https://doi.org/10.48048/tis.2023.4647

Assessment of Natural Fruit Ripening and Fruit Quality of Three Elite Durian Cultivars for Overland Export

Bancha Wiangsamut[1] and Maria Evangeline Loyola Wiangsamut[2,*]

[1]Department of Agricultural Technology, Faculty of Agro-Industrial Technology, Rajamangala University of Technology Tawan-Ok at Chanthaburi Campus, Chanthaburi 22210, Thailand
[2]Department of Liberal Arts, Faculty of Social Technology, Rajamangala University of Technology Tawan-Ok at Chanthaburi Campus, Chanthaburi 22210, Thailand

([*]Corresponding author's e-mail: ma.evangeline_wi@rmutto.ac.th)

Received: 11 June 2022, Revised: 27 August 2022, Accepted: 3 September 2022, Published: 28 February 2023

Abstract

The study aimed to assess the natural fruit ripening duration, fruit quality, and consumer preference of 3 elite durian cultivars-'Monthong', 'Musang King', and 'Ocee'-after harvest. From the day of harvest at maturity stage until the second day of the fresh fruits emitted aroma; 'Monthong' took 9 days for full ripening measured by the natural fruit ripening duration value significantly ($p < 0.05$) longer by 4 days than of 'Musang King' and 'Ocee'. This value indicated that the longer ripening duration, the longer storage life was. The flesh weight, percentage of flesh weight, and flesh thickness most significantly influenced fruit quality. 'Monthong' had significantly higher flesh weight, percentage of flesh weight, and thicker flesh ($p < 0.05$) than 'Musang King' and 'Ocee'. A questionnaire and interview guide were used to compare the sensory qualities (flesh smell and flesh taste) of the durian cultivars by 50 Thai consumers through smelling (mild, moderate, strong) and eating the flesh. Consumer preference was determined by eating the flesh and smelling each cultivar by the same 50 consumers and then chose the durian cultivar they mostly prefer. Consequently, consumers mostly preferred 'Monthong' (54 %) over 'Musang King' (28 %) and 'Ocee' (18 %) due to its mild aroma, mildly sweet taste, crispy but soft golden-yellow flesh. In conclusion, the significantly longer natural fruit ripening duration (or long storage life) of 'Monthong' plus its higher flesh weight, higher percentage of flesh weight, more flesh thickness, and consumers' high preference are good indicators of its export quality-suitable for shipping fresh overland especially to China, top importer of Thailand. 'Musang King' and 'Ocee' had short ripening duration (or short storage life); ergo, poor export quality. Shipping by land, sea, and air, including packaging technology development, should then be studied further for the benefit of export market.

Keywords: Elite durian, Cultivars, Fruit ripening, Fruit quality, Flesh weight, Fruit weight loss, Ripening duration

Introduction

Durian (*Durio zibethinus* Murr.) is a tropical fruit grown in Southeast Asia and is highly appreciated by consumers throughout Asia [1]. Durian is also known as the "king of fruits" due to its sweet custard-like flesh and its unique intense aroma [2]. Durian is under the category of exotic fruits having a specific taste-equivalent to a mixture of avocado and mango [3]. There are several different bioactive compounds containing in the durian flesh that are benefit to human health [4]. Caffeic acid and quercetin are the dominant antioxidant substances found in durian [5]. The most popular and commercial durian cultivar in Thailand is 'Monthong' [6] attributed to its full-bodied creamy and mildly sweet flesh taste with relatively moderate smell emitted and its smaller seeds [7]. Whereas 'Musang King' is the most popular durian breed from Malaysia, rendered in Chinese as 'Mao Shan Wang', which is usually the priciest of all cultivars [8]. Similarly, 'Musang King' is the preferred cultivar in Singapore and Vietnam [9]. It is said to be the richest and best-tasting durian cultivar due to its round or oblong shape, flat seed, bright yellow flesh, creamy texture, bittersweet taste, and strong smell [10]. However, to identify 'Musang King' among other cultivars, it has the distinctive 5-pointed star-shape lines at the bottom. While 'Ocee' (or Black Thorn) was described to have a round shape, reddish-orange flesh, creamy and fine texture (less fiber), sweet but with a hint of bitter taste, and has a black stem at the bottom of the fruit, hence the name Black Thorn [11,12]. As 'Ocee' became the "crown jewel" to the king of fruits, it has also been the durian cultivar champion in 2013 and 2014 at a durian competition held by the Malaysian Agriculture Department [13]. The selling price of

'Ocee' is more expensive than 'Musang King' in Malaysia and Thailand-most Thai durian producers export 'Ocee' fruits to Malaysia. It was noted that all 'Ocee' have a darkish lump in slightly concave center at the bottom where the stamen broke off [14]. Most of the world's major durian growing areas are in ASEAN countries such as Thailand, Vietnam, Malaysia, Indonesia, and the Philippines-but Thailand is being considered the world's number one producer and exporter of fresh durian with 501,439 tons worth 50,072.2 million Thai baht. The main export markets for fresh Thai durian in 2020 were countries like China (72.78 %), Hong Kong (13.92 %), and Vietnam (11.88 %) [15]. Thailand has always been the largest exporter of fresh durian to China, where the biggest markets are in Guangxi and Guangdong provinces [16]. However, the status of 'Monthong' as the leading durian cultivar exported to China is now being threatened by 'Musang King' due to its creamy flesh that has rich flavor of bitterness and sweetness that melts into the mouth and smells as good as it tastes. 'Musang King' is reported to be as equally delicious as ice cream or pastries [17].

At present, transportation of durian requires a reefer container to have good ventilation as it has a high exothermic reaction. With this reason, internal temperature control of a reefer container has to be set at 13 - 15 °C and the ventilator mode is at 15 - 20 % to release the heat from the inside to the outside of the container in order to preserve the fruit's quality until delivery to the consignees, and finally to the end consumers [18]. There has been a report of long transportation of durian where mature durians harvested in the Eastern region of Thailand were loaded onto a train at Map Ta Phut industrial estate in Rayong province heading to Thanalaeng station in Vientiane, Laos via the province of Nong Khai, Thailand. From Vientiane, the durians will be transferred to another train destined for China [19]. The rail freight helped in transporting fresh durian fruits from Thailand to China, which only took about 7 days, or around half the time it took to transport by combined highway and sea transportation [20]; which is the usual transportation methods of durians for customers abroad, that takes longer time.

'Monthong' fruits harvested at 110, 115 and 120 days after anthesis naturally ripened on days 9, 6 and 4 after harvesting, respectively [21]. The natural fruit ripening duration of lightweight durian was shorter than heavyweight durian when their fruit weights distinguished from each other for at least 1 kg fruit^{-1} [22]. Increased water loss during the inhibition phase of ripening increased the rate of respiration and ethylene production and advanced ripening by 2 days. The flesh aroma characteristic develops as the fruit ripens [23]. Ripeness is followed by ageing (often called senescence) and breakdown of the fruit [24]. Exporters often face problems in estimating the natural fruit ripening duration and fruit quality of 3 popular durian cultivars such as 'Monthong', 'Musang King' and 'Ocee' after harvest leading to credibility issues on the product quality, in turn, of the importers. To solve these problems, natural fruit ripening duration and fruit quality of 3 elite durian cultivars after harvest of mature fruits were assessed as a way to regain credibility concerning to product quality and consumer's preference. Accordingly, the study aimed to assess the natural fruit ripening duration, fruit quality, and consumer preference of 3 elite durian cultivars-'Monthong', 'Musang King', and 'Ocee'-after harvest.

Materials and methods

The experiment was carried out in a laboratory and was laid out in a completely randomized design (CRD). The treatments were the elite durian cultivars comprised of:1) 'Monthong', 2) 'Musang King', and 3) 'Ocee' (or 'Black Thorn'). The treatments were tested with 3 replications: 1 durian fruit per replication; totaling to 9 fruits with fruit weights between 1.9 and 2.3 kg fruit^{-1}. To determine the maturity stage of these durian cultivars, external observations (parameters) were identified by an expert on the durian fruit as follows: 1) peduncle of the fruit was as rough as sandy granule with dull olive-green to light yellowish-green color; 2) swollen abscission zone; 3) color of outer pericarp had changed from green to greenish-brown; 4) tip of the thorns had begun to dry and had turned brown; 5) seams had become visible; and 6) thorn base had widened. Following the said observations for fruit maturity stage, fruits were subsequently harvested from different locations in Thailand. The harvests totaled to 9 fruits were: 3 fruits of 'Monthong' from a 5-year-old tree (118 days old fruits after anthesis or full bloom) at Rajamangala University of Technology Tawan-Ok Chanthaburi Campus (RMUTTO) in Chanthaburi province on May 5, 2021; 3 fruits of 'Musang King' from a 9-year-old tree (95 days old fruits after full bloom) at Than to district in Yala province on July 5, 2021; and 3 fruits of 'Ocee' from a 5-year- old tree (105 days old fruits after full bloom) on July 15, 2021. All the fruits were weighed individually at harvest and were then recorded in a unit-of-kilogram-per-fruit (kg fruit^{-1}). Afterwards, they were tested at the Department of Agricultural Technology at RMUTTO in Chanthaburi province during the months of May to July of 2021 for their weights and natural ripening duration by placing them at room temperatures (31 - 34.4 °C and 65 - 77 %, 25 - 27.6 °C and 84 - 92 %, for an average temperature and relative humidity, at daytime and nighttime, respectively)

until each fruit ripened; then its individual weight was again recorded. To determine the ripening stage of 'Monthong', 'Musang King', and 'Ocee' durian cultivars as fully ripe and not overripe, external observations (parameters) were identified by an expert on the durian fruit as follows: 1) the top part of peduncle (or fruit stalk) had naturally broken off at the abscission zone leaving the lower part of peduncle still attached to the fruit; 2) a distinct aroma had emitted on its second day; 3) tip of the thorns had dried and had turned dark brown; 4) seams had become more evident. Consequently, the ripening fruit stage, duration of fruit ripening, and other fruit components (**Figure 1**) were then determined and gathered as follows: Natural fruit ripening duration was counted from the time of harvest until its natural ripeness; recorded in a unit-of-hours and was converted into a unit-of-day basis. Weight loss was computed from the fruit weight at maturity stage minus the fruit weight at ripening stage and recorded in a unit of kilogram-per-fruit (kg fruit^{-1}). Percentage of weight loss was computed from the formula (1) below:

$$\% \text{ of weight loss per fruit} = \left(\frac{\text{fruit weight at maturity stage} - \text{fruit weight at ripening stage}}{\text{fruit weight at maturity stage}} \right) \times 100 \quad (1)$$

Fruit weight at ripening was determined when the fruit gave off an aroma on its second day; each ripened fruit was then weighed and recorded in a unit-of-kilogram-per-fruit (kg fruit^{-1}) (**Figure 1(a)**). Peduncle weight was determined from the peduncle's abscission zone to the base that was joined to a fruit and then weighed in a unit of gram-per-fruit (g fruit^{-1}). Percentage of peduncle weight was computed from the formula (2) below:

$$\% \text{ of peduncle weight} = \left(\frac{\text{peduncle weight per fruit at ripening stage}}{\text{fruit weight at ripening stage}} \right) \times 100 \quad (2)$$

Flesh weight was the weight of the edible portion of the durian fruit recorded in a unit of kilogram-per-fruit (kg fruit^{-1}). Percentage of flesh (aril or pulp) weight was computed from the formula (3) below:

$$\% \text{ of flesh weight} = \left(\frac{\text{flesh weight per fruit at ripening stage}}{\text{fruit weight at ripening stage}} \right) \times 100 \quad (3)$$

Flesh thickness was measured from the flesh's outermost portion to the inner portion, at the middle part of the flesh where seed is located and then recorded in a unit of centimeter (cm) (**Figure 1(b)**). Pericarp weight (included all spines and septum of a fruit) was recorded at ripening stage in a unit of kilogram-per-fruit (kg fruit^{-1}). Percentage of pericarp weight was computed from the formula (4) below:

$$\% \text{ of pericarp weight} = \left(\frac{\text{pericarp weight per fruit at ripening stage}}{\text{fruit weight at ripening stage}} \right) \times 100 \quad (4)$$

Pericarp (husk or the walls of a ripened ovary) thickness was measured from the epicarp (the outermost layer) to the endocarp (the inner layer in a middle part of a carpel) then recorded in a unit of centimeter (cm) (**Figures 1(c)**).

Number of seeds was counted from each durian fruit and recorded in a unit of number of seeds-per-fruit (seeds fruit^{-1}). Seed weight was determined from all the seeds taken from an individual fruit then weighed in a unit of gram-per-fruit (g fruit^{-1}). Percentage of seeds weight was computed from the formula (5) below:

$$\% \text{ of seeds weight} = \left(\frac{\text{seeds weight per fruit at ripening stage}}{\text{fruit weight at ripening stage}} \right) \times 100 \quad (5)$$

Seed height (**Figure 2(a)**), seed width (**Figure 2(b)**), and seed thickness (**Figure 2(c)**) were determined using a Vernier caliper and recorded in a unit of centimeter (cm). Munsell color of durian flesh was determined using the Munsell Books of Color to compare the color of durian flesh. A questionnaire

and interview guide were used as instruments to compare the sensory qualities of 'Monthong', 'Musang King', and 'Ocee'; their flesh smell and flesh taste were determined by 50 Thai durian consumers (consisted of 15 experts, 20 qualified panel, and 15 trained panel) by means of smelling (classified in 3 levels: Mild, moderate, and strong) and eating the durian flesh; data were then recorded. Consumer preference was determined by the same 50 Thai durian consumers by eating the durian flesh and by smelling each cultivar; then, each consumer chose 1 durian cultivar that was the most preferred. The consumer preference was computed in the unit of percentage (%) by the formula (6) below:

$$\text{Consumer preference (\%)} = \left(\frac{\text{number of Thai consumer preference}}{\text{total number of Thai consumers tested}} \right) \times 100 \quad (6)$$

Through the software Statistix 7 (SXW) program, the one-way analysis of variance (ANOVA) was carried out to determine any statistically significant differences between the means of 3 treatments; their means comparisons were done using least significant difference (LSD) at 0.05 probability level.

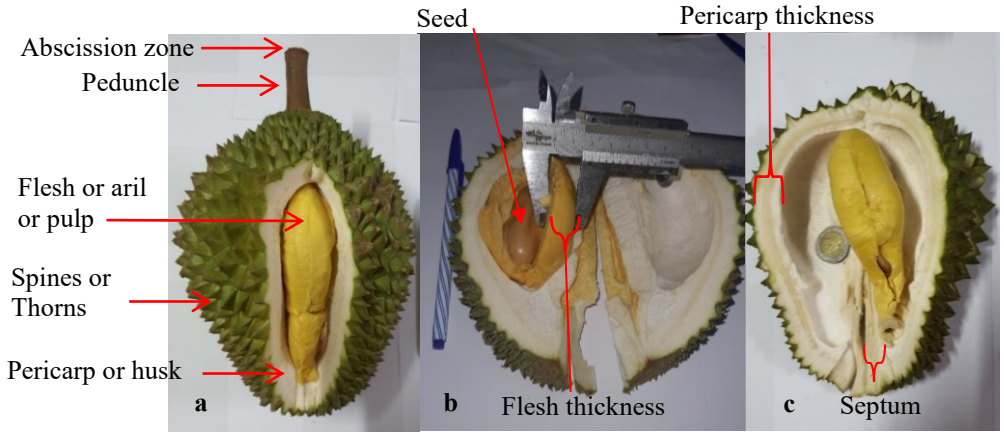

Figure 1 Fruit components of durian cv. 'Musang King' at 100-day-old fruit (a, c), and of durian cv. 'Ocee' at 109-days-old fruit (b).

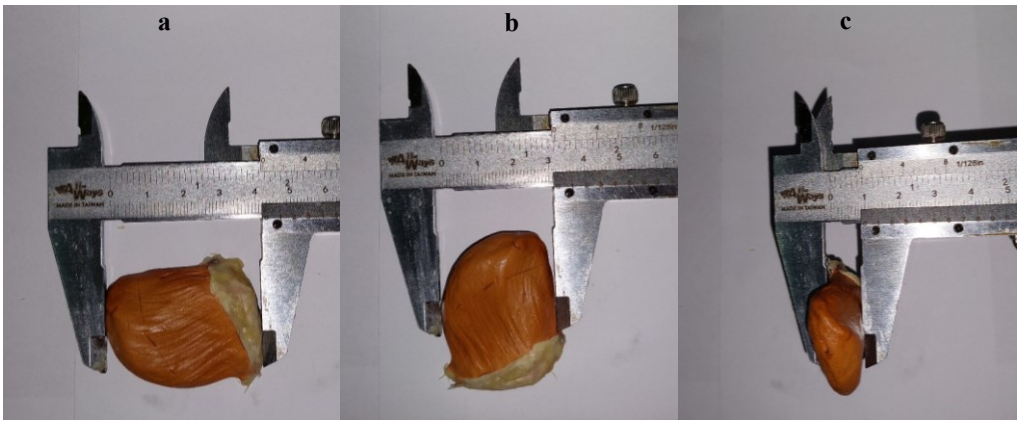

Figure 2 Seed measurement of durian cv. 'Monthong': a) seed height (cm); b) seed width (cm) and; c) seed thickness (cm).

Results and discussion

Fruit weight at harvest time, natural fruit ripening duration, weight loss, percentage of weight loss, and fruit weight at ripening

Fruit weight at harvest time for the 3 elite durian cultivars ('Monthong', 'Musang King', and 'Ocee') was not significantly different ($p > 0.05$) data ranged from 1.97 to 2.10 kg fruit^{-1}(**Table 1**). The natural fruit ripening duration of 'Monthong' cultivar was about 9 days that was significantly longer ($p < 0.05$) than that of 'Musang King' and 'Ocee' by 4 days; while the natural ripening duration between 'Musang King' and 'Ocee' did not change significantly ($p > 0.05$) (**Table 1**). The long natural fruit ripening duration of 'Monthong' tended to have slightly higher weight loss and percentage of weight loss than the short natural ripening duration of 'Musang King' and 'Ocee'. Consequently, fruit weights at ripening of 'Musang King' and 'Ocee' were significantly heavier ($p < 0.05$) than of 'Monthong' while fruit weights of the 2 former cultivars did not change significantly ($p > 0.05$) (**Table 1**). The start of ripening duration is accompanied by a rapid rise in respiration rate called the respiratory climacteric [25]. Unfortunately, the respiration rate in this study was not measured. Food and Agriculture Organization of the United Nations (FAO) [25] further added that after the climacteric, the respiration slows down as the fruit ripens and develops good eating quality as described. The natural fruit ripening duration of 'Monthong' was significantly longer ($p < 0.05$) than of 'Musang King' and 'Ocee' suggesting that there was a low respiration and ethylene production for 'Monthong' resulted in a delay of ripening duration. The export quality of 'Monthong', its longer storage life, and its low respiration rate make it suitable to shipping fresh to China, overland [26], except 'Ocee' and 'Musang King' due to their short storage life [27]. The longer the duration of durian fruit ripening after harvest, the higher percentage of weight loss per fruit [22]. The slightly higher weight loss and percentage of weight loss resulted in the lowest fruit weight of 'Monthong' as compared to 'Musang King' and 'Ocee'.

Table 1 Fruit weight at harvest, natural fruit ripening duration, weight loss, percentage of weight loss, and fruit weight at ripening.

Durian cultivar	Fruit weight at harvest (kg fruit^{-1})	[1/]Natural fruit ripening duration (days)	Weight loss (kg fruit^{-1})	Percentage of weight loss (%)	Fruit weight at ripening (kg fruit^{-1})
'Monthong'	1.97^{a}	8.67^{a}	0.44^{a}	22.28^{a}	1.53^{b}
'Musang King'	2.10^{a}	5.00^{b}	0.30^{a}	14.13^{a}	1.80^{a}
'Ocee'	2.10^{a}	4.33^{b}	0.31^{a}	14.46^{a}	1.79^{a}
CV.(%)	5.85	7.86	31.57	29.58	6.31

[1/]in the column of treatment means with the same letter is not significantly different at 0.05 probability level (LSD)

Peduncle weight, percentage of peduncle weight, flesh weight, percentage of flesh weight, and flesh thickness

The peduncle weight and percentage of peduncle weight did not vary significantly ($p > 0.05$) between 'Musang King' and 'Ocee' while that of 'Monthong' were significantly higher ($p < 0.05$) than the 2 former (**Table 2**). As similarly reported, the peduncle of 'Monthong' is thick and moderately long [26]. The significantly higher peduncle weight and percentage of peduncle weight was characterized to be an indicator for a better translocation of photoassimilate from the source (leaves) to the sink (fruit flesh) resulted in a higher carbohydrate accumulation in its fruit than both 'Musang King' and 'Ocee'. Thus, the edible parts of 'Monthong' were appreciably larger ($p < 0.05$) as measured by the values of flesh thickness, percentage of flesh thickness, and flesh weight; while those of 'Musang King' and 'Ocee' did not differ significantly ($p > 0.05$) (**Table 2**). The cultivar 'Monthong' produces a large fleshy fruit with 35 % flesh-to-seed ratio; its flesh has a mild odor and is of excellent quality, constituting more than 30 % edible portion which is good in making other local products such as cooked durian paste, durian chips, freeze-dried durian, and seedless flesh for bakeries [26]. According to the National Bureau of Agricultural Commodity and Food Standards [28], the qualification of 'Monthong' durian cultivar for export must be based on the following requirements: fresh fruit with attached peduncle; hard pulp, tip burn, and wet core must not

exceed 5 %; its fruit quality consists of 3 classes-1) Extra class: 4 fertile lobes fruit^{-1}, 2) Class I: At least 3 fertile lobes and 2 unfertile lobes fruit^{-1}, and 3) Class II: At least 2 fertile lobes and 2 unfertile lobes fruit^{-1} with good shape; fruit weight is between 1.5 - 6 kg fruit^{-1}; and the natural fruit ripening is between 6 - 9 days after harvest. The durian cv. 'Monthong' in this study had therefore achieved the agricultural commodity and food standards for export. Likewise, 'Musang King' and 'Ocee' durian cultivars had passed the said export standards except they had natural fruit ripening shorter than 6 days after harvest (**Table 1**). With this, 'Musang King' was prolonged by cryogenic freezing method at −110 °C in order to preserve the quality of its fruit and lengthen its storage life for market expansion [27]. During cryogenic freezing, durian fruit froze rapidly without any dehiscence and did not affect the physicochemical parameters of durian pulp during 36-h storage [27]. However, the Malaysian Ministry of Agriculture pointed out 1 issue in high value commodities (HVC)-identified as 1 was Malaysian durian such as *Musang King* and *Ocee*-that is having low financial investment from investors due to low visibility [29]. It was conformed that investing in HVC is high risk as demand can be volatile compared to staple commodities, and production tends to be in relatively small volume which leads to difficulty in adopting automation [29]. The Ministry had added that HVC also face strong competition from neighboring countries and require strong marketing and market access in order to grow. Many HVC are still not properly regulated and may cause pollution or health hazards to the environment [29].

Table 2 Peduncle weight, percentage of peduncle weight, flesh weight, percentage of flesh weight, and flesh thickness.

Durian cultivar	[1/]Peduncle weight (g fruit^{-1})	Percentage of peduncle weight (%)	Flesh weight (kg fruit^{-1})	Percentage of flesh weight (%)	Flesh thickness (cm)
'Monthong'	16^{a}	1.06^{a}	0.51^{a}	33.68^{a}	2.27^{a}
'Musang King'	10^{b}	0.56^{b}	0.37^{b}	20.47^{b}	1.45^{b}
'Ocee'	10^{b}	0.56^{b}	0.38^{b}	21.28^{b}	1.50^{b}
CV.(%)	19.27	19.29	9.93	9.72	6.71

[1/]in the column of treatment means with the same letter is not significantly different at 0.05 probability level (LSD)

Pericarp weight, percentage of pericarp weight, and pericarp thickness

Pericarp weight, percentage of pericarp weight, and pericarp thickness of 'Monthong' were significantly lower ($p < 0.05$) than of 'Musang King' and 'Ocee'; whereas the values between 'Musang King' and 'Ocee' were not significantly different ($p > 0.05$) except the value of pericarp thickness of the 'former' was significantly higher ($p < 0.05$) than the 'latter' (**Table 3** and **Figures 3(a) - 3(b)**). 'Musang King' and 'Ocee' had thicker pericarps ($p < 0.05$) than 'Monthong'. The thicker pericarp is a good indicator for shipping, which can reduce any damage to the fruits. However, 'Musang King' and 'Ocee' had shorter storage life making it unsuitable for shipping fresh to China overland.

Table 3 Pericarp weight, percentage of pericarp weight, and pericarp thickness.

Durian cultivar	[1/]Pericarp weight (kg fruit^{-1})	Percentage of pericarp weight (%)	Pericarp thickness (cm)
'Monthong'	0.96^{b}	62.75^{b}	0.53^{c}
'Musang King'	1.36^{a}	75.63^{a}	1.63^{a}
'Ocee'	1.29^{a}	71.75^{a}	1.47^{b}
CV.(%)	7.75	4.47	6.74

[1/]in the column of treatment means with the same letter is not significantly different at 0.05 probability level (LSD)

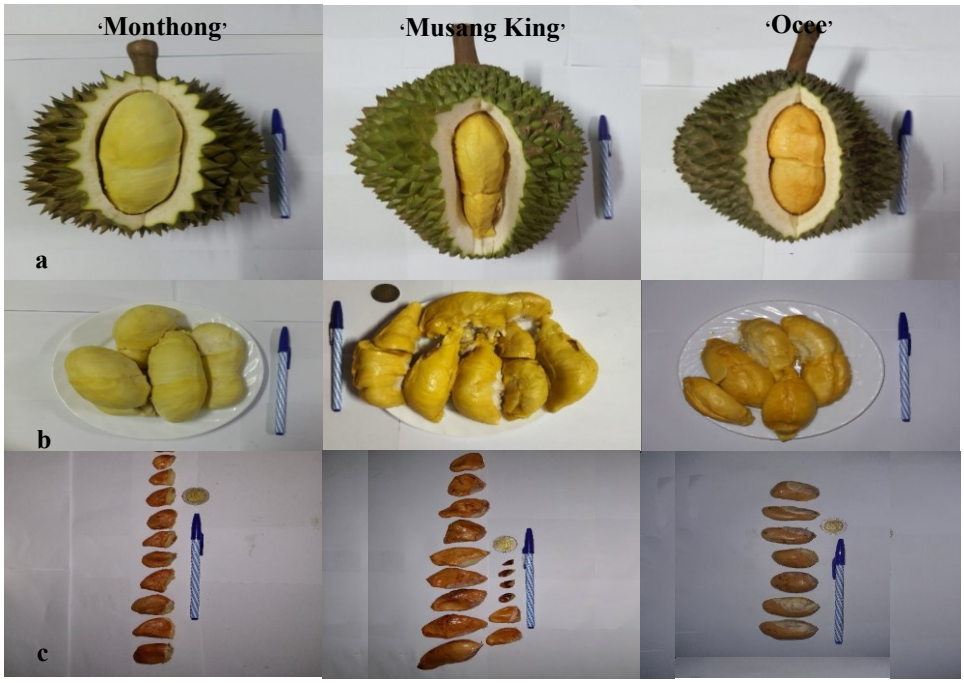

Figure 3 Durian fruit components of 'Monthong', 'Musang King', and 'Ocee' cultivars: a) fruit with its flesh; b) flesh and its Munsell color and; c) seed size, seed shape, and seed color.

Number of seeds, seed weight, percentage of seed weight, seed height, seed width and seed thickness

'Musang King' had significantly the highest number of seeds at 15 seeds fruit^{-1} ($p < 0.05$), followed by 'Monthong' (10.33 seeds fruit^{-1}) ($p < 0.05$), and 'Ocee' (7.33 seeds fruit^{-1}) ($p < 0.05$), respectively (**Table 4** and **Figure 3(c)**). Seed weight and percentage of seed weight of 'Ocee' were significantly higher ($p < 0.05$) than of 'Monthong' and 'Musang King' while the values between the 'latter 2' did not vary significantly ($p > 0.05$). The seed size of 'Ocee' was significantly bigger ($p < 0.05$) than of 'Monthong' and 'Musang King' as measured by the values of seed height, seed width, and seed thickness. While seed height of 'Musang King' was significantly taller ($p < 0.05$) than 'Monthong' but its seed width and seed thickness were significantly shorter ($p < 0.05$).

'Ocee' had all fertile seeds whereas 'Musang King' and 'Monthong' had mostly aborted seeds (**Figure 3(c)**). As reported, there were many small aborted seeds found in each fruit of 'Monthong' cultivar [26]. Thus, seed weight and seed weight percentage of 'Ocee' were significantly higher ($p < 0.05$) than 'Monthong' and 'Musang King'. 'Ocee' durian cultivar had big seeds [30] while 'Musang King' reportedly had narrow and flat, small red-brown seeds [31].

Table 4 Number of seeds, seed weight, percentage of seed weight, seed height, seed width, and seed Thickness.

Durian cultivar	[1/]Number of seeds (seeds fruit^{-1})	Seed weight (g fruit^{-1})	Percentage of seed weight (%)	Seed height (cm)	Seed width (cm)	Seed thickness (cm)
'Monthong'	10.33^{b}	37^{b}	2.50^{b}	2.89^{c}	2.19^{b}	0.83^{b}
'Musang King'	15.00^{a}	61^{b}	3.35^{b}	3.56^{b}	1.86^{c}	0.54^{c}
'Ocee'	7.33^{c}	115^{a}	6.41^{a}	4.62^{a}	2.51^{a}	2.00^{a}
CV.(%)	8.66	21.12	22.16	7.02	6.69	9/67

[1/]in the column of treatment means with the same letter is not significantly different at 0.05 probability level (LSD)

Munsell color, flesh smell and taste of durian flesh, and consumer preference

Niponsak *et al.* [32] stated that fresh-cut durians at the first 3 days of storage had high scores in 'sulfur odor' and 'sweet odor' while fresh-cut durians stored for 5 days had a high value of 'off-odor' and 'green odor' based on sensory analysis. Through principal component analysis (PCA), it explained 79.106 % of the total variance which revealed that the sulfur reduction could determine ripeness of fresh-cut durian during storage. In this study, fruit ripening was determined when the fruit emitted an aroma on its second day-fruit flesh of 'Monthong' cultivar had mild aroma, mildly sweet taste, crispy outer but soft inner flesh with a golden-yellow color (7.5Y8.5/6) (**Table 5**, **Figures 3(a) - 3(b)**). Whereas the fruit flesh of 'Musang King' cultivar had a turmeric-yellow color (5Y8/8), strong aroma, moderately sweet but slightly bitter taste, and very soft, extremely creamy and gummy flesh. Meanwhile, fruit flesh of 'Ocee' cultivar had a yellow-red color (10YR8/10), strong aroma, extremely sweet but slightly bitter taste, and extremely creamy and very soft flesh**.** As a result, 'Monthong' was the most preferred cultivar by the consumers (54 %), followed by 'Musang King' (28 %), and 'Ocee' (18 %) as scored by 50 Thai durian consumers (**Table 5**). In West Halmahera Island, Indonesia, consumer preferences of local durian scored by 60 respondents [33]. And only 30 testers [34] and 10 untrained panels [35] were used to compare the sensory qualities. 'Monthong' had the most preference mainly due to its flesh taste that had a crispy outer but soft inner flesh, mildly sweet taste, and mild aroma as compared to 'Musang King' and 'Ocee'. A similar study showed that 'Monthong' was the most preferred by Thai consumers due to its sweetness, buttery taste, soft and fine texture [36]. On the other hand, 95.2 % of Chinese consumers from Beijing, Shenzen, and Guangzhou preferred 'Musang King' more than 'Monthong' [37]. Similarly, Thai consumers preferred 'Musang King' over 'Ocee' due to its moderately sweet taste, and extremely creamy and gummy flesh. Although 'Ocee' had the highest sweetness among the 3 durian cultivars, it having no gummy flesh affected the consumer's preference (**Table 5**). 'Musang King' and 'Ocee' had similarly very soft and creamy flesh, which were softer and creamier than 'Monthong' when ripened. Among cultivars, 'Ocee' was reportedly the sweetest while 'Monthong' was the least [38]. The total sugar concentration of 'Ocee' was 257.63 μg mg^{-1}, while of 'Monthong' was 138.73 μg mg^{-1}. Considering the sweetness of sugars is different among cultivars, 'Ocee' durian has much higher sucrose content than those of 'Monthong' and 'Musang King', which masks the sweetness effect in the former 2. In terms of umami flavor (the most delicious), 'Monthong' had the highest umami, followed by 'Musang King', while 'Ocee' had the lowest, as the taste of durian varies according to its origin and cultivar [38]. Through statistical analysis, factors such as origin, education, and occupation had a relation to durian preference by the consumers, while gender, age, and income of the consumers had not [36]. The communities on West Halmahera Island have preference trend for a local durian fruit with agronomic characteristics such as small size, brownish green color, round shape, short and sparse size, and spines. Other agronomic characteristics include yellow flesh character, sweet taste, strong aroma, soft texture, thick flesh, less fibrous, and small seeds until deflated. The consumer preferences for local durian can be used as initial data for the national standard durian breeding program as suggested by Sundari and Roini [33].

As revealed by Sukloet [39] in his study, Thailand has a comparative advantage in the year of 2018 in terms of fresh durian exports to China consequent to government supporting under Thailand 4.0 policy, the growing Chinese middle class, e-commerce and China's preference for Thai fruits, in particular to durian. Despite that fact, the growth of Thai fresh durian market share in China grew at a declining rate as China had declared the intention to import Malaysian durians in 2019, thus it had become a main competitor in Chinese market for Thai durian. That being the case, Thailand must maintain its durian competitiveness by continuously developing production process and export. Moreover, Siriprasertchok and Panyagometh [40] suggested that the government should open new market opportunities especially in agro-tourism market with regard to durian consumption trends by creating new products to meet the demand of consumers. They identified online durian trade for agro-food products as a new marketing strategy that should be implemented as well. Durian-growing countries from the Association of Southeast Asian Nations (ASEAN) can also work together in adapting new packaging technologies for more efficient transportation [41].

Table 5 Munsell color, flesh smell and flesh taste of durian flesh, and consumer preference.

Durian cultivar	Munsell color of durian flesh	Smell and taste of flesh	Consumer preference (%)
'Monthong'	7.7Y8.5/6 or golden-yellow colored flesh	Mild aroma, mildly sweet, crispy outer but soft inner flesh	54
'Musang King'	5Y8/8 or turmeric-yellow colored flesh	Strong aroma, moderately sweet but slightly bitter, very soft, extremely creamy and gummy flesh	28
'Ocee'	10YR8/10 or yellow-red colored flesh	Strong aroma, extremely sweet but slightly bitter, extremely creamy and very soft flesh	18

Conclusions

It is therefore concluded that 'Monthong' obtained the significantly longer natural fruit ripening duration (or long storage life) (73 - 100 %), higher flesh weight (34 - 38 %), higher percentage of flesh weight (58 - 65 %), higher flesh thickness (51 - 57 %), and higher customer preference cultivar (93 - 200 %), better than of 'Musang King' and 'Ocee'. The said factors are good indicators of the export quality of 'Monthong', which is considered to be suitable for shipping fresh overland, especially to countries like China that highly imports durian from Thailand. Whereas, 'Musang King' and 'Ocee' had short ripening duration (4 - 5 days) (or short storage life) effecting to their poor export quality, which made them impossible or unsuitable for shipping fresh fruit overland. Based on these findings, Thai farmers can subsequently expand their growing areas for durian cv. 'Monthong' to increase its production whilst maintaining its quality standard in order to fulfill the needs of foreign consumers simultaneously to generate higher income from exports. Shipping methods by land, sea, and air, including the development of packaging technology, are therefore recommended for further study for the benefit of the export market.

Acknowledgements

The authors would like to thank Rajamangala University of Technology Tawan-Ok Chanthaburi Campus, Thailand for allowing the use of experiment station as well as their laboratory.

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