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Physicochemical and sensorial properties of durian jam prepared from fresh and frozen pulp of various durian cultivars

Tifani, K. T., Nugroho, L. P. E. and *Purwanti, N.

Department of Mechanical and Biosystem Engineering, Bogor Agricultural University, Dramaga Campus, PO Box 220, Bogor, West Java, 16002, Indonesia

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Abstract

Durian is a seasonal fruit that has a unique shape and distinctive odor of which pulp is the edible part. Durian pulp has limited shelf-life between 2 and 5 days at room temperature; therefore, processing of durian pulp is needed to prolong its shelf-life, e.g., durian pulp is processed into jam. This research aimed to determine the effects of various durian cultivars and of freezing on the physicochemical properties of durian jam. Durian cultivars Montong, Chanee, Hepe and Petruk were used. The research stages were freezing of durian pulp, jam processing, and observing the physicochemical properties of fresh and frozen pulp as well as the resulting jam. The sensorial properties of the jam were also studied. The physicochemical properties included pH, acidity, total soluble solids (TSS), texture and color. The results show that durian pulp from various cultivars had significant differences on TSS and color. Freezing process affected the physicochemical properties of durian pulp with significant differences on pH and color among the cultivars but it did not affect the properties of the jam. Therefore, freezing is a suitable preservation technique for durian pulp. The sensory analysis indicates that the panelists preferred the jam made from cultivars Chanee and Petruk.

Introduction

Durian is a climacteric fruit and it is a seasonal fruit in Asia. Durian has round or oval shape; it is about the size of a coconut with a green, yellowish green, or dark yellow color. Durian skin is covered with semi-sharp pointed spines. Inside, durian is usually divided into five compartments; each consists of several seeds surrounded by edible custard (pulp) with a sweet and slight bitter taste (Weenen *et al*., 1996). Chin *et al.* (2010) found that there are two keys of odor volatile compounds in durian pulp namely sulfide and ester. Another research identified 40 compounds in durian (Voon *et al*., 2007b) among which sulfur compounds, esters, and alcohols were the major constituents. The popular cultivars of durian include Indonesian ‘Sitokong’, ‘Petruk’, ‘Sunan’, ‘Sukun’ and ‘Simas’; Malaysian ‘D2’, ‘D10’, ‘D24’ and ‘D99’ and Thai ‘Monthong’, ‘Chanee’, ‘Kanyao’ and ‘Kradum’ (Yahia, 2011). Durian pulp has shelf-life about 3–4 days; therefore, preservation is needed to prolong its shelf-life. Preservation efforts that have been reported are for e.g., minimally process of the pulp (Booncerm and Siriphanich, 1991; Voon *et al*., 2006, 2007b), frozen pulp (Yahia, 2011), processing of the pulp into various products such as durian cake (Paweenakarn *et al*., 1992), durian chips (Ngew *et al*., 2011; Jamradloedluk *et al*., 2007) and dried powder (Man *et al*., 1999; Chin *et al*., 2008; Chin *et al*., 2010). Another desirable preservation method is processing of durian pulp into jam. Classic jams and confitures are widely consumed during breakfast and widely applied in dairy, bakery and confectionery products (Igual *et al*., 2014). This leads to a significant amount of jams that should be produced to fulfill the market demand.

Jam is a semisolid food prepared by boiling fruit pulp at 95–100^{o}C with sugar, pectin, acid, and flavoring materials until the mixture has a suitable gel consistency (Kurz *et al*., 2008; Holzwarth *et al*., 2013). The jam can be made from fresh fruits, frozen fruits, chilled fruits, whole fruits or fruit pulp preserved by heat, whole fruits or fruit pulp preserved with sulfur dioxide, dried dehydrated fruits (Hui, 2006) and osmodehydrated fruit (Martinez *et al*., 2002). The jam texture is influenced by gelling agent, for e.g., gelatin and pectin, acidity and sugar concentration. A previous study showed that the plum and cherry jam formulation consist of 50% w/w fruit, 48% w/w sugar, and the pH was set between 3.0 and 3.2 (Kim and Padilla-Zakour, 2004); meanwhile, the best texture of strawberry jam consisted of 450 g of fruit, 2 g of pectin, 0.4 g of citric acid and a final sucrose concentration of 63obrix (García-Viguera *et*

*Corresponding author.
Email: *nanik_purwanti@ipb.ac.id*

al., 1999). Sinha *et al.* (2006) stated that the best jam texture was generally obtained by mixing 45% of fruit pulp and 1.0% w/w of pectin set at pH 3.0 until the total soluble solids (TSS) reached 67.5obrix.

Processing fruits or fruit pulp into jam may cause changes in the physicochemical properties such as color (Holzwarth *et al*., 2013), texture (Lespinard *et al.,* 2012) and volatility (Chin *et al*., 2008). The sensorial properties of the jam are also completely different from those of the fruits or fruit pulp. In the previous research, the physicochemical and sensorial properties of various durian cultivars from Malaysia (D2, D24, MDUR78, D101 and Chuk) have been analyzed (Voon *et al*., 2007a). The results showed differences in the physicochemical and sensorial properties among the cultivars. The differences in the physicochemical properties of durian pulp might influence the resulting jam quality but this has not been studied. The objectives of this research were to determine the effects of various durian cultivars and conditions of durian pulp (fresh and frozen pulp) on the physicochemical and sensorial properties of durian jam. The ultimate goal of this research was to recommend the best cultivar for producing durian jam.

Materials and Methods

Materials

Durian cultivars namely Montong, Chanee, Hepe and Petruk were used in this research. Mature green durian (95–105 day after anthesis) were obtained from a local farm in Ciawi, West Java, Indonesia and collected during rainy season in May 2015. Fresh pulp was immediately taken out from the fruit and processed into jam. Frozen pulp was prepared from the fresh pulp that was frozen in -18^{o}C (Eshtiaghi and Knorr, 1996) for one week and thawed in room temperature before jam processing. Durian cultivars with their conditions were labeled as MS (cultivar Monthong, fresh pulp), MB (cultivar Monthong, frozen pulp), CS (cultivar Chanee, fresh pulp), CB (cultivar Chanee, frozen pulp), HS (cultivar Hepe, fresh pulp), HB (cultivar Hepe, frozen pulp), PS (cultivar Petruk, fresh pulp) and PB (cultivar Petruk, frozen pulp). Distilled water, sugar (Sugar Group Company, Lampung) and citric acid (Merck, Germany) were used as additive materials in the jam processing.

Jam processing

Fruit pulp was placed in a non-sticky pan and then 30% w/w sugar, 0.002% w/w citric acid and 60% v/w water were added simultaneously prior cooking. These ingredients were added based on 900 g of durian pulp. The fruit mixture was cooked at 95–100^{o}C for 60 min or until TSS of the jam was 65^{o}brix.

Total soluble solids

Total soluble solids (TSS) of fresh and frozen durian pulp and durian jam were determined using a digital refractometer (Atago, Tokyo, Japan) according to Martínez *et al.* (2013). The results were expressed as ^{o}Brix.

pH measurement

The pH of durian pulp and durian jam was measured according to Li-Tingting *et al.* (2013). Minced durian pulp or durian jam (10.0 g) was mixed with 90 ml of distilled water and the mixture was filtered. The pH values of the filtrate were measured using a digital pH meter (Digital Instrument, Taiwan).

Acidity

The acidity was measured by titrating a sample with phenolphthalein (PP) and 0.1 N NaOH solution according to AOAC Method 942.15 (AOAC, 1995) and expressed as % acidity. A hundred milligrams of sample was placed in a 100 ml volumetric flask and then diluted with distilled water until the boundary line. The mixture was homogenized and filtered. Ten milliliters of the filtrate was placed in an Erlenmeyer flask. The filtrate was added with 2-3 drops of PP. The filtrate was titrated with 0.1N NaOH solution until the color of the solution turned red and the color remained stable for 30 seconds. The total citric acid value (%) of the sample was calculated using the Equation 1:

$$Acidity = \frac{V \times N \times f_p \times M}{m} \times 100\% \quad (1)$$

where V is the volume of NaOH (ml), N is the normality value of NaOH solution, fp is the dilution factor (100/10), M is the molecular weight of NaOH, and m is the sample's mass (mg).

Texture

Texture of the samples was analyzed using a universal testing machine (Time Group Model WDW – 5E, China) connected to WinWDW software (WDW, China) for data acquisition. A cylindrical probe with a diameter of 5 mm was used. Homogenized pulp or jam was place in a plastic tube with diameter 2 cm and height 4 cm. The equipment was set for a puncture test performed at a constant velocity of 100 mm/min until the probe reached 25 mm of the sample's depth according to Holzwarth *et al.* (2013). The sample texture was expressed as the sample's firmness and defined as the maximum force (N) at the breaking point of the sample.

Color

The color of durian pulp and jam was evaluated using a chromameter (Minolta Chroma Meter CR-400, Minolta Corp., Osaka, Japan) according to Petzoldet *et al*. (2014). The instrument was calibrated with a standard white plate ($L^* = 98.56$, $a^* = 0.09$, $b^* = 1.25$). A glass Petri dish containing sample was placed above the white plate and then, the sample was subjected to the light source of the chromameter. Three parameters were recorded, i.e., L^* that represents lightness (black = 0, white = 100), a^* that represents redness ($a^*>0$) or greenness ($a^*<0$), and b^* that represents yellowness ($b^*>0$) or blueness ($b^*<0$). The color of the durian pulp and jam was expressed as hue angle (hue) that was calculated based on a^* and b^* values, as shown in Equation 2. The color intensity was also calculated from a^* and b^*, expressed as chroma (C^*), as shown in Equation 3.

$$hue = arctg\frac{a^*}{b^*} \quad (2)$$

$$C^* = \left(a^{*2} + b^{*2}\right)^{\frac{1}{2}} \quad (3)$$

Sensory evaluation

Quantitative descriptive analysis (QDA) was used for sensory evaluation of durian jams by 12 trained panelists (4 females, 8 males) based on the method of Stone et al. (1974). The panelists were trained to get acquainted with the sensorial attributes. During training, the panelists were provided durian jams prepared from various cultivars and the references as described in the attributes. For examples, the panelists were trained to get acquainted with the fruit aroma by comparing durian jam with fresh durian, sweet aroma by comparing the jam with caramel candy, alcohol aroma by comparing the jam with a fermented product, etc. They took water to clear their palates in between samples. The panelists were also obliged to take fresh air before proceeding to the next sample to prevent odor or aroma saturation.

Evaluation of the sensory attributes by the panelists was performed using a sensory score sheet based on the modified method of Voon *et al.* (2007b). A 10 cm unstructured scale horizontal line was used to indicate the intensity of each attribute. Quantification of the sensory attributes was done by measuring the distance of the scale marked by the panelists. Acceptability of each attribute was evaluated based on five point hedonic scale.

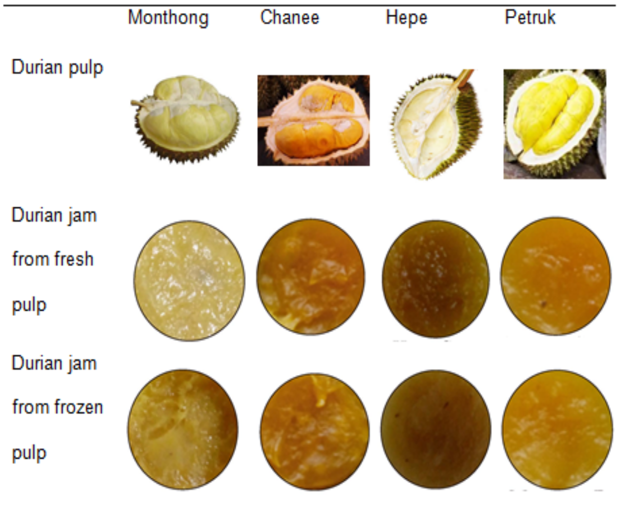

Figure 1. The color of durian pulp and jam prepared from fresh and frozen pulp of various durian cultivars.

Statistical analysis

All physicochemical and sensorial properties above were measured in triplicate and the results were reported in terms of the mean values. The data obtained from the physicochemical analysis and sensory evaluation were analyzed using analysis of variance (ANOVA). One-way ANOVA was performed using Excel software. Duncan Multiple Range Test (DMRT) with a significant difference of $p<0.05$ was applied to study the interrelation between physicochemical and sensorial properties. The Pearson correlation coefficients between the physicochemical and sensorial properties were calculated using Excel Stat.

Results and Discussion

Physicochemical properties of fresh and frozen durian pulps

Figure 1 shows the appearances of durian pulp from all cultivars used in this study. This figure clearly indicates that different cultivars have different colors of pulp which might also imply to different physicochemical properties. Table 1a shows physicochemical properties of fresh and frozen durian pulps from various durian cultivars. TSS provides an estimate of sugar content and this includes organic acids and other constituents such as amino acids or pectin (Martinez *et al.,* 2013). Fresh durian pulp from cultivar Chanee has the highest TSS followed by the pulp from cultivar Petruk, Hepe, and Monthong, respectively. There is a significant difference of TSS among the cultivars. TSS of the pulp changed when they were frozen as shown in Table 1a. The highest TSS in frozen pulp is found in the pulp from cultivar Petruk followed by the pulp from cultivar Chanee, Hepe, and Monthong, respectively. However, there

Table 1. Physicochemical properties of durian pulp (a) and jam (b) from various durian cultivars.

a.

Parameters[A]	Durian Cultivars[B]							
	MS	MB	CS	CB	HS	HB	PS	PB
TSS (°Brix)	27.63 ±0.86^{d}	28.17 ±0.92^{d}	35.17 ±0.15^{a}	32.33 ±0.21^{b}	30.00 ±0.35^{c}	27.77 ±0.70^{d}	32.27 ±0.83^{b}	32.87 ±0.25^{b}
pH	6.99 ±0.02^{c}	6.53 ±0.13^{f}	7.01 ±0.02^{c}	7.01 ±0.03^{c}	7.45 ±0.05^{b}	6.80 ±0.02^{d}	7.56 ±0.08^{a}	6.69 ±0.06^{e}
Acidity (%)	0.36 ±0.02^{ab}	0.40 ±0.02^{a}	0.34 ±0.02^{bc}	0.36 ±0.02^{ab}	0.32 ±0.02^{c}	0.37 ±0.01^{ab}	0.28 ±0.02^{d}	0.37 ±0.01^{ab}
Color								
*L**	71.09 ±0.16^{b}	64.97 ±1.59^{b}	72.98 ±0.32^{b}	75.24 ±0.23^{a}	53.00 ±0.79^{d}	64.82 ±0.17^{c}	74.74 ±1.81^{a}	69.06 ±1.04^{b}
*a**	-3.40 ±0.03^{f}	-2.46 ±0.16^{ef}	2.11 ±0.20^{a}	0.54 ±0.03^{b}	-1.80 ±0.51^{cd}	-2.21 ±0.04^{de}	0.23 ±0.15^{b}	-1.38 ±0.43^{c}
*b**	15.88 ±0.13^{d}	18.06 ±0.22^{c}	26.72 ±0.32^{b}	28.57 ±0.58^{a}	6.81 ±1.27^{e}	7.20 ±0.15^{e}	26.26 ±1.03^{b}	18.43 ±0.18^{a}
*C**	16.24 ±0.13^{d}	18.23 ±0.24^{c}	26.81 ±0.33^{b}	28.58 ±0.58^{a}	7.04 ±1.36^{e}	7.53 ±0.14^{e}	26.26 ±1.03^{b}	18.48 ±0.18^{c}
hue	2.5GY 7/2	2.5GY 6/3	2.5Y 7/4	2.5Y 7/4	5GY 5/1	5GY 6/1	2.5Y 7/4	5Y 7/2
Texture (N)	0.38 ±0.03^{a}	0.33 ±0.05^{ab}	0.32 ±0.03^{bc}	0.25 ±0.02^{d}	0.28 ±0.03^{cd}	0.19 ±0.03^{e}	0.32 ±0.02^{bc}	0.30 ±0.02^{bc}

b.

Parameters[A]	Durian Cultivars[B]							
	MS	MB	CS	CB	HS	HB	PS	PB
TSS (°Brix)	63.60 ±0.46^{b}	64.67 ±0.67^{a}	64.90 ±0.20^{a}	65.00 ±0.82^{a}	63.70 ±0.60^{b}	63.65 ±0.41^{b}	64.80 ±0.30^{a}	64.33 ±0.15^{ab}
pH	5.66 ±0.02^{de}	4.91 ±0.01^{f}	5.97 ±0.07^{a}	5.86 ±0.01^{b}	5.71 ±0.02^{d}	5.81 ±0.01^{c}	5.66 ±0.04^{de}	5.62 ±0.04^{e}
Acidity (%)	0.67 ±0.06^{ab}	0.89 ±0.09^{a}	0.50 ±0.09^{d}	0.55 ±0.03^{abc}	0.76 ±0.02^{ab}	0.51 ±0.04^{bcd}	0.63 ±0.03^{ab}	0.68 ±0.05^{ab}
Color								
*L**	68.46 ±0.41^{b}	52.78 ±0.32^{e}	56.58 ±0.69^{c}	53.67 ±0.90^{de}	54.97 ±1.59^{d}	76.27 ±0.33^{a}	54.31 ±0.48^{d}	49.74 ±0.21^{f}
*a**	-3.02 ±0.33^{ab}	-3.18 ±0.03^{a}	-0.16 ±0.85^{d}	-2.42 ±0.04^{bc}	-2.59 ±0.13^{abc}	-2.52 ±0.15^{abc}	-2.46 ±0.16^{abc}	-2.20 ±0.55^{c}
*b**	7.54 ±0.52^{d}	7.93 ±0.20^{d}	18.06 ±0.66^{b}	13.39 ±0.58^{c}	8.06 ±0.22^{d}	8.84 ±0.19^{d}	18.06 ±0.22^{b}	18.89 ±0.04^{a}
*C**	8.12 ±0.56^{d}	8.54 ±0.18^{d}	18.07 ±0.65^{c}	13.61 ±0.57^{b}	8.47 ±0.23^{d}	9.19 ±0.22^{d}	18.23 ±0.24^{b}	19.03 ±0.06^{a}
hue	2.5GY 6/1	2.5GY 5/1	5Y 5/3	10Y 5/2	2.5GY 5/1	2.5GY 7/1	10Y 5/3	10Y 4/3
Texture (N)	0.33 ±0.06^{a}	0.27 ±0.06^{a}	0.30 ±0.00^{a}	0.30 ±0.00^{a}	0.23 ±0.06^{b}	0.30 ±0.00^{a}	0.34 ±0.04^{a}	0.26 ±0.04^{ab}

[A]Mean ± SD group comparisons by means of parametric Duncan test

[B]Means within rows with changed letter are significantly different according to Duncan test ($p<0.05$)

is no significant difference among the cultivars for frozen pulp. The total sugar changes when a product is frozen because both oligo and polysaccharides are hydrolyzed by a unilateral attack of protons on the glucosidic bound, leading to the release of mainly glucose (Martins and Silva, 2003). Overall, by comparing all cultivars and conditions, there are no significant differences in TSS of fresh and frozen durian pulp.

The pH of fresh durian pulp ranges from 6.99 to 7.56 and there is no a significant difference among the cultivars. The pH significantly decreased by freezing, except for cultivar Chanee that remained constant. The pH trend with freezing is opposite to the acidity trend that increased with freezing. The decrease in pH of frozen fruits is similar to the findings previously reported by Chung *et al.* (2013). The decrease in pH might be explained by an ion leakage of intracellular constituents caused by the formation of ice crystals at -18 °C (Cai *et al.*, 2014).

Durian pulp, either fresh or frozen pulp, from all varieties was light, indicated by high L^* value. There are no significant differences among the cultivars, either in fresh or frozen pulp. However, the lightness of the pulp changed with freezing. Fresh pulp from cultivar Petruk has the highest L^* value followed by the pulp from cultivar Chanee, Monthong, Hepe respectively. This sequence changed when the pulp was frozen, i.e., cultivar Chanee followed by Petruk, Monthong and Hepe, respectively. Hue angel and color intensity of the fresh pulp indicate that the cultivars had different colors and color intensity. The color of durian pulp (fresh and frozen) from all cultivars based on its hue angel is depicted in Figure 2a. The highest hue angel was obtained in cultivar Petruk and the lowest was obtained in cultivar Monthong. The pulp from cultivar Petruk and Chanee have the most color intensity; meanwhile, the pulp from cultivar Hepe has the lowest color intensity. The color of cultivar Monthong, Chanee and Petruk is yellow but the color of cultivar Hepe is green yellow (as plotted in Figure 2a). The color of durian pulp and its intensity changed after freezing. The frozen pulp has more intense color than the fresh pulp, except for cultivar Petruk. According to Tijskenset *et al.* (2001), the color change could be attributed to the air removal around the surface, the air expulsion between the cells and its replacement with water and cell juice that was released from the deteriorated membranes that occurred during freezing. Nevertheless, there are no significant differences on colors and color intensity between the fresh pulp and frozen pulp for

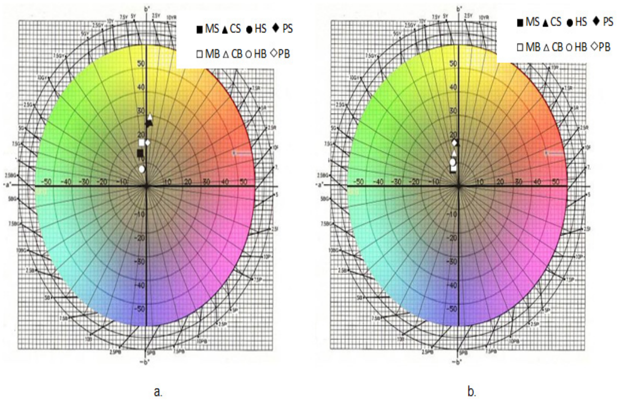

Figure 2. The color of fresh and frozen durian pulp (a) and the resulting jam (b) from various durian cultivars on the hue diagram.

all cultivars.

The firmness of fresh pulp from various cultivars does not have any significant differences. The highest value of firmness was found in cultivar Monthong followed by Petruk, Chanee, Hepe, respectively. The firmness of durian pulp from all cultivars decreased after freezing. Nevertheless, the firmness sequence of frozen pulp based on the cultivars is the same as that of fresh pulp. The decrease in pulp firmness might be attributed to the changes of cell wall structures during freezing. The formation of large ice crystals during freezing causes cell separation and eventually, the cells rupture which cause the loss of turgor (Paciulli *et al*., 2014; Ando *et al.*, 2015).

Physicochemical properties of durian jam

The physicochemical properties of durian pulp affect jam processing and subsequently, the properties of the resulting jam. The TSS and pH of durian pulp are important attributes that are used as a basis for sugar and citric acid addition. Mango pulp with TSS of 15–18% brix resulted in the best jam texture when the pulp was added with 60% w/w sugar, 1% w/w pectin, and set at pH 3.4 (Basu *et al.*, 2011). However, composition of the mango mixture could not be applied for making durian jam because durian pulp has higher TSS than mango pulp. Therefore, modification on the mixture composition when durian pulp is processed into jam was required. The preliminary research showed that durian pulp added with 30% sugar, 0.02% citric acid, and the pH set at 5 – 6 resulted in the best durian jam texture (data is not shown), i.e., good jelly-like consistency and spread ability.

The addition of sugar and citric acid during jam processing caused changes on the physicochemical properties of durian pulp (Table 1b). The durian jam has much higher TSS than durian pulp, regardless the durian cultivars and conditions of the pulp (fresh or frozen pulps). The increase in TSS is mainly attributed to the sugar addition. Overall, there is no a significant difference on TSS of durian jam manufactured from various cultivars. The pH of durian jam prepared from fresh and frozen pulp ranges from 4.91 to 5.97 and there is no a significant difference among the cultivars. The pH trend in durian jam is opposite to the acidity trend that increased in all of the jam. However, the acidity of durian jam prepared from fresh and frozen pulp of all cultivars does not have any significant differences. The acidity is one of the physicochemical parameters that are responsible for a longer shelf-life of the products because certain degree of acidity protects the products from microorganisms (Touati *et al*., 2014). Therefore, shelf-life of durian jam can be longer than fresh durian pulp by increasing the acidity.

The appearances of durian jam from fresh and frozen durian pulp are shown in Figure 1. The durian jam has different lightness, color, and color intensity from the durian pulp, as can be seen from Table 1b. The jam prepared from cultivar Monthong was the brightest among other cultivars, as can be seen from L^* value. Overall, the lightness of the jam was lower than the lightness of the pulp, except for frozen pulp of cultivar Hepe. This result is contradictive with the result of Holzwart *et al.* (2013) that reported increased L^* value when strawberry was processed into jam. This contradictive exists because durian and strawberry have different color pigments. Durian color is influenced by carotenoid (Yahia, 2011); meanwhile, the strawberry color is influenced by anthocyanin. Carotenoid content (especially β-cryptoxanthin) increases during freezing (Oliveira *et al*., 2016) but anthocyanin content decreases during freezing (Wrolstad *et al*., 1970; Holzwart *et al.*, 2013). Hue angle of the fresh and frozen pulp for all cultivars decreased when the pulp was processed into jam, except cultivar Chanee; meanwhile, the color intensity *(*C^**)* decreased significantly in all of cultivars, except for frozen pulp of cultivar Petruk (depicted in Figure 2b). The changes of three color parameters when durian pulp was processed into jam indicate that the jam has darker color than the pulp. The darker color of the jam might be attributed by browning reaction because the jam has high content of oxidized polyphenols (Holzwart *et al*., 2013).

This research confirmed that the texture or firmness of durian pulp decreased after it was processed into jam. This decrease might be attributed to the increase of polygalacturonase activity and soluble pectin that are concomitant with increasing temperature during jam processing. Therefore, the texture of durian jam is softer than durian pulp (Imsabai *et al*., 2002).

Table 2. Correlation matrix of physicochemical properties of durian jam (a) and sensorial properties (b).

a.

	TSS	pH	Acidity	C*	Texture
TSS	1				
pH	-0.058	1			
Acidity	-0.124	**-0.880**	1		
C*	**0.645**	0.362	-0.412	1	
Texture	0.203	0.243	-0.484	0.213	1

b.

	TSS	pH	Acidity	Texture
Sweetness	0.406	0.619	**-0.672**	-0.314
Aftertaste	**-0.643**	-0.456	0.426	-0.078
Color	-0.389	**-0.599**	0.617	0.104
Creaminess	0.147	**0.825**	**-0.736**	0.028
Stickiness	0.493	**0.777**	-0.685	0.106
Moist	0.367	**0.816**	**-0.715**	0.166

Correlation coefficients with p≤0.05 are marked in bold.

Nevertheless, this research concluded that the texture of durian jam prepared from fresh and frozen pulp does not have any significant differences for all cultivars. Firmness or hardness was associated as one of the spread ability parameters of jam in which this particular parameter was strongly affected pH, sugar and pectin content (Basu and Shivhare, 2010; Holzwarth *et al*., 2013)

The interdependence among the physicochemical properties was analyzed by Pearson correlation (Table 2a). The acidity of the jam has a good correlation (r = 0.880) with the pH. The TSS of the jam relates to color intensity (r = 0.645). This relation might be caused by sugar addition in jam making (Kamiloglu *et al*., 2015).

Sensorial properties of durian jam

The results of QDA of durian jam are listed in Table 3. There are no significant differences in sweet aroma and fruit aroma among the jam prepared from both fresh and frozen pulp of different cultivars. The aromas of durian pulp correlate with volatile compounds found in the pulp (Weenen *et al*., 1996; Voon *et al*., 2007a; Voon *et al*., 2007b). Sweet and fruity aromas correlate strongly with most esters and an aldehyde compound (Voon *et al*., 2007b). However, esters more contribute to the sweet aroma than aldehyde; meanwhile, aldehyde contributes to the fruity aroma (Voon *et al*., 2007b). Sulphur aroma of the jam prepared from the fresh pulp does not have any differences for all cultivars. The sulphur aroma decreased significantly in the jam prepared from the frozen pulp in cultivar Chanee, Hepe and Petruk, except cultivar Monthong. Voon *et al.* (2007a) reported that cultivar Monthong has the highest sulphur content among other cultivars; therefore, this cultivar has the most intense sulphur aroma. The jam prepared from the fresh pulp of cultivar Monthong has the highest value of alcohol aroma followed by Petruk, Chanee, Hepe respectively. However, the jam prepared from the frozen pulp of cultivar Petruk has the highest value of alcohol aroma. Ethyl 2-methylbutanoate, which contributes to the intense odor of durian (Weenen *et al.*, 1996), correlates strongly with alcohol notes. The alcohol notes are probably associated with acetaldehyde, ethyl acetate, methyl propionate, ethyl propanoate and propyl 2-methylbutanoate (Voon *et al.*, 2007b). Green aroma of the jam prepared from the fresh pulp does not have any significant differences among the cultivars. In cultivar Petruk, this aroma decreased significantly when the jam was prepared from the frozen pulp. Green aroma implies the freshness aroma of the jam. The green aroma correlates well with the concentrations of 1-hexanol and benzyl alcohol (Voon *et al*., 2007b). An intense nutty aroma is found in the jam prepared from cultivar Chanee, both fresh and frozen pulp. The perceived nutty aroma is suggested to have correlation with propanal, ethyl acetate, and total aldehyde (Voon *et al*., 2007b). Off-odor is the highest in the jam prepared from the fresh pulp of cultivar Monthong, whereas, the most intense off-odor is found in the jam prepared from the frozen pulp of cultivar Hepe. Off-odor correlates well with dipropyl disulfide, benzyl alcohol and 1-hexanol (Voon *et al*., 2007b). Overall, the panelists preferred the jam prepared from fresh and frozen pulp of cultivar Chanee for its aroma.

There are no significant differences in the sweetness flavor of the jam prepared from fresh and frozen pulp of all cultivars. However, the jam from cultivar Monthong has the lowest sweetness flavor. The high value in aftertaste might be the reason for the lowest sweetness of the jam from this cultivar. The aftertaste of durian jam is described as sour flavor, as indicated by high acidity and low pH in cultivar Monthong (Voon *et al*., 2007a). The panelists preferred the jams prepared from fresh and frozen pulp of cultivar Chanee and Petruk due to their sweetness, grassiness and overall flavor.

The color of the jam ranges from yellow to golden yellow. There are no significant differences in the color of the jam prepared from both fresh and frozen pulp of all cultivars. The jam texture is described as creamy, sticky, and moist. The jam prepared from fresh and frozen pulp of cultivar Hepe has the highest value in creaminess, stickiness and moist, followed by cultivar Monthong, Petruk and Chanee, respectively.

Table 3. Sensorial properties of durian jam prepared from various durian cultivars.

Parameters[A]	Durian Cultivars[B]							
	MS	MB	CS	CB	HS	HB	PS	PB
Aroma								
Sweet aroma	6.40 ±1.65^{a}	5.32 ±1.39^{a}	7.92 ±1.55^{a}	7.57 ±1.13^{a}	8.05 ±1.30^{a}	8.27 ±0.93^{a}	7.92 ±1.97^{a}	7.40 ±2.85^{a}
Fruit aroma	6.25 ±1.08^{a}	6.68 ±0.88^{a}	6.88 ±0.94^{a}	6.85 ±1.78^{a}	7.17 ±0.50^{a}	5.97 ±1.11^{a}	7.58 ±2.72^{a}	6.65 ±3.39^{a}
Sulphur aroma	2.87 ±2.59^{ab}	3.43 ±1.72^{ab}	5.10 ±1.45^{a}	1.73 ±1.48^{b}	4.30 ±0.88^{ab}	2.17 ±1.31^{ab}	2.40 ±2.60^{ab}	1.72 ±1.40^{b}
Alcohol aroma	6.88 ±1.75^{a}	3.90 ±1.64^{ab}	3.77 ±1.56^{ab}	2.58 ±2.53^{b}	3.63 ±2.56^{b}	3.87 ±2.88^{ab}	5.48 ±1.22^{ab}	4.85 ±1.53^{ab}
Green aroma	3.50 ± 1.57^{ab}	3.90 ±1.64^{ab}	4.83 ±1.64^{ab}	5.15 ±2.75^{ab}	4.27 ±1.00^{ab}	4.12 ±1.77^{ab}	6.45 ±2.37^{a}	3.03 ± 0.98^{b}
Nutty aroma	1.82 ±1.64^{b}	3.03 ±1.92^{ab}	5.58 ±1.62^{a}	5.97 ±2.71^{a}	5.03 ±0.99^{ab}	3.07 ±2.19^{ab}	3.85 ±2.08^{ab}	3.07 ±2.22^{ab}
Off odor	5.68 ±1.93^{a}	2.52 ±2.98^{a}	2.30 ±2.18^{a}	2.02 ±2.01^{a}	3.50 ±2.34^{a}	3.20 ±3.05^{a}	2.40 ±2.35^{a}	2.08 ±2.76^{a}
Overall aroma	6.02 ±2.14^{ab}	6.50 ±2.02^{ab}	7.82 ±1.33^{ab}	7.62 ±1.82^{ab}	4.68 ±1.99^{bc}	3.42 ±2.30^{c}	8.17 ±2.30^{a}	7.62 ±1.06^{ab}
Flavor								
Sweetness	4.10 ±2.25^{b}	4.60 ±2.42^{ab}	7.20 ±1.25^{a}	7.40 ±1.47^{a}	5.80 ±1.48^{ab}	6.80 ±1.21^{ab}	6.00 ±1.22^{ab}	7.30 ±2.01^{a}
Aftertaste	9.10 ±0.82^{a}	8.67 ±1.03^{a}	2.85 ±0.98^{c}	3.05 ±2.00^{c}	6.43 ±1.19^{b}	7.62 ±1.39^{ab}	1.98 ±1.78^{c}	1.63 ±2.13^{c}
Grassiness	4.42 ±2.38^{a}	4.25 ±2.12^{a}	6.98 ±0.76^{a}	6.53 ±1.00^{a}	4.65 ±2.73^{a}	5.02 ±1.75^{a}	5.43 ±2.30^{a}	6.33 ±1.96^{a}
Overall taste	4.65 ±2.47^{b}	4.65 ±2.40^{b}	8.22 ±0.78^{a}	9.02 ±1.05^{a}	6.72 ±1.47^{a}	7.50 ±2.22^{a}	7.62 ±1.81^{a}	7.85 ±1.76^{a}
Color								
Texture	4.32 ±1.28^{a}	4.22 ±1.75^{a}	5.65 ±0.55^{a}	5.45 ±0.79^{a}	1.63 ±0.92^{b}	2.47 ±0.70^{b}	5.93 ±0.77^{a}	5.10 ±0.96^{a}
Creaminess	7.50 ±1.21^{a}	7.80 ±1.71^{a}	4.70 ±1.53^{b}	3.55 ±1.84^{b}	7.50 ±1.15^{a}	8.17 ±1.13^{a}	7.67 ±1.56^{a}	6.87 ±2.39^{a}
Stickiness	4.90 ±1.72^{ab}	4.00 ±1.36^{ab}	3.02 ±1.66^{b}	1.97 ±1.54^{b}	7.18 ±1.96^{a}	6.10 ±1.18^{ab}	5.82 ±3.78^{ab}	5.23 ±2.47^{ab}
Moist	6.70 ±1.03a	6.32 ±1.13a	5.23 ±2.50a	4.35 ±2.83a	7.18 ±1.80a	7.63 ±1.65a	7.27 ±1.77a	6.15 ±2.39a
Overall acceptance	3.40 ±2.78^{d}	4.93 ±2.31^{cd}	8.43 ±0.80^{ab}	8.82 ±1.17^{a}	5.08 ±1.61^{bc}	5.78 ±1.75^{bc}	8.03 ±1.38^{ab}	7.20 ±1.15^{ab}

[A]Mean ± SD group comparisons by means of parametric Duncan test

[B]Means within rows with changed letter are significantly different according to Duncan test ($p<0.05$)

Based on overall acceptance value of all sensorial attributes, the panelists preferred the jam prepared from cultivar Chanee and Petruk, either from fresh or frozen pulp.

Table 2b shows the correlation between the physicochemical properties and several selected sensorial properties. The TSS has a correlation with the aftertaste (r = -0.6430). The aftertaste is mainly influenced by the presence of high concentration of sugar in the fruit (Voon *et al*., 2007b). The color and texture, that were described by the panelists as creaminess, stickiness and moist, correlate with pH. This finding is in line with Hui (2006) and Sinha *et al*. (2006) who reported that the pH affects the texture and color of the jam. Acidity is negatively correlates with sweetness. This is caused by the presence of succinic acid contained in durian (Voon *et al*., 2007b). The creaminess and moist correlate with the acidity because it has a correlation with the pH; therefore, the acidity could affect the texture (Voon *et al*., 2007b).

Conclusion

Durian pulp from various cultivars has significant differences on TSS and color, but different cultivars do not have significant differences on the other physicochemical properties. The properties changed with freezing with significant differences on pH and color among the cultivars. The physicochemical properties of fresh and frozen durian pulp also changed when they were processed into jam. There are no significant differences on the physicochemical properties of the jam prepared from fresh and frozen pulp of various cultivars, except for color of the jam from the fresh pulp. Overall, freezing affects the properties of the durian pulp but it does not affect the properties of the jam. Freezing also affects the aroma intensity of the jam. Nevertheless, manufacturing the jam from fresh or frozen pulp did not influence the panelist preference. Generally, the panelists preferred the jam manufactured from cultivar Chanee and Petruk prepared from both fresh and frozen pulp.

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