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Research Article

Chemical characterization of palm kernel (*Elaeis guineensis* Jackqu) oil

Otache Monday Abel[1]*, Abogunrin-Olafisoye Oladunni Bola[1], Afitijagun Iyabo Priscilla[1], Oghale Awenede Clementina[2] and Ajiboluwa Akpomejevwe Justina[3]

[1]Department of Industrial Chemistry, Michael and Cecilia Ibru University, Delta State, Nigeria

[2]Department of Biochemistry, Michael and Cecilia Ibru University, Delta State, Nigeria

[3]Department of Environmental Management and Toxicology, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria

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***Corresponding author:** Otache Monday Abel, Department of Industrial Chemistry, Michael and Cecilia Ibru University, Delta State, Nigeria,
E-mail: fillupotache2456@gmail.com

ORCiD: https://orcid.org/0000-0002-8111-5728

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Abstract

This study evaluates the Fatty Acids (FAs) components of Palm Kernel Oil (PKO). The fatty acids were obtained by alkaline hydrolysis of the PKO obtained through soxhlet extraction of the dry ground sample of the seeds using n-hexane. The fatty acids obtained were characterized and identified using Gas Chromatography-Mass Spectrometry (GC-MS). The GC-MS results revealed the presence of Saturated Fatty Acids (SAFAs) and Unsaturated Fatty Acids (UFAs). The results show the presence of abundant lauric acid (42.21%) is vital in the application of the seed oil as an antibacterial agent with the ability to effectively combat acne. The average iodine value of 6.23 indicates that the highly saturated PKO will be less prone to oxidation resulting in better oxidation stability. Furthermore, the acid value of 12.22 as reported in this study unravels the state and edibility of the oil under consideration. This indicates that the PKO has a high possibility to undergo easy hydrolysis. However, its ability to melt at too low a temperature, prompting the need for hydrogenation is a gap in its application for most industrial production that requires thermally induced temperature.

Introduction

Palm kernel oil is produced from the oil-rich kernel of the oil palm fruit (*Elaeis guineensis* Jackqu). This edible palm oil is obtained when the palm oil is removed from the mesocarp of the palm fruit, while the Palm Kernel Oil (PKO) is produced from the palm kernel. Also, there are significant differences in these two oil chemical make-up [1]. Products made from palm kernel oil are used most frequently in demand where their high solid fat content and precise melting qualities are crucial. Unfortunately, certain applications cannot use palm kernel oil because it melts at too low a temperature, prompting the need for hydrogenation. While making chocolate coatings for ice cream bars, unaltered palm kernel oil is typically combined with liquid oil or palm oil to get the proper consistency

However, from a general perspective, oil seeds from plants form the basic raw materials sources for industrial production [2]. However, the need to minimize production costs has triggered the search for alternative sources of oils with future prospects. According to some reports, oil usage varies by region, with rapeseed (European Union countries), soybean (Argentina and the United States), and palm oil (Asian). African pear seeds, rubber seeds, castor, etc., as the common sources of waste oil [2,3]. The use of seed oils as industrial raw materials has reduced the over-dependence on associated food oils. The future of oil as an industrial raw material can be channeled toward exploring alternative sources [4]. Some non-edible plants have attracted more emphasis as new-generation feedstock with high oil yield, easy availability, and ability to thrive well on poor soil [5]. Seed oil-bearing plants could potentially grow well with less extensive care, lowering cultivation costs [5]. The oil yield is a key selection criterion for seeds as industrial feedstock. Table 1 captures the summary of the estimated oil yield of certain seeds and kernels [6]. Fatty acid compositions depend mainly on the plant species and growth conditions [7]. These conditions, serve as an important characteristic that drives the relevance in ascertaining the efficiency of the required process applied [5]. The carboxyl groups on the aliphatic chain of the molecule describe its composition and distribution [8]. The

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Table 1: Approximate content (% $^{w}/_{w}$) of saturated and non-saturated fatty acids in some non-edible seed oils.

S/N	Seed oil	SFAs	nSFAs	Yield (%)	References
1	Castor seed	2	98	45–50	[10]
2	Jatropha seed	22	78	20–60	[11,12]
3	Jojoba	8	92	45–50	[13]
4	Rubber seed	20	80	40–60	[14]
5	Tung	20	80	50–60	[13,15]
6	Africa Pear seed	26	71	27-34	[16]
7	Allanblackia seed	63	37	40-50	[17]
8	Cottonseed	26	74	18–25	[18]

SFAs: Saturated Fatty Acids; nSFAs: Non-Saturated Fatty Acids

fatty acid site on the molecule creates room for a certain level of modification yielding several end products. Oil-bearing seed is predominantly high in unsaturated FAs [9]. However, certain properties such as octane number, heat of combustion, melting point, and viscosity are related to its chain length.

Palm oil plantation is dominantly found in East Asia such as Indonesia and Malaysia. However, South Africa contributes to only 4% of the palm oil that is produced from the African continent. Other African countries that produce palm oil in relatively large quantities include the Benin Republic, Cote d'Ivoire, Ghana, Cameroon, Liberia, Nigeria, Sierra Leone, and the Togo Democratic Republic of Congo. Its rich source of fatty acid is important for its nutritional value as a valuable industrial feedstock. This assertion is in line with the high linoleic acid and oleic acid content which accords it as a much suitable cosmetic product. The high consumption and ready availability of palm fruit and palm kernel during its season within the Niger Delta region of Nigeria informed the quest to exploit the possibility to harness its potential thereby converting one of the main sources of waste into valuable oil with diverse industrial applications. Sequel to the aforementioned, this study unveils the chemical composition of palm kernel oil and its relevance as domestic and industrial feedstock.

Seed oil characterization

Seed oil obtained from several sources of plants are hydrophobic substances insoluble in water [19]. This difference in composition has been accounted for due to variations in composition among the various seed oils. Triglycerides, the major component of the oil have a chemical configuration of glycerol and fatty acid bonded together via an ester linkage [20,21]. The hydrocarbon chain length differs with the oil type as well as the number of double-covalent bonds in each chain.

However, despite these variations, oleic, lauric, palmitic, stearic, linoleic, and linolenic, form the basis in terms of the composition of FAs in oils. This statement has been justified by findings made by Darnoko, et al. [22] who claimed that different seeds differ in their fatty acid composition. Furthermore, Knothe [23] pointed out a correlation between the composition of the oil and its level of unsaturation. As an illustration, he noted that coconut oil has about 90% of SAFAs in its composition with lauric acid showing more than half its composition. Likewise report for palm oil has about 49% SFAs with palmitic acid showing over 80% of its composition. Similarly, linoleic acid makes up 60% of the USFAs in soybean oil while oleic acid makes up more than 50% in peanut oil.

The fatty acid profiles of these seed oils are important to envisage their proper use in terms of application. The ester functionality of triglycerides is where the chemical transformations occur most frequently [24]. FAs are transformed into soaps, esters, amides, and amines through carboxy group reactions. Surprisingly, only a few processes exploit the unsaturation of the molecules, such as hydrogenation, ozone cleavage, or epoxidation routinely used in the production industry [25].

Reacting triglycerides with alkalis directly has been reported to yield glycerin and alkali soaps, with subsequent separation of fatty acids via acidification with inorganic acids [26]. The focus of most manufacturing industries is, however, to split the fats with water only, possibly using a catalyst [27]. Several developed methods for this course have shown limitations due to the insolubility of water in fat and the step-wise process involved in the triglyceride hydrolysis to fatty acid and glycerin, as well as their separation [28]. Therefore, the following methods have been used to address these challenges such as batch autoclave splitting, continuous high-pressure countercurrent, etc. The application of fatty acids has found usefulness in industries via diverse modifications, thereby advocating the need for environmental sustainability.

Materials and methods

Materials and apparatus

Palm kernel nut (*Elaeis guineensis*), Wij's solution, n-hexane, and other chemicals were products of Sigma Aldrich, USA. The methanol used (99% pure) is of analytical grade with a boiling point of 78°C; while the sodium hydroxide, potassium dichromate, and potassium iodide used were of analytical grade and purchased from Sigma Aldrich Chemical Co. Ltd. Sodium sulfate, Hydrochloric acid, starch, sodium thiosulphate, Phenolphthalein used were also of analytical grade and purchased from Merck Co Ltd. Laboratory oven (DHG 9030) magnetic stirrer with hotplate (UNICON), three necked round bottom flask, measuring cylinder, beaker, separating funnel, burette, density bottle, funnels, pet-bottle thermometers and measuring flask were also used.

Sample collection and treatment

Samples were obtained from the Michael and Cecilia Ibru University oil mill in Ughelli North Local Government Area of Delta State, Nigeria. The fruits were dehulled with a sharp stainless knife to remove the seed from the pulp. The prepared seeds samples were then dried to a temperature of 70 ˚C in a Gallenkamp hot air oven for 48 hrs. The dried samples were cracked and the inner pulp dried for 48 hrs and subsequently ground into uniform powder.

Soxhlet extraction of seeds oil

One hundred grams (100 g) of the powdered sample was wrapped with Whatmann filter paper (No. 1442) and transferred

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into a thimble of a Soxhlet extractor. The thimble was carefully fixed on a 1-litre capacity round-bottomed flask. 700 mL of n-hexane (b.p. 40-60 °C) was poured to about two-thirds of the volume of the flask and heated at 60 °C on a thermostatically controlled heating mantle and allowed to reflux continuously for 6 hrs. Percentage oil yield was determined as expressed and replicate extraction processes were performed [16].

$$\text{Seed oil content } (\%) = \frac{W0}{WS} \times 100$$

Where Wo = weight of the oil extracted

Ws = weight of the sample

Iodine value

The iodine value is a measure of the degree of unsaturation of oils and determines the stability of oxidation. Standard AOAC official methods of analysis by Enferadi, et al. [29] and Wij's iodine method were used for this analysis: 0.52 g of oil sample was dissolved in 10 mL of cyclohexane. 20 mL of Wij's solution (Iodine monochloride) was added, the stopper flask was allowed to stand for 30 min in the dark at room temperature, and 20 mL of 10% potassium iodide solution was added. The resulting mixture was then titrated with 0.1 M $Na_2S_2O_3$ using starch as an indicator. The iodine value was calculated thus;

$$\text{Iodine Value} = \frac{[V_2 - V_1] \times M \times 12.69}{W}$$

Where M = concentration of sodium thiosulphate used;

V_1 = volume of sodium thiosulphate used as blank;

V_2 = volume of sodium thiosulphate used for determination.

W = Weight in g of the material taken for the test.

Determination of % Free Fatty Acid (FFA)

The % FFA of the hydrolyzed seed oil was determined according to Mahesar, et al. [30]. Approximately 50 mL of isopropanol was placed into the flask, and about 0.5 mL phenolphthalein was added and then neutralized by the addition of sodium hydroxide (NaOH, 0.02N) until a permanent pink colour was obtained. The neutralized isopropanol was added to the 5 g of FFA, which was then placed into an Erlenmeyer flask, and about 0.5 mL of phenolphthalein (5 g/L) was added. After shaking the mixture gently, the mixture was neutralized by the addition of NaOH, 0.02N until the first permanent pink colour was obtained. The FFA% was calculated by using the equation.

$$\%\text{FFA as oleic} = \frac{28.2 \times N \times V}{2}$$

Where; V = Volume in ml of 0.5N NaOH required for titration in mL.

W = Weight in g of sample taken.

N = Normality of Sodium hydroxide solution

Acid value

Accurately 10 mL of the cooled oil sample was weighed into a 250 mL conical flask and 50 mL of the freshly neutralized hot ethyl alcohol and about 1 mL of phenolphthalein indicator solution was added to the content in the flask. The mixture was boiled for about five minutes and titrated while hot against standard alkali solution shaking vigorously during the titration. The weight of the oil/fat taken for the estimation and the strength of the alkali used for titration was such that the volume of alkali required for the titration did not exceed 10 mL [31].

Acid Value = Percent fatty acid (as oleic) x 1.99

GC-MS analysis

Gas Chromatography-Mass Spectrometry analysis was performed on a GCMS-3800 system (Shimadzu, Tokyo, Japan). This technique was adopted by Adams [32]. Twenty microliters of sample (extract or essential oil) was diluted to 1 mL with n-hexane (≥ 99%, Sigma–Aldrich, Germany). The column used was a 30 m × 0.25 mm i.d. × 0.25 µL film thickness RTX-5MS column. The flow rate of helium (99.999%, AGA Lithuania) carrier gas was set at 1.23 mL/min. The oven temperature was maintained at 40 °C for 2 min after injection and then programmed at 3 °C/min to 210 °C, at which the column was maintained for 10 min. The split ratio was 1:10. The mass detector electron ionization was 70 eV. Identification of volatile compounds was carried out using a mass spectra library search (NIST 14).

Results and discussion

Physicochemical properties

Hui [33] and Sanders [34] noted that the iodine value was a measure of the oil or fat's saturation or unsaturation. As iodine quantities have a direct correlation with the level of saponification and an inverse correlation with shelf-life, it is crucial in determining the oil's shelf life [34]. The iodine value of an oil or fat is the quantity of iodine that can be absorbed by 100g of that substance; iodine absorption is used to gauge saturation levels. The average Iodine value as captured in Table 2 recorded a value of 6.23 ± 0.365. The result shows that the highly saturated PKO will be less prone to oxidation resulting in better oxidation stability.

An acid value of 12.22 ± 0.215 was observed in this study. The acid value of lipids indicates the rate of decomposition of triglycerides by lipases or other exposures including heat, light, and temperature. This can be used to determine oil state and edibility. However, the result of the acid value of the lipids under consideration indicated that PKO has a high possibility to undergo easy hydrolysis as reported in other findings [16,34].

The Fatty acid value of PKO (4.130 ± 0.243) as presented in Table 3 reflects the presence of higher values of SAFA (68.39) compared to the UFA (31.41). Fatty acid composition is one of the most vital attributes that can be used to determine the identity of oils or fats. Therefore, the results from this study

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Table 2: Physicochemical properties of the extracted PKO.

Parameters	Units	PKO
Colour	-	Light green
Odour	-	Pleasant
State at room temperature	-	Liquid
Iodine value	g/100 g	6.23±0.365
Acid value	mgKOH/g	12.22±0.215
Free fatty acid	mgKOH/g	4.130±0.243
pH		4.98±0.083

Table 3: Fatty acid composition of PKO.

S/N	Fatty acids	Systematic names	Composition (%)
1	Capric acid; C10:0	Decanioc acid ($C_{11}H_{12}O_2$)	0.43
2	Lauric acid; C12:0	Dodecanoic ($C_{12}H_{24}O_2$)	42.21
3	Myristic acid; C14:0	Tetradecanoic $C_{14}H_{28}O_2$	11.34
4	Palmitic acid; C16:0	Hexadecanoic ($C_{16}H_{32}O_2$)	9.07
5	Palmitoleic acid; C16:1	cis-9-hexadecenoic $C_{16}H_{30}O_2$	5.22
6	Stearic acid; C18:0	Octadecanoic ($C_{18}H_{36}O_2$)	5.34
7	Oleic acid; C18:1	cis-9-octadecenoic ($C_{18}H_{34}O_2$)	17.76
8	Linoleic acid; C18:2	cis-9-cis-12-octadecedianoic ($C_{18}H_{30}O_2$)	4.93
9	Linolenic acid; C18:3	cis,cis,cis-9,12,15-octadactrienoic $C_{18}H_{30}O_2$	3.50
	SAFA		68.39
	UFA		31.41
	others		0.20

SFA: Saturated Fatty Acid; UFA: Unsaturated Fatty Acid

as captured in Table 3 showed that Palm kernel oil has a high content of lauric acid (42.21). This result also unveils a high content of saturated fatty acid values of 68.39 and a lower value of 31.41 for unsaturated fatty acid. A report according to Berger [35] highlighted that palm kernel oil has a relatively high solid fat content and a rather hard structure at 20 °C, but melts sharply at 28 °C. Therefore the process of hydrogenation can help to raise the solids content further.

The most abundant fatty acid reported was lauric acid with a value of 42.21%. This result is in agreement with the report from a study by Adeyemi, et al. [36]. Stearic acid was the next most abundant at 17.76%. The variation in the fatty acid content as highlighted by other authors is in agreement with the results of the report from this study [37,38]. Conversely, in the present study, the oleic acid percentage in the PKO (17.76%) was higher than myristic acid (11.34%). The palmitic acid content of 9.07% from this study was higher and at variance with a lower value of 7.5% obtained by Okullo et. al. [39]. In another study, Di Vincenzo et. al. [38] obtained a percentage of 3.4% for palmitic acid which is lower than the report from this study. Furthermore, the linoleic acid composition of 1.07% by Adeyemi, et al. [36] is lower than 4.93% in the present study, but lower than 7.9% obtained by Mbaiguinam et.al. [40]. Therefore due to the critical role of linoleic acid as an important fatty that is not synthesized by the body and is critical in the building of the cell membrane, PKO IS therefore positioned as an all-inclusive source for cell build-up, thereby making it a vital component in human nutrition. Linolenic acid according to other findings, varied from 0.2% to 1.6% [41] but a value of 3.50% was obtained for PKO in this study.

Conclusion

The quest to explore alternative oil sources to address both domestic and industrial concerns has positioned palm kernel oil as one of the rich sources of edible oil. The abundant content of lauric acid (42.21%) is vital in its application as an antibacterial agent with the propensity to effectively combat acne. Additionally, the average Iodine value of 6.23 indicates that the highly saturated PKO will be less prone to oxidation resulting in better oxidation stability. Furthermore, the acid value of 12.22 as reported in this study unravels the state and edibility of the oil under consideration, indicating that the PKO has a high possibility to undergo easy hydrolysis. However, one of the major drawbacks involving its application is its ability to melt at too low a temperature, prompting the need for hydrogenation. The ability to control the rapid impact of oxidation on the oil obtained is a challenge in this study, however the fatty acid contents from this study will be relevant in oleo-chemical industries.

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