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COMPARATIVE OIL YIELD AND FATTY-ACID COMPOSITION OF TARAP, CEMPEDAK AND NANGKA SEEDS

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ABSTRACT. *Plant seeds are a major source of edible oils and contain health-promoting unsaturated fatty acids such as oleic, linoleic, and α-linolenic acids. The increasing demand for alternative edible oils has driven interest in underutilized seed resources. Seeds of Artocarpus species, namely tarap (Artocarpus odoratissimus), cempedak (Artocarpus integer), and nangka (Artocarpus heterophyllus), are commonly discarded as agricultural waste after fruit consumption. This study evaluated the oil yield and fatty acid composition of these seeds using GC-FID to assess their potential as edible oils. Tarap seeds exhibited the highest oil yield (19.02 ± 2.14 g oil per 100 g of dry seed), whereas cempedak and jackfruit seeds contained significantly lower yields (1.16 ± 0.32 and 0.94 ± 0.19 g/100 g dry weight, respectively). Tarap seed oil was rich in cis-linoleic acid, oleic acid, and the rare omega-9 fatty acid which is nervonic acid. It also demonstrated a more favourable polyunsaturated-to-saturated fatty acid (P/S) ratio than palm kernel, peanut, and corn oils. These findings suggest that tarap seed oil warrants further investigation before its suitability for food and nutraceutical applications can be established.*

INTRODUCTION

Artocarpus from the Moraceae family is known for food-producing plant, which is indicated by the word Artocarpus itself in Greek phrases artos, which implies bread. Meanwhile, karpos implies fruit (Raihandhany *et al.,* 2018). Generally, about 50 species of Artocarpus trees are indigenous to tropical and subtropical Asia. Sabah is one of the main states in Malaysia known for producing a wide variety of distinctive fruits found mainly on Borneo Island and in the Southeast Asia region. These include the tarap fruit (*Artocarpus odoratissimus*), cempedak fruit (*Artocarpus integer*) and nangka fruit or known as jackfruit (*Artocarpus heterophyllus*).

Tarap fruit is a wild fruit that is extensively grown in Sabah. It has become one of the most well-liked fruits among the locals, particularly during fruit season from September to early the following year. Its skin is coated in gentle spines and resembles the durian or the jackfruit in appearance. The flesh, which is sweet, fruity, and emits a strong durian-like aroma, is typically consumed fresh (Abu Bakar & Abu Bakar, 2018) (Figure 1a). Cempedak fruit on the other hand can be green, brown, or yellow in colour and contains 100–500 seeds. It has a shape resembling that of a barrel or pear, with seeds that resemble kidneys. The soft yellowish or reddish flesh that surrounds the seeds can be consumed raw. Renowned for its potent and sweet aroma, the flesh of cempedak can occasionally be juicy (Jagtap & Bapat, 2010) (Figure 1b). Nangka or jackfruit remains the biggest fruit that grows on trees globally. It is ellipsoidal and aggregate, made up of several "bulbs" of flesh that comprise seeds encompassing a gristly core, shielded by a robust coating (Vazhacharickal *et al.,* 2015). The flesh has a distinct, sweet flavour reminiscent of a blend of banana and pineapple. Beneath its thick, rough exterior lies stringy flesh that can be consumed raw or roasted in an assortment of recipes (Figure 1c).

The global high demand of edible plant oil has prompted the hunt for more prospective oil-producing plants. The majority of edible commercial plant oils are produced from oilseeds such as soybean, rapeseed, sunflower, peanut, and palm (Konopka *et al.,* 2023). Edible plant seed oils contain a high percentage of unsaturated fatty acids (FAs) such as oleic acid (18:1), linoleic acid (LA/18:2) and a-linolenic acid (ALA/18:3). These fatty acids are known for their health-promoting effects in humans, making them increasingly valuable for nutritional and pharmaceutical applications (Otero *et al.,* 2021). To date, the seeds of tarap, cempedak and nangka are often treated as waste by the local community after fruit consumption. However, there is relatively inadequate study on the fatty acid profiling of oils isolated from the seeds of Artocarpus species (Chowdhury *et al.,* 1997; Tang *et al.,* 2013; Krupa *et al.,* 2020; Ramaiya *et al.,* 2022). Tang *et al.* (2013) did a proximate analysis of tarap fruits with the aid of gas chromatography-mass spectrometry (GC-MS), which revealed that the major fatty acid components detected were palmitic acid and stearic acid, based on the limited available fatty acid methyl esters (FAMEs). Meanwhile, Ramaiya *et al.* (2022) reported that nervonic acid (45.32%), palmitic acid (26.22%), behenic acid (9.26%), oleic acid (5.99%) and cis-11-eicosenoic acid (1.11%) were present in tarap seed oils. As for cempedak, Krupa *et al.* (2020) stated that its seed oil is anticipated to have a profile similar to other Artocarpus species, with lauric acid and palmitic acid are typically found in high concentration. For nangka, Chowdhury *et al.* (1997) stated that there were significant fatty acids present in diverse amounts in various nangka components, including capric acid, myristic acid, lauric acid, palmitic acid, oleic acid, stearic acid, linoleic acid, and arachidic acids although no numerical data were presented.

Despite the lack of extensive fatty acid profiling of these three Artocarpus seed oils, literature findings suggest the potential of these seeds to be explored as a source of edible oil with health-promoting and nutraceutical importance. Therefore, this study aimed to extensively characterize the fatty acids in the seed oils extracted from the three Artocarpus species using gas chromatography-flame ionization detector (GC-FID) and to evaluate their potential as health-promoting edible oils. In addition, comprehensive characterization of the fatty acid composition of underutilized tropical fruit seeds may contribute to the discovery of alternative sustainable lipid sources and support value-added utilization of agricultural by-products. The findings from this study are expected to provide useful scientific information regarding the nutritional quality and functional potential of seed oils from the three Artocarpus species. Furthermore, the study may encourage the utilization of these currently underexploited seeds in food, nutraceutical, and pharmaceutical applications, while simultaneously reducing fruit-processing waste and promoting sustainable resource utilization.

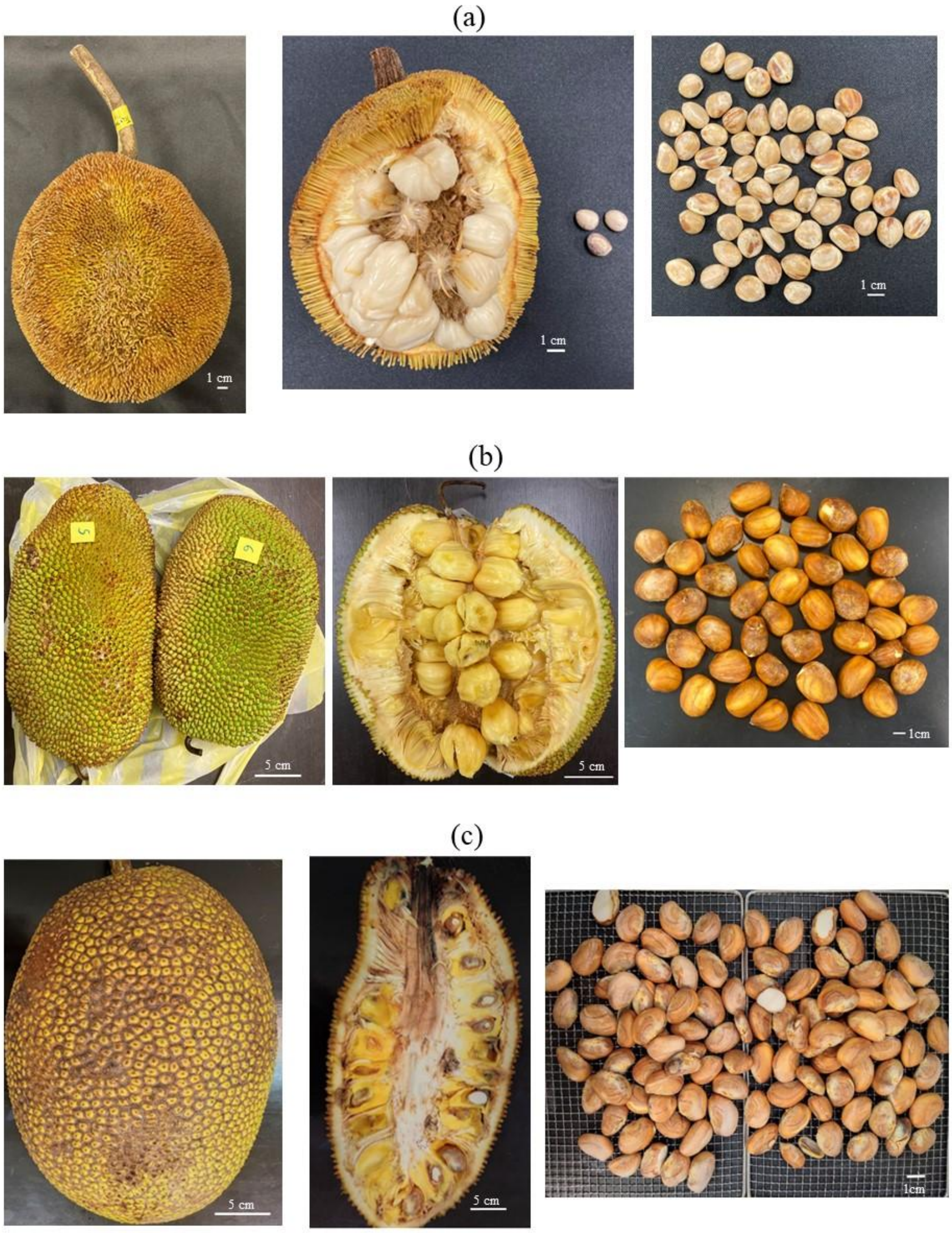

Figure 1. Morphology of Artocarpus fruits both before and after dissection, including their seeds. (a) Tarap, (b) Cempedak and (c) Nangka.

MATERIALS AND METHODS

Preparation of Plant Materials

A total of five ripe tarap fruits (n = 5), seven ripe *cempedak* fruits (n = 7) and five ripe nangka fruits (n = 5) were purchased from local markets in Kota Kinabalu, Sabah. The fruits were cleaned, dried and dissected at the Natural Product Chemistry laboratory of the Biotechnology Research Institute, Universiti Malaysia Sabah. The seeds were manually removed from the fruit mesocarp and cleaned by rinsing with tap water followed by distilled water. Fresh weight (FW) measurements were taken before the seeds underwent freeze-drying using a freeze dryer (Labconco, USA) at -55°C for seven days.

Subsequently, the dried seeds were weighed again (dry weight, DW) and ground into a fine powder using a heavy-duty blender. The dried seed powder was stored at -20°C prior to further analysis.

Extraction of Seed Oils

For oil extraction, approximately 15 ± 0.5 g of each seed sample was weighed and individually vacuum-packed prior to analysis. The prepared samples were subsequently submitted to UNIPEQ Sdn. Bhd., Universiti Kebangsaan Malaysia (UKM), for determination of fatty acid composition. Total lipid extraction was performed using a Soxhlet extraction system according to the laboratory's validated method (STP/Chem/A02), adapted from AOAC Official Method 991.36 (AOAC, 2012). Initially, finely ground seed material was treated with methanolic hydrochloric acid and incubated in a heated water bath for 15–25 minutes to facilitate hydrolysis. Following digestion, lipids were extracted using diethyl ether as the solvent in the Soxhlet apparatus. The solvent-containing lipid extract was then concentrated, and the solvent was removed under reduced pressure using a rotary evaporator, yielding the recovered oil fraction for subsequent analysis.

Transesterification of Seed Oils into Fatty Acid Methyl Ester (FAME) and GC-FID Analysis

Fatty acid composition was determined according to AOAC Official Method 996.06 (AOAC, 2016) using gas chromatography coupled with a flame ionization detector (GC-FID). Prior to analysis, the extracted seed oils were converted into fatty acid methyl esters (FAMEs) through derivatization with boron trifluoride in methanol (BF_3–MeOH). Following phase separation, the FAME-containing organic layer was collected and subjected to chromatographic analysis. FAME profiling was carried out using an Agilent GC-FID system (Santa Clara, CA, USA) equipped with an Agilent 7890A GC, 7693 autosampler and a DB-225 capillary column (30 m × 0.25 mm × 0.20 µm). Hydrogen was employed as the carrier gas with a flow rate of 1.3 mL/min. For injection, a 1 µL of sample was injected. The inlet temperature was 250 °C and the detector temperature was 260 °C. A split ratio of 50:1 was used. The temperature program started from 100 °C, which was kept constant for 3 min. Then, the column was heated at 20 °C/min to reach 166 °C, where it was kept for 5 min. Then, it was heated to 180 °C, at 1 °C/min, and finally to 240 °C at 10 °C/min, where it was kept for 1 min. Calibration mix was prepared from a Supelco 37 component FAME mixture (Sigma-Aldrich, St. Louis, Missouri, United States) with methyl nonadecanoate as internal standard (ISTD). The 37 FAMEs mixture consisted of C4:0, C6:0, C8:0, C10:0, C11:0, C12:0, C13:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0, C21:0, C22:0, C23:0, C24:0, C14:1, C15:1, C16:1, C17:1, C18:1n9t, C18:1n9c, C20:1n9, C22:1n9, C24:1, C18:2n6t, C18:2n6c, C18:3n6, C18:3n3, C20:2, C20:3n6, C30:3n3, C20:4n6, C20:5n3, C22:2, C22:6n3.

Statistical analysis

All experimental data were processed and analysed using GraphPad Prism version 9.0.0 (GraphPad Software, San Diego, CA, USA). Results are presented as the mean values with their corresponding standard deviations (mean ± SD). Statistical comparisons among groups for oil yield analysis were conducted using one-way ANOVA followed by Tukey's HSD post-hoc test. Significant difference was indicated by a p-value less than 0.05.

RESULTS

Yield and Physical Properties of the Extracted Oils

Among the three Artocarpus species, tarap seeds were found to contain the highest yield of oil, which was 19.02 ± 2.14 g oil per 100 g of dry seed (Table 1), and was significantly higher than the two other Artocarpus seeds. Meanwhile, the other two Artocarpus species, cempedak and nangka seeds were found to contain very low amount of oil, which were 1.16 ± 0.32 and 0.94 ± 0.19 g oil per 100 g dry seed, respectively and no significant difference between them (Table 1). Peanut, which is well known for oil production and used as control in this study, was found to produce the highest yield of oil, which was 52.53 ± 2.33 g oil per 100g of dry seed and was significantly different compared to the three Artocarpus seed oil yields (Table 1). For the physical properties of the extracted seed oils, it could be observed that tarap seed oil remained in liquid form at 27°C while solidified at -20°C. The colour of the oil was yellowish and deeper than peanut oil (Figure 2a). On the other hand, cempedak seed oil was semi-solid at 27°C but totally solidified at -20°C. The oil had a light orange (Figure 2b). Nangka seed oils shared similarity with tarap oil but the yield was very low despite having the largest seed size among the three Artocarpus species studied (Figure 2c). From the results obtained, it can be observed that among the three Artocarpus seeds, tarap seeds produce the highest yield, indicating their potential for oil extraction and further development as edible plant seed oil product.

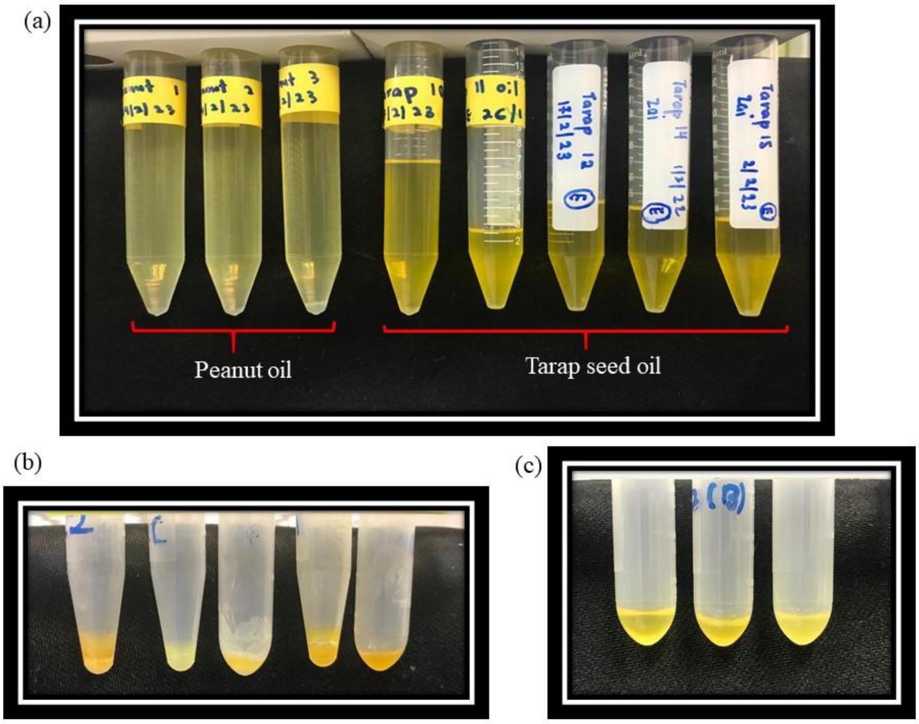

Figure 2. Physical properties of seed oils extracted from Artocarpus species. (a) Tarap, (b) Cempedak and (c) Nangka. Oils extracted from peanut were used as control.

Table 1. Oil yield extracted from the three Artocarpus seeds compared with peanut oil.

	Sample	**Yield of oil extracted (X g oil per 100 g of dry seed)**
1.	*Tarap* Seed	19.02 ± 2.14^{b}
2.	*Cempedak* Seed	1.16 ± 0.32^{c}
3.	*Nangka* Seed	0.94 ± 0.19^{c}
4.	Peanut (control)	52.53 ± 2.33^{a}

Values are expressed as mean ± standard deviation of tarap (n=5), cempedak (n=7) and nangka (n=5), analyzed using one-way ANOVA followed by Tukey's HSD post-hoc test in which different superscript letters (^{a}, ^{b}, and ^{c}) between groups indicate significant difference ($p<0.05$).

Fatty Acid Profiles of the Three Artocarpus Seed Oils

The fatty acid profile of tarap seed oil, as shown in Table 2, indicates that the seeds contained the highest percentage of polyunsaturated fatty acids, PUFA (46.15 ± 3.23%), followed by monounsaturated fatty acid, MUFA (38.04 ± 3.60%) and saturated fatty acid, SFA (15.81 ± 1.08%). In tarap seed oils, PUFA such as cis-linoleic acid (C18:2n6c) was found to be predominant, with 44.75 ± 3.13% of the total identified fatty acids. For MUFA contained in tarap seed oils, it was very interesting to detect a very long monounsaturated fatty acid (VLCMFA, with carbon number 22-26), which was the nervonic acid

(C24:1) which represents 20.43 ± 2.82% of the total identified fatty acids. The second most abundant MUFA found in tarap seed oils was oleic acid (C18:1n9c), representing 11.21 ± 2.72% of total amount. Another very long unsaturated fatty acid, erucic acid (C22:1n9) was also found in tarap seed oils, with 2.90 ± 0.55%. Nervonic acid, erucic acid and oleic acid are all omega-9 fatty acids. Palmitic acid (C16:0) was a major SFA found in tarap seed oils, with 9.70 ± 0.41%. A very long saturated fatty acid, behenic acid (C22:0) was also found in tarap seed oil, comprising 5.39 ± 0.96% of its composition. All the structures of the major fatty acid found in tarap seed oils were shown in the GC-FID profile (Figure 3).

Table 2. Fatty acid profiles of the three extracted Artocarpus seed oils compared with peanut oil.

	Fatty Acid	Fatty-acid Notation	*Tarap* Seed (%)	*Cempedak* Seed (%)	*Nangka* Seed (%)	Peanut (%)
Saturated Fatty Acid (SFA)	Butyric	C4:0	ND	0.03±0.07	ND	ND
	Caproic	C6:0	ND	0.17±0.18	0.02±0.03	ND
	Caprylic	C8:0	0.01±0.01	0.31±0.17	0.39±0.28	ND
	Capric	C10:0	ND	0.04±0.08	0.01±0.03	ND
	Undecanoic	C11:0	ND	ND	ND	ND
	Lauric	C12:0	0.14±0.16	0.41±0.28	0.29±0.19	ND
	Tridecanoic	C13:0	ND	0.05±0.07	0.01±0.02	ND
	Myristic	C14:0	0.05±0.02	1.15±0.63	0.99±0.83	0.03
	Pentadecanoic	C15:0	ND	0.96±0.49	0.86±0.26	0.01
	Palmitic	C16:0	9.70±0.41	59.06±14.18	35.71±1.92	12.52
	Heptadecanoic	C17:0	ND	0.26±0.27	0.27±0.19	0.07
	Stearic	C18:0	ND	1.91±1.12	3.90±2.34	ND
	Arachidic	C20:0	0.52±0.14	0.16±0.41	2.70±1.86	1.95
	Henicosanoic	C21:0	ND	0.09±0.25	0.43±0.49	0.03
	Behenic	C22:0	5.39±0.96	0.99±1.14	3.09±2.10	3.38
	Tricosanoic	C23:0	ND	ND	0.19±0.38	0.05
	Lignoceric	C24:0	ND	0.56±0.97	0.16±0.31	1.86
		Total	**15.81±1.08**	**66.13±14.43**	**49.01±7.81**	**19.66**
Monounsaturated Fatty Acid (MUFA)	Myristoleic	C14:1	0.02±0.02	0.36±0.19	0.09±0.08	ND
	cis-10-pentadecenoic	C15:1	ND	0.29±0.31	0.06±0.04	ND
	Palmitoleic	C16:1	0.10±0.10	2.66±3.08	0.42±0.48	0.09
	cis-10-heptadecenoic	C17:1	ND	0.22±0.38	0.06±0.12	0.03
	Elaidic (Trans)	C18:1n9t	1.79±1.79	0.34±0.89	ND	ND
	Oleic	C18:1n9c	11.21±2.72	8.31±7.83	2.79±2.56	43.52
	cis-11-eicosenoic	C20:1n9	1.60±1.60	ND	ND	0.96
	Erucic	C22:1n9	2.90±0.55	ND	0.11±0.23	0.21
	Nervonic	C24:1	20.43±2.82	0.23±0.61	ND	0.00
		Total	**38.04±3.60**	**12.41±4.02**	**3.53±3.01**	**44.85**
Polyunsaturated Fatty Acid (PUFA)	Linolelaidic (Trans)	C18:2n6t	ND	ND	ND	ND
	Linoleic (Cis)	C18:2n6c	44.75±3.13	21.07±12.41	43.73±7.52	35.40
	γ-Linolenic	C18:3n-6	ND	ND	ND	ND

	α-Linolenic	C18:3n-3	0.19±0.07	0.39±0.67	3.73±3.59	0.07
	cis-11,14-eicosadienoic	C20:2	0.72±0.07	ND	ND	0.02
	cis-8,11,14-eicosatrienoic	C20:3n-6	ND	ND	ND	ND
	cis-11,14,17-eicosatrienoic	C20:3n-3	ND	ND	ND	ND
	Arachidonic	C20:4n-6	ND	ND	ND	ND
	cis-5,8,11,14,17-eicosapentaenoic	C20:5n-3	ND	ND	ND	ND
	cis-13,16-docosadienoic	C22:2	0.48±0.07	ND	ND	ND
	cis-4,7,10,13,16,19-docosahexaenoic	C22:6n-3	ND	ND	ND	ND
		Total	**46.15±3.23**	**21.46±12.88**	**47.46±10.62**	**35.50**
Grand Total			**100**	**100**	**100**	**100**

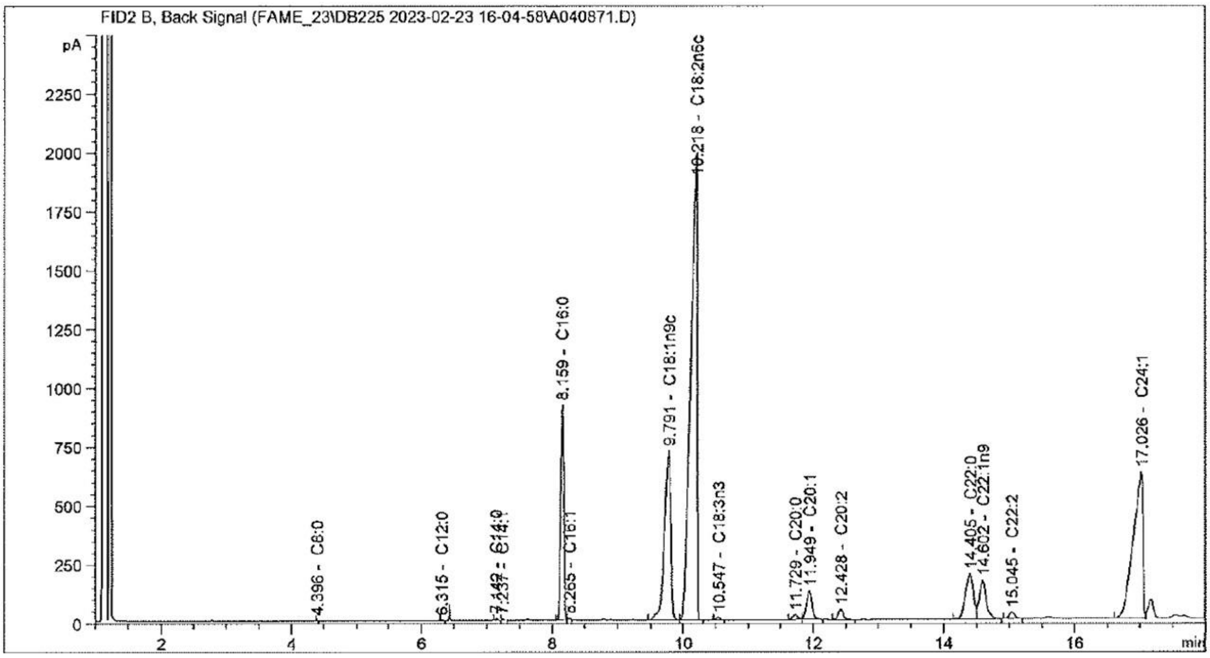

Figure 3. Fatty acid profile of tarap seed oil.

On the other hand, cempedak seed oils were found to show different fatty acid profiles as compared with tarap seed oils. As shown in Table 2, *cempedak* seeds contained the highest percentage of SFA (66.13±14.43%), followed by PUFA (21.46 ± 12.88%) then MUFA (5.69 ± 14.02%). In cempedak seed oils, palmitic acid (C16:0) was the main SFA, with 59.06±14.18% of total content. For PUFA, cis-linoleic acid (C18:2n6c) was the predominant fatty acid, accounting for 21.07 ± 12.41%. Among MUFA, oleic acid (C18:1n9c) was the major fatty acid, with the content of 8.31 ± 7.83%. The structures of all key fatty acids found in cempedak seed oils were displayed in the GC-FID profile (Figure 4).

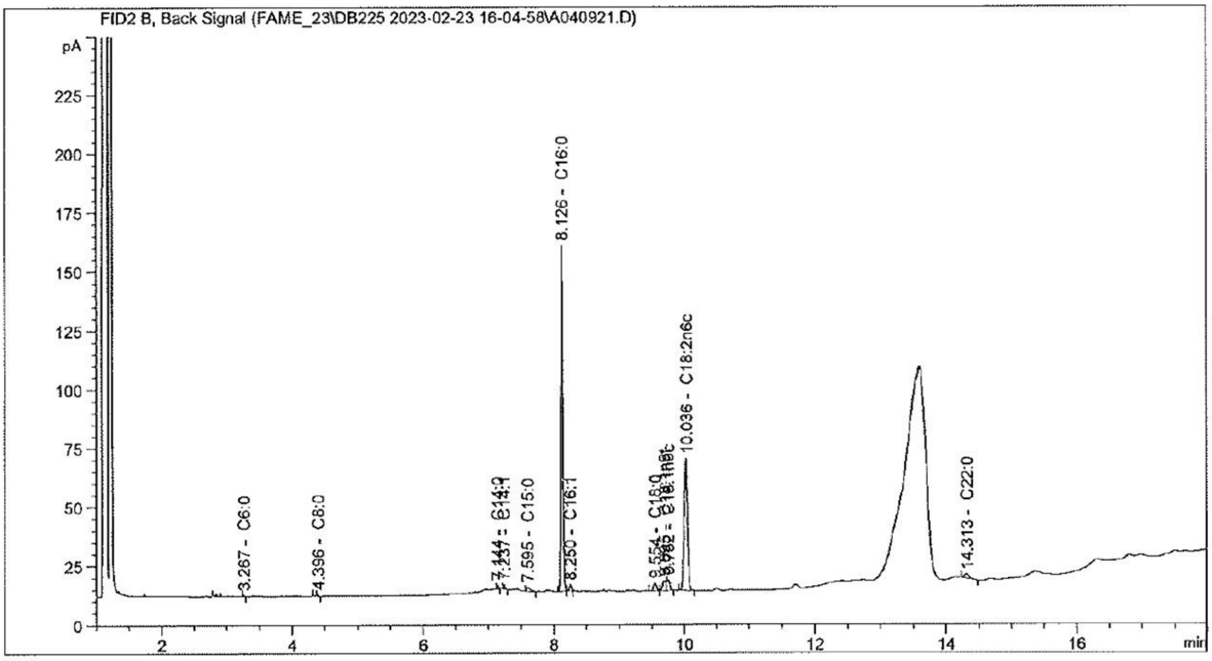

Figure 4. Fatty acid profile of *cempedak* seed oil.

Meanwhile, nangka seed oils were found to contain the highest amount of SFA (49.01 ± 7.81%), followed by PUFA (47.46 ± 10.62%) and MUFA (3.53 ± 3.01%). As depicted in Table 2, cis-linoleic acid (C18:2n6c), palmitic acid (C16:0) and oleic acid (C18:1n9c) were the predominant fatty acids detected in PUFA, SFA and MUFA of nangka seed oils, respectively. Their respective oil contents in each group are 43.73 ± 7.52%, 35.71±1.92%, and 2.79 ± 2.56%. The structures of these fatty acids were illustrated in the GC-FID profile (Figure 5).

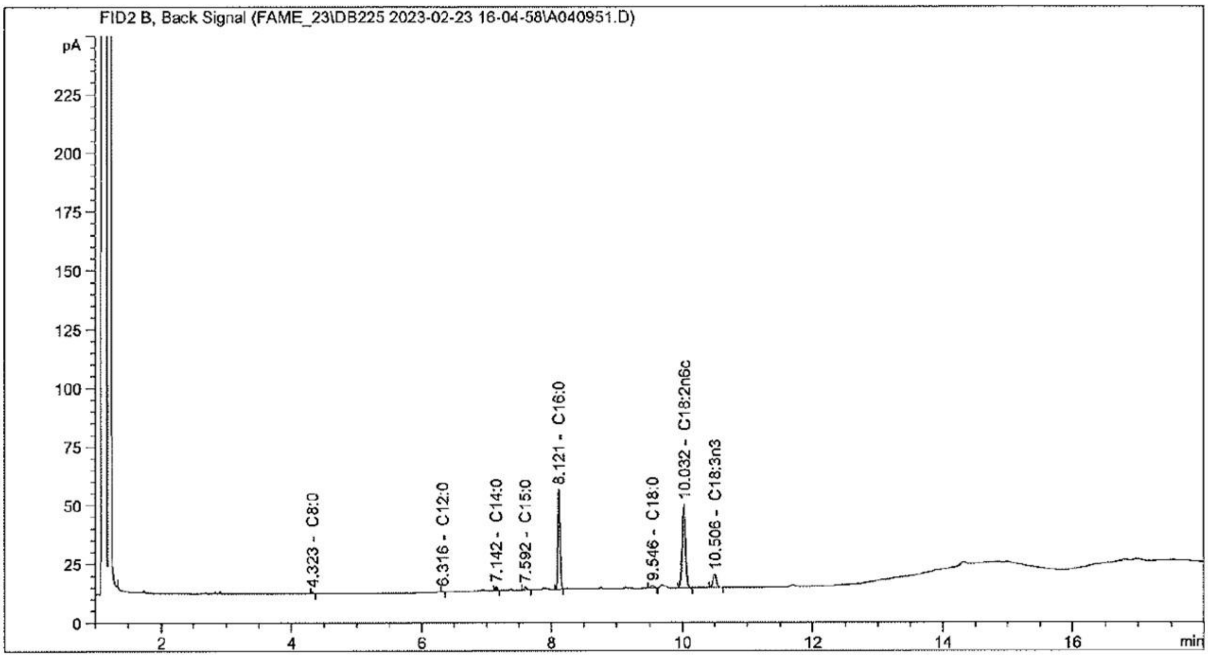

Figure 5. Fatty acid profile of *nangka* seed oil.

Ratio of Polyunsaturated to Saturated Fatty Acids in Artocarpus Seed Oils

Next, the relationship between polyunsaturated and saturated fatty acid content in each of the Artocarpus seed oils was also investigated. The value was expressed as P/S index as shown in Table 3. The P/S value is an important parameter for determining the nutritional value of oil. Oils and fats with a P/S index higher than one are considered to have nutritional value (Kostik et al., 2013). The P/S values obtained for each of the Artocarpus seed oils were also compared to those of other established plant seed oils such as peanut oil, soybean oil, corn oil, linseed oil, palm kernel oil and sunflower oil as reported by Kostik et al. (2013) as shown in Table 3. Among the Artocarpus seed oils, tarap seed oil had the highest P/S value at 2.92, followed by nangka seed oil with a P/S value of 0.97. In contrast, cempedak seed oil had the lowest P/S value at 0.32. The P/S value of tarap seed oil was also found to be higher to that of peanut oil (1.81 obtained from current study and 1.04 as reported by Kostik et al.), corn oil (1.91), and palm kernel oil (0.02). However, it was lower compared to linseed oil (7.05), sunflower oil (6.76), and soybean oil (4.26).

Table 3. Comparison of the SFA, MUFA and PUFA content and P/S index obtained from Artocarpus seed oils with other established plant seed oils.

Type of seed oil	SFA (%)	MUFA (%)	PUFA (%)	P/S Index	References
Tarap	15.81 ± 1.08	38.04 ± 3.60	46.15 ± 3.23	2.92	Current study
Cempedak	66.13 ± 14.43	5.69 ± 4.02	21.46 ± 12.88	0.32	Current study
Nangka	44.57 ± 12.09	3.28 ± 2.66	52.14 ± 13.94	0.97	Current study
Palm kernel	-	-	-	0.02	Kostik et al., 2013
Peanut	-	-	-	1.04	Kostik et al., 2013
Peanut	-	-	-	1.81	Current study
Corn	-	-	-	1.91	Kostik et al., 2013
Soybean	-	-	-	4.26	Kostik et al., 2013
Sunflower seed	-	-	-	6.76	Kostik et al., 2013
Linseed	-	-	-	7.05	Kostik et al., 2013

DISCUSSION

Among the three Artocarpus species studied, only tarap seeds was found to produce comparable yield of oil with the control, peanut oil. The seeds from two other Artocarpus species, cempedak and nangka, yielded very low amounts of oil despite their large sizes. Although the oil yield from tarap seeds was lower than that of peanut oil (control), it was comparable to that of soybean, which has been reported to possess an oil yield of approximately 16-19% (Grasso *et al.,* 2012). To date, the edible commercial plant oils are produced mainly from soybean, rapeseed, sunflower, peanut, and palm (Konopka *et al.,* 2023). The findings from this study suggest the potential of tarap seeds as a valuable source for seed oil production, whereas cempedak and nangka seeds may not be as suitable for this purpose. These three Artocarpus seeds also possessed different PUFA, MUFA and SFA distribution of the total oil content, despite belonging to the same Artocarpus genus. The tarap seed oils were found to be rich with cis-linoleic acid (C18:2n6c), which is an omega-6 fatty acid. It is also rich in omega-9 fatty acids such as oleic acid (C18:1n9c), erucic acid (C22:1n9) and nervonic acid (C24:1). Omega-6 and omega-9 fatty acids collectively constitute more than 80% of the total oil content in tarap seeds. Meanwhile, tarap seed oils contained a scarce amount of α-linolenic acid (C18:3n3), which is an omega-3 fatty acid. Omega fatty acids are essential for our health, as omega-3 and omega-6 must be obtained through diet or supplementation (Asif, 2011). Omega-3 fatty acids are known to improve cardiovascular health, prevent certain types of cancers, and enhance the immune system (Albert *et al.,* 2002; Calder, 2004; James *et al.,* 2000; Narisawa *et al.,* 1994). Omega-6 fatty acids are essential for normal immune function and blood clotting (Asif, 2011). Omega-9 fatty acids contribute to health by exhibiting anti-inflammatory and anti-cancer properties (Farag & Gad, 2022). However, over consumption of omega-6 fatty acid may promote abnormal clotting and an overactive immune system. The balance between omega-3 and omega-6 in the diet is crucial for maintaining normal immune function (Asif, 2011).

Besides the enrichment of common omega fatty acids such as oleic acid and cis-linoleic acid, tarap seed oils also contain nervonic acid (C24:1), a very long-chain monounsaturated fatty acid (VLCMFA) and an omega-9 fatty acid rarely found in plants. Nervonic acid was initially isolated from shark brain, and its molecular structure was determined over a century ago (Merrill *et al.,* 1997). Nervonic acid is an important resource in maintaining the brain and nerve cells development and regeneration (Yang *et al.,* 2023). It has been reported that supplementation with nervonic acid in the diet is effective in treating symptoms of several neurological diseases, such as demyelinating disorders (Sargent *et al.,*1994; Vozella *et al.,* 2017; Lewkowicz *et al.,* 2019). To date, nervonic acid has been identified in 38 plant species such as *Malania oleifera*, *Lunaria annua* (money plant), *Cardamine graeca* L. (bittercress), *Tropaeolum speciosum* (flame flower) and others (Liu *et al.,* 2021). Although these species are high in nervonic acid content (~12-63%), extracting oil or fatty acids from them faces obstacles due to factors such as their endangered status, issues with seed shattering, or difficulties in obtaining seeds (Asif, 2011). The tarap seeds investigated in this study do not encounter these challenges. The fruits are harvested during the season, which spans from September until early the following year. Each fruit used in this study weighed approximately 850 to 1100 g, with the seeds from each fruit weighing between 50 to 64 g. The fruits can be easily cut once fully ripened, and the seeds can be easily removed and separated from the fruit flesh at this stage. The ease of harvesting the fruits and extracting the seeds makes tarap a promising candidate for harnessing nervonic acid for nutraceutical product development. Moreover, tarap seed oils exhibit a favorable polyunsaturated fatty acid to saturated fatty acid ratio, quantified as the P/S index. This metric is crucial for assessing the nutritional quality of edible oils. Oils with a P/S index exceeding the value of one are recognized for their nutritional benefits (Kostik *et al.,* 2013). In this study, tarap seed oils demonstrated higher P/S values compared to palm kernel, peanut, and corn oils, underscoring their potential for development as edible oils with enhanced nutraceutical and health-promoting properties. However, investigation of P/S ratio for tarap seed oils alone is not sufficient to conclude the suitability of the seed oils as edible cooking oil. Based on the results obtained in this study, tarap seed oil warrants further investigation as a potential edible cooking oil due to its comparatively high oil yield and fatty acid profile, whereas further development of cempedak and nangka seed oils for this application may be less economically feasible given their low oil yields. Further studies such as residual-solvent testing, refining protocol, free-fatty-acid/acid value, peroxide or anisidine value, contaminants, anti-nutrients, toxicology, or biological assays need to be conducted for the tarap seed oil in the future.

CONCLUSION

In conclusion, among the three Artocarpus species investigated, tarap demonstrated the greatest potential as a source of seed oil, with an oil yield comparable to that reported for soybean oil and substantially higher than those of cempedak and nangka. The fatty acid profile of tarap seed oil was characterized by a high proportion of omega-6 and omega-9 fatty acids, particularly cis-linoleic and oleic acids, together with the notable presence of nervonic acid (C24:1), a rare very long-chain monounsaturated fatty acid with potential nutraceutical value. The relatively favorable P/S index further supports its potential nutritional value. However, the fatty acid composition and P/S ratio alone are insufficient to establish its suitability as an edible cooking oil. Therefore, tarap seed oil warrants further investigation for potential development as an edible cooking oil and as a potential source of nutraceutical compounds, particularly nervonic acid, while the low oil yields of cempedak and nangka seeds suggest limited economic feasibility for seed oil production. Future studies should evaluate the physicochemical quality, oxidative stability, residual solvents, free fatty acids/acid value, peroxide and anisidine values, contaminants, anti-nutritional factors, toxicological safety, and biological properties of tarap seed oil before its suitability for food and nutraceutical applications can be established.

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