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Physicochemical Comparison of Rambutan Nephelium lappaceum Seed Fat and Dairy Butter Fat for Alternative Use

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Abstract: Rambutan (*Nephelium lappaceum*) seed fat is a novel lipid from a plant source with promising applications as a functional and nutritional ingredient. In the current investigation, the physicochemical characteristics and fatty acid profile were examined and compared with that of dairy butter. The melting point of Rambutan seed fat was determined to be 28.5°C, which is about 3-6°C lower than that of butter (32-35°C). The saponification value of Rambutan seed fat was 201.54 mg KOH/g, which was lower than the value for butter (225-240 mg KOH/g), indicating a higher proportion of long-chain fatty acids. The peroxide value was found to be less than the limit of quantitation of 0.2 meq O_2/kg fat, implying that there was little primary oxidation when analyzed. The monounsaturated fatty acid content (74.3%) was high, especially oleic and eicosenic acids, compared to the content in butter (28-30%). On the contrary, saturated fatty acids were relatively lower (15.2% vs. 63-65%) than those of butter. Meanwhile, polyunsaturated fatty acids (10.5%) were relatively higher than those of butter (2-3%). These differences help explain the softer texture and lower melting behaviour of Rambutan seed fat. Overall, the findings suggest that it could be used as an alternative fat, though further studies on stability and application are needed.

Keywords: Rambutan seed fat, Saponification value, Fatty acid profile, Functional fat, Butter, Melting point, Peroxide value

1. Introduction

1.1 Importance of fat characterization in food science

Fats play a crucial role in food systems. It influences sensory characteristics such as flavour and texture, and also affects shelf life, processing performance, and overall nutritional quality. Analyzing characteristics such as saponification value, melting point, peroxide value, and fatty acid profile is a valuable tool for understanding the behavior of lipids in a variety of food matrices. This, in turn, affects the texture, stability, and nutritional impact of a product. These factors serve as guiding decisions throughout formulation and processing. These Physicochemical charcteristics directly affects the texture, flavour release and oxidative stability and emulsification capability in a variety of applications including diary, confectionery and bakery products (O'Keefe & Pike, 2010). In addition, as consumers become more aware

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of the impact that dietary lipids have on their health, it has become increasingly important to have a precise lipid profile in order to ensure regulatory compliance and to properly label nutritional information (O'Keefe & Pike, 2010).

1.2 Rambutan seed fat as a valorised waste product

Rambutan (*Nephelium lappaceum L.*), a tropical fruit grown extensively in Southeast Asia, produces a large amount of agro-industrial waste during its processing. Seeds make up over half of the fruit's volume (Mahmood *et al*., 2018). These seeds which has been previously regarded as waste and difficult to dispose of are now gaining attention because of their high lipid content which can reach up to 39% and its high content of essential fatty acids like oleic and arachidic acids. This change from waste to resource is a part of a growing trend toward circular economy practices. It makes Rambutan seed fat a sustainable choice to other fats. In addition to the positive impact, it has on the environment, the fat has the potential to be utilized in a wide range of industries, such as skincare, food, and nutraceuticals. More recent studies have shown that Rambutan seed fat is rich an antioxidant and could be used as an alternative for cocoa butter, which increases its nutritional and functional value (Nilmat *et al*., 2024).

1.3 The importance of dairy butter as a benchmark

Butter is derived from milk and it is often used as a standard in the comparison studies of fats. This is due to its wide range of application in cooking, well accepted composition and unique sensory characteristics. Premium dairy products are associated with a unique taste, smell, and creamy texture because they contain a high concentration of saturated and short-chain fatty acids, including butyric, palmitic, and stearic acids (Ziarno *et al*., 2023). Butter serves as an ideal reference standard for evaluating the functional properties of alternative lipid sources. This is because it is well known for its health benefits, its ability to resist oxidation, and its unique melting properties. A study by Mohammadi-Nasrabadi *et al.* (2024) showed that it is important and that plant-based fats can be a good substitute when properly used.

1.4 Objective of the study

The current study intends to evaluate the physicochemical characteristics and fatty acid composition of fat derived from the seeds of the rambutan fruit. Additionally, it compares these parameters with those of dairy butter. By considering both compositional and functional aspects, this study provides a clearer understanding of use of underutilized fat. The study helps in providing a better insight into the application of underutilized fat from the seeds of the rambutan fruit.

2. Materials and Methods

2.1 Sample Collection and Preparation

Rambutan fruits were procured from the local market in Aluva, Kerala, India. The fruits were deseeded. The peels and meat were removed. The seeds were thoroughly washed, tray-dried, and dehulled manually. After that, kernels were crushed and fat was extracted.

2.2 Determination of Total Fat Content

The Soxhlet extraction method was used to determine the amount of fat in Rambutan seed samples (FSSAI, 2022). About 5 grams of seed sample were weighed and placed into a Soxhlet thimble. The extraction of fat was carried out in a soxhlet apparatus for a period of 6-8 hours using petroleum ether at a boiling point of 40–60°C. After the extraction process was complete, the solvent was carefully burned off in a fume hood to prevent any potential hazards. The

extracted oil was then transferred into conical flasks that had been previously weighed to ensure accuracy. This step ensured the exact quantity of lipid was extracted for following analysis. After that, the flasks were put in a hot air oven at 105°C to dry until they were all the same weight. After that, the flasks were placed in a desiccator to cool and to prevent moisture absorption. Then the weight of the fat that had been extracted was recorded.

The total fat content was determined as a percentage of fat in relation to the initial sample weight using the formula:

$$\text{Total Fat (\%)} = \frac{\text{Weight of extracted fat (g)}}{\text{Weight of sample (g)}} \times 100$$

All reagents used were of analytical grade. Appropriate precautions were taken during sample preparation and handling to prevent moisture absorption and contamination. The analytical measurements were carried out at an external accredited laboratory F Q Lab and Research Centre (P) Ltd, Cochin, and the values reported correspond to the determinations provided by the laboratory

2.3 Determination of Saponification Value

The saponification value of Rambutan seed fat was determined using a standard procedure given by FSSAI (2022). A round bottom flask was used to measure approximately 2 g of the fat. This was followed by the addition of 25 mL of 0.5 N alcoholic potassium hydroxide solution. The mixture was refluxed for 30 minutes to complete saponification. Then it was allowed to cool. Subsequent to cooling, the excess alkali was titrated with 0.5 N hydrochloric acid. Phenolphthalein was used as an indicator. Under Identical conditions a blank titration was also conducted.

The saponification value (SV) was calculated using the formula:

$$SV = \frac{(B-S) \times N \times 56.1}{W}$$

Where:

B = Volume of HCl (mL) used for blank

S = Volume of HCl (mL) used for the sample

N = Normality of HCl

W = Weight of oil sample (g)

56.1 = Molecular weight of KOH

2.4 Determination of Melting Point

The melting point of Rambutan seed fat was determined by the slip melting point method. This method is established by FSSAI (2022). A small quantity of fat was inserted in the narrow capillary tube, which was subsequently immersed in a water bath. The temperature of the water bath was slowly raised. The melting point was the temperature at which the fat started to flow freely from the capillary. It was carefully monitored and recorded. The value reported corresponds to the analytical determination provided by the external laboratory

2.5 Determination of Peroxide Value

FSSAI (2022) standard method was employed in determining the peroxide value of Rambutan seed oil. The solution of glacial acetic acid and chloroform in 3:2 v/v ratio was mixed with approximately 5 g of Rambutan seed oil. The solution was added with saturated solution of potassium iodide (0.5 mL), and left for 1 minute standing in the absence of light. 30 mL of distilled water were then added, and iodine generated from the reaction was titrated against

0.01 N sodium thiosulfate using starch solution as the indicator. Blank titration was performed also. Peroxide value (PV) is determined based on formula:

$$PV\ (meq\ O_2/kg) = \frac{(S-B) \times N \times 1000}{W}$$

Where:
S = Volume of sodium thiosulfate for sample (mL)
B = Volume of sodium thiosulfate for blank (mL)
N = Normality of sodium thiosulfate
W = Weight of oil sample (g)

2.6 Determination of Total, Saturated, and Monounsaturated Fat

The lipid profile of the samples was determined following the protocol of AOAC International (Horwitz & Latimer, 2005).

2.6.1 Sample preparation

Each sample was thoroughly mixed. A Mojonnier flask was used to accurately weigh a sample that contained about 100 to 200 mg fat. Pyrogallic acid (antioxidant, ~100 mg) and an internal standard solution of triundecanoin (C11:0, 5 mg/mL in chloroform) were added. Along with these were added boiling granules.

2.6.2 Hydrolysis

For food samples that didn't contain dairy, the test portion was mixed with 2 mL of ethanol, 10 mL of 8.3 M HCl, and 1.0 g of anhydrous sodium sulfate. For 40 minutes, the mixture was placed in a shaking water bath that was between 70 and 80 °C. To make sure that hydrolysis was complete, mixing was done at regular intervals. Ammonium hydroxide or a combination of acid and alkali was used to hydrolyze samples of dairy, butter and cheese.

2.6.3 Lipid extraction

The mixture was left to cool. Then, ethanol was added, and it was made sure that the matrix was completely wet. Next, 25 mL of diethyl ether was added. The contents of the flask were then shaken up strongly to help with the extraction, and then they were spun in a centrifuge to separate the phases. The top ether layer was carefully gathered. It was run through anhydrous sodium sulfate to get rid of any leftover moisture. Finally, the lipid fraction was obtained by letting the solvent evaporate while nitrogen flowed through it.

2.6.4 Derivatization

Lipids were methylated by heating them with 2 mL of boron trifluoride–methanol reagent (7% BF_3 in methanol) and 1 mL of toluene in sealed vials at 100 °C for 45 minutes. After cooling, 5 mL of water and 1 mL of hexane were added. The upper hexane layer, which had fatty acid methyl esters (FAMEs), were then collected and dried over sodium sulfate.

2.6.5 Gas chromatography

FAMEs were analyzed using gas chromatography coupled with flame ionization detector (GC-FID) equipped with a very polar capillary column, e.g., SP-2560, 100 m × 0.25 mm, 0.20 µm film. Oven programming involved maintaining the initial temperature of 100 °C for 4 minutes, followed by increasing the temperature up to 240 °C at a rate of 3 °C/min for 15 minutes. The injection and detection temperatures were fixed at 225 °C and 285 °C, respectively. Helium gas was used as a carrier gas at a flow rate of 0.75 mL/min with a split ratio of 200:1. FAMEs were characterized by comparing them with commercial standard samples. The resolution between adjacent peaks like C20:3, C20:4, and C22:1, were kept ≥1.0.

2.6.6 Calculations

Using response factors from standard mixtures, the concentrations of fatty acids in relation to the internal standard were figured out. The right conversion factors were used. And the results were given in terms of triglyceride equivalents. The total fat was measured by adding up all the fatty acids. The saturated and cis-monounsaturated fractions were added separately and reported them as a percentage (w/w) of the sample.

2.6.7 Quality control

Blank runs, standard mixtures, and duplicate analyses were conducted in every batch. Certified reference materials were used periodically to check accuracy and precision.

2.6.8 Validation

Method validation, including calibration, precision, and sensitivity assessment, was conducted at F Q Lab and Research Centre (P) Limited, Cochin following standard analytical procedures.

2.7 Statistical Analysis

All analytical measurements were performed at an external accredited laboratory, F Q Lab and Research Centre (P) Limited, Cochin. The reported values are single analytical measurements provided by the laboratory. As replicate measurements were not available, it was not possible to estimate the statistical variability.

However, the analysis were carried out using standardized methods (Horwitz & Latimer, 2005; FSSAI, 2022) under strict quality control conditions, supports the reliability of the reported values. Therefore, the findings of the present study should be considered as a preliminary comparison, and future work should include replicated measurements for statistical validation.

3. Results and Discussion

The physicochemical properties and fatty acid profile of the seed fat of Rambutan fruit were investigated in this experiment. They were then compared to the literature values of dairy butter for evaluating its suitability as a substitute fat. Values for butter have been obtained from previous literatures and not under similar experimental conditions; therefore, comparison would be merely descriptive. Experimental results for Rambutan seed fat along with the standard values for butter are shown in Table 1.

3.1 Comparison of Physicochemical Properties of Rambutan Seed Oil and Butter

The saponification value (SV) for Rambutan seed fat was recorded as 201.54 mg KOH/g fat, which was found to be lower than butter (225-240 mg KOH/g fat) (Gunstone, 2011). Lower saponification value for Rambutan seed fat suggests that there is presence of more long chain fatty acids since saponification value is inversely proportional to the average molecular weight of fatty acids (Przybylski & Eskin, 2011). On the contrary, butter contains more short chain fatty acids such as butyric (C4:0) and caproic (C6:0) fatty acids, thus having a higher saponification value (O'Keefe & Pike, 2010). Such differences may affect their respective functions when used in food systems.

Total fat content in Rambutan seed fat was 34.83%, which is very low when compared to butter, where its fat content ranges between 80% and 82% (Ziarno *et al.*, 2023) because butter is a concentrated form of milk fat. This shows that Rambutan seed fat is not only a concentrated fat substance but rather a mixture of fats, proteins, and carbohydrates. The fat content in Rambutan seeds makes it a good source of fats derived from plants. It also suggests that they have value addition properties since it comes from fruit-processing waste (Mahmood *et al.*, 2018).

Table 1: Comparative Physicochemical Properties of Rambutan Seed Oil and Butter

Parameter	Rambutan Seed Oil (Lab Result)	Butter (Typical Values)	Observation / Discussion
Saponification Value	201.54 mg KOH/g	225 – 240 mg KOH/g	Lower in Rambutan seed oil, indicating longer-chain fatty acids compared to butter's short/medium-chain FAs.
Total Fat Content	34.83%	80 – 82%	Significantly lower; Rambutan seed is not pure fat, unlike butter which is concentrated dairy fat.
Melting Point	28.5°C	32 – 35 °C	Slightly lower, indicating a softer fat at room temperature; may influence texture in formulations.
Peroxide Value	<LOQ (0.2 meq O_2/kg)	≤ 1 meq O_2/kg	Low PV indicates high oxidative stability, comparable to fresh butter.

Melting point of Rambutan seed fat is 28.5°C, which is slightly lower when compared to butter fat which ranges between 32°C and 35°C (Gunstone, 2011). Low melting point in Rambutan seed fat might be attributed to high content of unsaturated fatty acids in the fat. Unsaturation means presence of carbon-carbon double bond that prevents molecules from coming closer to each other and hence lower melting point. This property would improve the spreadability and softness at room temperature, which could be advantageous for applications in bakery fillings, spreads, and fat blends.

The peroxide value of the Rambutan seed fat was determined to be less than the limit of quantification (LOQ; <0.2 meq O_2/kg fat), implying that there were trace amounts of primary oxidation products in the sample at the time of testing. The peroxide value in fresh butter is typically below 1 meq O_2/kg fat (depending on the freshness of the butter and storage conditions) (Ziarno *et al.*, 2023). It should be noted that the peroxide value is indicative of the early stages of oxidation and cannot be used to assess oxidative stability by itself. To determine oxidation, other tests should be conducted, including the anisidine value, thiobarbituric acid reactive substances (TBARS) test, induction period, and shelf life.

The fatty acid profile of Rambutan seed fat is shown in Table 2. Rambutan seed fat shows a predominance of monounsaturated fatty acids (MUFA, 74.3%), mainly oleic (39.4%) and eicosenic acids (34.2%). It also contained polyunsaturated fatty acids (PUFA, 10.5%), including linolenic (5.2%) and linoleic acids (2.2%), while saturated fatty acids (SFA) accounted for only 15.2%

The predominance of MUFA is nutritionally relevant because diets richer in monounsaturated fatty acids are commonly associated with improved lipid balance when replacing saturated fats

in diet. (Mohammadi-Nasrabadi *et al.*, 2024). In addition, the presence of PUFA contributes essential fatty acids required for normal physiological functions.

Table 2: Fatty Acid Composition of Rambutan Seed Oil (%)

Fatty Acid	Value (%)	Type
Myristic (C14:0)	0.3	Saturated
Palmitic (C16:0)	6.1	Saturated
Palmitoleic (C16:1)	0.7	Monounsaturated
Stearic (C18:0)	8.8	Saturated
Oleic (C18:1)	39.4	Monounsaturated
Linoleic (C18:2)	2.2	Polyunsaturated
Linolenic (C18:3)	5.2	Polyunsaturated
Eicosenic (C20:1)	34.2	Monounsaturated
Eicosatrienoic (C20:3)	2.3	Polyunsaturated
Arachidonic (C20:4)	0.6	Polyunsaturated
Eicosapentaenoic (C20:5)	0.2	Polyunsaturated

The relatively low saturated fat content distinguishes Rambutan seed fat from butter, in which saturated fatty acids generally account for approximately 63–65% of total fatty acids (Gunstone, 2011**).** Lower SFA and higher unsaturated fatty acid levels are also consistent with the softer consistency and lower melting point observed in the present study.

3.2 Comparison of fatty acid profile

A detailed comparison of the fatty acid composition of butter fat and Rambutan seed fat has been presented in Table 3. The fatty acid composition of Rambutan seed fat shows several important nutritional and functional characteristics when compared to butter. There is a predominance of oleic acid (C18:1) which is significant. Oleic acid (C18:1) is the major fatty acid present. It is known to improve the plasma lipid profile, increase HDL levels, and reduce the oxidation of cholesterol. (Gillingham *et al*., 2011; Schwingshackl & Hoffmann, 2012). The presence of eicosanoid acid (C20:1) affect the melting point of the fat and lipid crystal structure, resulting in a softer consistency at room temperature.

Rambutan seed fat contains less palmitic acid (C16:0) than butter. Palmitic acid is a major saturated fatty acid associated with increased LDL cholesterol and high risk of atherogenic effects when consumed in excess (Mensink, 2016). The reduced saturated fatty acid content results in a softer texture and lower melting point of Rambutan seed fat.

A higher proportion of polyunsaturated fatty acids (PUFA), especially linoleic and linolenic acids, also improves the nutritional quality of the fat. These are essential fatty acids are required for normal physiological functions and cannot be synthesized by the human body (Saini & Keum, 2018). However, increased unsaturation generally increases susceptibility to oxidation during storage and thermal processing. In spite of this, the very low peroxide value observed in the present study suggests good initial oxidative quality. This may also suggest the presence

of naturally occurring antioxidant compounds such as tocopherols or phenolic compounds in the seed fat (Choe & Min, 2006).

Overall, these findings indicate that Rambutan seed oil possesses desirable nutritional and functional properties that support its potential application as an alternative lipid source in food formulations.

Table 3: Comparative Fatty Acid Profile: Butter vs Rambutan Seed Oil

Fatty Acid	**Butter (%)** (Feingold, 2021)	**Rambutan Seed Oil (%)**	**Observation / Discussion**
Saturated Fatty Acids	63–65	15.2	Rambutan seed fat is much lower in SFA, explaining lower melting point and softer texture.
Monounsaturated Fatty Acids (MUFA)	28–30	74.3	Much higher in Rambutan seed fat, suggesting heart-healthy properties.
Polyunsaturated Fatty Acids (PUFA)	2–3	10.5	Higher PUFA content in Rambutan seed oil provides essential fatty acids.
Key Individual FAs	Palmitic, Stearic	Oleic, Eicosenic	Different dominant fatty acids contribute to functional and nutritional differences.

3.3 Functional and Industrial Implications

The present findings support the valorisation of Rambutan processing waste into a useful food ingredient. Rambutan seed fat combines:

- moderate lipid yield from seed kernel
- lower melting behavior
- high MUFA content
- lower saturated fat than butter
- low initial peroxide value

These features suggest that Rambutan seed fat could be used in specialty fats, bakery products, combination spreads, and cocoa butter alternative systems. This is in line with the previous reports on Rambutan seed fats (Nilmat *et al*., 2024; Issara *et al*., 2014).

4. Conclusion

The results of this study show that *Nephelium lappaceum* seed fat differs from dairy butter in its physicochemical and compositional characteristics compared. It has a lower melting point, less saturated fatty acid content, and higher percentage of monounsaturated fatty acids. These properties suggests that it can be used as a plant-based fat in certains food systems, especially when a softer structure and better nutrition are needed. Due to differences in composition and structure, Rambutan seed fat is more suitable as a partial replacer than a direct substitute for butter. Further research is needed on oxidative stability, functional performance, and product-level applications to prove its application in industries.

5. Limitations of the Present Study

A key limitation of this study is the lack of replicate measurements and statistical support; therefore, the results should be considered as indicative than definitive. This study provides only a preliminary comparison of composition and physicochemical properties. Butter values were taken from literature and not measured under same experimental conditions. In addition, oxidative stability was evaluated only by peroxide value. Other aspects such as whereas sensory properties, crystallization pattern, rheology, shelf-life study and food application trials were not included in the study.

Future studies should focus on direct comparison with butter under the same conditions. They should also include DSC-based melting and crystallization analysis, texture and rheological evaluation, oxidative stability during storage, sensory acceptability in food products, and trials on partial replacement of butter.

6. Overall Interpretation

In conclusion, the findings reveal that Rambutan seed fat is a lipids source from plant origin possessing favorable characteristics. The reduced amount of saturated fats together with increased amounts of monounsaturated fatty acids and lower melting point make it an appropriate option to be used in different products. Nevertheless, its use should not be generalized across all products by substituting it with butter. Further studies need to be conducted in this area.

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