

Research Article

# Characteristics of Dabai (*Canarium odontophyllum*) Seed Fat Fractions Produced from Solvent Fractionation

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## ABSTRACT

Interest in underutilized tropical fruit species such as *Canarium odontophyllum* (dabai) has increased due to their potential as alternative sources of plant-based fats. However, the high tripalmitin content limits its direct use in food formulations because of waxiness and incomplete melting at body temperature. This study aimed to characterize the fat fractions obtained from DSF through solvent fractionation in terms of their physicochemical, fatty acid, and thermal properties for potential applications. Solvent fractionation using acetone successfully separated DSF into two fractions, namely the hard (Hard-DSF) and a soft (Soft-DSF) fraction, with yields of 25.95% and 73.98%, respectively. Soft-DSF fraction exhibited higher unsaturation (iodine value: 44.55 g I<sub>2</sub>/g) and a lower slip melting point (35 °C), while Hard-DSF displayed greater saturation, a higher melting point (42 °C) and lower free fatty acid content, indicating better oxidative stability. Fatty acid analysis showed that palmitic (C16:0) and oleic (C18:1) acids predominated in all samples, with Hard-DSF enriched in palmitic acid (53.30%) and Soft-DSF higher in oleic acid (38.67%). Differential scanning calorimetry revealed distinct melting and crystallisation behaviours between the fractions, with Hard-DSF exhibiting higher melting (melting range from 4.82 to 49.98 °C) and crystallisation (21.35 °C) temperatures and enthalpy, while Soft-DSF melted near body temperature (36.29 °C) with lower enthalpy. These findings demonstrate that solvent fractionation significantly ( $p < 0.05$ ) modifies the composition and functionality of DSF. Soft-DSF shows potential for confectionery and soft-fat applications due to its desirable melting profile and unsaturation, whereas Hard-DSF may be used as high palmitic sources or a blending component. Further studies, including detailed crystallisation behaviour and stability assessments, are required to confirm functional performance. This study provides new insight into the fractionation characteristics of dabai seed fat as a prospective tropical fat source.

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# 1. Introduction

The growing interest in alternative plant-based fats has led researchers to explore underutilised tropical fruits such as *Canarium odontophyllum*. Locally, the species is known as kembayau in Sabah (Malaysia) and Brunei. It is an indigenous fruit tree native to the tropical rainforest of Borneo, particularly in Sarawak, Malaysia. Dabai belongs to the *Burseraceae* family, which comprises about 100 species distributed across tropical regions of Asia, Africa, and the Pacific Islands. Dabai is a seasonal crop, with its main fruiting periods occurring from July to August and November to December (Hanim et al., 2015; Salleh et al., 2022). In Malaysia, only four *Canarium* species have been recorded, with most of them primarily distributed in Sabah and Sarawak. Sarawak remains the primary producer, yielding approximately 5,302 tonnes of dabai fruit annually (Norazlina et al., 2023). The fruit has attracted increasing scientific and commercial interest due to its high nutritional value and economic significance (Hamzah et al., 2022; Kadir et al., 2021; Norazlina et al., 2023; Salleh et al., 2022).

The dabai fruit contains a single seed surrounded by edible, fleshy pulp. The seed fat is rich in saturated fatty acids and exhibits physical and thermal properties similar to palm stearin and palm mid-fraction. However, dabai seed fat (DSF) contains a high level of tripalmitin (9.80%) triacylglycerols, which contribute to incomplete melting at body temperature and result in processing challenges when producing edible fats, as they reduce fat plasticity (Norazlina et al., 2023). DSF also contains a high proportion of unsaturated fatty acids, approximately 40%, which can be separated to obtain fractions with different melting properties.

To address this issue, fat modification techniques such as solvent fractionation can be used to separate fats with various melting properties, thereby expanding their applicability in food applications. Fractionation is a widely applied modification technique in the edible oil industry, primarily aimed to altering the physicochemical characteristics of fats and oils. This process separates (TAGs) through selective crystallisation and filtration (Büyükebeşe, 2025; Norazlina et al., 2019). The fractions produced through fractionation exhibit distinct chemical profiles, and these compositional differences can significantly influence their thermal characteristics and, consequently, the physical and sensory qualities of the final products (Jin et al., 2018). Fractionation methods are generally classified into three main categories, namely dry fractionation (direct), solvent fractionation, and detergent fractionation (surfactant-assisted) (Büyükebeşe, 2025).

Among them, solvent fractionation offers several advantages, including high separation efficiency, higher yields of desired fractions, sharper melting profiles, and high purity of the final product (Harris, 2017; Mahisanunt et al., 2017; Norazlina et al., 2019). Despite extensive research on conventional vegetable oils, studies on the fractionation behaviour and compositional properties of DSF remain underexplored. No detailed data exist on the changes in the physicochemical, fatty acid composition, and thermal properties of DSF after the fractionation process.

Exploring this may uncover structural and functional characteristics that could serve as sustainable alternatives or enhancers in food formulation. In this study, investigating the fractionation of DSF may also provide insights into its potential industrial applications. Therefore, the objective of this study is to characterise the fat fractions obtained from DSF through solvent fractionation, focusing on their physicochemical properties, fatty acid composition, and thermal behaviour, as well as the potential of these fractions as functional ingredients and their suitability for food industrial applications.

## 2. Materials and Methods

Matured dabai fruits were obtained from the local market in Kuala Penyu, Sabah, Malaysia. Acetone, cyclohexane, n-hexane, Wijs solution, sodium thiosulfate, potassium iodide, starch solution, ethanol, phenolphthalein, sodium hydroxide, and mixed fatty acid standards (FAMES, Supelco) were purchased from Sigma, Germany. All chemicals used were of analytical and chromatography grade with the highest purity.

## 2.1 Methods

### 2.1.1 Preparation of Dabai Seed Fat (DSF)

Dabai fruits were washed with water to remove surface impurities. The fruits were then blanched in boiling water (100 °C) for 15 minutes to soften the flesh. The pulp was separated manually using a strong household knife from the kernel (Figure 1), and then the hard seed kernels were crushed to obtain the seed. The seeds were dried in a drying cabinet (Thermoline) at 60 °C for 8 hours, and the dried material was subsequently ground into fine powder (<250 µm) using a grinding mill (Panasonic). An amount of 2.00 ± 0.01 g of the dabai seed powder was further dried in an oven (Binder) at 105 °C for 24 hours to determine its moisture content, which was found to be 6.78 ± 0.03 %. This value indicates that the seed powder was in an optimal condition for storage and subsequent processing (Jahurul et al., 2018).



**Figure 1.** Dabai fruit seed

The fat extraction was carried out using the Soxhlet extraction method following the AOAC (2005) official method with slight modifications. The seed powder, which weighed 70.0 ± 0.01 g, was placed into a WHATMAN extraction thimble (single-wall, 38 × 325 mm) and extracted in a 500 mL Soxhlet extractor using petroleum ether (1:5, w/v) as the solvent for 8 hours. The extraction system was maintained at 40 °C using a heating mantle. After completion, the solvent was removed from the extract with a rotary evaporator (Heidolph Laborota 4001, Germany) at 40 °C, and the residual solvent was further removed by oven-drying at 60 °C for 2 hours. The extracted DSF was weighed to calculate the fat yield. Extraction yield was determined in triplicate and expressed as:

$$\text{Total extraction yield (\%)} = \frac{\text{Mass of fat extracted}}{\text{Mass of sample powder}} \times 100\% \quad (1)$$

### 2.1.2 Fractionation of DSF

Solvent fractionation was performed at 18 °C according to the method of Norazlina et al. (2020), with slight modifications. Crude DSF (50.00 ± 0.01 g) was first melted at 60 °C to ensure complete melting and removal of crystals, and then dissolved in 200 mL of pre-heated acetone (40 °C) at a weight ratio of 1:4 (w/v). The mixture was stored at a controlled temperature (18 °C) for 18 hours to allow the complete crystallisation process. After crystallisation, the mixture was filtered under vacuum using a Buchner funnel to separate the solid stearin fraction from the liquid fraction containing acetone. The filter cake (stearin) was rinsed with cold acetone to remove residual olein, while the filtrate containing the olein was collected separately. The acetone was removed from both fractions using a rotary evaporator at 40 °C to obtain the final fractionated products. The stearin fraction (hard-DSF) represented the high-melting solid fraction, whereas the soft fraction (soft-DSF) corresponded to the low-melting fraction.

### 2.1.3 Physicochemical analyses

Physicochemical analyses were conducted according to the AOCS (2003) official methods of Cd 1b-87, Ca 5a-40, Cc 3b-92, and Cc 7-25, as described by Norazlina et al. (2022). Before the analysis, crude DSF and its fractions were melted at 60 °C for 30 minutes to ensure a complete melting state.

#### a. Iodine value (IV)

0.20 ± 0.01 g of the fat samples was mixed with 10 mL of cyclohexane and 20 mL of Wijs solution. The mixture was left in the dark for 30 minutes, followed by the addition of 100 mL of distilled water and 15 mL of 10% potassium iodide. The mixture was then titrated with 0.1 N sodium thiosulphate until the solution turned colourless. A blank determination was carried out using a similar procedure. The IV was calculated as:

$$\text{IV (g iodine/g)} = \frac{(\text{Volume of titrated blank} - \text{volume of titrated sample}) \times 0.1 \times 12.69}{\text{Mass of sample, g}} \quad (2)$$

#### b. Free fatty acid (FFA)

5.00 ± 0.01 g of the fat samples was dissolved with 25 mL diethyl ether, followed by 25 mL absolute ethanol and 1 mL of phenolphthalein indicator. The mixture was swirled for homogeneity and then titrated with 0.25 N sodium hydroxide until the solution turned pink. The FFA values were expressed as:

$$\text{FFA as palmitic (\%)} = \frac{\text{Volume of sodium hydroxide} \times 0.25 \times 25.6}{\text{Mass of sample}} \quad (3)$$

$$\text{FFA as oleic (\%)} = \frac{\text{Volume of sodium hydroxide} \times 0.25 \times 28.2}{\text{Mass of sample}} \quad (4)$$

#### c. Slip melting point (SMP)

The SMP of the samples was measured using an open-end capillary glass tube (100mm, O.D.: 1.55mm, I.D.: 1.15mm). Each tube was dipped to a depth of 10 mm into the melted fat, after which the exterior was carefully wiped to remove any excess fat adhering to the surface. The filled tube was then solidified in an ice bath at 5 °C and subsequently mounted alongside a thermometer, with the fat column positioned at the same level as the mercury bulb. The assembly was immersed in a water bath maintained at 10 °C, and the temperature increased at a rate of 1 °C per minute. The fat column inside the tube was observed, and the SMP was recorded when the column rose to a height of 30 mm.

#### d. Refractive index (RI)

The RI was determined using a refractometer (DR-A1-plus, ATAGO, Japan) set at 40 °C. Two drops of the fat sample were placed on the surface of the lower prism and allowed to equilibrate for two minutes. The measurement was recorded after adjusting the light and instrument settings to obtain a precise reading.

#### e. Fatty acid composition

The fatty acid content of the DSF fractions was analyzed using a gas chromatography with a flame ionization detector (GC-FID, GC-2010, Shimadzu, Japan) equipped with a DB-23 column (30 m × 0.32 mm × 0.25 µm). The procedure followed the IUPAC 2.301 method with slight modifications. Before the analysis, the fat samples were melted at 60 °C for 30 minutes and converted to fatty acid methyl esters (FAMES). 0.50 ± 0.01 g of fat samples were dissolved in 2.5 mL of n-hexane, followed by the addition of 0.50 mL potassium hydroxide (2N in methanol). The mixture was vortexed for 1 minute at 1200 rpm and allowed to stand for 10 minutes. The clear upper layer was then collected and transferred into 2 mL GC vials for injection. Chromatographic conditions were as follows: the oven temperature was initially set at 90 °C and held for 5 minutes, increased to 185°C at 8 °C/min and held for 1 minute, then raised to 200 °C at 0.8 °C/min, and finally increased to 250 °C at 2 °C/min and held for 5 minutes. Both injector and detector temperatures were maintained at 250 °C, with a split ratio of 1:20. Fatty acids were identified and quantified based on the retention times of the FAMES standard.

### 2.1.4 Melting and crystallisation

The thermal properties of DSF and its fractions were analysed using Differential Scanning Calorimetry (DSC Diamond, Pekin Elmer, USA). The DSC was calibrated with indium. For sample preparation, the fat samples were first melted at 80 °C, and 3-5 mg of the molten sample was transferred into the DSC aluminum pan using a micropipette, which was then hermetically sealed. The sealed pans were placed in vials and reheated at 80 °C for 30 minutes to ensure a complete melting state. To stabilize the samples, the pans were then incubated at 25 °C for seven days. After incubation, the pans were transferred to the DSC head, with an empty hermetically sealed aluminium pan used as the reference. The DSC program consists of the following steps: cooling to -60 °C at 10 °C/ min and heating at 10 °C/ min to 80 °C with an isothermal hold of 2 minutes. During the melting and cooling phases, the enthalpy change, onset, and offset temperatures of the fat samples were determined.

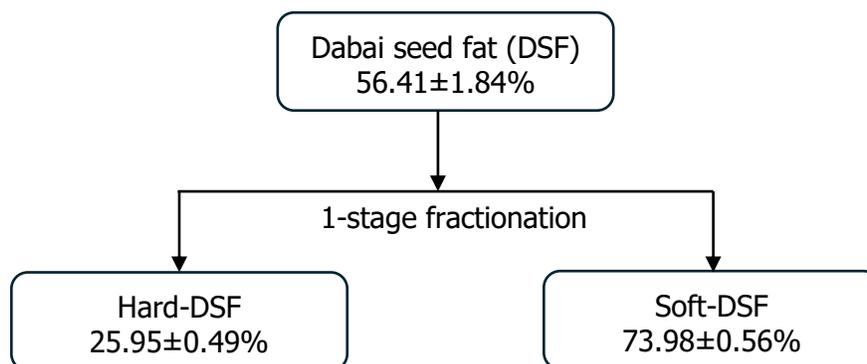
### 2.1.5 Statistical analysis

All analyses were conducted in triplicate, and results were expressed as mean  $\pm$  standard deviation. Data was analyzed using IBM SPSS Statistics software (version 29). One-way ANOVA was performed, and differences were considered statistically significant at  $p < 0.05$ .

## 3. Results and Discussion

### 3.1 Fraction Yield of Dabai Seed Fat (DSF)

The purpose of solvent fractionation of DSF is to obtain fractions with improved functional properties compared to the pure DSF. After a single-stage fractionation process, DSF produced two fractions: hard (Hard-DSF) and soft (Soft-DSF), with yields of 25.95% and 73.98% (Figure 2), respectively. The predominance of the soft fraction (Soft-DSF) suggests a higher concentration of low-melting triacylglycerols and unsaturated fatty acids such as oleic and linoleic acids, which remain in the liquid phase during crystallisation at low temperatures. This gives the fraction better functional properties due to increased fluidity compared to pure DSF, and the waxiness of the fat may also be reduced. In contrast, the hard fraction, although recovered in smaller amounts, is composed of higher saturated fatty acid content, such as palmitic acid, which is suitable for applications where solid fats are required. These components crystallise more readily and contribute to the solid consistency of the fraction, making it suitable for applications that require structural fats, such as in confectionery, bakery shortenings, or as a cocoa butter alternative. This study successfully fractionated the two fractions, tailoring the properties of the DSF. The high-yielding soft-DSF could be incorporated into food formulations with reduced waxiness, while the hard-DSF fraction may serve as an alternative to palm kernel oil or cocoa butter in solid fat applications. Fractionation enhances the versatility of DSF by providing improved control over its melting profile, oxidative stability, and nutritional characteristics, thereby broadening its applicability across the food, cosmetic, and pharmaceutical industries.



**Figure 2.** Dabai seed fat extraction and fractionation yield.

### 3.2 Effect of Fractionation on the Physicochemical Properties of DSF

The physicochemical analysis of Dabai seed fat (DSF) and its fractions revealed significant ( $p < 0.05$ ) differences in properties and potential functionality. Table 1 presents the physicochemical properties of the fractionated DSF. Iodine value (IV) is a quality indicator used to determine the degree of unsaturation and hardness in fat samples. A fat sample with a high IV contains a high level of unsaturated fatty acids. The IV was highest in the Soft-DSF (44.55 g iodine/g), followed by DSF (42.17 g iodine/g), and lowest in the Hard-DSF (40.53 g iodine/g). This suggests that the soft fraction contains a greater proportion of unsaturated fatty acids, particularly oleic and linoleic acids (Norazlina et al., 2023).

During the fractionation process, the unsaturated fatty acids were removed into the soft fraction, lowering the IV of the hard fraction. This is due to the solubility of low-melting triglycerides in acetone, causing the unsaturated fatty acid-rich triglycerides to be transferred into the soft fraction, allowing separation of the hard and soft fractions. A low IV in the hard fraction suggests higher saturation, better oxidation resistance, and a longer shelf life than pure DSF. This result is supported by the low free fatty acid (FFA) content in the hard fraction, indicating a stable and less rancid fraction (Norazlina et al., 2019), which is useful for storage applications.

**Table 1.** Physicochemical properties of dabai seed oil and its fraction

Physicochemical properties	Dabai seed fat (DSF)	Stearin fraction (Hard-DSF)	Soft fraction (Soft-DSF)
Iodine value (g iodine/g)	42.17±0.14 <sup>b</sup>	40.53±0.90 <sup>a</sup>	44.55±1.16 <sup>c</sup>
Free fatty acid as palmitic (%)	3.91±0.30 <sup>b</sup>	2.70±0.23 <sup>a</sup>	4.81±0.11 <sup>c</sup>
Free fatty acid as oleic (%)	3.78±0.33 <sup>b</sup>	2.49±0.26 <sup>a</sup>	4.67±0.12 <sup>c</sup>
Slip melting point (°C)	38.00±0.01 <sup>b</sup>	42.00±0.00 <sup>c</sup>	35.00±0.00 <sup>a</sup>
Refractive index	1.46±0.00 <sup>b</sup>	1.43±0.00 <sup>a</sup>	1.46±0.00 <sup>b</sup>

Values are the mean ± standard deviation of triplicate; means with a different letter within a column are significantly different ( $p < 0.05$ ).

The free fatty acid (FFA) content, expressed as palmitic and oleic acids, also showed significant ( $p < 0.05$ ) variation among Dabai seed fat (DSF) and its fractions. Soft-DSF recorded the highest FFA levels (palmitic: 4.81 ± 0.11%, oleic: 4.67 ± 0.12%), followed by pure DSF (palmitic: 3.91 ± 0.30%, oleic: 3.78 ± 0.33%), while Hard-DSF exhibited the lowest FFA content (palmitic: 2.70 ± 0.23%, oleic: 2.49 ± 0.26%). The elevated FFA in Soft-DSF can be attributed to its higher unsaturation, making it more prone to hydrolytic reactions. In contrast, the lower FFA levels observed in the hard fraction are indicative of reduced hydrolytic breakdown and are commonly associated with improved oxidative stability. The FFA values of DSF and its fractions are comparable to those reported for dabai pulp oil (FFA as oleic acid: 2.57%) and palm oil (FFA as oleic acid: 5.00%) (Kadir et al., 2021), suggesting that the fractionated fats are of acceptable quality.

From a compositional perspective, the relatively low FFA content of Hard-DSF suggests potential suitability for ambient or moderate-temperature storage conditions, where minimisation of hydrolytic rancidity is important. However, storage performance under prolonged or high-temperature conditions was not evaluated in the present study. Corresponding to the IV, the slip melting point (SMP) values also varied among the samples. Hard-DSF exhibited the highest SMP (42.00 ± 0.00 °C), indicating a more solid consistency and a higher proportion of saturated fatty acids. In contrast, Soft-DSF showed the lowest SMP (35.00 ± 0.00 °C), consistent with a higher degree of unsaturation and a softer texture.

This fraction showed melting at body temperature, which is potentially acceptable in confectionery applications, specifically for the formulation of chocolate. The intermediate SMP observed in pure DSF ( $38.00 \pm 0.00$  °C) also reflects a balanced mixture of solid and liquid triglycerides. These findings confirm that fractionation effectively separated fats with different melting behaviours, an important attribute for optimising functionality in various food formulations, particularly under tropical ambient conditions (Norazlina et al., 2023).

Refractive index (RI) measurements further supported the compositional differences among the fractions. DSF and Soft-DSF had higher RI values ( $1.46 \pm 0.00$ ), while Hard-DSF recorded a slightly lower RI ( $1.43 \pm 0.00$ ). The higher RI in Soft-DSF indicates a greater degree of unsaturation due to the presence of more double bonds in its fatty acid chains (Endo, 2018). These findings on the RI and unsaturation complements the iodine value data, reinforcing the conclusion that Soft-DSF is richer in unsaturated components, whereas Hard-DSF is more saturated and thermally stable. The fractionation of Dabai seed fat successfully produced fractions with different physicochemical properties that suggest their potential industrial applications. Hard-DSF, which has a low iodine value, high melting point, and stability, has potential for improving the hardness of fat products with oxidative resistance, while Soft-DSF, rich in unsaturated fatty acids and with a lower melting point, can be used directly for confectionery applications.

### 3.3 Fatty Acid Composition

Table 2 presents the fatty acid composition of pure DSF and its fractions. The profile is dominated by palmitic acid (C16:0) and oleic acid (C18:1), with moderate amounts of stearic acid (C18:0) and linoleic acid (C18:2), consistent with our previous study (Norazlina et al., 2023). In pure DSF, palmitic acid is the most abundant saturated fatty acid at 52.03%, while oleic acid and linoleic acid account for 38.20% and 3.20%, respectively. This composition is comparable to palm stearin and the palm oil mid-fraction, which typically contain 30.00–54.28% palmitic acid, 35.00–45.00% oleic acid, and 10.00–15.00% linoleic acid (Jahurul et al., 2019; Jin et al., 2018). The fatty acid composition was significantly affected by the fractionation process ( $p < 0.05$ ). The hard fraction contains a higher level of saturated fatty acids and a higher melting point than the soft fraction, a compositional shift that is commonly associated with a higher melting behaviour. The hard fraction (Hard-DSF) contained 59.30% saturated and 39.54% unsaturated fatty acids, while the soft fraction (Soft-DSF) contained 55.03% saturated and 43.51% unsaturated fatty acids.

Fractionation of DSF resulted in an increase in palmitic acid from 52.03% to 53.30% in the hard fraction, whereas oleic acid decreased from 38.20% to 35.13%. In contrast, the palmitic acid decreases from 52.03% to 49.62% in the soft fraction, and the oleic acid slightly increases its content from 38.20% to 38.67%. Similar trends were observed in the fractionation of tropical fats using acetone fractionation, which showed an increase in saturated fatty acid content in the stearin (hard) fraction and unsaturated fatty acids in the olein fraction (Azzatul et al., 2020; Jin et al., 2018). The variations in the fatty acid profile of DSF fractions resulted from the dilution and solubilization effects that occur during solvent fractionation. The solubility of low-melting triglycerides, which predominantly consist of unsaturated fatty acids, in acetone caused the unsaturated fatty acids to accumulate in the soft fraction, thus increasing the unsaturated fatty acid content in the soft fraction.

The hard fraction (Hard-DSF) showed an increased proportion of saturated fatty acids, particularly palmitic acid (53.30%), and a reduced level of oleic acid, indicating enrichment in high-melting triacylglycerols such as tripalmitin. This is supported by the high palmitic content in DSF found in our previous study, which reported 9.80% tripalmitin (Norazlina et al., 2023). Norazura et al. (2018) reported that tripalmitin levels as low as 4% can contribute to waxy characteristics in fat-based systems, indicating that an increase in palmitic acid in Hard-DSF may be accompanied by a higher tripalmitin proportion. However, the impact of this enrichment on textural or sensory properties was not evaluated in the present study.

Conversely, the lower palmitic acid content and higher oleic acid proportion in Soft-DSF are indicative of a softer fat composition, which is compositionally comparable to palm oil mid-fraction. While functional equivalence was not directly assessed, such a fatty acid profile suggests potential suitability for applications requiring softer fat characteristics, including cocoa butter alternatives and confectionery fats. The relatively stable linoleic acid content across all fractions contributes to the nutritional value of both. Meanwhile, the Hard-DSF fraction, although structurally solid, may require further modification or blending to reduce waxiness and can serve as a compositional source of palmitic-rich fat, particularly in applications such as plastic fats or as a blending component with other vegetable oils.

**Table 2.** Fatty acid composition of dabai seed fat and its fractions

Fatty acid (%)	Dabai seed fat (DSF)	Stearin fraction (Hard-DSF)	Soft fraction (Soft-DSF)
C14:0	0.08 ±0.04 <sup>a</sup>	0.10±0.19 <sup>b</sup>	0.10±0.11 <sup>b</sup>
C16:0	52.03 ±0.28 <sup>b</sup>	53.30±0.27 <sup>c</sup>	49.62±0.32 <sup>a</sup>
C16:1	0.20 ±0.08 <sup>a</sup>	0.20 ±0.09 <sup>a</sup>	0.20±0.01 <sup>a</sup>
C17:0	0.10 ±0.01 <sup>a</sup>	0.10 ±0.17 <sup>a</sup>	0.10±0.00 <sup>a</sup>
C18:0	5.71±0.03 <sup>b</sup>	6.00±0.21 <sup>c</sup>	5.41±0.01 <sup>a</sup>
C18:1	38.20±0.11 <sup>b</sup>	35.13±0.37 <sup>a</sup>	38.67±0.37 <sup>b</sup>
C18:2	3.20 ±0.07 <sup>b</sup>	3.00±0.01 <sup>a</sup>	3.43±0.03 <sup>c</sup>
C18:3	0.30±0.08 <sup>b</sup>	1.21±0.01 <sup>a</sup>	1.21±0.01 <sup>a</sup>
C20:0	0.30±0.14 <sup>a</sup>	0.32±0.03 <sup>b</sup>	0.32±0.03 <sup>b</sup>

Values are the mean ± standard deviation of triplicate; means with a different letter within a column are significantly different ( $p < 0.05$ ).

### 3.4 Melting and Crystallisation Properties

Differential scanning calorimetry (DSC) data revealed that the melting properties of the fractions exhibited distinct thermal properties (Table 3). The stearin fraction (Hard-DSF) showed the highest melting onset ( $4.82 \pm 0.24$  °C) and offset ( $49.98 \pm 0.22$  °C) temperatures, indicating a higher melting range and greater thermal stability compared to the pure DSF (onset:  $3.75 \pm 0.45$  °C; offset:  $42.09 \pm 0.24$  °C) and the soft fraction (onset:  $3.40 \pm 0.83$  °C; offset:  $36.29 \pm 0.22$  °C). The melting properties of the soft fraction are similar to those reported for tropical cocoa butter alternatives such as bambangan seed fat, rambutan seed fat, and palm oil mid-fraction (Azzatul et al., 2020; Jahurul et al., 2019; Jin et al., 2018), due to their melting behaviour at body temperature.

Overall, the higher melting temperatures observed for HARD-DSF are indicative of a greater proportion of high-melting, saturated triglycerides, which are typically associated with more ordered crystalline structures. This compositional characteristic presumably contributes to a more rigid fat matrix and higher solid fat content at ambient temperature. While functional performance was not directly evaluated in this study, such thermal properties are commonly associated with fats used in applications requiring structural integrity and thermal resistance, including confectionery coatings, bakery shortenings, and margarine formulations. Conversely, the lower melting range of the soft fraction suggests potential suitability for applications requiring softer fat characteristics, such as confectionery fats analogous to palm oil mid-fraction.

The enthalpy of melting ( $\Delta H$ ) further supports this observation. Hard-DSF showed the highest enthalpy value ( $78.91 \pm 1.11$  J/g), followed by DSF ( $60.36 \pm 4.30$  J/g) and Soft-DSF ( $53.81 \pm 5.78$  J/g). A higher enthalpy indicates a more ordered crystalline network and greater energy required for melting, whereas the lower enthalpy in Soft-DSF suggests a less ordered crystalline structure with more unsaturated triglycerides, explaining its lower melting point and softer texture.

**Table 3.** Melting and crystallisation properties of dabai seed fat fractions

	<b>Dabai seed fat (DSF)</b>	<b>Stearin fraction (Hard-DSF)</b>	<b>Soft fraction (Soft-DSF)</b>
<b>Melting Properties</b>			
Onset temp (°C)	3.75±0.45 <sup>a,b</sup>	4.82±0.24 <sup>b</sup>	3.40±0.83 <sup>a</sup>
Offset temp (°C)	42.09±0.24 <sup>b</sup>	49.98±0.22 <sup>c</sup>	36.29±0.22 <sup>a</sup>
Enthalpy (J/g)	60.36±4.30 <sup>b</sup>	78.91±1.11 <sup>c</sup>	53.81±5.78 <sup>a</sup>
<b>Crystallisation properties</b>			
Onset temp (°C)	11.53±0.27 <sup>a</sup>	21.35±0.20 <sup>c</sup>	15.01±0.32 <sup>b</sup>
Offset temp (°C)	-11.53±0.27 <sup>a</sup>	-8.79±0.17 <sup>b</sup>	-11.54±0.25 <sup>a</sup>
Enthalpy (J/g)	59.27±1.10 <sup>b</sup>	58.80±1.42 <sup>b</sup>	46.46±6.10 <sup>a</sup>

Values are the mean  $\pm$  standard deviation of triplicate; means with a different letter within a column are significantly different ( $p < 0.05$ ).

Crystallisation analysis also revealed significant differences among the fractions. Hard-DSF had the highest crystallisation onset temperature ( $21.35 \pm 0.20$  °C), followed by Soft-DSF ( $15.01 \pm 0.32$  °C) and DSF ( $11.53 \pm 0.27$  °C). Higher crystallisation temperatures indicate a greater tendency to solidify upon cooling, which may be beneficial in certain fat formulations. In contrast, Soft-DSF and DSF exhibited lower crystallisation onset and negative offset temperatures ( $-11.54 \pm 0.25$  °C and  $-11.53 \pm 0.27$  °C, respectively), indicating their ability to remain liquid over a wider temperature range.

This property enhances their suitability for use in liquid or semi-solid formulations such as spreads, salad oils, and frying fats, where flowability and low crystallisation points are desirable (Norazlina et al., 2023). Crystallisation enthalpy ( $\Delta H_c$ ) followed a similar trend, with DSF ( $59.27 \pm 1.10$  J/g) and Hard-DSF ( $58.80 \pm 1.42$  J/g) showing higher values than Soft-DSF ( $46.46 \pm 6.10$  J/g). The higher enthalpy of Hard-DSF reflects its strong crystalline structure, while the lower value of Soft-DSF suggests a more amorphous form dominated by unsaturated triglycerides.

The relationship between melting and crystallisation behaviour shows that the Hard-DSF fraction has superior thermal stability, due to its higher saturation and organised crystalline network, while Soft-DSF remains fluid at lower temperatures because of its higher degree of unsaturation. Overall, the fractionation process successfully modified the thermal and physicochemical profiles of Dabai seed fat, producing fractions with tailored functional properties. Hard-DSF, with its higher melting and crystallisation temperatures and enthalpy values, is better suited to applications requiring firm, stable fats capable of maintaining structure at elevated temperatures. In contrast, Soft-DSF, characterised by its melting at body temperature, lower melting point, and enthalpy, is more suitable for formulations that require fluidity, melting at the desired body temperature, and easy spreadability.

## 4. Conclusion

The solvent fractionation of Dabai (*Canarium odontophyllum*) seed fat (DSF) successfully separated DSF into two distinct fractions, Hard-DSF (stearin) and Soft-DSF (olein), each with different fatty acid compositions, physicochemical, and thermal properties. The Soft-DSF fraction, which constituted the high-yielding soft fraction (73.98%), has higher unsaturated fatty acids with reduced palmitic content. It exhibited a melting point at body temperature, a higher iodine value, and greater fluidity, indicating potential functional properties relevant to soft fat formulations. In contrast, the Hard-DSF fraction was dominated by saturated fatty acids such as palmitic acid and showed higher melting and crystallisation temperatures and greater oxidative stability, indicating potential for applications requiring solid or structural fats, such as bakery shortenings, margarines, cocoa butter alternatives, and POP-rich fat sources. The findings confirm that solvent fractionation can effectively modify the functionality of DSF, broadening its potential industrial applications. However, the lack of triacylglycerol profiling limits the comprehensive interpretation of the fractionation behaviour and the confirmation of fat functionality. Further work incorporating triacylglycerol profiling and polymorphic analysis is recommended to establish clearer relationships between molecular structure and physical properties, and to optimise the use of DSF as a novel tropical fat source.

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