International Food Research Journal 20(6): 3033-3040 (2013)
Journal homepage: *http://www.ifrj.upm.edu.my*

Physico-chemical changes in dabai (*Canarium odontophyllum* Miq.) fruit during modified atmosphere storage

*Ding, P. and Diana, J.

Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

Article history

Received: 10 May 2013
Received in revised form: 11 July 2013
Accepted: 12 July 2013

Keywords

Firmness
Polyethylene bag
Respiration rate
Soluble solids concentration
Weight loss

Abstract

Dabai or *Canarium odontophyllum* Miq., from the family Burseraceae, is an important indigenous fruit to Borneo Island. However, it is a highly perishable fruit with short shelf life. Postharvest technology such as modified atmosphere packaging (MAP) can be used to maintain highly perishable fresh fruit quality and increase its shelf life. There is not much work has been carried out to study effect of MAP on dabai fruit. Therefore, this study was conducted to determine the effect of four different types packaging methods on the postharvest quality of dabai fruits. Total of 240 fruit were used for each replication and the experiment was repeated thrice. Fruit were divided equally into four groups with each group packed in low-density polyethylene plastic bag, low-density polyethylene plastic bags lined with tissue paper, low-density polyethylene plastic bag with vacuumed and control (unwrapped). The fruit were then stored in a cold room of 10°C for 8 days. The fruits were analyzed for peel and flesh colour (L^*, C^* and hue angle), CO_2 and C_2H_4 production, weight loss, firmness, soluble solids concentration (SSC), titratable acidity (TA) and pH at every two days interval. Data were analyzed using analysis of variance and means was separated using Duncan's multiple range tests. The use of MAP retained peel colour (L^*, C^* and hue angle values), flesh colour (L^* values), SSC and TA of dabai fruit. The CO_2 production in MAP fruit was significant lower than control. Although vacuum packed showed lowest weight loss, flesh discolouration, soggy texture and foul sour odour developed during 8 days of storage. Neither packing dabai fruit in low-density polyethylene plastic bag nor bag lined with tissue paper retained better fruit quality. Thus, it is recommended packing dabai fruit in low-density polyethylene plastic bag is sufficient to retain fruit quality during 8 days of storage at 10°C.

Introduction

Dabai (*Canarium odontophyllum* Miq.) which belongs to Burseraceae family is indigenous fruit from Borneo Islands (Kueh, 2003). The ripe fruit has dark purple thin skin and oblong in shape (3.5 – 4 cm long and 2.0 – 2.5 cm side) (Ding and Tee, 2011). The flesh of ripe fruit is white or yellow with 0.4 – 0.7 cm thick and covers a single large three-angled seed. Since the fruit resembles olive, therefore it is also known as tropical olive or Sibu olive by the locals. Dabai is very nutritious and high in phenolic compounds (Chew *et al.*, 2012). The way of eating this fruit is rather unique where steeping fruit in lukewarm water is needed to soften the flesh before eating with salt and/or sugar (Ding and Tee, 2010).

The respiration rate of dabai fruits is very high with 1411.6 ± 218.73 ml/kg/h at 20°C (Ding and Tee, 2011) and this probably causes the fruit only last for about 2 days after harvest (Lau and Fatimah, 2007). When dabai fruits exposed to 27°C for 2 days, the fruits shrink, shrivel and loose its quality (Jugah, 2006). Due to its short shelf life, the marketing life of dabai has been constrained. It also limits the fruit's market potential, mainly in terms of distribution to local and overseas markets. Since dabai is an extremely perishable commodity, proper postharvest handling is essential to maintain the fruit quality. Among the postharvest technologies available for maintaining fruit quality is by packing and storing the fruits at low temperature.

Modified atmosphere packaging (MAP) is a technique of sealing actively respiring produce in polymeric film packages to modify the O_2 and CO_2 levels within the package atmosphere (Mangaraj *et al.*, 2009). MAP has the advantage of low cost and easy implementation at commercial levels (Flores *et al.*, 2004). According to Ding *et al.* (2002) simple MAP can maintain fresh fruit quality and increase its shelf life. The red colour of rambutan stored under MAP at 8°C retained better than control (Mohamed and Eshah, 1988). MAP can also retain flesh colour of ciku fruit that stored at 10°C for 2 weeks (Mohamed *et al.*, 1996). Besides retaining peel and

*Corresponding author.
Email: *phebe@upm.edu.my / phebeding@hotmail.com*
Tel: +603 8947 4829; Fax : +603 8940 8445

flesh colour, a significant reduction in weight loss has been reported in MAP applied litchi (Somboonkaew and Terry, 2010). For the firmness, it is reported that film wrapped pomegranate has higher firmness than control throughout storage period (Nanda *et al.*, 2001).

According to Patricia *et al.* (2006), MAP has the ability to reduce respiratory activities inside the packages due to the inhibition of fruit respiration rate caused by the low O_2 and high CO_2 levels that MAP creates. MAP not only control respiration rate of fruit, but also decrease the intensity of catabolic activity and degradation processes (Lougheed, 1987). Since MAP lowers the respiration rates of fruit, the soluble solids concentration of MAP fruits are expected to be higher than those without MAP, but it also depends on the behaviour and type of the fruit as well as storage conditions (Mangaraj *et al*., 2009). MAP can also affect the pH and titratable acidity (TA) levels in fruits. According to Mortazavi *et al.* (2007), MAP was most effective in maintaining the TA of date fruit during 20 days of storage at 4°C. The control fruit showed significant increase in TA.

In MAP industry, there is an increasing choice of packaging films, however, most films are made from four basic polymers, which are polyvinyl chloride, polyethylene terephthalate, polypropylene and polyethylene (Mangaraj *et al*., 2009). Low-density polyethylene is the most commonly used packaging film for fruits and vegetables. It has many advantages which among them are, it is a soft, flexible and easy to seal, relatively transparent, light weight and has a high ratio of CO_2 and O_2 permeability. Highly perishable and high-value commodities are commonly packaged in sealed packs made from low-density polyethylene bags and vacuum packaging. Although there are numerous reports stated that low-density polyethylene packaging reduces decay development, there are others who have reported that packaging in films did increase decay development due to water condensation inside the packaging and induce secondary infection (Ben-Yehoshua, 1985). Therefore, absorbent materials such as tissue papers are placed inside the packaging together with the fruit to absorb excess moisture. Meir *et al.* (1995) reported that packaging of red pepper fruit using perforated polyethylene lined with three tissue papers could maintain the fruit quality during 14 days of storage at 7.5°C.

Another type of MAP is vacuum pack. The produce is placed in a pack made from film of low O_2 permeability such as low-density polyethylene film and air is evacuated, then the package is sealed. As a result, the film collapse around the produce because the pressure inside is lower than the atmospheric pressure outside the pack (Geetha and Thirumaran, 2010). This type of packaging is widely used for packaging oxygen-sensitive products. Geetha and Thirumaran (2010) reported that papaya packed under vacuum in polyethylene bags was more effective in prolonging its shelf-life with minimum changes in chemical composition. Apparently, the critical evaluation of different packaging materials and methods for storage stability is crucial to avoid postharvest losses (Khan *et al*., 2007). However, there are limited reports about the use of MAP for fresh dabai fruit. Hence, the objective of this study was to determine the effect of different packaging methods on the quality of dabai fruit during storage.

Materials and Methods

Raw materials

Mature dabai fruits were obtained from a market located at third mile Kuching, Sarawak. Initially, the fruits were harvested early in morning from a farm in Sibu, Sarawak and transported to Kuching by express boat. The duration from Sibu to Kuching took about 4 h by express boat and another hour to reach the market. Fruits that were uniformed in size and colour as well as defect and diseased-free were selected. The fruits were then kept at 7°C for 10 h before transporting to Universiti Putra Malaysia (UPM) by airplane which took about 2 h. The duration from airport terminal to UPM is about 1 h. Upon arrival at UPM, the dabai fruit were kept in a cold room of 10°C.

The experiment was arranged as a randomized complete block design. Fruit (n = 240) were divided equally (n = 60) into four groups. Each group of fruit was subdivided into five lots with each lot consisted of 12 fruit. Each lot of the first group fruit was then placed in low-density polyethylene plastic bags and sealed using a hand-operated heat sealer. Similarly, the five lots of second group fruit were also placed in low-density polyethylene plastic bag but it was lined with a layer of kitchen paper (tissue paper) and sealed using a hand-operated heat sealer. The five lots of third group fruit were also placed in low-density polyethylene plastic bags and the air in each bag was sucked out using a household vacuum cleaner (Electrolux Lite Model Z/650, Malaysia). After vacuumed, the bags were immediately sealed using a hand-operated heat sealer. The last group of fruit remained unwrapped and used as control. After dividing into five lots as other treatment, each lot of the fruit was placed in a plastic basket with a diameter of 21 cm and depth of 8.5 cm. The thickness of low-density polyethylene bags used in the study was 0.04

mm with size of 20.32 cm x 30.48 cm.

Fruits were stored at 10°C with 90% relative humidity and sampled on 0, 2, 4, 6 and 8 days. For each out-turn, a lot of fruit from each treatment were individually weighed and processed. Fruit were analyzed for their peel and flesh colour, CO_2 and C_2H_4 production, weight loss, firmness, titratable acidity (TA), soluble solids concentration (SSC) and pH.

Peel and flesh colour determination

Peel and flesh colour of dabai fruits were determined using a Minolta CR-400 chroma meter (Minolta Corp., Japan). The chroma meter was equipped with a measuring head that has an 8 mm-diameter measuring area and was calibrated with a standard white tile. The calibration value was $L^* = 97.95$, $a^* = -0.07$, $b^* = 1.66$ using the illumination C.

The values of lightness (L^*), red-green axis (a^*) and yellow-blue axis (b^*), which represent coordinates in colour chart indirectly, reflect chroma (C^*) and hue angle (h°). The L^* coordinates indicate the lightness, which form the vertical axis values ranging from 0 = black to 100 = white. The C^* which refers to the vividness of colour was computed from values of a^* and b^*. The hue angle which refer to colour was the angle of tangent b^*/a^*. Three measurements at the mid region of a dabai fruit were taken and the mean value was obtained. Results of the colour determination were expressed in chromaticity values L^*, C^* and hue angle.

CO_2 and C_2H_4 production determination

One milliliters of gas was withdrawn directly from fruit packed in polyethylene plastic bag, polyethylene plastic bag lined with tissue paper and vacuumed polyethylene plastic bag at every sampling day. For control, a fruit was incubated for 4 h at storage temperature (10°C) in a 1900 mL air-tight container. Headspace gas was sampled with a 1.0 mL syringe and the gas was analyzed using a gas chromatography (Clarus 500, Pekin Elmer, Shelton, USA) with 25 mL min^{-1} of flow rate. The gas chromatography was equipped with a flame ionization detector and thermal conductivity detector with a stainless steel Porapak Q Column (3 m x 3.125 mm, 50/80 mesh) and nitrogen (flow rate 48 mL min^{-1}) was used as the carrier gas. Gas was withdrawn 3 times from each treatment and means were taken.

Weight loss determination

Fruit was weighed using a digital weighing scale. Weight loss during storage was determined by weight difference at day 0, 2, 4, 6, 8 compared with day 0, and expressed in percentage. After determining fruit weight, they were repacked according to its initial treatment and transferred into the cold room again.

Flesh firmness determination

The flesh firmness of the dabai fruit was evaluated by using a computer controlled Instron 5543 Material Testing Machine (USA). Samples were subjected to puncture test at a constant speed of 4 mm min^{-1}, using a 5 mm diameter plunger probe. Force deformation curves were recorded and firmness (as represented by the slope N mm^{-1} of linear section of the force-deformation curve) was used as the indicator of textural property. Three measurements were taken from the mid region of a fruit for each treatment and total of 3 fruits from each treatment was used.

Titratable acidity (TA) determination

The TA of the fruit was determined by slicing out 10 g of the fruits. Then, 40 mL of distilled water was added to the 10 g of fruit and were blended in a high-speed blender (Panasonic MX 799S) for 60 s. The macerate was filtered with cotton wool and the filtrate was filtered again with filter paper (Whatman No. 1) into a conical flask. Next, 5 mL of filtrate was titrated with 0.1M sodium hydroxide. The filtrate was titrated until it reaches pH 8.2. From the titrated value, the percentage of citric acid was calculated as follows:

$$\% \text{ Titratable acidity (TA)} = [(\text{mL NaOH x 0.1 mL/ weight of sample titrated) x 0.64}]$$

Soluble solids concentration (SSC) determination

The SSC of fruits was determined by using a hand refractometer (Atago N-1E, JAPAN). A drop of the extracted juice from the remainder of TA determination was then placed on the prism glass of refractometer to obtain the %SSC reading. The readings were then corrected to a standard temperature of 20°C by adding 0.28% to obtain %SCC at 27°C. The percentage of SSC was calculated as follows:

$$\% \text{ SSC} = (\text{Refractometer reading x dilution factor}) + 0.28$$

pH determination

The remaining filtrate from the SSC determination was used to measure the pH of the filtrate by using the glass electrode pH meter (Crison pH Meter GLP 21). The pH meter was calibrated with a buffer at pH 4.0 and 7.0 before being used.

Statistical analysis

The experimental design was a randomized complete block design with 3 replications. Data was analyzed by using General Linear Model (GLM). When the F values of GLM showed significance (P

≤ 0.05), Duncan's multiple range test (DMRT) was used to separate the means using Statistical Analysis System (SAS Institute, Cary, N. C., 1989). A correlation analysis by means of Pearson's correlation matrix was performed to establish the association between quality characteristics of dabai fruits.

Results and Discussion

Peel and flesh colour changes

There was no significant interaction found between packaging methods and storage days on the peel and flesh colour of fresh dabai fruits (Table 1). Packaging methods did not affect L*, C* and hue angle of dabai fruit peel. A similar finding was reported by Van *et al.* (2002), where no significant differences were detected in the peel colour of strawberry and raspberry fruits using four different types of MAP. The retention of fruit colour indicated dabai fruit did not show advanced stages of ripening after wrapping with different types of packaging methods.

Storage days affected the L* values of dabai fruits peel significantly (Table 1). The L* values dropped significantly by 26% when fruit stored from day 0 to 2. However, at day 8, the L* values significantly rose to 29.98. This finding is similar to the work of Meheriuk *et al.* (1995) where the L* values of 'Lapin' sweet cherry packed in MAP for 10 weeks decreased at the week 2, then increased to values found at harvest until week 8 and 10. However, Somboonkaew and Terry (2010) found out the L* and C* values of litchi cv. Mauritius pericarp in control (unwrapped), perforated polypropylene (PP), PropaFresh™ PFAM (PF), NatureFlex™ NVS and Cellophane™ WS decreased during 9 days storage. The decrease of litchi L* values was significantly affected by the increased fruit weight loss. But this was different with present study where no significant correlation was found between peel L* values and weight loss (Table 2). Even though the L* values of the peel of the dabai fruit changed during storage, all the readings (L*, C* and hue angle) of peel colour during storage days still indicated that the fruits were in dark purple. This showed that the pigments of dabai fruit are stable even after 8 days of storage.

For flesh colour, packing methods did not have any effect on L* values but significant effect was found on C* and hue angle. Fruit packed in low-density polyethylene plastic bags have higher values of C* than fruit packed in vacuumed and those without packing (control). The hue angle of dabai fruit flesh packed in low-density polyethylene plastic bags lined with tissue paper was higher than vacuumed packed fruit. The hue angle of vacuumed packed dabai fruit flesh was 74.33° (yellowish red colour) which might due to the dissolved anthocyanin from the peel into flesh. The peel of dabai fruit contains anthocyanin (Khoo *et al.*, 2012) and anthocyanin has water-soluble property (Marcin *et al.*, 2008), thus the pigment has most likely caused flesh discolouration in vacuumed packed fruit. This showed that the vacuumed packaging is not suitable for dabai fruit.

Table 1. Main and interaction effects between packaging methods and days on peel and flesh colour (L*, C* and h°) of dabai fruits during 8 days of storage at 10°C

	Peel colour			Flesh colour		
Factors	L*	C*	h°	L*	C*	h°
Packaging methods (P)						
PE	26.51 a[z]	2.05 a	286.05 a	68.23 a	32.23 a	82.32 ab
PE lined with tissue paper	26.34 a	2.05 a	283.02 a	65.25 a	26.05 ab	88.34 a
PE with vacuumed	26.00 a	1.75 a	284.81 a	60.23 a	23.85 b	74.33 b
Control	25.27 a	1.86 a	282.80 a	63.77 a	24.50 b	82.39 ab
Storage days (S)						
0	31.51 a	1.69 b	286.73 a	66.04 a	28.09 a	82.38 a
2	23.16 b	1.81 b	273.98 a	65.65 a	25.46 a	85.68 a
4	22.16 b	1.20 b	271.28 a	62.92 a	25.47 a	82.88 a
6	23.31 b	1.84 b	288.22 a	58.98 a	24.19 a	81.66 a
8	29.98 a	3.12 a	300.63 a	68.26 a	30.06 a	76.64 a
Interaction						
P x S	ns	ns	ns	ns	ns	ns

PE = Low-density polyethylene plastic bag, L* = lightness, C* = chroma and h° = hue angle
[z]For each treatment, means within a column followed by the same letter are not significantly different by DMRT at P ≤ 0.05.
ns Non significant at P ≤ 0.05.

Table 2. Correlation coefficients (r) for peel L*, firmness, weight loss, soluble solids concentration, pH and titratable acidity of dabai fruit stored using four different packaging methods at 10°C for 8 days

	Peel L*	Firmness	Weight Loss	Soluble solids concentration	pH	Titratable Acidity
Peel L*	-					
Firmness	0.098	-				
Weight Loss	-0.23	-0.13	-			
Soluble solids concentration	-0.17	-0.60**	-0.062	-		
pH	-0.23	0.34*	0.027	-0.36*	-	
Titratable Acidity	0.12	-0.32*	-0.11	0.60**	-0.40*	-

n = 60
*,** significant at P ≤ 0.05 or highly significant at P ≤ 0.01, respectively.

Table 3. Main and interaction effects between different packaging methods and days on CO_2 and C_2H_4 productions, weight loss, firmness, soluble solids concentration (SSC), titratable acidity (TA) and pH of fresh dabai fruits during 8 days of storage at 10°C

Factors	CO_2 (mL/kg/h)	C_2H_4 (µL/kg/h)	Weight loss (%)	Firmness (N)	SSC (%SSC)	TA (%)	pH
Packaging methods (P)							
PE	43.671 b[z]	0.007 a	0.47 c	151.43 a	6.18 a	0.21 a	5.37 a
PE lined with tissue paper	50.022 b	0.022 a	0.88 b	163.32 a	6.21 a	0.22 a	5.61 a
PE with vacuumed	44.122 b	0.008 a	0.10 d	109.48 b	7.35 a	0.24 a	5.39 a
Control	82.569 a	nd[y]	2.57 a	142.77 a	6.36 a	0.22 a	5.38 a
Storage days (S)							
0	156.712 a	nd	0.00 c	185.29 a	5.47 b	0.22 bc	5.36 b
2	59.839 b	0.021 a	1.35 ab	150.19 b	5.71 b	0.21 bc	5.82 a
4	28.436 c	0.019 a	1.29 ab	147.87 b	5.74 b	0.19 c	5.54 b
6	13.393 c	0.004 b	1.02 b	124.03 bc	7.91 a	0.23 b	5.36 b
8	17.102 c	0.002 b	1.37 a	101.37 c	7.79 a	0.27 a	5.10 c
Interaction							
P x S	ns	ns	**	ns	ns	ns	*

PE = Low-density polyethylene plastic bag
[z]For each treatment, means within a column followed by the same letter are not significantly different by DMRT at P ≤ 0.05.
[y]nd = non-detectable
ns, *,** Non significant or significant at P ≤ 0.05 or highly significant at P ≤ 0.01, respectively.

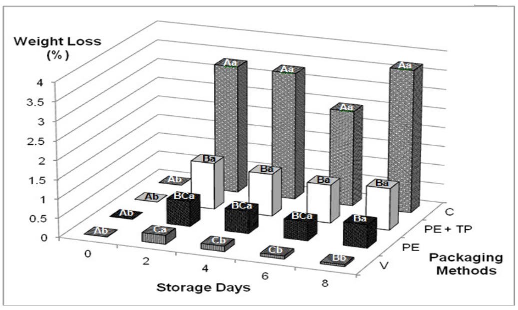

Figure 1. Effects of packaging materials and storage days on weight loss of dabai fruit. Different letters on a bar indicate significant differences ($P \leq 0.05$, DMRT) for storage days (lowercase letters) and packaging methods (uppercase letters). C = control, PE = low-density polyethylene plastic bag, V = PE with vaccumed, PE + TP = PE lined with tissue paper.

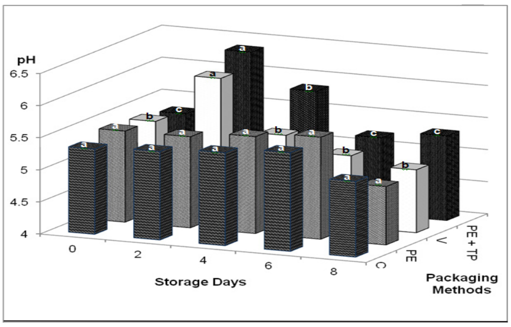

Figure 2. Effects of packaging materials and storage days on pH of dabai fruit. Different letters on a bar indicate significant differences ($P \leq 0.05$, DMRT) for storage days. C = control, PE = low-density polyethylene plastic bag, V = PE with vaccumed, PE + TP = PE lined with tissue paper.

Physiological changes

There was no significant interaction between packaging methods and storage days on CO_2 and C_2H_4 production of dabai fruit (Table 3). However, packaging methods and storage days affected the production of CO_2 production. MAP fruit has significant lower CO_2 production as compared to control fruit (Table 3). This reflected low-density polyethylene plastic bag used in this study has reduced respiration rate of dabai fruit. With low respiration rate, all metabolic processes of fruit proceed at a slower rate, thus, the fruit can be stored for longer period.

At day 0, dabai fruit showed high respiration rate and decreased significantly as storage days progressed. By storage day 4, the respiration rate leveled off. Most probably the steady-state atmospheres have been achieved by MAP after 4 days of storage. For yellow and purple plum, the steady-state atmosphere was achieved after 7 days at 2°C (Diaz-Mula *et al.*, 2011). It seems cultivar and storage condition affected the achievement of steady-state atmosphere in MAP.

Ethylene production of dabai fruit was not affected by packaging methods but was significantly affected by storage days (Table 3). Ethylene was being detected in MAP dabai fruit while no C_2H_4 was found in control fruit. The presence of C_2H_4 in MAP could due to enclosed environment and gasses being accumulated in sealed bag. The failure to detect any C_2H_4 in control fruit could due to insensitivity of gas chromatography used in this study to determine low C_2H_4 concentration. Another reason for the failure may due to physiological characteristics of dabai fruit that did not produce any C_2H_4 when stored at 10°C.

At day 0, no C_2H_4 was being detected and the fruit showed sudden increase in C_2H_4 by day 2 and maintained high for another 2 days. After storage day 4, the C_2H_4 production decreased significantly. Sudden increase in C_2H_4 production has been associated with climacteric fruit ripening. However, there is not much of works has been carried out to study the physiological characteristics of dabai fruit. Until present, it is still not clear whether dabai is classified as a climacteric or non-climacteric fruit. Both studies carried out by Ding and Tee (2010 and 2011) who collected dabai fruit from two different regions in Borneo Island with 600 km apart, found out the dabai fruit from both regions has similar pattern of response towards exogenous C_2H_4. When induced with exogenous C_2H_4, the CO_2 production rate of dabai fruit increased tremendously while endogenous C_2H_4 decreased sharply as compared to non-C_2H_4 induced fruit. The CO_2 and C_2H_4 production of dabai was 1411 ml CO_2/kg/h and 4.56 µl C_2H_4/kg/h at 20°C (Ding and Tee, 2011). In present study, dabai fruit that stored in 10°C showed much lower CO_2 and C_2H_4 production (Table 3) as compared to those stored at 20°C as reported by Ding and Tee (2011). Also, although control (unwrapped) dabai fruit has been incubated for 4 h, no C_2H_4 was detected. Obviously low temperature is able to reduce dabai fruit respiratory processes and suppressed enzymes activities that involve in C_2H_4 biosynthesis pathway. Ethylene plays a very important role in accelerating or retarding ripening and senescence of fruit (Pandey *et al.*, 2000). Thus, low C_2H_4 production in the present study is beneficial to dabai fruit.

Weight loss changes

There was significant interaction between packaging methods and storage days on weight loss of dabai fruit (Table 3). Control (unwrapped) fruit showed highest weight loss with average of 3.2% after 2 days of storage among packaging methods (Figure 1). This followed by fruit packed in low-density polyethylene plastic bag and plastic bag lined with tissue paper; while vacuumed packed fruit showed the lowest weight loss with average of 0.1%. As storage days progressed, only vacuumed packed fruit showed significant decrease in weight loss from day 2 to 4. Fruit in the rest of packaging methods did not show significant decrease of weight loss as storage days progressed from day 2 to 8. Jugah (2006) reported that dabai fruits packed in polyethylene bag showed lowest (1.2%) weight loss compared to those packed in newspaper (16.8%) and unwrapped (20%) after being kept at 14°C for 8 days. In the present study, the weight loss was much lower than those reported by Jugah (2006). This could probably due to differences in film permeability, storage temperature and relative humidity used in the study.

Increases in weight loss over storage time have also been reported in many other MAP applied fruits such as litchi cv. Mauritius (Somboonkaew and Terry, 2010), Honoeye and Korona strawberries (Nielsen and Leufven, 2008) and, peaches and nectarines (Akbudak and Eris, 2004). Weight loss can be associated with loss of quality, such as reduced firmness and other undesirable changes in colour, palatability and loss of nutritional quality. Weight is lost as water vapour from the internal air spaces within the fruit (intercellular spaces) to the surrounding atmosphere (Mitchell, 1986). There is a lot of opening spore distribute randomly on the peel surface of dabai fruit (Ding and Tee, unpublished data). This could explain high weight loss and finally lead to shriveling in control (unwrapped) fruit. This phenomenon did not happen to MAP applied dabai fruit indicating polyethylene bag has barred the loss of moisture from fruit to storage room.

Firmness changes

The flesh firmness of dabai fruit was affected by packaging methods where fruit packed in vacuumed was softer than other packaging methods (Table 3). A soggy texture was found in the vacuumed packed fruit (unpublished data) in addition to flesh discolouration as reported in earlier part of this article. On top of this, the fruits also emitted a foul sour odour (unpublished data). The softening, foul sour odour and flesh discolouration of vacuum packed dabai fruit could due to low O_2 levels in the packaging and that lead to fermentative metabolism (Mikal, 2004). Fruit quickly used up the limited O_2 in the packaging and finally leads to anaerobic respiration. When respiratory gas exchange through fruit peels is excessively impaired, off-odours and flavours may develop as fruit ferment (Banks *et al*., 1997).

During 8 days of storage, the flesh firmness of dabai fruit decreased by 45% (Table 3). This indicated that the firmness of the fruits declined as storage days progressed. This finding is similar to 'Hass' avocadoes who reported the firmness of either unwrapped or wrapped with perforated bags had reduced after 5 weeks of storage at both temperatures of 5 and 7°C (Meir *et al*., 1997). The softening of fruit and vegetable texture is due to many factors such as loss in cell turgor pressure and the degradation of cell wall constituents and polysaccharides (Rungsinee and Patratip, 2008). Firmness of papaya showed strong significant correlation (r = -0.87) with weight loss (Ding and Ng, 2008). However, for dabai fruit, there was no significant correlation between firmness and weight loss (Table 2). This indicated weight loss of dabai fruit did not contribute to softening. The softening of dabai fruit as storage days progressed may due to cell wall degradation.

SSC and TA changes

The SSC and TA of dabai fruit was not affected by packaging methods (Table 3). This result showed that MAP did not alter SSC and TA of dabai fruit. The SSC and TA are major chemical compositions affecting flavor of fruit. The insignificant change in chemical composition of dabai fruit indicated fruit flavor can be retained by using MAP. In litchi, although the total sugar was not affected by packaging treatment, the total acid concentration was significantly higher in fruit packed with PF and PP films (Somboonkaew and Terry, 2010). In MAP loquat fruit, non-perforated polyethylene bags retained higher amount of organic acids than those packed in perforated polyethylene bags (Ding *et al*., 2002). Plums stored under MAP showed lower increase of SSC and decrease of TA as compared to control (Diaz-Mula *et al*., 2011). It seems response of fruits towards MAP is cultivar and films type dependent.

Although MAP did not affect SSC and TA of dabai fruit, these chemical compositions was affected significantly by storage days (Table 3). During initial stage of storage, there was no change in SSC, but after 4 days of storage, the SSC increased significantly and remained high until day 8. The increase of SSC as storage days progressed could be due to the breakdown of polysaccharides into water soluble sugar, thus, increased the SSC values of dabai fruit. Similar to SSC, TA of dabai fruit increased significantly as storage days progressed and achieved highest TA values by day 8. The increase of TA value during storage was uncommon to most of the fruit. Usually fruit TA decrease as storage day progressed due to oxidation of organic acids and further utilization in metabolic process in fruit (Hafeez *et al*., 2012). The increase of TA in dabai fruit during storage indicated organic acids being accumulated in fruit and not being used for metabolic processes. This was contrary to results of SSC where breakdown of polysaccharides has occurred (a kind of metabolic process). Furthermore, correlation analysis showed that there was significant positive correlation between SSC and TA (r = 0.60) of dabai fruit (Table 2) indicating SSC increase with TA. Unfortunately, the current literature on dabai fruit is too scarce to explain the unusual behavior of this fruit during storage.

pH changes

There was significant interaction between packaging methods and storage days on pH of dabai fruit (Table 3). The pH of fruit packed in vacuumed and low-density polyethylene plastic bag lined with tissue paper showed significant increase when fruit stored from day 0 to 2, then followed by significant decrease (Figure 2). This did not happen in fruit packed using polyethylene plastic bag and control (unwrapped). This result showed that packing dabai fruit using low-density polyethylene plastic bag lined with tissue paper and vacuum affect its metabolic processes during storage. The increase in fruit pH indicated that more ion hydrogen was being released from the fruits, due to the high metabolic processes at the beginning of storage as compared to the later stage of storage period (Figure 2). The non-significant changes in dabai fruit pH that packed using low-density polyethylene plastic bag and control indicated these fruit did not encounter changes in metabolic process during storage.

Conclusions

Results indicated that vacuum packing showed lowest weight loss, but flesh discolouration, soggy texture and foul sour odour developed during 8 days of storage. Thus, it is not suitable for packing dabai fruit. Neither low-density polyethylene plastic bag nor those lined with tissue paper could retain peel and flesh colour, firmness, SSC, pH, TA and reduce weight loss of dabai fruit during storage. In terms of practicability, it is much easier and cheaper to pack dabai fruit in low-density polyethylene plastic bag as compared to packing fruit in bag lined with tissue paper.

References

Akbudak, B. and Eris, A. 2004. Physical and chemical changes in peaches and nectarines during the modified atmosphere storage. Food Control 15: 307-313.

Banks, N. H., Cutting, J. G. M. and Nicholson, S.E. 1997. Approaches to optimizing surface coatings for fruits. New Zealand Journal of Crop and Horticultural Science 25: 261-272.

Ben-Yehoshua, S. 1985. Individual seal-packaging of fresh fruit and vegetables in plastic film – a new postharvest technique. HortScience 20: 32-37.

Chew, L.Y., Khoo, H.E., Amin, I., Azrina, A. and Lau, C.Y. 2012. Analysis of phenolic compounds of dabai (*Canarium odontophyllum* Miq.) fruits by high-performance liquid chromatography. Food Analytical Methods 5: 126-137.

Diaz-Mula, H.M., Martinez-Romero, D., Castillo, S. Serrono, M. and Valero, D. 2011. Modified atmosphere packaging of yellow and purple plum cultivars. 1. Effect on organoleptic quality. Postharvest Biology and Technology 61: 103-109.

Ding, C-K., Chachin, K., Ueda, Y., Imahori, Y. and Wang, C.Y. 2002. Modified atmosphere packaging maintains postharvest quality of loquat fruit. Postharvest Biology and Technology 24: 341-348.

Ding, P. and Ng, S.B. 2008. Effects of 1-methylcyclopropene on the postharvest life of Eksotika papaya. Journal of Applied Horticulture 10: 123-128.

Ding, P. and Tee, Y.K. 2010. Application of exogenous ethylene on postharvest quality of dabai (*Canarium odontophyllum* Miq.) fruit. African Journal of Agricultural Research 5: 3483-3492.

Ding, P. and Tee, Y.K. 2011. Physicochemical characteristics of dabai (*Canarium odontophyllum* Miq.) fruit. Fruits 66: 1-6.

Flores, F.B., Martínez-Madrid, M.C., Amor, M.B., Pech, J.C., Latché, A. and Romojaro, F. 2004. Modified atmosphere packaging confers additional chilling tolerance on ethylene-inhibited cantaloupe charentais melon fruit. European Food Research Technology 219: 431-435.

Geetha, P. and Thirumaran, A.S. 2010. Increasing shelf life of papaya through vacuum packaging. Acta Horticulturae 851: 527-532.

Hafeez, O., Malik, A.U., Khan, A.S., Rehman, A. and Javaid, Q.A. 2012. Impact of different packaging types and low temperature shipping durations on fruit quality and marketability of Pakistani mangoes. International Journal of Agricultural and Biology 14: 47-54.

Jugah, D.J. 2006. Study on the effect of packaging and temperature on improving the shelf life of Dabai (*Canarium odontophyllum*). Paper presented at Research Officers' Meeting, 7 – 9 September 2006, Kuching, Sarawak.

Khan, D., Khan, R.A., Bibi, S., Ali, S. and Khalil, I.A. 2007. Storage storability of persimmon fruits (*Diospyros kaki*) stored in different packaging methods. Journal of Agricultural and Biological Science 2: 20-23.

Khoo, H.E., Azlan, A., Ismail, A. and Abas, F. 2012. Antioxidative properties of defatted dabai pulp and peel prepared by solid phase extraction. Molecules 17: 9754-9773.

Kueh, H.S. 2003. Indigenous Fruits of Sarawak. Sarawak: Lee Miing Press Sdn. Bhd.

Lau, C.Y. and Fatimah, O. 2007. Cold storage of dabai fruit (*Canarium odontophyllum* Miq.): Effect of packaging methods and storage duration on quality. Paper presented at the Sarawak Fruit Seminar, 8-9 August 2007, Sibu, Sarawak.

Mangaraj, S., Goswami, K. and Mahajan, P.V. 2009. Applications of plastic films for modified atmosphere packaging of fruits and vegetables. Food Engineering Review 1: 133-158.

Marcin, H., Ryszard, K., Anna, G. and Henryk, D. 2008. Anthocyanins of fruits and vegetables-their occurrence, analysis and role in human nutrition. Vegetable Crops Research Bulletin 68: 5-22.

Meheriuk, M., Girard, B., Moyls, L., Beveridge, H.J.T., Mc Kenzie, D.L. Harrison, J., Weintraub, S. and Hocking, R. 1995. Modified atmosphere packaging of 'Lapins' sweet cherry. Food Research International 28: 239-244.

Meir, S., Akerman, M., Fuchs, Y. and Zauberman, G. 1995. Further studies on the controlled atmosphere storage of avocados. Postharvest Biology and Technology 5: 323–330.

Meir, S., Naiman, D., Miriam, A., Julian, Y.H., Giora, Z. and Yoram, F. 1997. Prolonged storage of 'Hass' avocado fruit using modified atmosphere packaging. Postharvest Biology and Technology 12: 51-60.

Mikal, E.S. 2004. Respiratory metabolism. US: University of California, Davis.

Mitchell, F.G. 1986. Influence of cooling and temperature maintenance on the quality of Californian grown stone fruit. International Journal of Refrigeration 11: 77-81.

Mohamed, S. and Eshah, O. 1988. Effect of packaging and modified atmosphere on the shelf life of rambutan (*Nephelium lappaceum*). Pertanika 11: 217-228.

Mohamed, S., Taufik, B. and Harim M.N.A. 1996. Effects of modified atmosphere packaging on the physicochemical characteristics of ciku (*Achras sapota* L.) at various storage temperatures. Journal of the Science of Food and Agriculture 70: 231-240.

Mortazavi, S.M.H., Arzani, K. and Barzegar, M. 2007. Effect of vacuum and modified atmosphere packaging on the postharvest quality and shelf life of date fruits in khalal stage. Acta Horticulturae 736: 471-477.

Nanda, S., Suhakar, R.D.V. and Shantha, K. 2001. Effects of shrink film wrapping and storage temperature on the shelf life and quality of pomegranate fruits cv. Ganesh. Postharvest Biology and Technology 22: 61-69.

Nielsen, T. and Leufven, A. 2008. The effect of modified atmosphere packaging on the quality of Honeoye and Korona strawberries. Food Chemistry 107: 1053-1063.

Lougheed, E.C. 1987. Interactions of oxygen, carbon dioxide, temperature, and ethylene that may induce injuries in vegetables. HortScience 22: 791–794.

Pandey, S., Ranade, S.A., Nagar, P.K. and Kumar, N. 2000. Role of polyamines and ethylene as modulators of plant senescence. Journal of Bioscience 25: 291-298.

Patrícia, C, Eliane, A.B., José, M.M.S., Claire, S., Léa, M. O. and Marisa, P. 2006. Modified atmosphere packaging for extending the storage life of 'Fuyu' persimmon. Postharvest Biology and Technology 42: 228-234.

Rungsinee, S. and Patratip, R. 2008. Effect of a mango film on quality of whole and minimally processed mangoes. Postharvest Biology and Technology 47: 407-415.

Somboonkaew, N. and Terry, L.A. 2010. Physiological and biochemical profiles of imported litchi fruit under modified atmosphere packaging. Postharvest Biology and Technology 56: 246-253.

Van, D.S.C., Jacxsens, L., Devlieghere, F. and Debevere, J. 2002. Combining high oxygen atmospheres with low oxygen modified atmosphere packaging to improve the keeping quality of strawberries and raspberries. Postharvest Biology and Technology 26: 49–58.