

## Physical Chemical Properties of Fermented and Roasted Rambutan Seed Fat (RSF) as A Potential Source of Cocoa Butter Replacer

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**Abstract**— Rambutan (*Nephelium lappaceum* L) is one of the most important tropical fruits that is originally found in Malaysia, Thailand, the Philippines, Vietnam, Borneo and other countries in this region. The industrial processing of this fruit produces seeds and peels as waste materials. The aim of this work was to determine the physical-chemical properties of fermented-roasted Rambutan seed fat (RSF) and its mixtures with Cocoa butter (CB) in term of viscosity, texture (hardness), thermal stability, and fatty acid composition, and free fatty acid, acid value. The mixtures M3, M4, and RSF which possess similar crystal formation showed almost similar hardness index in the range of 11.18 to 24.77. The mixtures M1 and CB exhibited higher hardness index than M2, M3, M4 and RSF in the range of 57.55 to 63.85. The results showed that a low viscosity was observed in the mixture CB and M1 with increasing the temperatures at 35, 40 and 50 oC whereas, a high viscosity was observed in the other mixture such as M3, M4, and RSF with increasing the temperature, respectively. The result found that the major fatty acid composition was present in CB (100%CB+0%RSF) and M1 (80%CB+20%RSF), such as palmitic, stearic and oleic acid, respectively. The results showed no significant differences ( $P > 0.05$ ) in FFA among CB ( $2.72 \pm 0.65\%$ ), M1 ( $3.01 \pm 0.32\%$ ) and M2 ( $3.47 \pm 0.16\%$ ). At the same time, the results of A.V showed significant differences ( $P < 0.05$ ) among CB ( $4.68 \pm 1.29$ ), M1 ( $5.98 \pm 0.64$ ) and M2 ( $6.92 \pm 0.33$ ) mgKOH/g, respectively, but M1 value was very close to CB value. The results exhibited that CB and M1 had a lower viscosity than M2, M3, M4 and RSF with increasing temperature. From these results, it was found that it is possible to utilize rambutan seed fat as a cocoa butter replacer in a suitable ratio depending on the final products.

**Keywords**— rambutan seed; cocoa butter; texture; thermal stability; fatty acid composition

### I. INTRODUCTION

Fats are used as main ingredients in food, cosmetic, and pharmaceutical products [1]. The crystallization of fats has industrial applications when it is controlled; end products such as chocolate, margarine, and whipped cream can be obtained; the crystallization phenomenon of fats can be used to isolate fats from natural resources [2]. Cocoa butter (CB) is one of the natural fats, obtained from cocoa seeds (*Theobroma cacao*); it is typically used as a major component of chocolate and other confectionery products because of its physical and chemical properties [3]. CB is solid at room temperature (below 25 °C) and liquid at body

temperature (~37 °C); it consists mostly of palmitic ( $C_{16}$ ), stearic ( $C_{18:0}$ ), and oleic acids. Virtually, all oleic acids are esterified in the central position of all glycerol molecules (Sn-2), whereas saturated fatty acids are typically located in (Sn-1,3) positions. The composition and allocation of fatty acids lead to a symmetrical triglyceride composition of CB that is rich in 1,3-dipalmitoyl-2-oleoyl-glycerol (POP) and 1-palmitoyl-3-stearoyl-2-oleoyl-glycerol (POS) [4]. This triglyceride composition of CB is generally responsible for its diverse crystalline polymorphic forms, while fatty acid compositions are responsible for fat solidification in its liquid state [5]. CB is known to be more expensive than other vegetable fats because of its specific characteristics

and it is cultivated in only a few countries [6]. Therefore, the food industry is keen to find other sources of fats as alternatives to CB in producing chocolates for various reasons, including economic [7]. CB alternatives are defined as non-lauric fats that can replace CB either partially or completely in chocolate or other food products. Lipp and Anklam [8] previously mentioned that the utilization of natural or processed lipids as cocoa butter alternative can be decided using its compositional data (fatty acid composition and triacylglycerol conformation) and thermal characteristics such as crystallization and melting characteristic. This work was intended to determine the physical properties of fermented-roasted RSF and its mixtures with CB in viscosity, texture (hardness), thermal stability, fatty acid composition, free fatty acid, acid value to compare these mixtures with CB and to determine the mixture which was more similar to cocoa butter properties.

## II. MATERIALS AND METHODS

### A. Materials

CB was purchased from an Indonesian coffee company and the Cocoa Research Institute, Jember, East Java, Indonesia. Meanwhile, raw rambutan (*Nephelium lappaceum* L.) seeds were supplied by a rambutan canning industry in Sungai Petani, Kedah, Malaysia.

### B. Fermentation and Roasting of Rambutan Seeds

The fermentation process was performed on rambutan seeds, which were still covered by small amounts of rambutan pulp. The rambutan seeds were transferred into plastic baskets (625 mm × 425 mm × 294 mm), which were previously lined with banana leaves. After filling in the baskets with raw rambutan seeds, the baskets were covered with banana leaves for 6 days, with mixing every 3 days. On the 6<sup>th</sup> day of fermentation, the banana leaves cover was opened and the *rambutan* seeds inside the fermentation container were stirred with a wood spatula. After the fermentation time was sufficient, the dried rambutan seeds were roasted at 150 °C for 30 minutes by oven-drying (AFOS Mini Kiln, Hull, England). After roasting, the samples were cooled at room temperature and stored until the screw-pressing process for RSF production [9].

### C. RSF Extraction

RSF extraction was performed using a KOMET screw oil expeller DD 85 IG (IBG Monforts Oekotec GmbH & Co. KG, Ger-many). Dried rambutan seeds were dehusked and heated at 60 °C for 30 minutes by oven-drying (AFOS Mini Kiln, Hull, England). The screw-pressing process produced RSF, which was a viscous mixture of rambutan seed powder and RSF. The separation of RSF from rambutan seed butter was achieved through filtration under a heated condition (60 °C). Afterward, the collected RSF was transferred into inert-screw-cap bottles [9].

### D. Preparation of RSF and Cocoa Butter Mixtures

Mixtures of *rambutan* seed fat and cocoa butter were prepared following proportions as mentioned in Table 3.1. The levels were in the range of 0% to 100% with the total mixture was 100% (CB+RSF=1). The mixing process was

carried out by adding predetermined proportions (w/w) of cocoa butter and *rambutan* seed fat.

TABLE I  
PROPORTION OF THE RSF AND COCOA BUTTER

Mixtures of CB & RSF	CB% <sup>a</sup>	RSF% <sup>b</sup>
Mixture 1 (CB)	100	0
Mixture 2 (M1)	80	20
Mixture 3 (M2)	60	40
Mixture 4 (M3)	40	60
Mixture 5 (M4)	20	80
Mixture 6 (RSF)	0	100

<sup>a</sup>CB% = proportion of cocoa butter, <sup>b</sup>RSF% = proportion of Rambutan seed fat

CB was incorporated into RSF in six proportions, namely, 100/0, 80/20, 60/40, 40/60, 20/80, and 0/100 (w/w) CB to RSF, as CB, M1, M2, M3, M4 and RSF respectively. Then, the mixtures were melted in the oven (AFOS Mini Kiln, Hull, England) at 60 °C for 15–20 minutes. The melted mixtures were then homogenized using a vortex and transferred into inert-screw-cap bottles and then stored at –4 °C until they were used for analysis.

### E. Texture Properties (Hardness Index)

Texture properties analysis was carried out using TA.XT Plus texture analyzer (Stable Micro System, Ltd., UK) following the method of Lannes *et al.* [10]. Cone probe was utilized during this analysis and was set to penetrate the samples with a constant speed of 2.0 mm/s for 10.0 mm. The analysis was performed at 20°C. The result of the analysis was expressed as hardness diagram.

### F. Thermal Stability Analysis

Thermal stability of RSF and CB mixture samples were analyzed by means of thermal gravimetric analysis (TGA) in nitrogen atmospheres employed TGA 4000 equipped with C6 cooler (Perkin Elmer, Waltham, Massachusetts, USA). The nitrogen flow rate was set at 50 ml/min at a heating rate of 20°C/min. Mass changes were recorded between 25 until 700 °C.

### G. Viscosity Measurement

The viscosity was measured by use Viscometer Model (SV-10 Japan). It was taken 45 ml of the sample and transfers to Viscometer vial and then read the number of the viscosity. Each value was taken triplicate at temperature 25 °C.

### H. Fatty Acid Composition

Fatty acid methyl ester (FAME) was prepared according to the method of Mondello *et al.* [11]. Melted samples (0.05 g) were transesterified in a Pyrex tube by using 2 ml of borontrifluoride-methanol (20:80) reagent then heated for 30 min at 100°C in water bath. The heated solution was cooled to room temperature. After cooling down, 2 ml of n-hexane and 8 ml of distilled water were added to the mixture, which was then mixed manually for 1 min and centrifuged at 3500 rpm for 2 minutes. Approximately 1 ml of the upper n-hexane layer was transferred to a 1.5 ml glass insert for 2 ml vials after diluting the extracted hexane to obtain a suitable chromatographic response. Gas Chromatography (GC)

analysis was done using GC 2010 plus- FID (flame ionization detector) (Shimadzu Corp., Nagakyo-ku, Kyoto, Japan) equipped with SGE BPX70 (90% Cyanopropylphenyl Polysiloxane, 0.32mm ID × 0.25µm × 30m) column (SGE Analytical Science Pty Ltd, Victoria, Australia). The condition of GC during the analysis was set as follows: The injection port was set using split mode (split ratio = 1:10) at temperature 250°C employed Helium (He) as carrier gas [11]. The column temperature was set at 70°C maintained for 1 min, then increasing to 150°C at 20° C/min ramp and then increasing to 250°C at 10° C/min ramp. The final temperature was maintained for 15 min. Fatty acids were grouped as follows: saturated (SFA), mono (MUNA) and poly (PUFA) fatty acids.

#### I. Analysis of Free Fatty Acid (FFA) and Acid Value (A.V)

The FFA was determined according to the method [12]. The first step was prepared 50 ml of alcohol by added in 2 ml phenolphthalein solution and 0.1 M sodium hydroxide (NaOH) and produced a faint permanent pink. 7.05 grams of melted fat sample were weighed into 250 ml conical flask and mixed with prepared neutralized 50 ml of alcohol at first step. Then, the mixture was titrated with 0.25 M sodium hydroxide (NaOH) with a vigorous shaking until a permanent faint pink developed. The volume of 0.25 sodium hydroxide (NaOH) used in the titration steps was taken as final read. The free fatty acid of the samples was expressed as a percentage of oleic acid that was ml of 0.25 M sodium hydroxide (NaOH) used in the titration of the sample. All samples were measured in triplicate. The acid value of RSF and its mixture with CB samples are correlated with free fatty acid determination. FFA may also be expressed in terms of acid value. The acid value of the samples was calculated by the equation below:

$$A.V = \text{percentage of fatty acid (as oleic)} \times 1.99 \quad (1)$$

#### J. Statistical Analysis

Samples were carried out in triplicate and the data analysis was using (ANOVA) followed by post hoc analysis, Duncan multiple comparison analysis and all the data were analysis using SPSS (Statistical Package for Social Science) software version 20 (IBM Corporation, Armonk, New York 10504-1722 United State). The statistical analysis was performed at 0.05 significant levels.

### III. RESULTS AND DISCUSSION

#### A. Texture Properties (Hardness Index)

The differences in crystal formation of the mixtures greatly affected their texture properties. As shown in Fig. 1, the mixtures M3, M4 and RSF which possess similar crystal formation showed almost similar hardness index in the range of 11.18 to 24.77. The mixtures M1 and CB exhibited higher hardness index than M2, M3, M4 and RSF in the range of 57.55 to 63.85. These results were agreed with Febrianto [9], he found the hardness of the mixtures (RSF: CB) were lower ranged from 21.32 to 27.91 compared to 56.34 in CB. However, he showed a slightly different characteristic of hardness in the mixture (90%CB/10%RSF) compared to cocoa butter. Size and the distribution of crystal formation

may be the responsible factor for the difference between M2, M3, M4 and RSF mixtures with M1 and CB. Smaller and well-distributed crystal formation provides a higher hardness index, whereas bigger crystal formation resulted otherwise.

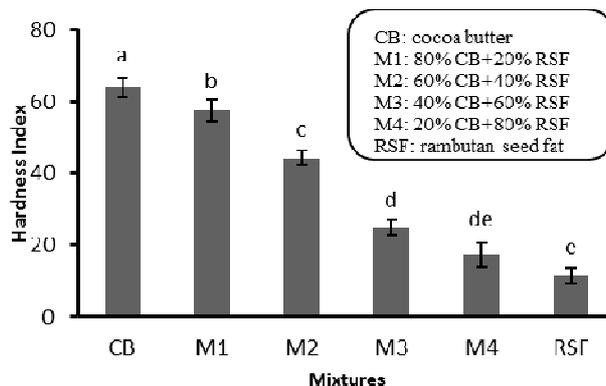


Fig. 1 Changes in the hardness index of RSF and its mixtures with CB

#### B. Thermal Stability

The result of thermal stability analyses carried out on RSF and its mixture with CB are shown in Table 2. The decomposition temperature of M1 was more similar to CB, it was observed in onset 344.39 and 394.59, mass loss rate 1.38 and 0.79, and the final decomposition temperature 521.14 and 616.06 of the M1 and CB, respectively. This result indicated that CB and M1 were more resistant from thermal decomposition than other mixtures. However, the other mixtures showed different results; decomposition of M2, M3, M4, and RSF started at 308.62, 306.75, 302.60 and 291.91, and ended at a lower temperature ranged around 489.89, 487.52, 485.85 and 482.83 than that of the CB and M1 with the highest mass loss recorded at around 1.25 to 1.12%/°C, respectively.

Previously, Lawler and Dimick [13] showed that cocoa butter possessed the unique characteristic of polymorphism. As mentioned in section 3.3.3; CB and M1 crystallized as  $\beta$  form crystal, The  $\beta$  crystal formation possesses hard, but the brittle texture of cocoa butter which is usually used for storage and product development. This formation of the crystal is also desirable due to its unique snap characteristic and fast melting in the mouth feature. Therefore, CB and M1 were more resistant from thermal decomposition than the mixture M2, M3, M4 and RSF, which crystallized in  $\beta$  and  $\beta'$  form crystal. Nonetheless, similar to the thermal behavior discussed in section 3.3.2; different thermal stability of RSF compared to the CB may be also contributed by the TAG composition.

#### C. Viscosity Measurement

The changes in physical properties of rambutan seed fat and its mixture with cocoa butter during the roasting process are considered a reliable guide to follow up the changes in viscosity affected by different temperature.

TABLE II  
TGA DEGRADATION POINT OF RSF AND ITS MIXTURE WITH CB

Sample	Degradation point (°C)					Offset
	Onset	Max 1	Mass loss rate 1 (%/°C)	Max 2	Mass loss rate 2 (%/°C)	
CB	394.59	431.69	0.22	522.12	0.79	616.06
M1	344.39	391.66	0.81	482.66	1.38	521.14
M2	308.62	338.53	0.87	432.92	1.25	489.89
M3	306.75	311.66	0.64	430.68	0.98	487.52
M4	302.60	307.96	0.71	429.53	1.12	485.85
RSF	291.91	306.39	0.52	425.01	1.12	482.83

The results of viscosity measurement are given in Fig. 2. The results showed that a low viscosity was observed in the mixture CB and M1 with increasing the temperatures at 35, 40 and 50 oC. whereas, a high viscosity was observed in the other mixture such as M3, M4, and RSF with increasing the temperature, respectively.4

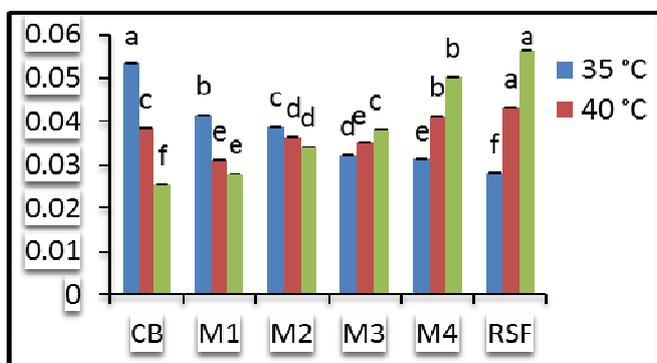


Fig. 2 Changes in viscosity of RSF and its mixtures with CB at different temperature

These results correspond with Zzaman et al. [14], he suggested that mixture proportion up to 30% rambutan seed fat had a higher viscosity than cocoa butter. Accordingly, cocoa butter had a lower viscosity than rambutan seed fat, which can be explained by type and long chain structure of fatty acid and triacylglycerol composition [15]. According to Lannes et al. [16] noted that characterized by the melting of fat crystals is defined as the level of fat in a reticular structure which are typically structured in the form of  $\beta'$  that conducted lead to higher viscosity more than  $\beta$  form structure that given their smaller size, higher surface area and potentially increased interfacial viscosity in emulsions.

#### D. Fatty Acid Composition

Cocoa butter contains many different lipids or fats. According to Lannes and Gioielli [17] described that primary triacylglycerols that combined with the cocoa butter including; palmitic, stearic, and oleic fatty acids. Saturated and unsaturated acids are obtained from many fats and lipids combination of the fatty acids, which half of them are heterogeneous. The fatty acid composition of all mixtures was significantly different ( $p < 0.05$ ) from one another as shown in Table 3.

TABLE III  
FATTY ACID COMPOSITION (% AREA) IN THE CB AND RSF MIXTURE

Fatty acid	M1	M2	M3	M4
C8:0	1.13±0.02 <sup>c</sup>	1.27±0.01 <sup>d</sup>	1.41±0.01 <sup>c</sup>	1.55±0.01 <sup>b</sup>
C11:0	0.15±0.01 <sup>c</sup>	0.30±0.01 <sup>d</sup>	0.46±0.01 <sup>c</sup>	0.61±0.01 <sup>b</sup>
C12:0	15.69±0.01 <sup>b</sup>	12.38±0.01 <sup>c</sup>	9.08±0.01 <sup>d</sup>	5.77±0.01 <sup>c</sup>
C13:0	0.88±0.01 <sup>c</sup>	1.76±0.01 <sup>d</sup>	2.65±0.01 <sup>c</sup>	3.53±0.01 <sup>b</sup>
C14:0	0.63±0.01 <sup>c</sup>	1.25±0.02 <sup>d</sup>	1.87±0.01 <sup>c</sup>	2.51±0.01 <sup>b</sup>
C15:0	0.82±0.01 <sup>c</sup>	1.65±0.01 <sup>d</sup>	2.47±0.01 <sup>c</sup>	3.31±0.01 <sup>b</sup>
C16:0	22.14±0.01 <sup>b</sup>	18.55±0.01 <sup>c</sup>	14.97±0.01 <sup>d</sup>	11.38±0.01 <sup>c</sup>
C16:1	2.65±0.01 <sup>c</sup>	5.31±0.01 <sup>d</sup>	7.94±0.01 <sup>c</sup>	10.59±0.01 <sup>b</sup>
C18:0	18.05±0.01 <sup>b</sup>	15.56±0.01 <sup>c</sup>	13.08±0.01 <sup>d</sup>	10.57±0.02 <sup>c</sup>
C18:1 cis	23.06±0.01 <sup>c</sup>	23.68±0.01 <sup>d</sup>	23.96±0.01 <sup>c</sup>	24.91±0.01 <sup>b</sup>
C18:1 trans	0.74±0.01 <sup>c</sup>	1.47±0.01 <sup>d</sup>	2.21±0.01 <sup>c</sup>	2.94±0.01 <sup>b</sup>
C18:2 trans	3.54±0.01 <sup>b</sup>	2.65±0.01 <sup>c</sup>	1.77±0.01 <sup>d</sup>	0.88±0.01 <sup>c</sup>
C18:3	2.72±0.01 <sup>b</sup>	2.54±0.01 <sup>c</sup>	2.38±0.01 <sup>d</sup>	2.21±0.01 <sup>c</sup>
C20:0	3.11±0.01 <sup>c</sup>	6.21±0.01 <sup>d</sup>	9.34±0.01 <sup>c</sup>	12.45±0.01 <sup>b</sup>
C20:1	0.65±0.01 <sup>c</sup>	1.31±0.01 <sup>d</sup>	1.94±0.01 <sup>c</sup>	2.58±0.01 <sup>b</sup>
C22:0	0.27±0.01 <sup>c</sup>	0.54±0.01 <sup>d</sup>	0.82±0.01 <sup>c</sup>	1.08±0.01 <sup>b</sup>
SFA	<b>63.52</b>	<b>60.78</b>	<b>58.09</b>	<b>55.34</b>
MUFA	<b>26.45</b>	<b>30.46</b>	<b>34.11</b>	<b>38.44</b>
PUFA	<b>6.26</b>	<b>5.19</b>	<b>4.15</b>	<b>3.09</b>

-GC analysis and expressed as % area.

-Different superscript letter on the same row represented significantly different value ( $p < 0.05$ ).

The result found that the major fatty acid composition was present in CB (100%CB+0%RSF) and M1 (80%CB+20%RSF), such as palmitic, stearic and oleic acid, respectively. Whereas, two main fatty acid composition was found in RSF, such as oleic and arachidic acid, add up to almost 75%; present also are palmitic, stearic, gondoic, palmitoleic, and behenic acids. The Palmitic acid in the RSF was present in much smaller amounts (7.81%) than CB and M1 (25.72%–22.14%); and stearic acid in RSF also showed like a palmitic acid (8.11%, 20.53% and 18.05%), respectively. The results showed that the oleic acid was found in CB and M1 (22.44% and 23.06%) lower than RSF (25.53%), respectively. The lauric acid content in CB and M1 (18.99% and 15.69%) was higher than RSF (2.47%). Moreover; Arachidic acid and other saturated fatty acid such as gondoic and behenic acid found in RSF, but those fatty acids were absent in cocoa butter, which may affect to high melting point and high viscosity of rambutan seed fat [18]-[19]. However, around 50% of the fatty acids in RSF is saturated, including a high percentage of arachidic acid, a fatty acid with a long chain and a relatively high melting point. This composition gives RSF characteristic physicochemical properties, thermal and phase behavior. These results agree with Zzaman et al. [14] they founded that lauric, palmitic, and stearic fatty acid in rambutan seed fat were less than cocoa butter, but oleic acid found almost the same. On the other hand, these results are quite different compared with Sirisompong et al. [20] reported that RSF is composed of 36.79% of oleic acid, 34.32% arachidic acid and 4.69% palmitic acid. However, the differences in these fatty acid proportions have also been reported previously; in which, the differences in cultivar and plantation area was suspected to be the most influencing factors. The increase of

oleic acid in CB and RSF sample during fermentation was previously mentioned by Teng et al. [21], who found that the increase of lipase activity during fermentation using *Rhizopus* spp resulted the formation of oleic acid. Meanwhile, the specific microorganism such as *R. oligosporus* could utilize the fatty acids in lipid body, mainly palmitic and stearic acid to support their cell wall phospholipid development, resulting in the decrease of palmitic and stearic acid in RSF. Moreover, Sudaryatiningsih and Supyani [22] mentioned that PUFA such as linoleic and linolenic acid could be generated by converting oleic acid with desaturase enzymes.

#### E. Analysis of Free Fatty Acid (FFA) and Acid Value (A.V)

The free fatty acid (FFA) and acid value (A.V) in cocoa butter and the mixtures with rambutan seed fat under study were in (Table 4). The results showed no significant differences ( $P > 0.05$ ) in FFA among CB ( $2.72 \pm 0.65\%$ ), M1 ( $3.01 \pm 0.32\%$ ) and M2 ( $3.47 \pm 0.16\%$ ). At the same time, the results of A.V showed significant differences ( $P < 0.05$ ) among CB ( $4.68 \pm 1.29$ ), M1 ( $5.98 \pm 0.64$ ) and M2 ( $6.92 \pm 0.33$ ) mgKOH/g, respectively, but M1 value was very close to CB value.

TABLE IV  
ANALYSIS OF FREE FATTY ACID AND ACID VALUE IN RSF

Samples	FFA (% oleic acid)	A.V (mgKOH/g)
<b>CB</b> (100%CB+0%RSF)	$2.72 \pm 0.65^c$	$4.68 \pm 1.29^d$
<b>M1</b> (80%CB+20%RSF)	$3.01 \pm 0.32^c$	$5.98 \pm 0.64^{cd}$
<b>M2</b> (60%CB+40%RSF)	$3.47 \pm 0.16^c$	$6.92 \pm 0.33^c$
<b>M3</b> (40%CB+60%RSF)	$4.89 \pm 0.81^b$	$9.73 \pm 1.61^b$
<b>M4</b> (20%CB+80%RSF)	$6.49 \pm 0.00^a$	$12.91 \pm 0.00^a$
<b>RSF</b> (0%CB+100%RSF)	$6.86 \pm 0.16^a$	$13.66 \pm 0.23^a$

-Values are mean  $\pm$  standard deviation of three replications.

-Different superscript letter on the same row represented significantly different value ( $p < 0.05$ ).

These differences in free fatty acid and acid value between CB, M1, and M2 were small, some sample had a higher content, others had a lower content of Diacylglycerols (DAGs). Diacylglycerols are important because they retard the phase transformation from  $\beta'$  to  $\beta$ , this can negatively influence the cooling curve and thus be a disadvantage for the tempering of chocolates. These values are comparable to those reported by Zaidul et al. [23] who obtained free fatty acid and acid value during incorporated Palm kernel oil with cocoa butter, they found most of the blend similar values to that of cocoa butter. On the other hand, Manaf et al. [24] found that the FFA values of rambutan seed fat and cocoa butter they studied were  $6.1 \pm 2.33\%$  and  $1.44 \pm 0.42\%$ , respectively. The presence of the FFA content of the cocoa butter due to the use of beans from diseased pods or hydrolysis by lipase from mold contamination. These molds can be present due to insufficient drying, extended fermentation or prolonged storage of the beans [25]. In addition, the increase in FFA and A.V values in the roasted

seed fat could be contributed by hydrolysis of triacylglycerol during roasting process which produces free fatty acids with diacylglycerol. Another cause can be too quick drying of the beans, leading to lack or inadequate loss of volatile acids, but also hydrolysis occurring during storage can lead to FFA formation [26].

The free fatty acid liberated from triglycerides in the other mixtures, such as M3 ( $4.89 \pm 0.81\%$ ), M4 ( $6.49 \pm 0.00\%$ ) and RSF ( $6.86 \pm 0.16\%$ ) were higher as compared to CB ( $2.72 \pm 0.65\%$ ), M1 ( $3.01 \pm 0.32\%$ ) and M2 ( $3.47 \pm 0.16\%$ ) (Fig. 3). The variation of the free fatty acid due to differences in the proportion of the mixture's component of cocoa butter and rambutan seed fat. The result showed that rambutan seed fat contains a higher proportion of oleic acid than that observed in cocoa butter. Therefore, we can exhibit that M3, M4 and RSF had the highest ratio of rambutan seed fat and free fatty acid, respectively.

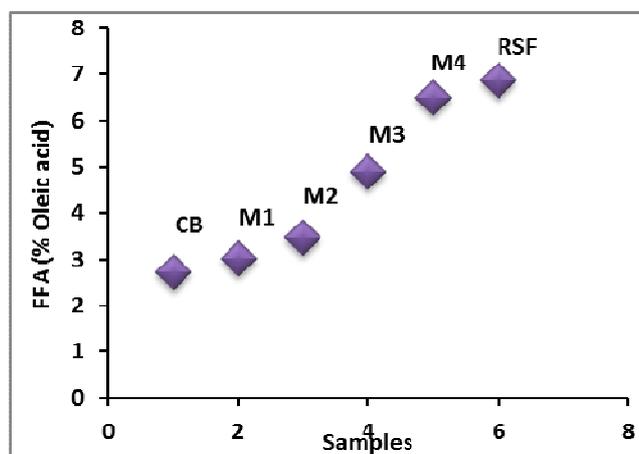


Fig. 3 Analysis of free fatty acid (FFA) of RSF and its mixture with CB

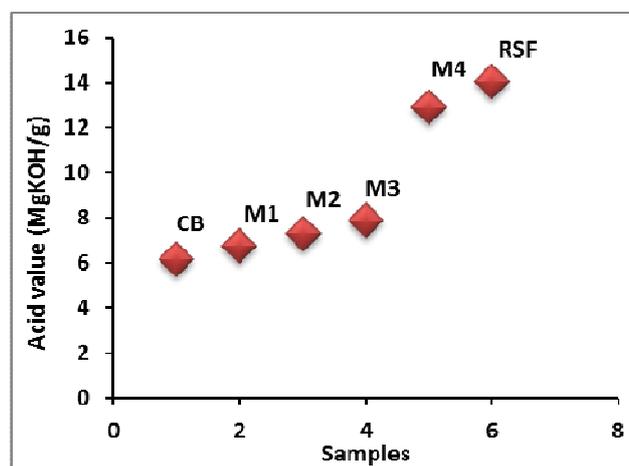


Fig. 4 Analysis of acid value (A.V) of RSF and its mixture with CB

With regard acid value (Fig. 4), high acid value was found in sample RSF ( $13.66 \pm 0.23$ ) and M4 ( $12.91 \pm 0.00$ ) followed by M3 ( $9.73 \pm 1.6$ ) and M2 ( $5.98 \pm 0.64$ ) mgKOH/g, whereas a low acid value was found in the samples CB ( $4.68 \pm 1.29$ ) and M1 ( $5.98 \pm 0.64$ ) mgKOH/g, respectively. From our results, the proportion of monounsaturated fatty acid (MUFA) in rambutan seed fat was (42.46%) significantly higher than found in cocoa butter (22.44%). That can be explained the

highest value of the acid value in rambutan seed fat in comparison with cocoa butter.

#### IV. CONCLUSIONS

Our analysis on texture properties, thermal stability, and viscosity of the mixtures between fermented-roasted rambutan seed fat and cocoa butter resulted in a conclusion that the incorporation between RSF and CB may potentially be applied. The hardnesses of the mixtures were lower ranged from 11.18 to 24.77 in M3, M4 and RSF compared to 57.55 to 63.85 in M1 and CB. The thermal stability of fermented-roasted RSF was lower than M1 and CB. The degradation point exhibited in M1 ranged from 344.39-521.14°C and 394.59-616.06 in CB compared to 291.91-482.83 in RSF. Effect of different temperature on the viscosity of CB and M1 shows significant differences in comparison with other mixtures. The results exhibited that CB and M1 had a lower viscosity than M2, M3, M4 and RSF with increasing temperature. From these results, it was found that it is possible to utilize *rambutan* seed fat as a cocoa butter replacer which allows the mixing with cocoa butter in small ratio or can also be utilized for other confectionery product in the absence of cocoa butter.

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