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Physicochemical Analysis of Oil Extracted from *Raphia sudanica* Fruit Sold in Edu Local Government Area of Kwara State, North Central Nigeria

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Abstract

Raphia sudanica, commonly called Raphia hookeri or bamboo palm fruit, is one of the most valuable species among known palm fruits found in Nigeria and is widespread in major parts of West Africa. In this study, oils extracted and analyzed from Raphia sudanica fruits (pulp and seed) revealed the respective physicochemical values; acid value (5.56, 6.10 mgKOH/g), peroxide value (2.44, 5.82 Meq/kg), iodine value (41.30, 68.10 gI$_2$/100 g), saponification value (184.90, 179.20 mgKOH/g), unsaponifiable matters (8.24, 1.54%), kinematic viscosity (81.20, 75.95 @40 mm²/s), specific gravity (0.925, 0.895 @15) and refractive index (1.469, 1.405 @40). The outcome of the study revealed that the nutritious parameters (acid value, peroxide value) are significantly within the SON/NAFDAC standards, which are indicators of good quality edible fruit oil, as compared to the iodine and saponification values of oil extracted from the seed. However, the non-nutritious parameters (unsaponifiable matters, kinematic viscosity) are above the established standards, while the results of specific gravity and refractive index are within the standard range. The paper, therefore, recommends that the Raphia hookeri fruit oil should be exploited for its industrial and nutritional benefits, while the high unsaponifiable matter should be further investigated for its specific triglyceride components. Additionally, the observed variations between pulp and seed oils highlight the influence of fruit anatomy on oil quality and functionality. This distinction supports targeted utilization of Raphia hookeri oils in specific nutritional and industrial applications, emphasizing the need for optimized extraction and refinement strategies. Further characterization of fatty acid composition and bioactive constituents will enhance product standardization, safety evaluation, and commercial viability.

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INTRODUCTION

Raphia sudanica is a tropical species among the known palm fruits found in West Africa. It is commonly known as *Raphia hookeri* or bamboo palm fruit. It is an evergreen palm that is at least 2–3 meters tall, with a robust stem. A rosette of leaves, each up to 12 meters long, covers the summit of the stem [1–4].

Plants are frequently gathered from underutilized wild fruits for local use as food, medicine, and a source of materials. This species is widely distributed in Western Africa. However, it is heavily exploited, and a variety of activities, such as drought and the loss of wetlands for crop production, endanger its habitat [5–7]. The population is thought to be declining (at an undetermined rate) while the level of harvesting is rising. The plant is harvested for its sap, which is fermented to produce an alcoholic beverage. In addition to consumption, the oily yellow pulp beneath the outer scales is a source of cooking oil. Like *Raphia palma-pinus*, fronds and midribs are used to treat blood problems.

Fruits are natural gifts for humans. Fruits are important commodities in our daily diet because they are part of life-enhancing medicines that contain vitamins, minerals, antioxidants, and many plant-derived micronutrients called phytonutrients. Fruits are rich in water, carbohydrates, dietary fiber, proteins, vitamins, and other nutrients that are vital to human health. In total, carbohydrates among the rest of the nutrients are the main component of fruits, representing more than 90% of their dry matter [8–11].

The fruits also contain different classes of sugars, including glucose, sucrose, and fructose. It is known that more sugars are associated with fruit, but some sugars are also important components of vegetables, such as carrots, sweet corn, and peas.

Vegetables and fruits also contain dietary fiber molecules such as cellulose, lignin, and pectin, which have been shown to offer several health advantages, including decreased blood sugar and cholesterol levels [12–16].

A fruit is a seed-bearing structure formed from the ovary after the flowering of a flowering plant. Humans and many animals have become dependent on fruits as a source of food and, in most cases, as a supplement to fill the gaps created in balanced and healthy diets for humans. Fruits have a greater impact on a substantial fraction of the world's agricultural output, with more potential in some special fruits, such as apples and cherries, that have acquired extensive cultural and symbolic meanings.

Fruits and vegetables are categorized according to their flavors from a culinary standpoint. Fruits often have sweet or tart flavors and can be utilized in sweets, snacks, or liquids. Examples of culinary vegetables that are botanical fruits include corn, cucumbers, tomatoes, beans, peanuts, and peas [17–21].

Wild fruits are different from cultivated ones in the sense that they are the fruits of wild plants that are growing in a natural state, not cultivated or uninhabited. Wild fruits are exotic or underutilized, because they contain many bioactive compounds, such as anthocyanins, anticancer, antioxidant, and flavonoids.

Established trends for years in the physicochemical assays of foods, particularly fruit start-ups, crudely and later gained acute technological innovations within which the initial scopes were widened for reliable results. An analytical measure in wild fruits is to determine the quality and quantity of the physicochemical contents of their components. Some of these contents include the composition of oil, antioxidant properties, and the physical and chemical properties of the general body of the fruits, which include the pulp and their seeds [22–27]. These factors have helped improve the rate of nourishment amidst the control of the economy gained from food security. However, after several tests were conducted by different bodies that connect their qualitative and quantitative assays with the analysis of nutritional value of edible substances, various health problems were attributed to excessive intake of some foods' contents, such as oil varieties, which are liable to increase the size of cholesterol and other chemical fractions, which will upset the functional equilibrium of the body enzymes.

The best among the practical measures explored to determine the nutritional value of fruit is to estimate the physicochemical properties, antioxidant activities, and oil characterization of the specific fruit and its components. The most prevalent lipids in nature are fats and oils. They carry fat-soluble vitamins through the blood, insulate bodily organs, and supply energy to living organisms.

Triglycerides are esters made up of three fatty acid units connected to glycerol, which make up fats and oils. The melting point of fat or oil decreases when the proportion of shorter-chain and/or unsaturated fatty acids increases. Saponification is the process of hydrolyzing fats and oils in the presence of a base to produce soap. Unsaturated triglycerides contain double bonds that can be hydrogenated to convert liquid oils to solid margarine. Fatty acid oxidation produces molecules that smell unpleasant. It is possible to reduce this oxidation by adding antioxidants [28, 29].

Saponification is the process of hydrolyzing fats and oils in the presence of a base to create soap. Currently, many soaps are made by hydrolyzing triglycerides (often from tallow, coconut oil, or both) with water at a high pressure of 700 lb/in² (about 50 atm or 5,000 kPa) at 200°C. Fatty acids are subsequently transformed into sodium salts (soap molecules) using sodium hydroxide or carbonate [30, 31].

The degree of unsaturation of oils and fats can be determined using the iodine value. In the palm oil industry, this metric is crucial for tracking fractionation processes. Titration procedures such as the Wijs method are typically included in the process of determining iodine values [32–35].

The amount of potassium hydroxide required to neutralize the free fatty acids in one gram of fat is known as the acid value. Because free fatty acids are typically produced during the breakdown of triglycerides, they are a relative indicator of rancidity [36–39].

The purpose of this study was to present data on the nutritional and non-nutritional value of *Raphia hookeri* wild fruit sold in North Central Nigeria's Edu Local Government Area.

MATERIALS AND METHODS

Materials and Reagents

All equipment, apparatus, and reagents for analysis were provided by the Plant Science and Botanical Laboratory of the Federal University of Lafia.

Sample Collection: Sampling and Sample Preparation

Raphia sudanica fruits were purchased from the Edu Local Government Area of Kwara State, North Central Nigeria (Figure 1). The plant fruits (Figure 2) collected were identified and authenticated botanically in the Federal University of Lafia's Department of Plant Science and Biotechnology Laboratory and given the Voucher Number FUL/SC/PSB/H.LAB/0097 in accordance.

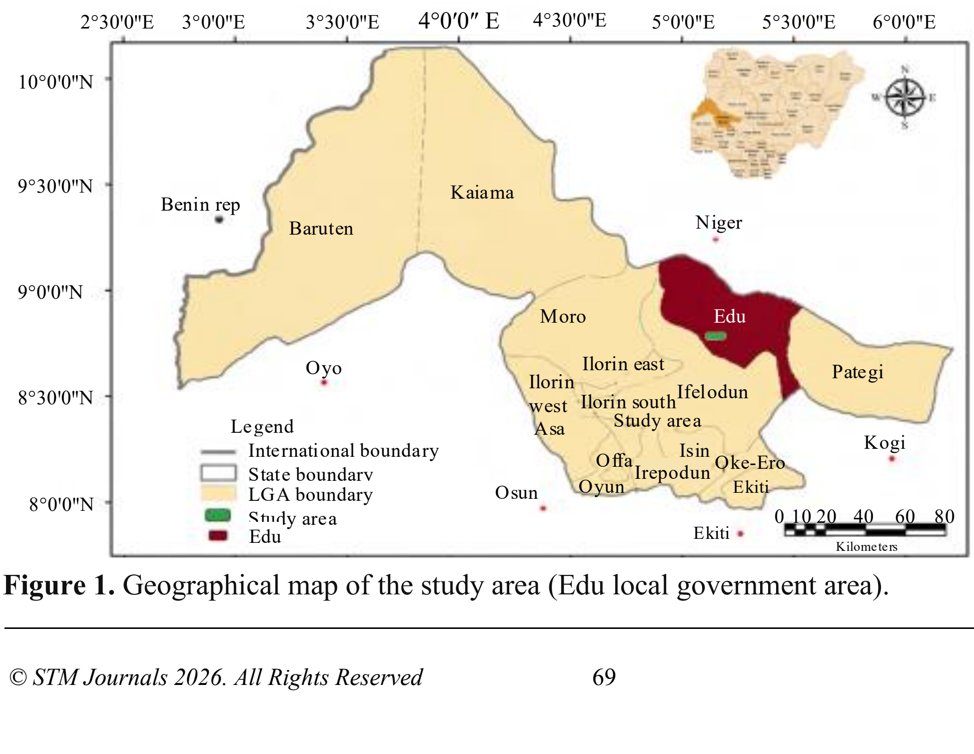

Figure 1. Geographical map of the study area (Edu local government area).

Figure 2. *Raphia hookeri* fruits.

Sample Preparation

Mature and ripe *Raphia hookeri* fruits were washed to remove any dirt, and the two major components of the fruits, pulp and seed, were separated. The pulp samples used for physicochemical analysis were weighed and dried in an oven at 100°C until a constant weight was achieved. The dried pulp of *Raphia hookeri* fruits was blended in a blender to form a paste that was spread in a tray for sun-drying. When dried, it was stored in a labeled container until analysis.

The seeds of *Raphia hookeri* fruits were sun-dried before they were crushed in a mortar and pestle device, after which they were sun-dried before pulverizing into coarse powder. Similar preparation of samples to be used for physicochemical properties was performed on the pulp and seeds of *Raphia hookeri* fruits.

Extraction of Oil

Extraction of oil from the pulp of *Raphia hookeri* fruits was carried out via the cold-pressed method or soaking method, and the Soxhlet extraction method, while the extraction of oil from the seed was performed via the Soxhlet extraction method only. Cold-pressed extraction was carried out on the pulp by placing 100 g of the prepared pulp of the fruit into a sieve and squeezing it until the oil flowed out. Oil was collected and stored in a hermetically closed bottle. For Soxhlet extraction, the samples were extracted with petroleum ether (50°C) in a Soxhlet extractor for 6 h, and petroleum ether was used as the solvent, which was recovered. The separated oil was then placed in a sealed glass bottle.

Determination of Physical Properties

The analysis of the physicochemical properties of the pulp and seed of *Raphia sudanica* fruit (which involves oil/fat extraction) was carried out using the methods described by the Association of Official Analytical Chemists (AOAC, 2000) or the American Oil Chemists' Society (AOCS, 2017).

ALL CALCULATIONS WERE DONE IN TRIPLICATE

Calculating Acid Values

According to the AOAC Official Method, the acid values of the oils and fatty acid compositions were determined using the titrimetric method. The following formula was used to determine acid value:

$$\text{Acid value (mgKOH/g)} = \frac{V \times C \times 56.1}{m}$$

where V is the average milliliter of potassium hydroxide required for titration. In this instance, m is the mass of oil utilized in grams, and C is the concentration of the KOH solution (0.1 N).

Calculating the Peroxide Value

According to the AOAC Official Method, the acid values of the oils and fatty acid compositions were determined using the titrimetric method. The following formula was used to determine acid value:

$$Peroxide\ value = \frac{1000 \times (S-B) \times N}{W}$$

where S is the volume of $Na_2S_2O_3$ solution (ml) used for the samples, B is the volume of $Na_2S_2O_3$ solution (ml) used for the blank, N is the $Na_2S_2O_3$ solution's normality (ml), and W is the weight of the oil sample in grams.

Calculating the Iodine Value

In accordance with the AOAC standard protocols, the titrimetric method was utilized to ascertain the iodine values of the oil samples based on the Wijs method.

The iodine value was calculated using the equation:

$$IV\ (gI_2/100g\ oil) = \frac{(B-S) \times N \times 12.691}{Weight\ of\ Sample}$$

Where, IV is the iodine value, B is the blank titration, S is the sample titration, and N is the $Na_2S_2O_3$ solution's normality.

Calculating Saponification Values

The saponification values of the oil samples were determined using the titrimetric method, in accordance with the AOCS process. Next, the equation was used to determine the saponification value.

$$Saponification\ value\ (SV) = \frac{5.61 \times (B-S)C}{m}$$

Where, B is the volume of HCl required by the blank, S is the volume of HCl required by the sample, C is the concentration of HCl (0.5N), 5.61 is the molar mass of KOH, and m is the mass of the sample.

Identification of Unsaponifiable Substances

The AOCS method was used to determine the unsaponifiable matter content of the oil samples. The following formula was used to determine unsaponified matter:

$$Unsaponified\ matter = \frac{R-(B+F)}{W}$$

Where, R is the weight of the residue (g), F is the weight of the fatty acid (g), B is the weight of the blank (g), and W is the weight of the sample (g).

Determination of Kinematic Viscosity

The viscosities of the oil samples were determined using a Brookfield Viscometer. The dynamic (absolute) viscosities of the oil samples determined by a Brookfield Viscometer were converted to kinematic viscosities using the following equation:

$$\nu = \frac{\mu}{\rho}$$

Where, ν = kinematic viscosity, μ = absolute or dynamic viscosity and ρ= density

Calculating Specific Gravity

The pyrometer gravimetric method, which allows the density of a fluid such as oil to be accurately measured with reference to a suitable working fluid such as water or mercury, was used to calculate the specific gravity of the oils. According to the AOCS guidelines, a 50 ml pyrometer was utilized. Calculation of specific gravity:

$$\text{Specific gravity} = \frac{W3 - W1}{W2 - W1}$$

Where, W_1 = weight of empty pyrometer bottle; W_2 = weight of empty pyrometer bottle + distilled water; W_3 = weight of empty pyrometer bottle + oil.

Determination of Refractive Index

The standard analytical technique for determining the refractive index of oils extracted from the pulp and seeds of *Raphia sudanica* fruit involves using a refractometer in accordance with established international standards, such as those from the AOAC (Association of Official Analytical Chemists) or the American Oil Chemists' Society (AOCS).

RESULTS AND DISCUSSION

The values of acid from Table 1 obtained from the pulp (5.56 mgKOH/g) and seed (6.10 mgKOH/g) are within the threshold of 6.0 mgKOH/g. However, the acid value of the seed was higher than that of the pulp, which may be attributed to the compositional differences and higher free fatty acid (FFA) content in the oil. In some cases, a higher acid value often indicates that the material may have been damaged or improperly stored, leading to increased lipase activity. The lower the acid value of the oil, the better the quality, which makes it less exposed to the phenomenon of rancidity.

The peroxide values of both pulp (2.44 Meq/kg) and seed (5.82 Meq/kg) were lower than the tolerable limit of 10 Meq/kg. The peroxide value is a measure of the primary oxidation (rancidity) of oil. Higher values suggest a lower oxidative stability.

The iodine value of pulp (41.30 gI_2/100g) is lower compared to that of seed (68.10 gI_2/100g) against the threshold limit (44.55 gI_2/100g). This suggests a higher proportion of unsaturated fatty acids with applicability in the soap and paint industries. Iodine is a measure of the degree of unsaturation.

The saponification value of pulp (184.90 mgKOH/g) and seed (179.20 mgKOH/g) is below the tolerable limit (190–209 mgKOH/g). Long-chain fatty acids predominate in relatively low acids, which have little potential for use in the manufacturing of liquid soap and shampoos.

The unsaponifiable matter of pulp (8.24%) and seed (1.54%) was higher in the case of pulp and the same in the case of the seed compared to the recommended value of 1.5%. This is because of the greater concentration of various phytochemicals, such as alkaloids, phenols, and vitamins.

In contrast, the seeds were lower in these non-nutritious parameters. Unsaponifiable matter in oils refers to the fraction that does not react with caustic alkali to form soap and includes compounds, such as hydrocarbons, higher alcohols, sterols, and oil-soluble vitamins.

Table 1. Results of nutritious and non-nutritious parameters of oils extracted from pulp and seed from *Raphia hookeri* fruits.

Parameter	**Concentration**		
	Pulp oil	***Seed oil***	***SON***
Acid value (mg KOH/g)	5.56	6.10	6.0
Peroxide value (Meq//kg)	2.44	5.82	10
Iodine value (mg 12/g)	41.30	68.10	44-45
Saponification value (mg KOH/g)	184.90	179.20	190-209
Unsaponifiable matters, %	8.24	1.54	1.5%
Kinematic viscosity @ 40℃ (mm^2/s)	81.20	75.95	33-35
Specific gravity @ 15℃	0.925	0.895	0.91-0.92
Refractive index @ 40℃	1.469	1.405	1.6-1.48

SON, Standards Organization of Nigeria

The kinematic viscosity values of pulp (81.20 @40 mm^2/s) and seed (75.95 @40 mm^2/s) are higher than the threshold limits of 33–35 @40 mm^2/s. The higher kinematic viscosity values observed were primarily due to its inherent chemical composition, specifically the presence of long fatty acid chains and triglycerides.

The specific gravity values of the pulp (0.925 @ 15) and seed (0.895 @ 15) were within standard ranges. Specific gravity is determined by the chemical composition, dry matter, and moisture content. These values remain within the threshold limits owing to the consistent genetic composition of the mature fruit, and by implication and indication of the purity assessment of the oil.

The refractive index values of the pulp (1.469 @ 40) and seed (1.405 @ 40) are within the threshold limits (1.46–1.48 @ 40), primarily due to their characteristic fatty acid compositions and minimal adulteration. The consistency in these values is a result of the standard biological and chemical properties and an indicator of oil purity.

CONCLUSION

The oil extracted from the pulp and seed of *Raphia hookeri* generally shows properties that suggest that the oils have the potential for both edibility and industrial applications, especially in soap making. Most of the measured values were within or near the standard ranges for typical vegetable oils, although some parameters indicated a need for potential refining, particularly the acid value. In conclusion, both the pulp and seed oils of *Raphia hookeri* possess physicochemical properties that are potentially valuable.

1. Their low peroxide values indicate good initial quality.
2. Their moderate iodine and saponification values suggest that they are stable, non-drying oils suitable for general culinary use and industrial applications such as soap production.
3. The high unsaponifiable matter content in pulp oil warrants further investigation into its specific non-triglyceride components.

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