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Characterization of three varieties of Malaysian rambutan seed oil

Caracterización de tres variedades de aceite de semillas de rambután de Malasia

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ABSTRACT

Introduction: Rambutan seed is considered a waste by-product of fruit processing. The seed waste is usually discarded or disposed in a large amount without an economic value which has become an issue that needs to be solved. However, the seed contains a considerable amount of crude fat. Aim: the purpose of this study was to characterize the physicochemical properties of oil of the seeds of three varieties of Malaysian rambutan fruit (R4, R7 and Serjan) for potential application.

Method and Materials: In this study, colour, refractive index, viscosity, free fatty acid content, peroxide value, p-anisidine value, iodine value, saponification value, unsaponifiable matter, fatty acid composition, thermal behaviour, melting point, and solid fat content of rambutan seed oil from three varieties were used to characterise physicochemical properties of rambutan seed oil.

Results: No significant differences ($p > 0.05$) were observed for free fatty acid content, peroxide value, p-anisidine value, saponification value, unsaponifiable matter, colour, viscosity and refractive index among three varieties. There are significant differences ($p < 0.05$) in the iodine value and melting point among the rambutan seed oil of three varieties. Varieties R7 and R4 seed had the highest (37.62 ± 0.10 %) and lowest (34.25 ± 0.07 %) crude fat content, respectively. Oleic (37.75-40.58 %) and arachidic (35.24-36.89 %) acids were the major fatty acids in the oil. Both melting and crystallization curves showed that the oil exhibited three distinct peaks**.** The complete melting and crystallization onset temperatures of the oil were 24.76–26.57°C and 21.19–22.79°C, respectively. **Conclusions**: This study reveals that the rambutan seed oil has potential to be used in various sectors of food industry. Therefore, rambutan seed can be fully utilized and, subsequently, the amount of waste can be minimized.

Keywords: Rambutan; *Nephelium lappaceum*; chemistry.

RESUMEN

Introducción: la semilla de rambután se considera un subproducto residual del procesamiento del fruto. Los residuos de semillas generalmente se desechan o se eliminan en grandes cantidades sin un valor económico que se ha convertido en un problema que debe resolverse. Sin embargo, la semilla contiene una cantidad considerable de grasa cruda. **Objetivo**: el propósito de este estudio fue caracterizar las propiedades fisicoquímicas del aceite de las semillas de tres variedades de rambután de Malasia (R4, R7 y Serjan) para su posible aplicación. **Método y materiales**: En este estudio, el contenido de aceite de semilla de rambután de tres variedades se utilizó para caracterizar las propiedades fisicoquímicas del aceite de semilla de rambután en color, índice de refracción, viscosidad, contenido de ácidos grasos libres, índice de peróxido, índice de p-anisidina, índice de yodo, valor de saponificación, materia insaponificable, composición de ácidos grasos, comportamiento térmico, punto de fusión y grasa sólida. **Resultados**: No se observaron diferencias significativas (p> 0.05) para el contenido de ácidos grasos libres, el valor de peróxido, el valor de p-anisidina, el valor de saponificación, la materia insaponificable, el color, la viscosidad y el índice de refracción entre tres variedades. Existen diferencias significativas (p <0.05) en el valor de yodo y el punto de fusión entre el aceite de semilla de rambután de tres variedades. Las variedades R7 y R4 tuvieron el contenido de grasa cruda más alto (37.62 ± 0.10%) y más bajo (34.25 ± 0.07%), respectivamente. El ácido oleico (37.75-40.58%) y el ácido araquídico (35.24-36.89%) fueron los principales ácidos grasos en el aceite. Las curvas de fusión y cristalización mostraron que el aceite exhibía tres picos distintos. Las temperaturas de inicio de fusión y cristalización completas del aceite fueron 24.76–26.57 ° C y 21.19–22.79 °C, respectivamente. **Conclusiones**: Este estudio revela que el aceite de semilla de rambután tiene potencial para ser utilizado en varios sectores de la industria alimentaria. Por lo tanto, la semilla de rambután se puede utilizar por completo y, en consecuencia, se puede minimizar la cantidad de desechos.

Palabras clave: Rambután; *Nephelium lappaceum*; química.

INTRODUCTION

Vegetable fats and oils are widely used as main ingredient in food, medicines, and cosmetics products. In recent years there is a growing demand to exploit newer sources of plant-based oils such as plant seeds that are important sources of oils with high nutritional, industrial and pharmaceutical importance. On the other hand, no oil from a single source has been found to be suitable for all purposes because oils from different sources generally differ in their fatty acid composition (1). Nowadays, research on the characterization of by-products in the food processing industry has gained considerable attention, since the by-products can be utilized in pharmacological, cosmetic, and food applications as potentials source of oils. Fruit seed usually thrown out after processing as an agro-industrial residue, while, they can be used potentially as a natural oil source.

Rambutan (*Nephelium lappaceum* L.), which is a seasonal fruit is believed to originates from Malaysia (2). It is widely cultivated in Southeast Asian countries such as Thailand (430,000 tons/year), Indonesia (148,000 tons/year), Malaysia (80,000 tons/year), and the Philippines (20,000 tons/year) (3). This fruit is generally consumed fresh, but it can be industrially processed to obtain juice, jams, jellies and marmalades (4). Rambutan seeds (4-9 g/100 g) are known as a major waste by product of fruit canning industry (5). The problems of industrial waste are becoming harder to solve, and much effort will be needed to develop nutritional and industrial potential of by-products, waste, and underutilized agricultural product. It is reported that rambutan seed contains a relatively high amount of fat, with oleic acid and arachidic acid being the major fatty acids (6, 7). Unlike most vegetable oils and fats, rambutan seed oil contains high level of arachidic acid, which is a long-chain (20 carbons) saturated fatty acid (6). This characteristic allows the fat to be used without being subjected to hydrogenation and makes it strong resistant to oxidative rancidity (8). Rambutan seed oil not only could be used for manufacturing candles, soaps, and fuels, but also has a potential to be used in different branch of industries from confectionary products to cosmetics (7, 9).

Although physicochemical characteristics of rambutan seed fat has been published earlier (6-8, 10-12), there is no detailed information available for rambutan seed fat varieties grown in the Malaysia. More detailed research on the lipid characteristics of rambutan seed varieties will enhance knowledge and application of rambutan seed oil in a variety of food and specialty products. Thus, the aim of this study was to characterize the physicochemical properties of

rambutan seed oil from three rambutan seed varieties (R4, R7 and Serjan) grown in Malaysia to evaluate possible applications of an industrial scale.

MATERIALS AND METHODS

2.1. Materials

Three different varieties of fresh and ripe rambutans namely R4, R7 and Serjan were obtained from the University Agricultural Park, Universiti Putra Malaysia (UPM). One batch of samples (each obtained from several trees for each variety during fruiting season which was November 2015-January 2016) was used in this study. The fruits (a total of between 30-35 kg for each variety) were manually peeled and deseeded. The seeds represent between 6-8 % (~ 2 kg) of the total fruit. Seeds cleaning process was carried out under running tap water and they were then dried in an oven at 60ºC for 48 hours. Dried seeds were finely ground using a Waring blender (Model 32BL 80, Dynamic Corporation of America, New Hartford Connecticut, USA) and stored in sealed plastic bags in -20ºC for further analysis. All reagents and solvents used were of analytical or HPLC grade purchased from Merck (Darmstadt, Germany). The standard FAME Mix (C8-C24) was purchased from Supleco (Bellefonte, Pennsylvania, USA).

2.2. Oil Extraction

A hundred and fifty grams of ground rambutan seed were placed into a cellulose paper cone and extracted with petroleum ether (b.p 40–60 ºC) in a 250mL Soxhlet extractor for 8 hours (13). The solvent was removed via a rotary evaporator Model N-1 (Eyela, Tokyo Rakakikal Co., Ltd., Japan) and residual solvent was removed by drying in an oven at 60°C for 1 hour and flushed with 99.9% nitrogen. The extracted oil was stored at -20ºC until it was analysed. Oil extraction was carried out in triplicate for each variety while each analysis was conducted also in triplicate.

2.3.1. Seed Analysis

Moisture content and crude fat content was determined according to AOAC official Methods 930.15 and 945.16, respectively (13).

2.3.2. Oil analysis

AOCS Official methods (14, 15) were used to determine free fatty acid (FFA) content (method Ca 5a-40), peroxide value (method Cd 8b-90) and p-anisidine value (method Cd 18-90), iodine value (method Cd 1-25), saponification value (method Cd 3-25), unsaponifiable matter (method Ca 6a-40). PORIM test methods (16, 17) were used to determine viscosity, colour (p4.1) and refractive index (method p4.4). Viscosity was determined at 40°C using Brookfield DV-II viscometer with

temperature control (Stoughton, Massachusetts, USA) at 30 rpm rotor speed. An oil sample (20mL) was poured into the sample adaptor. The attached spindle of the viscometer was then immersed into the oil. Colour was determined using a Lovibond tintometer Model E (Salisbury, England) according to PORIM test method (p4.1). The oil samples were placed into 1-inch cell and the color was determined at 60°C by achieving the best possible match with the standard colour slides of red and yellow indices. The refractive index of the oil was determined at 40°C using a digital refractometer Model 300034 (Sper scientific LTD, Scottsdale, Arizona, USA). Frozen rambutan seed oil was first melted to a temperature of 40˚C and homogenized. Then, the sample was filtered by a dry Whatman No.1 filter paper to clarify the oil before the determination process. The refractive index (RI) was determined at a temperature of 40˚C by placing a few drops of the oil in the space between the prisms and determined values were recorded.

Fatty acid composition (FAC) was determined by conversion of oil to fatty acid methyl esters (FAME) according to the method of Cocks and Van Rede (18) by reacting 50 mg of fat with 0.05 mL of 1 mol/L sodium methoxide in 0.95 mL of n-hexane. The mixtures were vortexed for 5 seconds and allowed to settle for 5 min. The top layer (1 µL) was injected into a gas chromatograph (Model 6890N, Agilent Technologies, Santa Clara, California, USA), equipped with a flame ionization detector (FID) and a polar capillary column BPX70 (0.32 mm internal diameter, 30 m length and 0.25 mm film thickness) (SGE Incorporated, USA) to obtain individual peaks of fatty acid methyl esters. The detector temperature was 250ºC and column temperature was 120ºC held for 5 min and increased at the rate of 8ºC/min to 240ºC and held for 10 min. The run time was 30 min. The fatty acid methyl esters peaks were identified by comparing their retention time mixed standard of fatty acids, Supelco FAME mix C8–C24 (Bellefonte, PA, USA). Percent relative fatty acid was calculated based on the peak area of a fatty acid species to the total peak area of all the fatty acids in the oil sample.

A Perkin-Elmer Diamond Differential Scanning Calorimeter (DSC) (Shelton, Connecticut, USA) with PYRIS data processing software was used to determine the thermal properties of oil according to the method used by Abdulkarim et al. (19). The instrument was calibrated using indium and zinc. A data processing software, PYRIS Instrument Managing Software, version 10.1, was used to analyse the thermal property of oils. The purge gas was 99.99% nitrogen administered at 100 mL/min and 20 psi. The oil was first heated in an oven until completely melted. Approximately 3–5 mg of oil was placed into a volatile aluminium pan (Perkin Elmer, Shelton, Washington, USA) and hermetically sealed. An empty aluminium pan was used as a

reference. Oil samples were subjected to the following programmed temperature: cooling from 60 to -60ºC with a cooling rate of 5ºC/min and held for 2 min; then, heating from -60 to 60ºC with a heating rate of 5ºC/min and held for another 2 min; then, cooling from 60°C to -60°C also at the rate of 5°C/min. The heating and cooling thermograms were recorded and the peak, onset and offset temperature were tabulated. The melting point was determined using melting curve obtained by DSC according to (20) Nassu and Gonçalves (1999). The melting point measured as the temperature at the end of the curve, where the melting phenomenon finishes and all crystals in solid state became liquid.

The solid fat content percentage (SFC%) for all oil samples was derived from the melting thermogram of the respective oil samples according to the method described by Lee et al. (21). The PYRIS data processing software was used to generate the partial peak areas (%) of the melting peaks against the temperature. It is the fact that when the partial area of melting peak was 0%, the SFC of the oil was 100% and vice versa. Thus, by reversing the percentage of partial area from 0-100 % to 100-0%, the SFC of the oil sample at different temperature was obtained.

2.3. Statistical Analysis

The analytical data were analyzed by one-way analysis of variance followed by Tukey's test using Minitab v. 16 Statistical Software (Minitab Inc., State College, PA, USA). The results were expressed as mean of triplicate determination with standard deviation. Statistical significance differences were considered at the level of $p < 0.05$.

RESULTS

The crude fat content and moisture content of rambutan seed of three varieties are shown in Table 1.

Table 1. Crude fat content and moisture content of rambutan seed for varieties R4, R7 and Serjan.

Parameter	R4	R7	Serjan
Crude fat content (%)	34.25 ± 0.07^{c}	37.62± 0.10^{a}	35.40± 0.28^{b}
Moisture content (%)	34.07±0.10^{a}	34.25± 0.07^{a}	34.15± 0.07^{a}

Mean ± standard deviation.

Means in the same row with different letters are significantly different (P< 0.05).

Physicochemical properties such as colour, refractive index (RI), viscosity, melting point, free fatty acid (FFA), peroxide value (PV, p-anisidsine value (p-AV), iodine value (IV), saponification value (SV) and unsaponifiable matter (USM) of rambutan seed oil for varieties R4, R7 and Serjan are shown in Table 2.

Table 2. Physicochemical properties of rambutan seed oil for varieties R4, R7 and Serjan.

Parameter	R4	R7	Serjan
Lovibond Colour (Red/Yellow)	R: 0.45 ± 0.07[a] Y: 3.00 ± 0.00[a]	R: 0.52 ± 0.03[a] Y: 3.00 ± 0.07[a]	R: 0.55 ± 0.07[a] Y: 3.00 ± 0.07[a]
RI (40°C)	1.4647± 0.001[a]	1.4631± 0.001[a]	1.4620± 0.001[a]
Viscosity (Cp)	49.25 ± 0.35[a]	50.40 ± 0.84[a]	50.95 ± 0.77[a]
Melting point	24.54 ± 0.05[c]	25.67 ± 0.10[b]	26.60± 0.14[a]
FFA (as oleic %)	0.62 ± 0.08[a]	0.56 ± 0.04[a]	0.68 ± 0.09[a]
PV (meq O_2/kg)	2.00 ± 0.14[a]	1.82 ± 0.11[a]	1.74 ± 0.15[a]
p-AV	0.66 ± 0.02[a]	0.49 ± 0.08[a]	0.54 ± 0.06[a]
IV (g I_2/100g oil)	47.49 ± 0.04[a]	46.00 ± 0.03[b]	44.26 ± 0.10[c]
SV (mg KOH/g oil)	181.75 ± 0.36[a]	182.10 ± 0.14[a]	181.69 ± 0.21[a]
USM (%)	0.67 ± 0.03 [a]	0.82 ± 0.03[a]	0.72 ± 0.04 [a]

Table 3 shows the fatty acid composition of rambutan seed oil for varieties R4, R7 and Serjan.

Table 3. Fatty acid composition of rambutan seed oil for varieties R4, R7 and Serjan.

Fatty acid	Relative percent (%)		
	R4	R7	Serjan
Myristic acid (C14:0)	0.03 ± 0.02^{a}	0.02 ± 0.00^{a}	0.02 ± 0.00^{a}
Palmitic acid (C16:0)	4.74±0.01^{a}	4.58 ± 0.00^{a}	5.00 ± 0.50^{a}
Palmitoleic (C16:1)	0.59 ± 0.00^{a}	0.41 ± 0.00^{b}	0.60± 0.00^{a}
Stearic acid (C18:0)	6.35 ± 0.09^{c}	7.99 ± 0.04^{a}	7.30 ± 0.01^{b}
Oleic acid (C18:1)	40.46 ± 0.05^{a}	40.58 ± 0.05^{a}	37.75 ± 0.12^{b}
Linoleic acid (C18:2)	2.31±0.07^{a}	2.01 ± 0.01^{b}	2.08 ± 0.00^{b}
Linolenic acid (C18:3)	0.17 ± 0.00^{b}	0.16 ± 0.00^{b}	0.23 ± 0.00^{a}
Arachidic acid (C20:0)	34.75 ± 0.06^{b}	35.24 ±0.05^{b}	36.89 ± 0.49^{a}
Gondoic acid (C20:1)	6.69 ± 0.21^{a}	5.78 ± 0.02^{b}	6.04 ± 0.00^{b}
Behenic acid (C22:0)	3.05 ± 0.00^{a}	2.64 ± 0.09^{b}	3.07± 0.01^{a}
Erucic acid (C22:1)	0.56 ± 0.01^{a}	0.44 ± 0.02^{b}	0.54 ± 0.01^{a}
Lignoceric acid (C24:0)	0.22 ± 0.12^{a}	0.09±0.01^{a}	0.39± 0.09^{a}
SFA (%)	49.16 ± 0.05^{c}	50.56 ± 0.02^{b}	52.68 ± 0.11^{a}
USFA (%)	50.79 ±0.05^{a}	49.38 ±0.02^{b}	47.25± 0.11^{c}
Ratio of USFA /SFA	1.030±0.00^{a}	0.97±0.00^{b}	0.89± 0.00^{c}

Mean values with the same letter within the same row are not significantly different ($p > 0.05$).

SFA: saturated fatty acids, USFA: unsaturated fatty acids.

Thermal behavior of rambutan seed oil of varieties R4, R7 and Serjan is shown in Table 4 and Figure 1. There are three peaks in both melting and crystallization curves.

Table 4. Temperature of phase transition of melting and crystallization of rambutan seed oil

Variety	Phase transition temperature (ºC)				
	T_{Onset}	T1	T2	T3	T_{End}
Melting					
R4	-35.75±0.33[a]	-32.95±0.36[a]	5.43±0.06[a]	23.19±0.11[b]	24.76±0.20[c]
R7	-35.63±0.22[a]	-32.88±0.39[a]	5.61±0.18[a]	23.36±0.45[b]	25.61±0.16[b]
Serjan	-35.44±0.09[a]	-33.04±0.04[a]	5.89±0.09[a]	25.02±0.09[a]	26.57±0.07[a]
Crystallization					
R4	21.19±0.33[a]	20.51±0.05[b]	3.00±0.169[a]	-42.42±0.44[a]	-45.20±0.94[a]
R7	21.54±0.22[a]	20.73±0.33[b]	3.30± 0.12[a]	-42.69±0.63[a]	-45.69±0.64[a]
Serjan	22.79±0.09[a]	21.75±0.29[a]	3.70 ± 0.28[a]	-42.81±0.11[a]	-45.78±0.24[a]

Ton: onset temperature; Tend: end set temperature.

1, 2, 3, are transition phases, based on Figures 1 (melting and crystallization curves of rambutan seed oil). Mean values in the same column with same letter are not significantly different ($p > 0.05$)

Figure 1. Melting (a) and Crystallization (b) thermogram of rambutan seed oil of R4, R7 and Serjan.

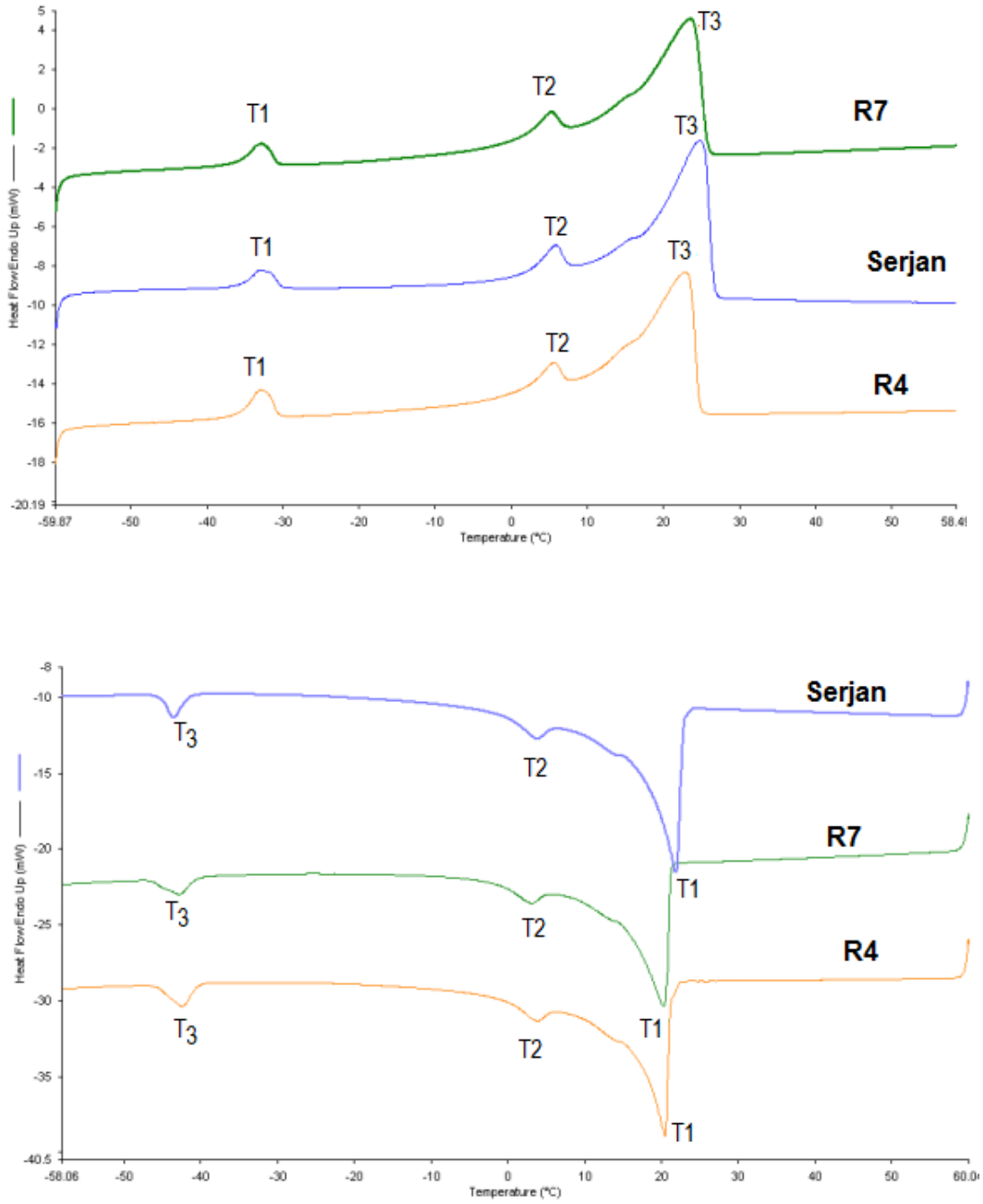
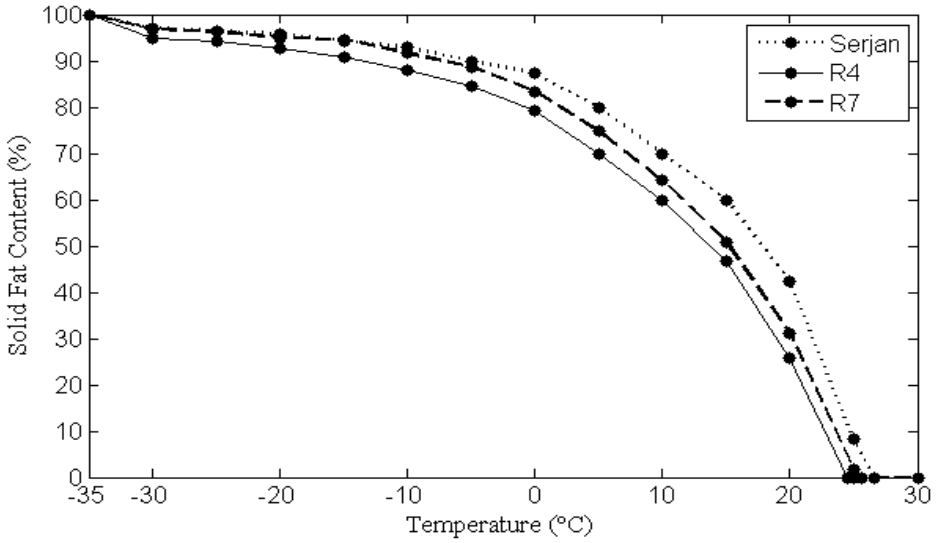


Figure 2 shows solid fat content (%) of rambutan seed oil for varieties R4, R7 and Serjan.

Figure 2. Solid fat content (%) of rambutan seed oil of varieties R4, R7 and Serjan.



DISCUSSION

4.1. Seed analysis (moisture content and crude fat content)

There was no significant difference in the moisture content of the three varieties. The data obtained for three varieties are like values reported by Augustin & Chua (22) and Solís-Fuentes et al. (10). There were significant differences ($p<0.05$) in the crude fat content of the seed between three varieties. As it can be seen, among the three varieties R7 has the highest oil content (37.55%) than Serjan (35.6%) and R4 (34.2%) and is like the value reported by Augustin & Chua (22). In contrast, in a study by Chai et al. (7), variety R4 had the highest crude fat content than Serjan and R7. The high percentage of the oil in the seed (37.5 %) makes it a distinct potential source for the oil industry. Several authors have reported that the seed yields between 32% and 39% fat (6-8, 10, 11, 22, 23). Variation can occur in the seed composition and the differences in moisture and fat content reported by different researchers may be from differences in plant variety, ripening stage at harvesting time and cultivation climate and extraction method applied.

4.2. Physicochemical properties of rambutan seed oil

There are no significant differences ($p>0.05$) in colour, refractive index and viscosity for three rambutan varieties of R4, R7 and Serjan. Rambutan seed oil has golden yellow colour. Colour is one of the food properties that it has been widely used as an index of oil quality. Results obtained in this study shows that red colour over yellow colour ratio (R/Y) is less than 0.3 for all three rambutan seed fat indicating that rambutan seed oils appear visually more yellow than red (21).

The refractive index (RI) of rambutan seed oils from varieties R4, R7 and Serjan were 1.4647, 1.4631 and 1.4620, respectively. These values are consistent with the values of Sirisompong et al. (8) and Solís-Fuentes et al. (10), who reported that rambutan seed oil had a refractive index of 1.469 and 1.468, respectively. The refractive index of oil is a basic value that is related to molecular weight, fatty acid chain length, degree of conjugation and degree of unsaturation (24). High concentrations of the unsaturated fatty acids result in increase of oil refractive index.

Viscosity defines as the resistance of one part of the fluid to move relative to another one. The viscosity of vegetable oils is affected by many of the physical and chemical properties of oils such as the density, molecular weight, melting point and degree of unsaturation (25). Generally, viscosity for vegetable oil increases with molecular weight but decreases with increase in unsaturation and temperature (26). The viscosity of rambutan seed oils from varieties R4, R7 and

Serjan were 49.25, 50.40 and 50.95 at 25˚C, respectively. These results are comparable with the viscosity of some other vegetable oils such as sunflower, corn, soybean, (52, 54.4, 53.4, respectively) which analysed under the same conditions (27).

Melting point is a significant physical property of fats and oils which is used in identification purpose and many technological applications of fats and oils. According to the results obtained, significant ($P<0.05$) differences were observed among the three varieties in their melting point (Table 2). Serjan showed a significantly higher melting point (26.60ºC) than the R4 and R7 which were 24.54ºC and 25.67ºC, respectively. This is probably because of presence of high melting TAG in Serjan rather than R4 and R7. These values are within the range of slip melting point (25.1ºC to 51.3ºC) and (24.8°C and 50.6°C) of various rambutan varieties that were reported by Kheiri and Mohd Som (28) and Chai et al. (7). Similar to the findings in this study, Romain et al. (29) reported that the melting point of rambutan seed fat is 24ºC. Sonwai and Ponprachanuvut (12) and Manaf et al. (6) reported that rambutan seed fat has melting point of 39.2ºC and 41.55ºC, respectively.

Free fatty acid and peroxide value have been frequently used as two of the most important parameters to monitor the quality of edible oils (30). Table 2 shows that no significant differences ($P>0.05$) of free fatty acids was obtained in all three varieties of rambutan seed. According to Kheiri and Mohd Som (28), FFA of rambutan seed fat obtained from 13 rambutan varieties is between 0.32 and 0.52% which are comparable with the results obtained.

The peroxide values for seeds of R4, R7 and Serjan were 2.00, 1.82 and 1.74 meq of O_2/kg of oil, respectively. There are no significant differences ($p>0.05$) of PV for these seeds. These values were lower than the maximum limit for PV defined by Codex Alimentarius Commission (31). The commission permits maximum peroxide value of 10 meq of peroxide/kg of oil for vegetable oils. The PV obtained in this study indicates that rambutan seed oil can be stored for a long period without deterioration.

Table 2 shows that there are no significant differences in p-anisidine value (p-AV) for the oils of varieties R4, R7 and Serjan. The p-AV of R4, R7and Serjan (0.66 ,0.49 and 0.54 respectively), is lower than the value (2.00 p-AV) reported by Subramanian et al., (32), as p-AV of high quality oil is less than 2. Based on the results obtained, it is found that in three varieties the rate of oxidation is very low.

The iodine value (IV) indicates the degree of unsaturation of the oil. Iodine value for the R4, R7 and Serjan were significantly different ($p<0.05$) (Table 2). The iodine value of R4 (47.49 g I_2/100g oil) is significantly ($p<0.05$) higher than R7 (46.00 g I_2/100g oil) and Serjan (44.26 g I_2/100g oil) and indicates R4 is high in unsaturated fatty acids. IV is lower in Serjan due to low content of unsaturated fatty acids (47.25 %) and high content of arachidic acid (36.89 %). The values obtained are in agreements with IV reported by Kheiri and Mohd Som (28) for 13 varieties of rambutan ranging from 41.8 to 49.6 g I_2/100g oil. The IV obtained are in agreement with those obtained by Manaf et al. (6), Solís-Fuentes et al. (10), Lourith et al. (23), Mahisanunt et al. (5) and Chai et al. (7) who reported that IV of rambutan seed fat ranged from 44 to 47 g I_2/100 g.

As presented in Table 2, saponification value (SV) for three varieties of rambutan seed oil were not significantly different ($p>0.05$) with values of 181.75, 182.10 and 181.69 mg of KOH/g oil for R4, R7 and Serjan, respectively. The SV of these three seeds oil was within the SV range of rambutan seed fat for 13 varieties (157-190 mg KOH/g oil) reported by Kheiri and Mohd Som (28). Solís-Fuentes et al. (10) and Manaf et al. (6) found that SV of rambutan seed fat was 186 and 182.1 mg KOH/g oil, respectively.

The unsaponifiable matter were not significantly different ($p>0.05$) in the varieties R4, R7 and Serjan (Table 2). The values obtained are within the unsaponifiable matter value range (0.43-0.82%) reported by Kheiri and Mohd Som (28) for 13 rambutan varieties. These three varieties have small amount of unsaponifiable matter (0.67–0.82%) which is like value (0.5 %) reported for rambutan seed oil by Manaf et al. (6). Sirisompong et al. (8) found that the unsaponifiable of rambutan seed fat was 0.19 % which is lower than value obtained in this study probably due to varietal differences.

Twelve fatty acids are identified, where the major fatty acids in three rambutan seeds oil are arachidic acid (34.75-36.89 %) and oleic acid (37.75-40.58 %). These two fatty acids constitute 74.62-75.82% of the total fatty acids which is consistent with reported data in previous studies (6-8, 10, 12, 22). Augustin & Chua (22), in a study using three rambutan varieties reported that seeds contained oleic acid and arachidic acid ranging from 37.91-40.15 % and 36.14-36.77 %, respectively, which is in agreement with the obtained data in this study. Solís-Fuentes et al. (10) and Harahap et al (11) also reported that rambutan seed fat contains oleic acid 40.3% and 40.45% and arachidic acid 34.5% and 36.36%, respectively which is in accordance with the results reported in this study. The other main fatty acids are palmitic acid, stearic acid and gondoic acid

which are present in amounts of 4.47-5%, 6.35-7.99% and 5.78-6.69%, respectively. The oil contains small amounts of myristic acid, palmitoleic acid, linolenic acid, erucic acid and lignoceric acid. Differences in the fatty acid composition of the seeds may be due to different varieties, different age of maturity of the rambutan fruits and different climate. The total saturated fatty acid of three rambutan seed oils is 49.16-52.68%, which makes it a strong resistant to oxidative rancidity. Since rambutan seed fat is abundant in both oleic acid and arachidic acid, it may also be a good source of nutritious low-calorie fat suitable for human consumption. Studies have shown that oleic acid has blood pressure reducing effect (33), while arachidic acid is less likely to be nutritionally available to the body following hydrolysis by pancreatic lipase due to very high melting temperature (76°C) (7).

The phase change in DSC relates to different TAG sets due to different fatty acids compositions. The melting and crystallization thermograms of oils from R4, R7 and Serjan seeds showed three distinct endothermic peaks and exothermic peaks (Figure 1), which correspond to a group of high, middle and low melting point triglycerides, respectively (5, 8, 10, 12). The onset of crystallization and melting process for three seed oils were R4, 21.19ºC and -35.75ºC; R7, 21.54ºC and -35.63ºC; Serjan, 22.79ºC and -35.44ºC. According to results for melting thermogram, there is a significant difference in endset temperature among R4, R7 and Serjan seeds. The endset temperature shows higher value in Serjan (26.57ºC) than R4 (24.76 ºC) and R7 (25.61ºC). This is because of high content of saturated fatty acids in TAG profile of Serjan. Romain et al. (29) reported that the rambutan seed fat melted completely at below 30°C. However, studies by Manaf et al. (6) and Sonwai and Ponprachanuvut (12) showed that the complete melting point of rambutan seed fat was 40°C and 41.55°C, respectively, while Chai et al. (7) reported that the complete melting temperature of the 11 varieties of rambutan seed fat was between 24.8°C and 50.6°C. Generally, the oils have high content of saturated fatty acids present DSC crystallization and melting profiles at higher temperature regions as compared to the oils have high content of unsaturated fatty acid.

Solid fat content (SFC) is a useful tool to determine the suitability of oils and fats for a particular application (34). The SFC profile of rambutan seed oil for varieties R4, R7 and Serjan shows similar trend of thermal properties. It can be seen from the Figure 2 that among three oils, SFC of Serjan and R4 were clearly highest and lowest at all temperature, respectively. The highest content of long chain saturated fatty acids (C20:0) in Serjan could be the reason of its high SFC over the studied temperature range and this inversely apply to R4. The SFC of R4 and R7 seed oil

decreased gradually from 0ºC to 15ºC then decreased more rapidly after 15ºC to melt completely at 24.5ºC and 25.6ºC, respectively (Figure 2). The SFC% of Serjan shows a gradual decrease from 0ºC to 15ºC and after 15ºC the SFC exhibits sharp melting behaviour until 26.6ºC. Based on results, rambutan seed oils are completely liquid at normal ambient temperature because SFC at that temperature was 0%. These results are in good agreement with SFC results of rambutan seed fat found by Romain et al. (29).

CONCLUSION

In this study, three varieties of rambutan seed oil were characterized. The seeds of three rambutan varieties contain relatively high level of crude fat. Rambutan seeds contain a high arachidic acid content which makes the fat very resistant to oxidation. The melting and crystallization curves showed that the oil has three distinct melting and crystallization peaks. The rambutan seed oil melted completely at the range of 24.54ºC-26.60ºC. Based on these results, modification of rambutan seed fat by blending and interesterification with softer oil or harder fat may lead to products with wider applications. According to the results attained through this study, rambutan seed fat is applicable for a wide variety of industries ranging from confectionery production to cosmetics. Therefore, rambutan seed can be fully utilized and, subsequently, the amount of waste can be minimized.

CONFLICT OF INTERESTS

Authors state that there are no conflicts of interest in preparing the manuscript.

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