Physicochemical characteristics of dabai (*Canarium odontophyllum* Miq.) fruit

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Abstract — Introduction. Dabai (*Canarium odontophyllum* Miq.) fruit is an underutilized fruit found in Borneo, Palawan and Sumatra. To our knowledge, no literature exists about the postharvest quality characteristics of dabai fruit. Furthermore, it is a unique fruit whereby the fruit is served by steeping at about 60 ºC for 15–20 min to soften the flesh. Therefore, a preliminary study was conducted to determine the physicochemical characteristics of dabai fruit before and after steeping. **Materials and methods**. Physicochemical characteristics (skin color, size, shape, weight, mesocarp thickness, firmness, soluble solids concentration, pH, titratable acidity, organic acids, respiration production rate and ethylene concentration) of dabai fruit were determined before and after steeping in hot water at 60 ºC for 15 min. **Results**. The color of mature dabai fruit is dark purplish with very low chromaticity. The fruit is oval-shaped with a length to diameter ratio of 1.40. The seed contributes 61% of the fruit weight. After treating fresh dabai fruit with 10 mL·L^{-1} ethylene at 20 °C, the respiration production rate decreased while ethylene concentration increased. After steeping dabai fruit at 60 ºC for 15 min, the flesh firmness decreased while soluble solids concentration increased tremendously. After steeping, the pH of fruit decreased and titratable acidity increased, as did the citric, malic and succinic acids of dabai fruit, especially citric acid. **Conclusion**. Steeping softens dabai fruit flesh and makes it palatable, with high soluble solids concentration and organic acids. The high respiration production rate means that dabai fruit has a short shelf life under non-cold chain handling practices.

Malaysia / *Canarium odontophyllum* / fruits / postharvest physiology / ethylene production / respiration rate

Caractéristiques physico-chimiques du fruit de *Canarium odontophyllum* Miq.

Résumé — Introduction. *Canarium odontophyllum* Miq. est une espèce fruitière sous-utilisée de Bornéo, Palawan et Sumatra. À notre connaissance, rien n'a encore été publié sur les caractéristiques après-récoltes des fruits de cette espèce. En outre, c'est une espèce originale dans la mesure où le fruit est consommé après trempage à environ 60 °C pendant (15 à 20) min pour ramollir la chair. Par conséquent, une étude préliminaire a été menée pour déterminer les caractéristiques physico-chimiques des fruits de *C. odontophyllum* avant et après trempage. **Matériel et méthodes**. Les caractéristiques physico-chimiques (couleur de peau, taille, forme, poids, épaisseur mésocarpe, fermeté, concentration en solides soluble, pH, acidité totale, acides organiques, taux de respiration et concentration d'éthylène) de fruits de *C. odontophyllum* ont été déterminées avant et après trempage dans l'eau à 60 °C pendant 15 min. **Résultats**. Les fruits mûrs de *C. odontophyllum* sont violet foncé avec des chromatiques très faibles. Ils sont de forme ovale avec un rapport [longueur/diamètre] de 1,40. Les graines contribuent pour 61 % au poids des fruits. Après traitement des fruits frais avec 10 mL éthylène·L^{-1} à 20 °C, le taux de respiration a diminué alors que la concentration en éthylène augmentait. Après trempage des fruits à 60 °C pendant 15 min, la fermeté de la chair a diminué alors que la concentration en solides solubles a considérablement augmenté. Après trempage, le pH des fruits a diminué, et leur acidité titrable a augmenté, ainsi que les acides citrique, malique et succinique, et surtout l'acide citrique. **Conclusion**. Le trempage a ramolli la pulpe de fruits de *C. odontophyllum* et l'a rendu agréable à consommer avec une forte teneur en sucres solubles et en acides organiques. Le fort taux respiratoire a diminué la durée de conservation des fruits placés en conditions de manutention non refroidies.

Malaisie / *Canarium odontophyllum* / fruits / physiologie après récolte / production d'éthylène / taux de respiration

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***RESUMEN ESPAÑOL**, p. 52*

1. Introduction

Dabai (*Canarium odontophyllum* Miq.) is indigenous to Borneo [Sarawak and Sabah (Malaysia), Brunei and Kalimantan (Indonesia)], Palawan (Philippines) and Sumatra (Indonesia). It belongs to the Burseraceae family of the Sapindales order in the class of Eudicotyledoneae [1]. In Sarawak, it is found naturally along riverbanks in the Sibu, Sarikei, Kapit and Limbang Divisions. Locally, dabai fruit is also known as Sibu olive, as the fruit resembles an olive with a stony seed inside.

Dabai fruit is a drupe, with thin skin (epidermis) surrounding the flesh (mesocarp) and seed (endocarp) [2]. It is white when immature, turning blue-black or dark purple when ripe. The shape is oblong (3.5–4.0 cm long and 2.0–2.5 cm wide) and the fruit has a thin and edible skin. The white or yellow flesh is 0.4–0.7 cm thick and covers a single large three-angled seed. The fruit is hard and locals prepare it by steeping it in hot water (at about 50 °C) for a period of 15–20 min to soften the flesh, which is then eaten with salt and/or sugar. The flavor is unique and it has a fine creamy texture like a ripe avocado. The kernel of the seed is edible too [3].

In Sarawak, dabai fruit is normally available from November to January. It fetches a good price in the market, USD 2.9–5.1·kg^{-1}, and is only available in local markets of Sarawak and Sabah due to its short shelf life: the shelf life of dabai fruit is about 3 d at 27 °C, then the hard fruit will wrinkle [2]. Dabai fruit is very nutritious, with high energy (339 kcal·100 g^{-1} edible portion), protein (3.8%), fat (26.2%), carbohydrate (22.1%), crude fiber (4.3%), ash (2.3%), phosphorous (65 mg·100 g^{-1} edible portion), potassium (810 mg·100 g^{-1} edible portion), calcium (200 mg·100 g^{-1} edible portion), magnesium (106 mg·100 g^{-1} edible portion) and iron (1.3 mg·100 g^{-1} edible portion) [4].

Due to the nutritional quality of the fruit, dabai has been promoted as a specialty fruit by the Agricultural Department of Sarawak, Malaysia [5]. To our knowledge, the information on postharvest quality of dabai fruit is lacking. Thus, such a study is necessary to provide basic information for developing handling and storage strategies. Therefore, a preliminary study was conducted to determine the physicochemical characteristics of dabai fruit before and after steeping in hot water.

2. Materials and methods

Mature dabai fruit was harvested at 10 A.M. from an orchard in Papar, Sabah, Malaysia, and transported to the postharvest laboratory in Peninsular Malaysia by airplane. By 7 P.M., the fruits arrived at the laboratory and were kept at 25 °C until the following morning. Ten fruits were chosen randomly to study skin color, size, shape, weight, mesocarp thickness, firmness, soluble solids concentration, pH, titratable acidity, organic acids, and ethylene production and respiration rates. As the fruit is only palatable after steeping, another ten fruits were chosen randomly to steep at 60 °C for 15 min and firmness, soluble solids concentration, pH, titratable acidity and organic acids were then determined.

2.1. Determination of skin color

Skin color was determined using a Minolta CR-300 Chroma Meter (Minolta Corp., Osaka, Japan) using the 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 color 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. Measurements were carried out at three points on the skin of the fruit.

2.2. Determination of length, diameter, weight and flesh thickness

Fruit length, width and flesh thickness were measured using a digital caliper. Fruit and seed fresh weights were measured using an electronic balance.

2.3. Determination of flesh firmness

Flesh firmness was evaluated using a computer-controlled Instron 5543 Material

Testing Machine (Canton, MA, USA). Dabai fruit was subjected to a puncture test at a constant speed of 20 mm·min^{-1}, using a 5-mm diameter plunger probe. Force formation curves were recorded and firmness (as represented by the slope N·mm^{-1} of the linear section of the force-deformation curve) was used as the indicator of textural property.

2.4. Determination of soluble solids concentration

The skin and flesh of dabai fruit were separated from the kernel. Ten grams of flesh tissue were 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 soluble solids concentration (%SSC). The readings were corrected to a standard temperature of 20 °C by adding 0.28% to obtain SSC at 27 °C.

2.5. Determination of titratable acidity (TA) and pH

The remainder of the juice from the SSC determination was used to measure the titratable acidity (TA) by titrating with 0.1 mol·L^{-1} NaOH using 1% phenolphthalein as an indicator. The results were calculated as percentage of citric acid [(mL NaOH × 0.1 mol·L^{-1} / weight of sample titrated) × 0.064 × 100].

The pH of the juice was measured using a glass electrode pH meter (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.

2.6. Determination of carbon dioxide and ethylene production rates

Carbon dioxide and ethylene production rates of fruit were determined using a continuous flow-through system on three fruits. The fruit was sealed in a jar with 1000-mL volume of respiration and put in a ripening chamber at 20 °C with a continuous flow of purified air at 16.7 mL·min^{-1}. Fruit was incubated for 4 h and headspace gas was sampled with a 1.0-mL syringe. The gas was analyzed using a gas chromatograph (Clarus 500, Pekin Elmer, Shelton, USA) with a 25 mL·min^{-1} flow rate. The gas chromatograph was equipped with a flame ionization detector and thermal conductivity detector with a stainless steel Porapak Q Column (3 m × 3.125 mm, 50/80 mesh) and hydrogen (flow rate 48 mL·min^{-1}) was used as the carrier gas. To study the effect of exogenous ethylene on dabai fruit, the fruits were incubated for 24 h at 20 °C using 10 mL·L^{-1} of ethylene injected directly into the container through the rubber septum.

2.7. Determination of organic acids

Ten grams of flesh were homogenized with 20 mL of sulfuric acid (0.005 mol·L^{-1}). The homogenate was topped up to 50 mL with sulfuric acid and filtered before being centrifuged at 13000 rpm for 15 min. The sample was analyzed using a high performance liquid chromatograph (HPLC) with a Shimadzu UV/Vis detector (Model SPD-10A, Kyoto, Japan) at 210 nm. The HPLC was equipped with an Aminex HPX-87H column (CA, USA). A sample of 20 µL was injected into the HPLC system with a 0.5 mL·min^{-1} flow rate. Malic, succinic and citric acids were identified by comparison with the retention and integrated peak areas of external standards.

2.8. Statistical analysis

Standard deviation was calculated using Microsoft Office Excel 97-2003 Worksheet for physical and physiological characteristics of dabai fruit. Analysis of variance and Duncan's multiple range test were performed using SAS to evaluate the significance of differences before and after steeping for dabai fruit chemical characteristics at the level of $p \leq 0.05$.

3. Results

The skin color of dabai fruit was dark purplish with very low chroma of 0.91. The length of fruit was longer than the diameter, thus forming an oval shape. The flesh of the

Table I.
Physical characteristics (mean ± standard deviation) of fresh dabai fruit collected from Papar, Sabah, Malaysia (n = 10).

Skin color			Length (cm)	Diameter (cm)	[Length / diameter] ratio	Fruit weight (g)	Flesh weight (g)	Seed weight (g)	Flesh thickness (cm)
L^*	C^*	h°							
25.17 ±1.15	0.91 ± 0.32	52.83 ± 13.22	3.11 ± 0.33	2.24 ± 0.25	1.40 ± 0.18	9.00 ± 2.23	3.50 ± 1.05	5.50 ± 1.71	0.38 ± 0.05

Table II.
Respiration production rate and ethylene concentration of fresh dabai fruit without and with exogenous ethylene during storage at 20 °C.

Treatment	CO_2 ($mL \cdot kg^{-1} \cdot h^{-1}$)	C_2H_4 ($\mu L \cdot kg^{-1} \cdot h^{-1}$)
Without exogenous C_2H_4	1411.66 ± 218.73	4.56 ± 0.79
With exogenous C_2H_4	665.29 ± 0.90	89.17 ± 0.73

Values are mean ± standard error of the mean (n = 3).

fruit is thin and seed contributes to 61% of the fruit weight (*table I*).

The respiration production rate of dabai fruit at 20 °C was 1411.66 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$ and ethylene concentration was 4.56 µL $C_2H_4 \cdot kg^{-1} \cdot h^{-1}$ (*table II*). After giving 10 $mL \cdot L^{-1}$ of ethylene for 24 h at 20 °C, the respiration production rate decreased to 665.29 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$ while ethylene concentration increased to 89.17 µL $C_2H_4 \cdot kg^{-1} \cdot h^{-1}$ (*table II*).

Before steeping, the flesh of dabai fruit is hard and unpalatable. After steeping at 60 °C for 15 min, the firmness decreased tremendously by 92% to 15.74 N (*table III*). Similarly, after steeping, the soluble solids concentration increased by 580% to 10.95% SSC (*table III*). After steeping, the pH of dabai fruit decreased while titratable acidity increased (*table III*). The citric, malic and succinic acids of dabai fruit increased after steeping, and citric acid was the dominant organic acid.

4. Discussion

There are a few varieties of dabai fruit found around Borneo. The fruit in this work was collected from Sabah and its physical properties were similar to those found in Sarawak [6]. Most probably, the variety used in this study was the same as the one studied by Azlan *et al.* [6].

The respiration production rate of dabai fruit was very high as compared with other tropical fruits. In 'Red Maradol' papaya, the respiration production rate for the ¼ yellow stage was 10 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$ at 25 °C [7]. Lime, native to South East Asia, produced 15.04 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$ at 30 °C [8]. However, dabai fruit produced 1411 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$ at 20 °C. Dabai fruit handlers in Borneo do not apply cold chain management and the average daily ambient temperature in the

Table III.
Physicochemical characteristics of dabai fruit before and after steeping at 60 °C for 15 min.

Time of analyses	Firmness (N)	Soluble Solids Concentration (%)	pH	Titratable acidity (% citric acid)	Citric acid	Malic acid	Succinic acid
					($mg \cdot g^{-1}$)		
Before steeping	201.48 ± 40.89 a	1.61 ± 0.58 b	5.88 ± 0.01 a	0.0033 ± 0.00033 b	67.48 b	61.69 b	23.79 b
After steeping	15.74 ± 3.09 b	10.95 ± 1.15 a	5.04 ± 0.13 b	0.0092 ± 0 a	99.72 a	71.75 a	47.12 a

Values are mean ± standard deviation of the mean.

Means followed by the same letter in a row are not significantly different at $p \leq 0.05$ (n = 10).

area is 27 °C. With this high temperature, dabai fruit exhibits a high metabolism and respiration production rate. From the results obtained, it is very clear that dabai fruit at 27 °C exhibits a higher respiration production rate than 1411 mL $CO_2 \cdot kg^{-1} \cdot h^{-1}$, which was determined at 20 °C. This could explain the short shelf life of dabai fruit under current local handling practices.

The ethylene concentration of dabai fruit was 4.56 µL $C_2H_4 \cdot kg^{-1} \cdot h^{-1}$ at 20 °C. This concentration is higher than that of lime, which produces 0.028 µL $C_2H_4 \cdot kg^{-1} \cdot h^{-1}$ at 30 °C [8]. The 'Red Maradol' papaya produces 2200 µL $C_2H_4 \cdot kg^{-1} \cdot h^{-1}$ at 25 °C [7], where the ethylene level is sufficient to induce ripening of a climacteric fruit. After moving dabai fruit from 20 °C to 27 °C (the local ambient temperature), most probably the ethylene production will be higher than 4.56 µL $C_2H_4 \cdot kg^{-1} \cdot h^{-1}$ due to a higher metabolism rate at higher temperature. However, we did not determine ethylene concentration at 27 °C in our study. Nevertheless, from our results, dabai fruit produced a rather high amount of ethylene, thus suggesting that a mixed load with other fresh horticultural produce should be avoided during handling of dabai fruit.

A quantity of 10 mL ethylene$\cdot L^{-1}$ was used to treat dabai fruit in order to understand its responses towards exogenous ethylene. The respiration production rate of dabai fruit decreased while ethylene concentration increased as compared with untreated fruit. This phenomenon is unusual to our knowledge. Both the respiration and ethylene production rates of fruit increase once the concentration of exogenous ethylene applied is more than the threshold level. Kiwifruits that were treated with 100 µg ethylene$\cdot mL^{-1}$ for 24 h at 20 °C showed significantly higher ethylene and respiration production than untreated fruits [9]. 'Fuyu' persimmons exposed to (5 and 10) µL ethylene$\cdot L^{-1}$ for 48 h at 20 °C showed immediate increase in ethylene and respiration production [10]. In response to exogenous ethylene, the respiration rate of dabai fruit behaves differently as compared with most other fruits. However, only one concentration of exogenous ethylene was used in our study. Further study using a range of exogenous ethylene should be carried out to fully understand the physiological responses of dabai fruit towards ethylene.

To our knowledge no other fruit is consumed like dabai, where steeping is needed. Steeping is to soften the fruit; otherwise the fresh fruit is too hard (201 N) to consume. The steeping process broke down cell wall enzymes, solubilized the cell wall and, finally, fruit turned soft. This finding is supported by papaya polygalacturonase heat denaturation kinetics, where 60% of the polygalacturonase denatured at 70 °C for 20 min [11]. Thus, the heat denaturation kinetics of dabai fruit cell wall enzymes would be expected at about 60 °C since the firmness reduced by 92% after steeping.

Heat from steeping could have broken down the cellular membrane too, released the soluble solids in cell sap, and caused the concentration to increase tremendously, by 580% after steeping. A quick test using 1% [I_2 / KI] solution was used to examine the presence of starch in dabai flesh (unpubl. data). A negative finding was obtained, indicating that starch is not present in fresh dabai, and the increase in soluble solids concentration after steeping was not contributed by starch hydrolysis that converted into sugar. The steeped dabai fruit did not taste sweet (unpubl. data).

Steeping caused a decrease in the pH of dabai fruit while titratable acidity increased. The increase in titratable acidity was parallel with the increase in citric, malic and succinic acids, which were the principal organic acids detected. Dabai fruit contains high amounts of organic acids as compared with Chinese bayberry (*Myrica rubra* Sieb. & Zucc.) fruit, a naturally high-acid fruit [12]. The total organic acids in a mature Chinese bayberry fruit were 11.81 mg$\cdot g^{-1}$ while in a dabai fruit the content was 152.96 mg of total organic acids$\cdot g^{-1}$. The high acidity in dabai fruit could be further explained by fruit being sourly volatile when rot development occurred (unpubl. data).

5. Conclusions

Dabai fruit is a unique fruit, as the manner of eating it is different from that of other fresh fruits. It needs heat to soften the flesh

and turn it into palatable fruit with high soluble solids concentration and organic acids. Dabai fruit has a very high respiration rate and, thus, a short shelf life under non-cold chain handling practices. To our knowledge, this is the first report on physicochemical characteristics of dabai fruit. Comprehensive work needs to be carried out to fully understand the biological and physiological metabolisms of dabai fruit before developing postharvest technology.

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Características físico-químicas del fruto de *Canarium odontophyllum* Miq.

Resumen — Introducción. *Canarium odontophyllum* Miq. es una especie frutal poco utilizada de Borneo, Palawan y Sumatra. Por lo que sabemos, aún no se ha publicado nada sobre las características post-cosecha de los frutos de esta especie. Además, se trata de una especie original, porque el fruto se consume después de inmersión a aproximadamente 60 °C durante (15 a 20) min para ablandar la pulpa. Por lo tanto, se efectuó un estudio preliminar con el fin de determinar las características físico-químicas de los frutos de *C. odontophyllum* antes y después de inmersión. **Material y métodos**. Las características físico-químicas (color de envoltura, tamaño, forma, peso, espesor mesocarpio, firmeza, concentración en sólidos solubles, pH, acidez total, ácidos orgánicos, tasa de respiración y concentración de etileno) de los frutos de *C. odontophyllum* se determinaron antes y después de inmersión en agua a 60 °C durante 15 min. **Resultados**. Los frutos maduros de *C. odontophyllum* son violeta oscuros con ligeros matices. Su forma es ovalada con una relación [longitud/diámetro] de 1,40. Las semillas contribuyen en un 61% al peso de los frutos. Tras tratamiento de los frutos frescos con 10 mL etileno·L^{-1} a 20 °C, la tasa de respiración disminuyó, mientras que la concentración de etileno aumentaba. Tras inmersión de los frutos dabai a 60 °C durante 15 min, la firmeza de la pulpa disminuyó mientras que la concentración en sólidos solubles aumentó considerablemente. Tras inmersión, el pH de los frutos disminuyó, y su acidez valorable aumentó, así como los ácidos cítrico, málico y succínico, y sobre todo el ácido cítrico. **Conclusión**. La inmersión ablandó la pulpa de frutos de *C. odontophyllum* y lo convirtió más agradable para el consumo con un fuerte contenido en azúcares solubles y en ácidos orgánicos. La fuerte tasa respiratoria disminuyó la duración de conservación de los frutos situados en condiciones de manutención no enfriadas.

Malasia / *Canarium odontophyllum* / frutas / fisiología postcosecha / producción de etileno / tasa de respiración