tee, 2011).

Empirical evidence shows that *dabai* is rich in nutritional values, including protein (3.8%), carbohydrate (22.1%), fat (26.2%), potassium (0.81%), and calcium (0.2%) in 100 g of edible coating (Hoe and Siong, 1999). Tan and Azrina (2016) stated that different parts of *dabai* contain various phytochemicals that act as anti-microbial,

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anti-diabetic, anti-cholesterol, and anti-hyperlipidaemic. Furthermore, oil extracted from the fruit contains abundant antioxidant properties (Azrina *et al.*, 2010), which allows new formulation designs to produce *dabai*-based products, such as butter, margarine, cooking oil, cocoa butter, and sauce.

Despite being a highly nutritious fruit and has an excellent potential to be marketed globally, *dabai* is hardly known by the people outside the regions of origin. This mainly owes to the lack of marketing and promotion, thus resulting in a decrease in its market price due to over-supply during the peak season (Ding, 2011). Furthermore, *dabai* is highly perishable even though the texture is hard right after harvest. Such issue must be addressed to improve the marketability of *dabai via* proper handling and packaging to extend its shelf life, maintain its quality, and maximise its freshness. According to Wong (1992), *dabai* typically has a shelf life of up to three days after harvest. Meanwhile, studies by Ding (2011) and Lau and Fatimah (2007) showed that the fruit can maintain its fresh-like properties only up to two days after harvest under the storage condition of 27°C. The authors concluded that temperature stands as a main factor that will affect the quality and shelf life of *dabai*.

Previous studies have proven that low storage temperatures could extend the shelf life of various fresh commodities. In the case of *dabai*, Lau and Fatimah (2007) found that *dabai* can be stored in cold storage and vacuum packaging for six months; however, it may result in an unappealing physical appearance and terrible taste. Meanwhile, *dabai* stored at 5°C and coated with a thin layer of edible oil could minimise its moisture loss (Voon, 2003). Additionally, storing *dabai* in LDPE film with modified atmosphere packaging (MAP) at 10°C creates a steady-state atmosphere that can minimise its respiration rate. It was also claimed that packing *dabai* in polyethylene bags could extend the shelf life until eight days when stored at 14°C (Jugah, 2006).

However, empirical evidence to date remains scarce on the practicality of using commercial films as a low-cost, economical, and procurable packaging to maintain the quality of *dabai* throughout storage. There is also a lack of research on the respiration rate of *dabai*, and the mathematical modelling associated with it. The present work thus aimed to address these gaps by comparing the quality and shelf life of *dabai* packed in nylon, polyethylene terephthalate (PET), and low-density polyethylene (LDPE) films, as well as performing mathematical modelling on the respiration rate of *dabai* using the uncompetitive Michaelis-Menten equation model.

Materials and method

Sample preparation

Ripe *dabai* fruits were received from a local *dabai* plantation in Kuching, Sarawak, Malaysia. The fruits were harvested 1 d earlier, and packed in a sealed polystyrene box before it was transported to Universiti Putra Malaysia (UPM), Serdang, Malaysia. The overall journey took 6 h. The fruits were stored in a chiller at 5°C for one night prior to the experiment day. Uniform size, colour, and defect-free *dabai* fruits were chosen for the experiment. The samples were arranged randomly and packed into three packaging films: nylon (OTR: 55 cc/m^2/day; WVTR: 334 g/m^2/day), polyethylene terephthalate (PET) (OTR: 90 cc/m^2/day; WVTR: 35 g/m^2/day), and low-density polyethylene (LDPE) (OTR: 8000 cc/m^2/day; WVTR: 200 g/m^2/day). All films had a thickness of 0.01 μm, and a dimension of 200 × 300 mm, while the control samples remained unwrapped. All samples were kept in a chiller at 5°C for 14 d. The sampling for firmness and fresh weight loss was taken on days 0, 4, 8, 12, and 14, while the physical appearance and colour reading sampling was done on days 0, 4, 8, and 14.

Gas exchange

A 1-L glass jar was used to store a 200 g of sample of each treatment throughout storage. A piece of nylon, PET, and LDPE films was used to cover the jar opening. Three replications were prepared for each film. The changes in oxygen (O_2) and carbon dioxide (CO_2) concentrations within the closed system were monitored using a gas analyser (Headspace Advance, Systech, US). Prior to sampling, a resealable septum was placed on top of the film to prevent any gas leakage in or out of the glass jars. The gas concentrations of the packed samples were taken every 1-h interval for 6 h on days 0 and 4. For days 8 and 14, the gas readings were taken every 3-h interval for 6 h. It was necessary to take the gas reading often due to the vigorous respiration rate occurring at the initial stage of the storage. The gas concentration readings were obtained in percentage (%). The O_2 and CO_2 values were then used to calculate the respiration rate of *dabai* using Eqs. 1 and 2:

$$R_{O_2} = \left[\frac{(C_{O_2})_t - (C_{O_2})_{t+\Delta t}}{\Delta t}\right]\frac{V}{W} \quad \text{(Eq. 1)}$$

$$R_{CO_2} = \left[\frac{(C_{CO_2})_t - (C_{CO_2})_{t+\Delta t}}{\Delta t}\right]\frac{V}{W} \quad \text{(Eq. 2)}$$

where, R_{O_2/CO_2} = respiration rate for O_2 consumption or CO_2 production (mL/kgh); C_{O_2} = O_2 concentration (%); C_{CO_2} = CO_2 concentration (%); t = storage time (h), Δt = difference of time between two gas measurements (h); V = void volume of a storage chamber (mL), and W = weight of the sample (kg).

L, a*, b*, hue angle, and chroma*

A colorimeter (CR-200, Konica Minolta U.S.A) was used to determine the colour changes of *dabai* throughout storage. Five pieces of *dabai* were packed into three different films (nylon, PET, and LDPE) with the dimension of 225 × 200 mm. The packs were sealed using an electric sealer (DS-300H, Daily Sealing, Taiwan). Control samples were also prepared but left unwrapped. Three replications were prepared for each film. *L**, *a**, and *b** values were taken at two points for each sample, and *a** and *b** values were further used to calculate the chroma and hue angle (h°) using Eqs. 3 and 4:

$$\text{Chroma, } C = [(a^*)^2 + (b)^2]^{1/2} \quad \text{(Eq. 3)}$$

$$\text{Hue angle, } h° = \tan^{-1} |b^*/a^*| \quad \text{(Eq. 4)}$$

where, the *L** value indicates the sample lightness, ranging from lighter (+) to darker (-); *a** value indicates the sample is redder (+) or greener (-); and *b** value indicates the sample is yellower (+) or bluer (-). Chroma defines colour intensity as higher value indicates higher colour intensity, and further away from the pure colour. Fruit colour changes were represented by hue angle where 0° = blue; 90° = blue-green; 180° = yellow, and 270° = purple-red.

Fresh weight loss

An electronic weighing balance BE610 (Beetle, UK) was used to weigh the *dabai* samples. Briefly, 200 g of *dabai* were packed and sealed inside nylon, PET, and LDPE films. The dimension of all films was 225 × 200 mm. Three replications were prepared for each treatment including control, and the percentage of fresh weight loss was calculated using Eq. 5:

$$W_{loss} = \frac{W_{initial} - W_{(final)}}{W_{initial}} \times 100 \quad \text{(Eq. 5)}$$

where, W_{loss} = percentage of fresh weight loss (%), W_{intial} = initial weight of *dabai* (g), and W_{final} = final weight of *dabai* (g).

Firmness

Firmness analysis was conducted using a texture analyser (TA.XT2 Stable Micro Systems, UK). The equipment was set with a pre-test speed of 1.50 mm/s, a test speed of 4 mm/s, and a post-test speed of 10 mm/s. A 2 mm cylindrical stainless-steel probe (P/2) was used to pierce the sample at 4.5 mm. There were four samples in each film including control, and each sample was punctured twice at two different positions.

Modelling the respiration rate

The impact of gaseous, specifically O_2 and CO_2, on the respiration rate of *dabai* was investigated using an uncompetitive Michaelis-Menten equation model. This model has been used to simulate the respiration rate of various fresh fruits, including fresh-cut *Anggun*-type sweet potato (Shapawi *et al.*, 2021), papaya (Rahman *et al.*, 2013), spinach (Saenmuang *et al.*, 2012), apple (Torrieri *et al.*, 2009), 'Rocha' pear (Gomes *et al.*, 2010), and strawberry (Barrios *et al.*, 2014). The respiration rate of fresh fruits was calculated using the uncompetitive Michaelis-Menten equation model based on Eq. 6:

$$R_{O_2/CO_2} = \frac{V_m C_{O_2}}{K_m + \left[1 + \left(\frac{C_{CO_2}}{K_i}\right)\right] C_{O_2}} \quad \text{(Eq. 6)}$$

where, V_m = maximal respiration rate for O_2 consumption or CO_2 production (mL/kgh); K_m = inhibition constant for O_2 consumption or CO_2 production in unit percentage (%); K_i = Michaelis-Menten constant for O_2 consumption or CO_2 production in unit percentage (%); C_{O_2} = oxygen concentration in unit percentage (%); and C_{CO_2} = carbon dioxide concentration in unit percentage (%). The equation was linearised as in Eq. 7 where V_m, K_m, and K_i were the model parameters obtained to investigate the effect of films and storage days on the respiration rate of *dabai*.

$$\frac{1}{R_{O_2/CO_2}} = \frac{1}{V_m} + \frac{K_m}{V_m}\frac{1}{C_{O_2}} + \frac{1}{K_i V_m} C_{CO_2} \quad \text{(Eq. 7)}$$

Statistical analysis

Two-way ANOVA was performed using RStudio version 4.1.2 to compare the mean difference between groups. Mean separation test was further conducted using Tukey HSD to determine the least significant difference ($p < 0.05$) between the mean of the compared groups. Regression analysis was also done to obtain an R^2 value between the experimental and modelled data. R^2 value near 1 indicates that the data are a good fit and in good agreement. Mean relative percentage (E) was calculated to support the accuracy of estimated parameters using Eq. 8:

$$E = \frac{R_{exp} - R_{pre}}{R_{exp}} \times \frac{100}{N} \quad \text{(Eq. 8)}$$

where, R_{exp} = experimental respiration rate (mL/kgh), R_{pre} = predicted or modelled respiration rate (mL/kgh), and N = number of respiration rate data points.

Results and discussion

Colour analysis

The lightness (L^*) and hue angle (h°) values showed no significant changes between the samples stored in different films and storage days (Table 1). Ding and Tee (2011) reported that the L^* value, chroma, and h° were not affected by the films and storage days of *dabai*; however, the present work found that chroma resulted in a significant change ($p < 0.05$) in *dabai* between storage days. Chroma is represented by colour intensity where higher reading will have a higher colour intensity, which is further away from the pure colour (Jochum, 2020). On day 14, the chroma readings of *dabai* were found higher for all films than at the early stage of storage. This could be attributed to the differences in film permeability and inconsistencies in relative humidity and temperature, which could increase the metabolic activity of *dabai* and cause colour changes. Even though chroma was affected by the type of films and storage days, all samples were grouped in a dark purple region with hue angles ranging from 299.73° to 338.64° following the CIE Chromaticity Diagram by Pathare *et al*. (2013). Besides, no significant physical appearance and colour changes were observed on *dabai* up to day 8 (Table 2). On day 14, however, whitish moulds were observed on the surface of the samples stored in LDPE film. This was due to inappropriate internal conditions such as excessive relative humidity and insufficient O_2 and CO_2 gaseous levels inside the package, thus allowing microbial growth. De Ell *et al.* (2003) mentioned that having low O_2 and high CO_2 values in the internal environment of a package could influence ethylene production, and lead to microbial growth. Moreover, wrinkles on the fruit's skin were obvious at day 14 as compared to day 0 across all samples regardless of the film types, which initiated freshness loss. The high temperature and non-optimal relative humidity inside the package can degrade fresh produce quality and shorten its shelf life.

Firmness

The firmness degradation of *dabai* was significant throughout storage days, and in consequence with the type of films ($p < 0.05$). Both control and PET samples recorded decreased firmness by 68 and 49%, respectively, throughout storage, while there was no significant difference in firmness between both nylon and LDPE samples where the values decreased by 45% (Figure 1a). On day 8, samples stored in PET showed a gradual firmness decrease as compared to day 4 ($p < 0.05$). Previous studies reported that storing *dabai* in a PET package at 10°C could only maintain its firmness for 5 or 6 d before it turned soft and spoiled. Fruit softening commonly occurs due to several factors that disrupt the internal environment of the package, such as severe tissue deterioration, loss of cell turgor pressure, respiration activity, and moisture loss (Ding and Diana, 2013). It has been demonstrated that nylon and LDPE films have good permeability properties for gaseous and moisture, hence optimising the relative humidity inside the package and keeping the samples firmer for a longer time than PET film.

Fresh weight loss

Both storage days and types of films had a significant effect ($p < 0.05$) on the fresh weight loss of *dabai* (Figure 1b). The percentage of weight loss was found to increase as storage days increased. Siracusa (2012) reported that weight loss occurs in fresh produce due to the evaporation of moisture and nutrient loss in the fruits or vegetables, which leads to quality reduction and shorter shelf life. On the final day of storage, samples stored in nylon had the least weight loss (1.04%), followed by LDPE (1.36%), PET (1.76%), and control (2.42%). However, past

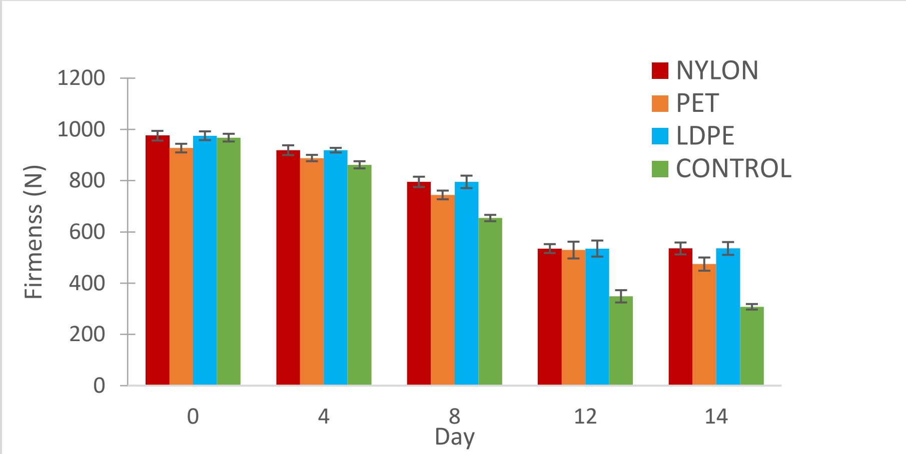
Table 1. *L**, chroma, and hue angle values for *dabai* fruits stored in different packaging films for 0, 4, 8, and 14 days.

Film	Day	*L**	Chroma	Hue angle (h°)
Nylon	0	28.35[a]	1.87[a]	312.78[a]
	4	27.18[a]	1.87[a]	319.61[a]
	8	28.60[a]	2.74[a]	317.69[a]
	14	28.40[a]	5.29[b]	337.75[a]
PET	0	28.78[a]	1.83[a]	311.39[a]
	4	28.21[a]	1.82[a]	320.16[a]
	8	27.82[a]	2.49[a]	318.49[a]
	14	27.16[a]	5.24[b]	338.64[a]
LDPE	0	28.93[a]	1.85[a]	307.35[a]
	4	28.03[a]	1.53[a]	318.15[a]
	8	27.54[a]	2.74[a]	323.79[a]
	14	26.99[a]	4.71[b]	337.45[a]
Control	0	28.69[a]	2.31[a]	299.73[a]
	4	28.17[a]	1.58[a]	315.49[a]
	8	28.35[a]	2.72[a]	316.09[a]
	14	27.18[a]	2.72[a]	309.04[a]

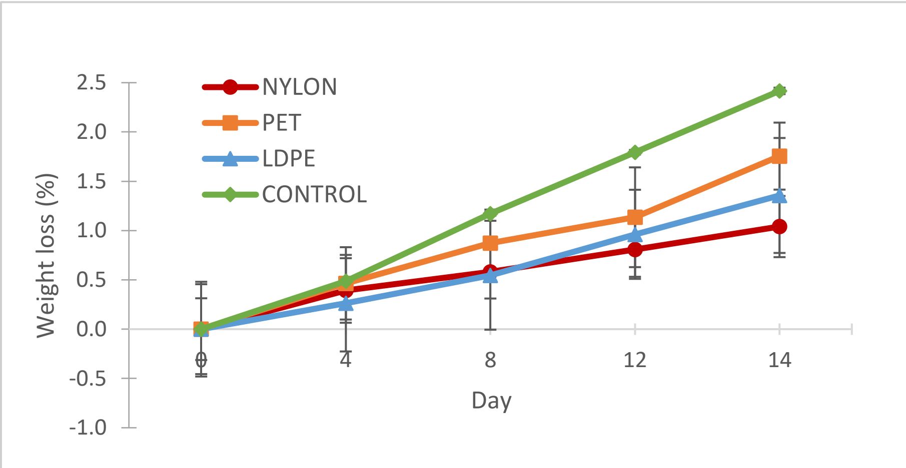
Means in the same column with different superscript letters are significantly different ($p < 0.05$) between storage days . Means between films were not significantly different.

Table 2. Physical appearance of *dabai* fruits stored in nylon, PET, and LDPE films for 0, 4, 8, and 14 days.

	Nylon	PET	LDPE	Control
Day 0				
Day 4				
Day 8				
Day 14				



(a)



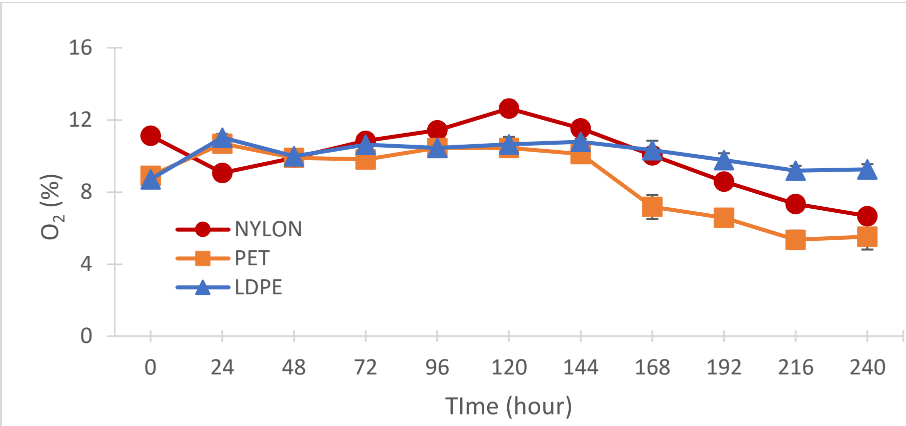
(b)

Figure 1. Firmness **(a)** and weight loss **(b)** of *dabai* fruits stored in nylon, PET, LDPE, and control at 10°C for 0, 4, 8, and 14 days.

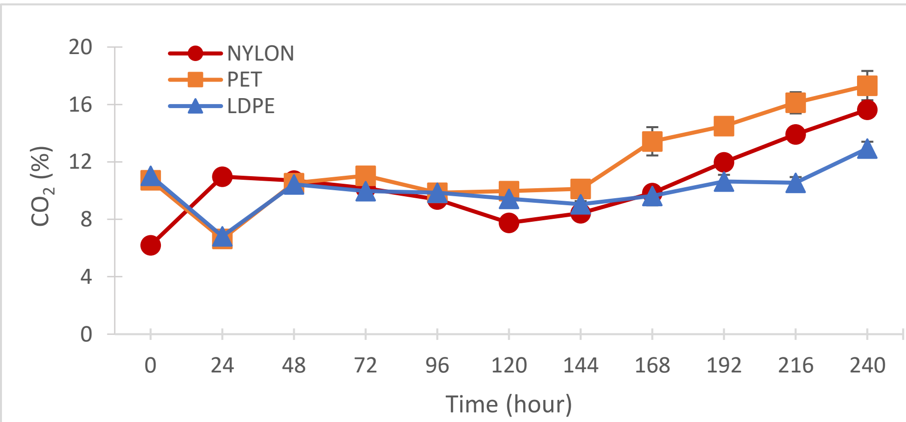
research suggested that PET film could be more effective in minimising weight loss for fresh-cut sweet potatoes than nylon and LDPE (Shapawi *et al.*, 2021). It was shown that different fruit products would react differently to packaging films due to the differences in their physical, chemical, and biological properties. In the present work, nylon had a good moisture permeability property and higher water vapour transmission rate (WVTR), which could optimise the relative humidity in the internal environment of the nylon pack that could cause moisture condensation, microbial growth, and decay of the *dabai* fruit. Nevertheless, Ohta *et al.* (2002) posited that fruits and vegetables should not reach 5% weight loss as this could reduce their marketability and customer acceptance. Under proper storage condition, the fresh weight loss of *dabai* stored in nylon, PET, or LDPE would be acceptable to the industry as this did not reach 5% weight loss.

Gas concentration

Fresh fruits and vegetables require O_2 to perform metabolic processes, particularly respiration. This process can lead to ripening, senescence, and subsequent deterioration of the fresh produce (Geeson, 1989; Gross *et al.*, 2005). In the present work, the O_2 concentration remained constant for samples packed with LDPE and uncovered (control). In contrast, samples stored in nylon and PET packaging were observed to have a sudden decrease in O_2 after 120 h of storage. This was probably due to the vigorous metabolic reaction and anaerobic respiration when the temperature was higher, especially during the sampling days when the samples were taken out to room temperature to obtain the gas reading (Figure 2). This is supported by Rahman *et al.* (2013) who found a sudden increase in the respiration rate of papaya stored at 30°C on day 4 of storage due to the initiation of anaerobic respiration at high temperatures. *Dabai* stored in LDPE had the least difference (1.05%) of O_2 concentration from the beginning to the end of the storage hours as compared to nylon and LDPE, which resulted in 4.46 and 3.39% difference in O_2 concentration, respectively. Inversely, the CO_2 concentration differences for nylon, PET, and LDPE were 3.48, 6.60, and 0.48%, respectively. This indicated that LDPE had an excellent O_2 permeability that would be suitable for the storage of *dabai* fruit because it had the least O_2 consumption and CO_2 reduction as compared to nylon and PET. This will reduce the respiration of *dabai* fruit during storage, thus resulting in prolonged shelf life. Similar results were reported by Ding and Diana (2013) where LDPE bags used to store *dabai* fruit in MAP at 10°C obtained the lowest respiration rate, and extended the shelf life to 8 d. However, other researchers have found that the low OTR value of packaging film helps to prolong the shelf life and maintain the quality of fresh produce better than the high OTR value. Shapawi *et al.* (2021) reported that fresh-cut sweet potatoes *(Anggun)* can minimise respiration rate, and retain better texture and colour when stored in nylon (OTR: 55 cc/m^2/day) at 5 and 30°C in comparison to when stored in films with higher OTR value. Furthermore, Kizilirmak and Yalcin (2016) stated that pomegranate arils had a shelf life of up to 10 d when stored at 125 - 290 cm^3/m^2/day in a passive modified environment at 5°C and 90% relative humidity (RH). This indicated that the respiration rate of fresh produce does not solely depend on the OTR values but rather various factors such as fruit properties and storage conditions, which also need to be considered.



(a)



(b)

Figure 2. Gas concentration of O_2 consumption **(a)** and CO_2 production **(b)** of *dabai* fruits stored in nylon, PET, and LDPE films.

Modelling the respiration rate

The respiration rate trend showed that *dabai* had a rapid respiration rate at the initial hours, and the readings became constant after 24 h of storage for all the films tested. As a result of low O_2 concentration, the rate of respiration will gradually slow down over time (Rahman *et al.*, 2013). Corresponding to the O_2 and CO_2 gaseous exchanges, LDPE had the lowest initial respiration rate with 2.52 mL/kgh for O_2 consumption and 2.04 mL/kgh for CO_2 production. In comparison, PET had the O_2 consumption and CO_2 production rates of 2.96 and 3.46 mL/kgh, respectively, while nylon had the O_2 consumption and CO_2 production rates of 3.71 and 2.58 mL/kgh, respectively. This indicated that LDPE had an excellent permeability property that helped to minimise respiration and prolong the shelf life of *dabai*. At the end of the storage hour, the decreased amount of the remaining O_2 in the internal package of *dabai* led to a low respiration rate due to the reduction of the overall metabolic activity (Solomos, 1989).

The respiration rate of *dabai* fruits was modelled using the uncompetitive Michaelis-Menten equation in linear form, and the model parameters were determined by evaluating the experimental data with multiple linear regression (Table 3). The parameters included maximum respiration rate (V_m), Michaelis-Menten constant (K_m), and inhibition constant (K_i). The lowest V_m values were found for samples stored in LDPE, which were 0.16 mL/kgh for O_2 concentration, and 0.15 mL/kgh for CO_2 concentration. Additionally, samples across all films showed a good fit (R^2 near 1) between experimental and modelled data.

Model validation

Mean relative deviation (Eq. 8) was used to determine the goodness of fit, and the value was termed E (%). The E values (%) obtained for the respiration rate of samples stored in all films were less than 10%, thus indicating that the model data by the regression analysis and experimental data were in good agreement (Table 3). Boquet and Chirife (1978) and Rahman *et al.* (2013) also suggested that model data should obtain error of less than 10% between the experimental data, which would indicate a very good fit data for practical applications.

Table 3. Model parameters for respiration rate using uncompetitive Michaelis-Menten equation model for *dabai* fruits stored in nylon, PET, and LDPE films.

		V_m (mL/kgh)	K_m (%)	K_i (%)	R^2	E (%)
Nylon	O_2	0.23	0.82	3.88	0.992	0.93
	CO_2	0.21	0.80	2.10	0.994	0.40
PET	O_2	0.29	0.43	2.75	0.990	0.81
	CO_2	0.30	0.65	2.21	0.996	0.77
LDPE	O_2	0.16	0.55	1.87	0.993	0.34
	CO_2	0.15	0.62	1.62	0.995	0.44

Conclusion

There were no changes in *L** and hue angle throughout storage days or between films, although there were changes in chroma value throughout storage days. The slight changes in the physical colour of *dabai* could have been due to the different film permeability and inconsistency of the relative humidity during storage. Even so, the hue angle readings remained in the dark purple region range, approximately 299.73° to 338.64° from the initial to the end of storage days. The control sample had a significant decrease in firmness, and immense weight loss ($p < 0.05$) between day 0 and 14 as compared to the packed samples. As a result, the consumers' acceptance rate of the product might have decreased due to the decrease in quality. *Dabai* stored in LDPE film had the least difference (1.05%) in O_2 concentration from the beginning to the end of the storage hours as compared to nylon and PET films, which obtained a 4.46 and 3.39% of O_2 concentration difference, respectively. In correspondence to the O_2 and CO_2 gaseous exchange (%), LDPE recorded the lowest initial respiration rate with 2.51 and 2.04 mL/kgh of O_2 consumption and CO_2 production, respectively. This proved that despite the high OTR value of LDPE film, its gas permeability property was excellent in optimising the respiration activity of *dabai* as compared to nylon and PET films. Furthermore, nylon film showed good moisture permeability as it maintained firmness, and minimised fresh weight loss of the samples. Modelling parameters obtained using the uncompetitive Michaelis-Menten equation model showed good fit (R^2 close to 1) between the experimental and modelled data for all of the films tested. Furthermore, the E values were less than 10%, thus indicating that the data were good for practical application. The findings obtained in the present work can benefit the fresh fruit industries, especially to minimise quality loss in the storage and packaging of *dabai* for transportation, be it for local or export purposes.

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