African Journal of Agricultural Research Vol. 5(24), pp. 3483-3492, 18 December, 2010
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.802
ISSN 1991-637X ©2010 Academic Journals

Full Length Research Paper

Application of exogenous ethylene on postharvest quality of dabai (*Canarium odontophyllum* Miq.) fruit

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Accepted 26 October, 2010

Dabai (*Canarium odontophyllum* Miq.) is an indigenous fruit to East Malaysia, Palawan (Philippines) and Sumatra (Indonesia). The fruits are hard, and locals prepare the fruit by seeping it in about 50°C water for 15 to 20 min to soften the flesh and eaten with salt and/or sugar. It is hypothesized; and exogenous ethylene could be used as an alternative method to soften the fruit. Therefore, this study was carried out to determine postharvest quality of dabai fruit using 0, 10, 50 and 100 ml/L of exogenous ethylene exposed for 0, 24, 48 and 72 h at 27°C. Carbon dioxide production in ethylene treated dabai fruit followed a pattern, in that as concentration of exogenous ethylene increased, the carbon dioxide production decreased. Exogenous ethylene induced production of endogenous ethylene with highest ethylene production at 24 h exposure among four ethylene exposure duration. The skin and flesh colour of dabai fruit changed as ethylene exposure duration progressed. Exogenous ethylene affected dabai fruit firmness significantly while soluble solids concentration increased as exposure duration advanced. The titratable acidity of dabai fruit increased irrespective of exogenous ethylene concentration and exposure duration. In contrast, pH of dabai fruit decreased as ethylene exposure duration progressed. In short, dabai fruit is sensitive to ethylene at tropical temperature of 27°C.

Key words: Ethylene production, carbon dioxide, softening, colour, soluble solids concentration.

INTRODUCTION

Malaysia has many indigenous fruits and many related species are still growing wild in the natural forests especially in Sarawak and Sabah. Dabai (*Canarium odontophyllum* Miq.), durian (*Durio* spp.), dempedak (*Artocarpus champeden* Spreng) and isau (*Dimocarpus longan* Lour) are among indigenous fruit species (Kueh, 2003). Dabai belongs to Burseraceae family of Sapindales order in the class of Eudicotyledoneae (Leenhouts, 1956). In Sarawak, it is found naturally along river banks in Sibu, Sarikei, Kapit and Limbang Divisions. Locally, dabai fruit is also known as Dabei, Sibu olive, tropical olive or 'Zaitun tropika' where the fruit resembles olive with stony seed in it. Dabai is also indigenous to Palawan (Philippines) and Sumatra (Indonesia).

Dabai is a drupe berry with thin skin (epidermis) surrounding a flesh (mesocarp) and seed (endocarp) (Wong, 1992). The fruits are white colour when immature, turning blue-black or dark purple when ripe. The shape is oblong (3.5 to 4.0 cm long by 2.0 to 2.5 cm wide) and has a thin, edible skin. The white or yellow flesh is 0.4 to 0.7 cm thick and covers a single large three-angled seed. The fruits are hard and locals prepare the fruit by steeping it in lukewarm water (at about 50°C) for a period of 15 to 20 min to soften the flesh and eaten with salt and/or sugar. The flavor is unique and oily like an avocado while seed kernel is edible too (Gadug and Yusup, 1992). Recently, dabai seed was found to have the potential of providing biodiesel that will conform to the biodiesel standards of the European Standard Organization and the American Society for Testing Materials (Razon, 2008). Dabai fruit is a very nutritious

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fruit with high energy (339 kcal /100 g edible portion), protein (3.8%), fat (26.2%), carbohydrate (22.1%), crude fibre (4.3%), ash (2.3%), phosphorous (65 mg /100 g edible portion), potassium (810 mg /100 g edible portion), calcium (200 mg /100 g edible portion), magnesium (106 mg /100 g edible portion) and iron (1.3 mg /100 g edible portion) (Hoe and Siong, 1999). In addition, the skin, flesh and kernel contain antioxidant (Azrina et al., 2010). Dabai is a unique fruit where local soften the hard fruit using lukewarm water. It is hypothesized exogenous ethylene could be used as an alternative method to soften the fruit so that it is palatable. Ethylene has been reported to be responsible for softening in immature-green guava (Reyes and Paull, 1995), 'Hayward' kiwifruits (Park et al., 2006), 'Chiripa' peach (Girardi et al., 2005), cucumber (Hurr et al., 2009), papaya (Fabi et al., 2007) and 'Fuyu' persimmons (Besada et al., 2010). Tissue softening is a physiological process particularly sensitive to ethylene (Gray et al., 1994). Ethylene is a naturally occurring plant growth regulator that has effects on growth, development and storage of horticultural products (Saltveit, 1999). Harvested fruits that exposed to biologically active levels of ethylene could trigger both endogenous and exogenous sources of ethylene contribute to its biological activity where fruit might ripen rapidly, soften excessively and thus lead to short shelf life. Thus, the possible changes in dabai fruit firmness and other postharvest quality attributes following a range of exogenous ethylene using differential exposure duration at 27°C was studied. A temperature of 27°C was used to imitate the ambient temperature of local environment during dabai fruit handling.

MATERIALS AND METHODS

Plant materials

Mature dabai (*C. odontophyllum* Miq.) fruit were purchased from a fruit wholesaler in Kuching, Sarawak and transported to the postharvest laboratory of Universiti Putra Malaysia by airplane within 24 h. Fruit were divided into 16 lots with each lot consisted of five fruit. Each lot of fruit was then placed in a sealed polyethylene bag (thickness 45 μm) and subjected to ethylene concentration of 0, 10, 50 or 100 ml/L for 0, 24, 48 or 72 h exposure. Fruit were kept at 27 ± 2°C, 65 to 75% relative humidity room throughout the study. Fruit were then measured for its carbon dioxide and ethylene production rates, skin and flesh colour, firmness, soluble solids concentration, titratable acidity and pH. The experiment was repeated three times.

Determination of carbon dioxide and ethylene production rates

Carbon dioxide and ethylene production rates were determined using a static system with a gas chromatography (Clarus 500, Pekin Elmer, and Shelton, USA). 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) where hydrogen was used as the gas carrier with 25 ml/ min of flow rate. Following treatment, three dabai fruit were sealed individually in 1.9 L respiration containers at 25 ± 2°C for 2 h and headspace gas was sampled with a 1.0 ml syringe. The gas was then injected into the injector port on gas chromatography.

Determination of skin and flesh colour

Skin and flesh colour were determined using a Minolta CR-300 Chroma Meter (Minolta Corp., Osaka, Japan) with Illuminate C and results were expressed as lightness (L*), chroma (C*) and hue (h°). The L* value ranges from 0 = black to 100 = white. The h° is an angle in a colour wheel of 360°, with 0, 90, 180 and 270° representing the hues red, yellow, green and blue, respectively, while C* is the intensity or purity of the hue. Three measurements were made around the fruit equator and the measurements averaged.

Determination of flesh firmness

Flesh firmness was evaluated using a computer-controlled Instron 5543 Material Testing Machine (Canton, MA, USA). Dabai fruit were subjected to a puncture test at a constant speed of 20 mm/min, using a 5 mm diameter plunger probe. Force formation curves were recorded and firmness (as represented by the slope newton (N)/mm of linear section of the force-deformation curve) was used as the indicator of textural property.

Determination of soluble solids concentration (SSC)

Skin and flesh of dabai fruit were separated from the kernel. Ten grams of flesh tissue was homogenized with 40 ml of distilled water using a mortar. The mixture was filtered with cotton wool. A drop of the filtrate was then placed on the prism glass of a refractometer (Atago Co, Ltd., Model N1, Tokyo, Japan) to obtain the %SSC. The readings were corrected to a standard temperature of 20°C by adding 0.28% to obtain %SSC at 27°C.

Determination of titratable acidity (TA) and pH

The remainder of the juice from the SSC determination was used to measure TA by titrating with 0.1 mol/L NaOH using 1% phenolphtalein as indicator. The results were calculated as a percentage citric acid [(ml NaOH x 0.1) / (weight of sample titrated) x 0.064 x 100]. The pH of the juice was measured using a glass electrode pH meter model Crison Micro pH 2000 (Crison Instruments, S.A., Barcelona, Spain). The pH meter was calibrated with buffer at pH 4.0 and 7.0 before being used.

Statistical analysis

The experimental design was a completely randomize design with three replications of five fruit per replicate. Data was analyzed by using the analysis of variance (SAS Institute, Cary, NC) and means were separated by Duncan's multiple range test.

RESULTS

Carbon dioxide production of dabai fruit was in the range of 344.1 to 346.0 ml/kg/h when study began (Figure 1).

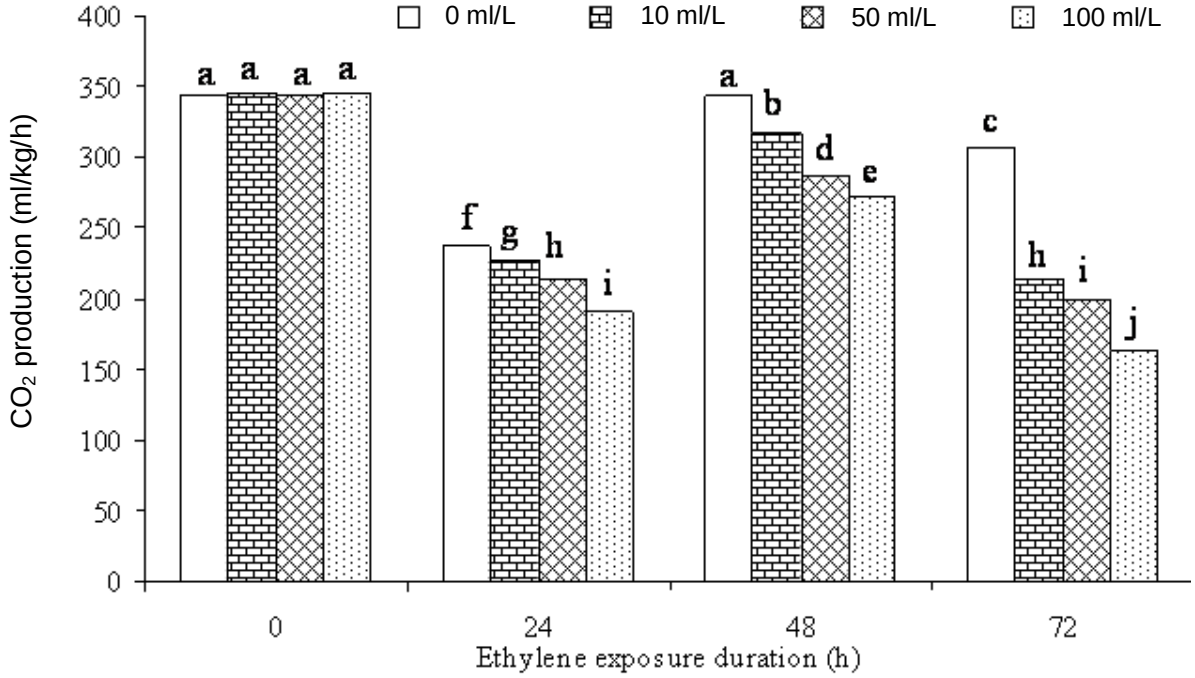

Figure 1. Carbon dioxide production of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly ($P \leq 0.05$).

After 24 h ethylene exposure, exogenous ethylene at all concentrations decreased dabai fruit carbon dioxide production significantly. Carbon dioxide production in ethylene treated dabai fruit followed a pattern, in that as concentration of exogenous ethylene increased the carbon dioxide production decreased. Control fruit without exogenous ethylene treatment showed highest carbon dioxide production (236.6 ml CO_2/kg/h) among ethylene concentration. After 48 h exposure, the carbon dioxide production in dabai fruit increased significantly in all concentration of ethylene applied as compared to 24 h exposure. The carbon dioxide production in control fruit was as high as during fruit at 0 h ethylene exposure. Again, carbon dioxide production of dabai fruit follow the trend as occurred in 24 h ethylene exposure where concentration of exogenous ethylene increased the carbon dioxide production decreased. After 72 h exposure, the carbon dioxide production of dabai fruit decreased irrespective of ethylene concentration. At 72 h ethylene exposure, the carbon dioxide produced by dabai fruit treated with 10, 50 and 100 ml/L were the lowest among exposure duration. Control fruit produced 306.8 ml CO_2/kg/h which was higher than control fruit at 24 h.

Dabai fruit produced 0.51 - 0.6 µl C_2H_4/kg/h at 0 h ethylene exposure (Figure 2). After ethylene exposure for 24 h, ethylene production in fruit treated with 10 and 50 ml/L ethylene increased rapidly by 36.6% while fruit treated with 100 ml/L ethylene showed 33.9% increase. The control fruit also showed significant increase in ethylene production with increase of 4.7% but the ethylene production was the least among all ethylene concentration used. After 48 h ethylene exposure, the ethylene production of dabai fruit has decreased significantly in 10, 50 and 100 ml/L ethylene treated fruit. Fruit exposed for 100 ml/L of 72 h ethylene showed significant decrease as compared to same ethylene concentration treated at 48 h. Fruit exposed for 0, 10 and 50 ml/L of 72 h ethylene did not show significant changes as compared to 48 h. There was no significant change in ethylene production of control fruit at 24, 48 and 72 h ethylene exposure and it showed lowest ethylene production among treatment.

Skin lightness or L* values of dabai fruit treated with 0 and 10 ml/L ethylene increased significantly following 24 h ethylene exposure (Figure 3). After 48 h ethylene exposure, skin lightness of dabai fruit decreased regardless of ethylene concentration applied. Following 72 h ethylene treatment, the skin L* values of fruit retained about same value as those during 48 h exposure. The skin chromaticity or C* values of dabai fruit showed reciprocal trend as L* values where there was significant decrease when fruit exposed to 50 and 100 ml/L ethylene for 24 h (Figure 4). The skin chromaticity decreased significantly by about 94% to a very low value of less than one after 48 and 72 h ethylene exposure despite ethylene concentration. There were no significant changes in skin h° values of dabai fruit following 0 and 24 h ethylene exposure where the

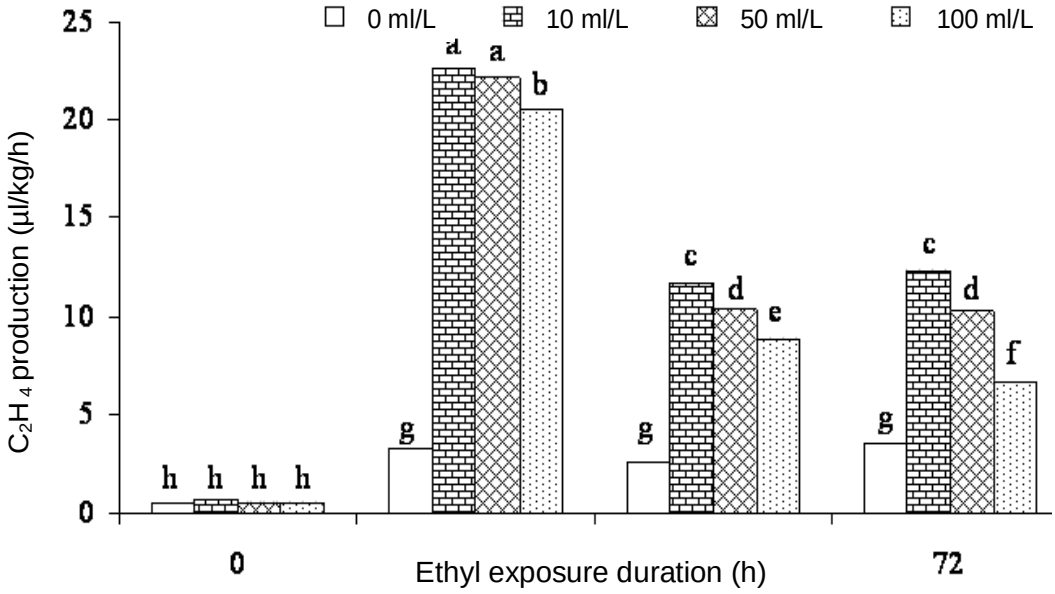

Figure 2. Ethylene production of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

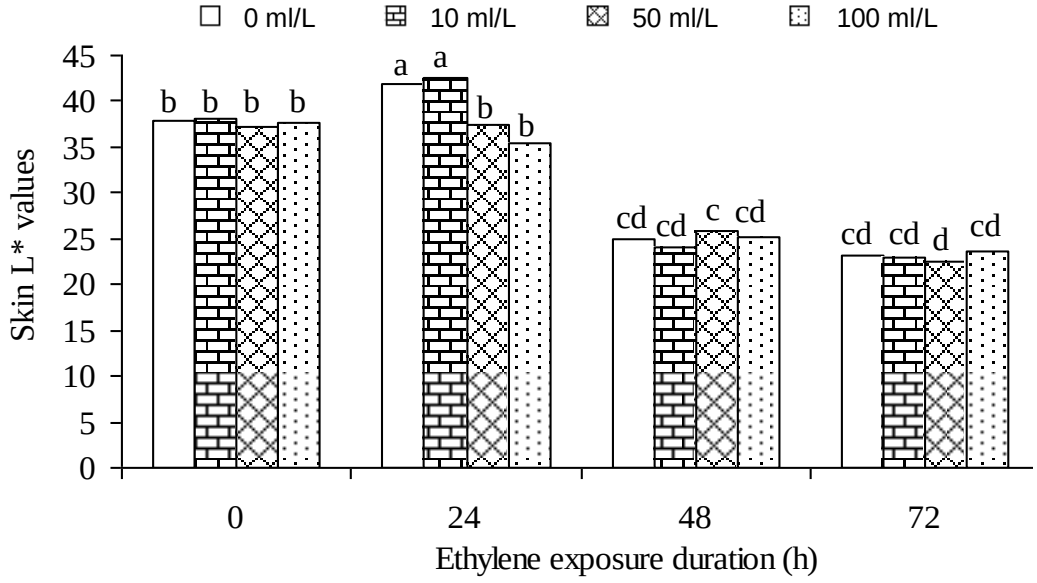

Figure 3. Skin L* values of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

skin retained as bluish-purple colour (Figure 5). After 48 h ethylene exposure, the skin of dabai fruit showed purplish-blue colour. Fruit following 72 h ethylene exposure of 10, 50 and 100 ml/L showed purplish-red while control fruit has more red than purple.

The dabai flesh L* values showed similar trend as skin L* values where the L* values retained high at 0 and 24 h ethylene exposure (Figure 6). The lightness of dabai flesh decreased significantly as ethylene exposure duration increase regardless of ethylene concentration. The chromaticity of dabai flesh did not show any significant changes in all treatments with C* values in the range of 13-20 (Figure 7). The h° values of dabai flesh decreased as ethylene exposure duration increased irrespective of

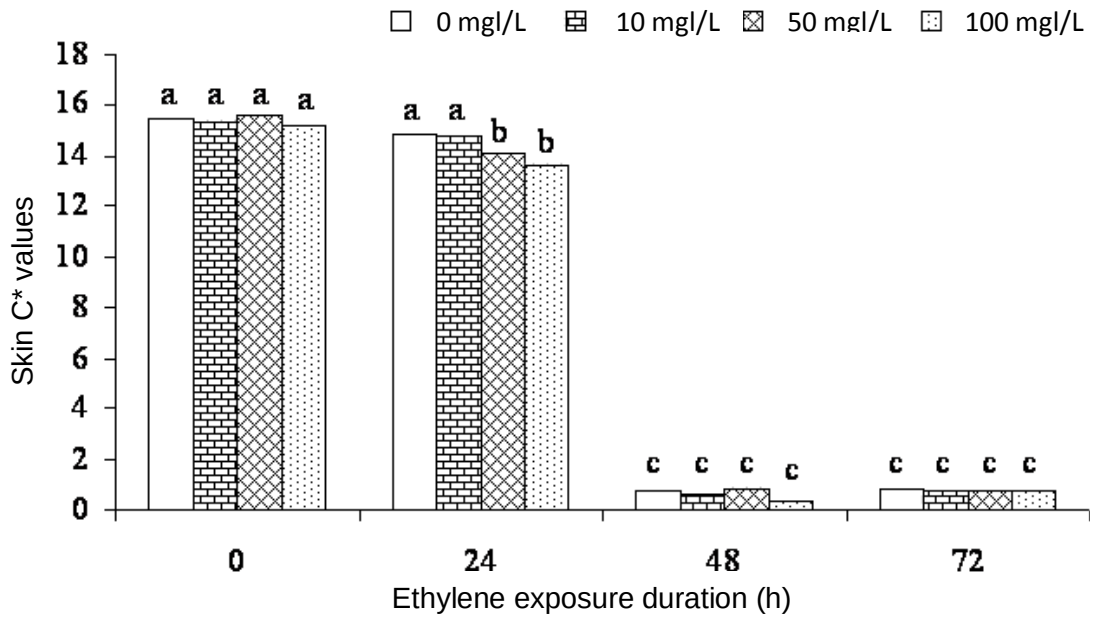

Figure 4. Skin C* values of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

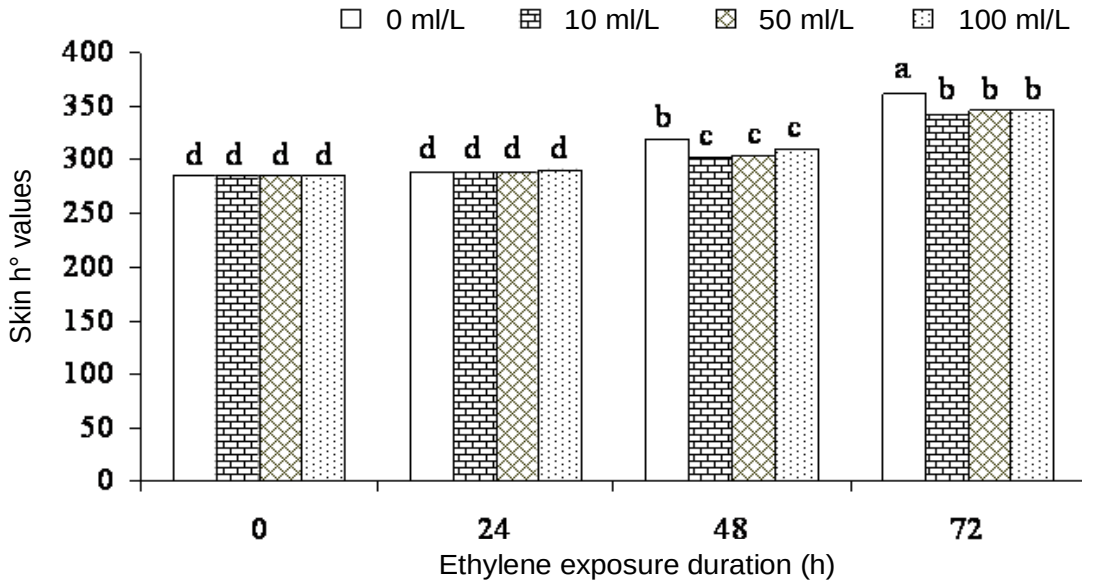

Figure 5. Skin h^{o} values of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

its concentration (Figure 8). Initially dabai has yellow flesh with values about 97°. As ethylene exposure duration increased to 72 h the values reduced to 65 to 75^{o} where the flesh showed orange-yellow.

The flesh firmness of dabai fruit was high with about 200 N before exposure to exogenous ethylene (Figure 9). Following 24 h ethylene exposure, the flesh firmness of control dabai fruit decreased significantly by 37% while others ethylene treated fruit decreased by about 89%. After 48 h ethylene exposure, the firmness of control fruit decreased tremendously by 91% while the firmness of 10, 50 and 100 ml/L treated dabai fruit reduced to about 9 N.

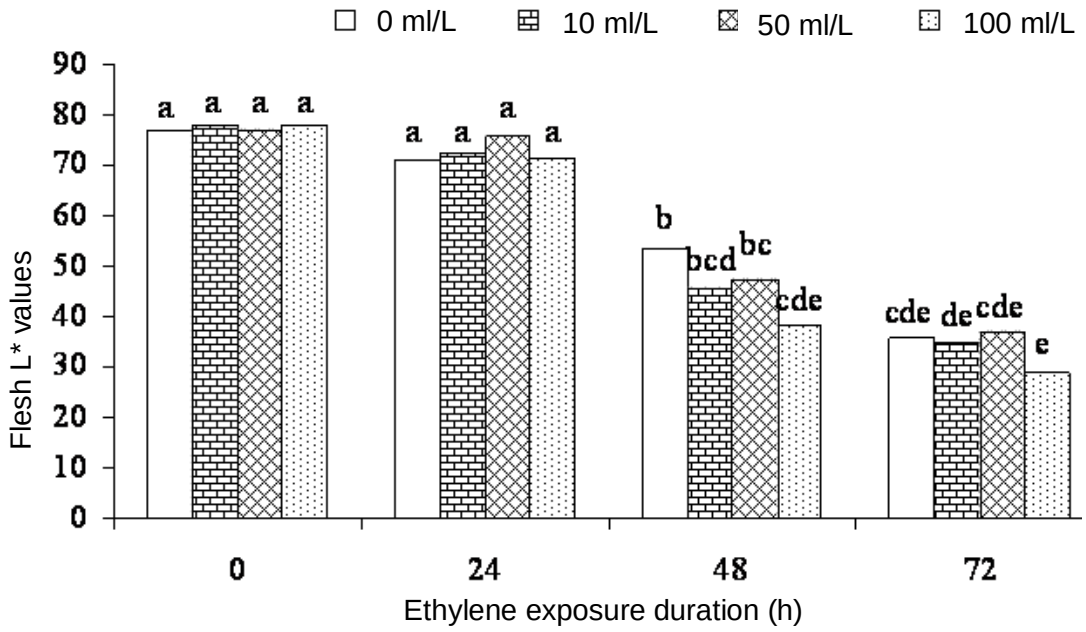

Figure 6. Flesh L* values of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

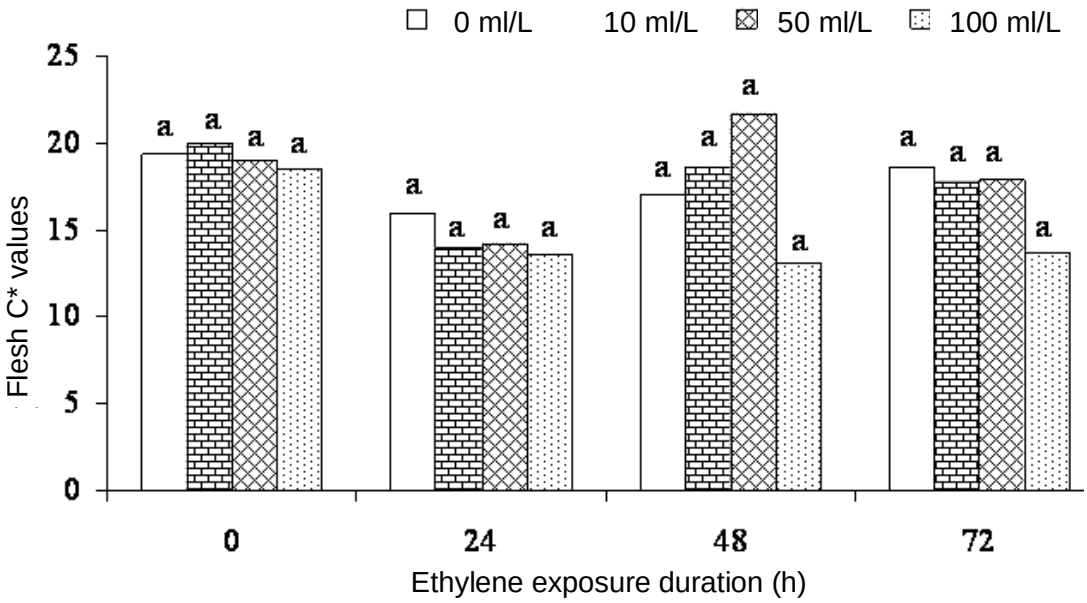

Figure 7. Flesh C* values of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

The firmness was retained at about 9 N after 72 h ethylene exposure despite ethylene concentration. The SSC of dabai fruit at 0 h ethylene exposure was about 2.2% SSC and increased significantly after 24 h ethylene exposure irrespective of ethylene concentration applied (Figure 10). The higher ethylene concentration applied to dabai fruit the higher its SSC and this tendencies occurred in 24, 48 and 72 h ethylene exposure fruits. Fruit SSC at 72 h was the highest among ethylene exposure duration regardless of ethylene concentration. The TA of dabai fruit was low at 0 h ethylene exposure (Figure 11). The TA increased as ethylene exposure

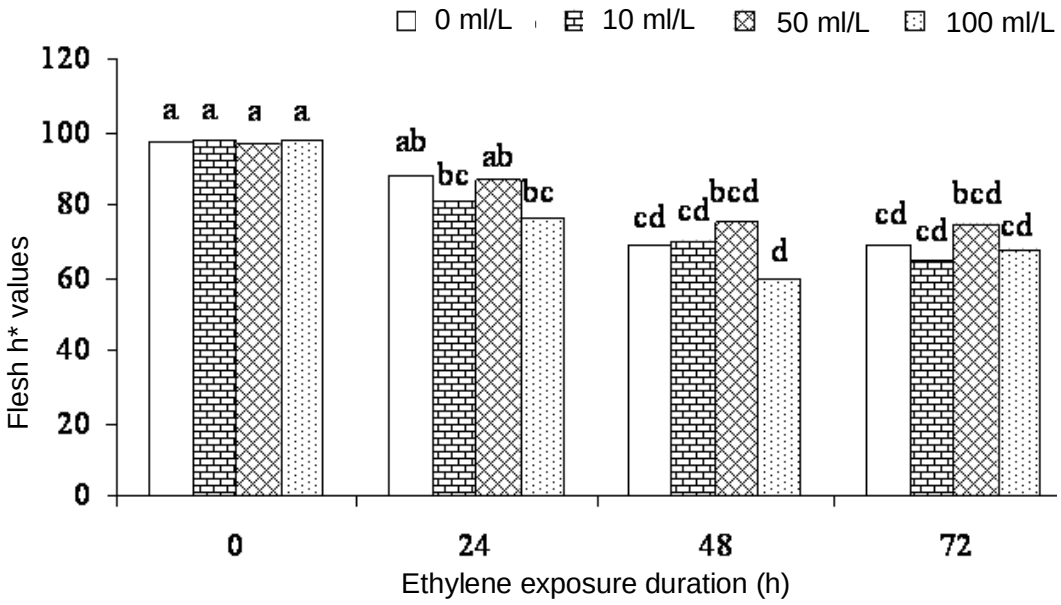

Figure 8. Flesh h° values of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

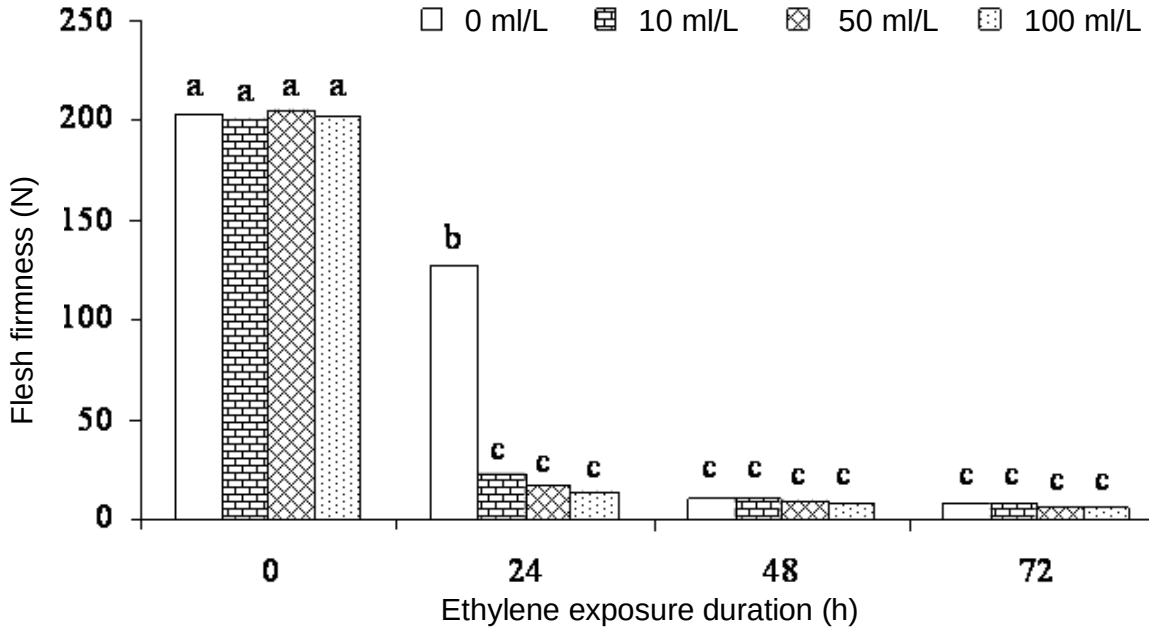

Figure 9. Flesh firmness of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

duration progress and fruit achieved its highest values by 72 h in all ethylene concentration treated fruit. The pH of dabai fruit was high at 0 h ethylene exposure and the values decreased as ethylene exposure duration advance (Figure 12). The pH of fruit treated with 100 ml/L ethylene was the lowest among treated fruit when exposed to 48 and 72 h ethylene.

DISCUSSION

The carbon dioxide production rate of dabai fruit was very high as compared to other tropical fruits. The carbon

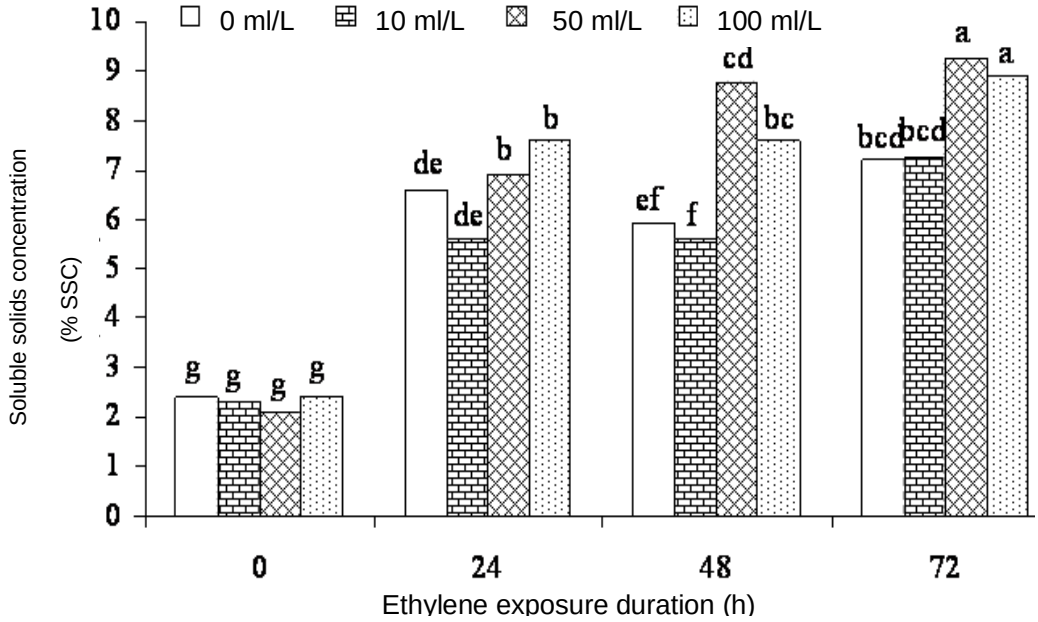

Figure 10. Soluble solids concentration of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

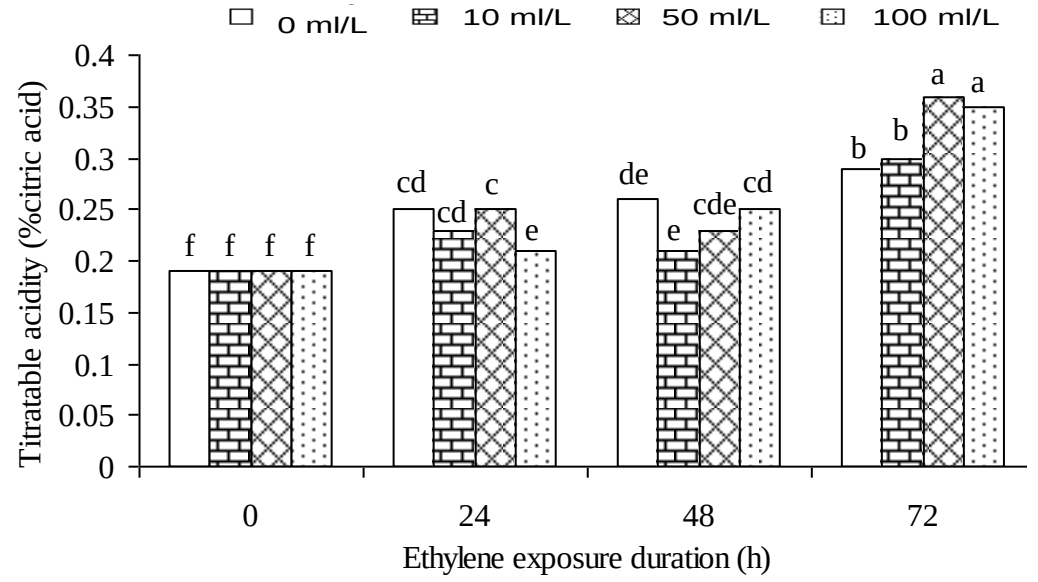

Figure 11. Titratable acidity of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly (P ≤ 0.05).

dioxide production for 'Red Maradol' papaya was 10 ml/kg/h at 25°C (Krongyut et al., 2008) while lime produced 15.04 ml CO_2 kg/h at 30°C (Win et al., 2006). The finding of this study showed the exogenous ethylene inhibited carbon dioxide production with higher concentration exogenous ethylene inhibited more carbon dioxide production. Control fruit exhibited highest carbon dioxide production as compared to ethylene-treated fruit. This was contrary to effect of exogenous ethylene on most fruits. The carbon dioxide production in papaya (Fabi et al., 2007), persimmon (Besada et al., 2010), mango (Montalvo et al., 2007) and kiwi (Park et al., 2006) that exposed to exogenous ethylene was higher than control fruit. Even in sugarbeet root carbon dioxide production also showed positive response towards exogenous ethylene (Fugate et al., 2010).

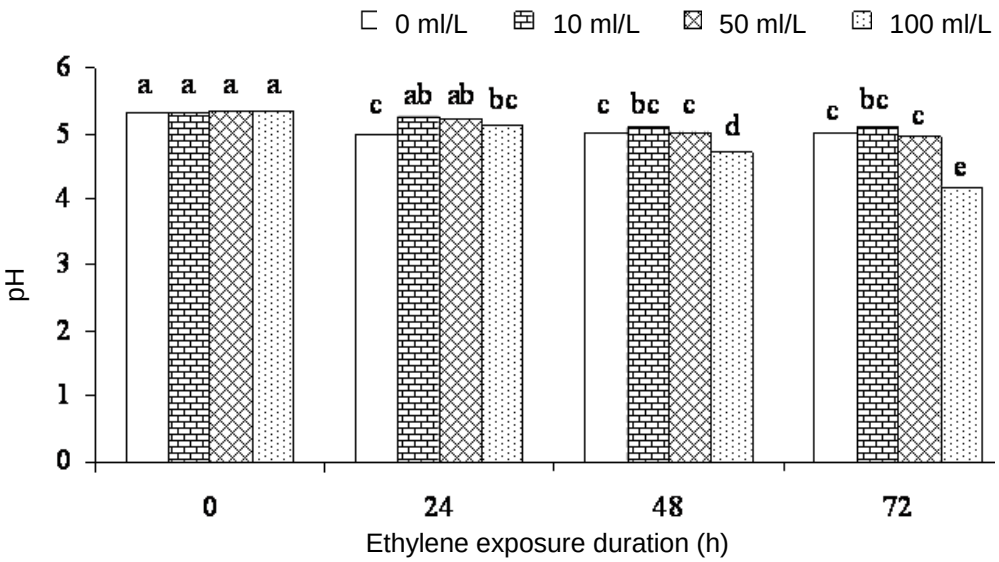

Figure 12. pH of dabai fruit exposed to 0, 10, 50 and 100 ml/L of exogenous ethylene for 0, 24, 48 and 72 h. Bars with different letters differ significantly ($P \leq 0.05$).

The exogenous ethylene has induced the production of endogenous ethylene in dabai fruit within 24 h of exposure. This indicated exogenous ethylene has induced autocatalytic ethylene production in dabai fruit. This has also been observed in persimmon (Besada et al., 2010), kiwi (Park et al., 2006), mango (Montalvo et al., 2007) and peach (Girardi et al., 2005). In addition, exogenous ethylene has induced microorganism growth on dabai fruit even at exposure duration of 24 h (unpublished data). This finding is in line with cucumber (Hurr et al., 2009) and peach (Girardi et al., 2005) where decay incidence increased in ethylene exposed fruit. This indicated dabai fruit is sensitive to exogenous ethylene and during fruit handling ethylene accumulation and exposure should be avoided. In other words, ventilation is essential during dabai fruit handling.

Exogenous ethylene and its concentration may or may not cause colour change in fruits. For example in 'Bing' and 'Brooks' cherry, the skin colour was significantly lower in 0.01, 0.1 or 1 µl/L ethylene exposed fruit as compared to control fruit (Palou et al*.,* 2003). However, exogenous ethylene with differential concentration fails to degreen Harumanis mango (Ding, unpublished data). In the present study, the exogenous ethylene affect dabai fruit colour. Generally, the effect of ethylene exposure duration on skin and flesh colour of dabai fruit was more than effect of ethylene concentration. The lightness, chromaticity and hue of fruit changed as ethylene exposure duration increase to 48 h. This indicated the skin pigments of dabai fruit degrade as time progress. A similar finding was reported in 'Ataulfo' mangoes where fruit exposed to 12 h produced more yellow as compared to those only exposed to 6 h (Montalvo et al., 2007).

Firmness of dabai fruit treated with 10, 50 and 100 ml/L ethylene decreased significantly and reached minimum levels after 24 h exposure, while firmness of control fruit decreased gradually and remained at low level after 48 h exposure. These data were in agreement with the data of kiwi (Park et al., 2006), papaya (Fabi et al., 2007), persimmon (Besada et al., 2010), immature-green guava (Reyes and Paull, 1995), peach (Girardi et al., 2005) and cucumber (Hurr et al., 2009). Ethylene has induced ethylene-dependent cell wall enzymes such as polygalacturonase, β-galactosidase and pectinesterase (Brummell and Harpster, 2001) and possibly this explain flesh softening of dabai fruit treated with ethylene. Firmness of ethylene–treated fruit for 24 h was similar to fruit firmness that soften using lukewarm water (Ding and Tee, unpublished data). However, sourish smell has been established by these ethylene treated fruit besides decay (unpublished data).

In addition to flesh softening, SSC is another important quality attribute of fruit. SSC of kiwi (Park et al., 2006), papaya (Fabi et al., 2007), mango (Montalvo et al., 2007) and banana (Ahmad et al., 2006) treated with ethylene increased as compared to control fruits. Exposing dabai fruit to 50 and 100 ml/L ethylene caused higher SSC than control and 10 ml/L ethylene-treated fruit. A contrary finding was found in peaches and nectarines where ethylene concentration did not affect fruits SSC (Palou et al., 2003). Increase in SSC is usually correlates with starch conversion to sugar. Using iodine test it was found out that dabai fruit was lack of starch (unpublished data), however, it could be possible to speculate that some mechanisms of cell wall disassembly have provided a source of carbon for sugar synthesis during storage as

occurred in papaya (Fabi et al., 2007). It seems high concentration of ethylene (50 and 100 ml/L) and prolonged exposure duration has caused high degree of cell wall disassembly during dabai fruit storage.

TA which quantified organic acids of dabai fruit increased while pH decreased as ethylene exposure duration progressed. The increase in organic acids indicating most probably these compounds were not utilized as respiratory substrates. pH depends on the concentration of free H^+ ions. Since organic acids of dabai fruit increased thus increase free H^+ ion and consequently decreased the pH.

Conclusion

Dabai fruit is sensitive to ethylene at tropical temperature of 27°C and flesh firmness decreased tremendously to palatable level once exposed to ethylene. In addition, other physico-chemical quality attributes such as carbon dioxide and ethylene production, colour, firmness, SSC, TA and pH are affected by ethylene exposure concentration and duration. It is postulated that the metabolism of dabai fruit could have risen to a peak following 10 ml/L and 24 h ethylene exposure, thereafter senescence started. Dabai fruit did not go through ripening process before senescence took place. However, further study needs to be carried out to understand this fruit better and thus minimize postharvest losses during handling and transportation.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the invaluable help of Ms Diana Mendoh Jitam in sourcing and bringing fruit from Sarawak to Peninsular Malaysia.

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