Asian Journal of Research in Biochemistry

Volume 14, Issue 4, Page 126-137, 2024; Article no.AJRB.118829
ISSN: 2582-0516

Proximate Analysis, Extraction, and Characterization of Oil from *Terminalia catappa* Fruit in Anambra State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajrb/2024/v14i4301

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/118829

Original Research Article

Received: 24/04/2024
Accepted: 26/06/2024
Published: 28/06/2024

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Cite as: *Patrick, Aniekwensi Obinna, Ogbonna Esther Ozioma, Gemadi Kwasi Shine, Akinpelu Toyosi Michael, Samuel Nzube Nwosu, Etim Blessing Bassey, Nwachukwu Chinemerem Favour, Awoyungbo Modupeoluwa Damilola, and Nkwocha Stephen Tochi. 2024. "Proximate Analysis, Extraction, and Characterization of Oil from Terminalia Catappa Fruit in Anambra State, Nigeria". Asian Journal of Research in Biochemistry 14 (4):126-37. https://doi.org/10.9734/ajrb/2024/v14i4301.*

ABSTRACT

Context: Terminalia catappa, also known as tropical almond, is a well-known plant recognized for its edible parts, including fruit, bark, leaves, and roots. It is also noted for its medicinal usefulness and numerous pharmacological actions.
Aim: This study aims to analyze the proximate composition of the seeds of tropical almonds, extract and characterize the oil from Terminalia catappa seeds and mesocarp. The goal is to assess the nutritional value of Terminalia catappa and to evaluate the oil's physicochemical properties.
Materials and Methods: Standard methods were used to assess physicochemical parameters such as saponification, acid, peroxide, iodine, and specific gravity. The seed's proximate composition was also analyzed, revealing moisture, ash, crude fiber, fat, protein, and carbohydrate content.
Results: The results indicate that the saponification value (mg KOH/g), acid value (mg KOH/g), iodine value (mg iodine/mg), peroxide value (mg/peroxide/kg), and specific gravity of the oil are 162, 1.68, 89, 1.40, and 0.95 respectively. The proximate composition reveals that the seed contains 23.24% moisture, 5.50% ash, 12.30% crude fiber, 16.51% fat, 21.22% protein, and 39.99% carbohydrate. These findings suggest that tropical almond seed is a good source of protein, carbohydrates, and oil and contains minerals that can contribute valuable amounts of essential nutrients to the human diet. The low acid value suggests that the oil is edible, while the high saponification value indicates its potential in industrial applications such as cosmetics. The low iodine value reveals that it is a non-drying oil unsuitable for the paint industry. Additionally, the low peroxide value of the oil indicates low susceptibility to oxidative rancidity and deterioration, confirming the presence of antioxidants in the seed oil.
Conclusion: Terminalia catappa seeds exhibit a high level of most chemical components, making them a promising raw material for various industries. Their high protein value and low level of anti-nutrients indicate their potential usefulness in animal and poultry feed supplements. They also serve as beneficial dietary supplements and should be encouraged in diets.

Keywords: Terminalia catappa; tropical almond; seeds.

1. INTRODUCTION

“Seeds are one of the most important food sources, providing humans and animals with essential nutrients. These nutrients include carbohydrates, lipids, proteins, vitamins, and minerals” [1]. “Seeds contain proteins and bioactive peptides classified as nutraceuticals. Proteins and peptides are essential in the human diet because they provide the raw materials needed for protein biosynthesis and are a good energy source” [2-5]. “Incorporating seeds into the human diet provides nutritional and functional health benefits, reducing the risk of contracting some chronic diseases”” [6].

“Oilseed crops have been grown around the globe under various agroclimatic situations and are considered essential crops due to their commercial value. The rising demand is also one of the main factors that have led the producers to increase their production of oilseeds. Besides the upsurge in the production of oilseeds, the world is still facing a significant supply shortage” [7]. “Fatty acids are generally incorporated into a triglyceride structure in plant oils, which indicates that plant oils are a source of fatty acids” [8]. Oils are liquid, while fats are solid at room temperature.

1.1 Taxonomy of *Terminalia catappa*

Plant scientists have classified *Terminalia catappa* as follows:

Kingdom	:	*Plantae*
Division	:	*Magnoliophyta*
Class	:	*Magnoliopsida*
Order	:	*Myrtales*
Family	:	*Combretaceae*
Genus	:	*Terminalia L.*
Specie	:	*Terminalia catappa*

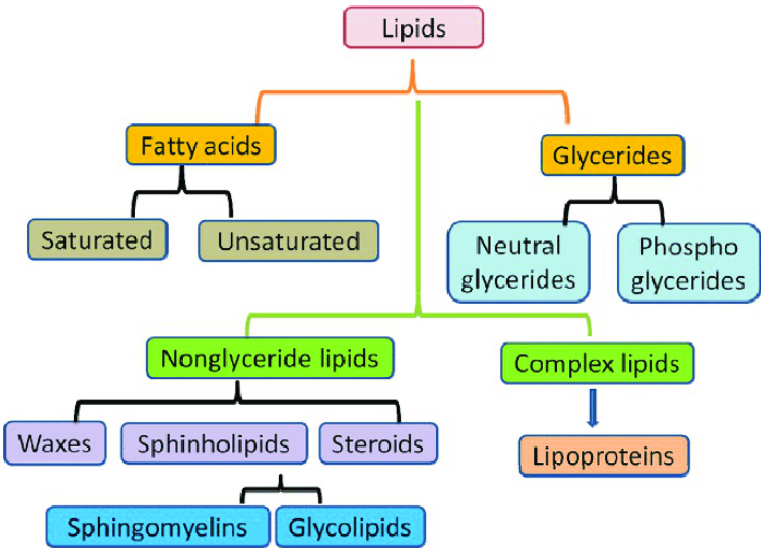

Fig. 1. Terminalia catappa plant

"Terminalia catappa, also known as a tropical plant widely recognized by its common name; the indian almond or tropical almond plant. It is the second-largest genus of the family Combretaceae" [9]. "It is a well-known plant recognized for its edible parts including fruit, bark, leaves, and roots. *T. catappa* has been acknowledged for its medicinally essential phytoconstituents, such as phenols, flavonoids, and carotenoids. Numerous pharmacological investigations have confirmed this plant's ability to exhibit antimicrobial, anti-inflammatory, anti-diabetic, antioxidant, anthelmintic, hepatoprotective, anti-tumor, hematological, and anticancer activities, all of which support its traditional uses" (Saharan et al., 2022), [10].

"The tropical almond tree (*Terminalia catappa)* grows predominantly in the tropical regions of Asia, Africa, and Australia" [10]. "*Terminalia catappa* is locally known by different names in Nigeria, such as Mbansan Mbakara (groundnut of the Whiteman) in Efik/Ibibios, Ebelebo in Benin, Egboen-nebi in Edo, Afara dudu in Yoruba, Fasakorihi in Fulani and fruits by some Nigerians" [11]. "*Terminalia catappa* have significant cultural, culinary, and medicinal importance and are used for various purposes such as providing shade, wood for timbers, bark, leaves, fruit, and nuts for medicinal purposes" [12-14].

"The tree grows from 10 m to 25 m high and has horizontal whorls of branches with shiny, ovate leaves 10-25 cm long, tapering below a narrow, heart-shaped base with an expanded, rounded apex. Its fruit is smooth and ellipsoid, 3-6 cm long, and prominently bi-ridged or keeled down to the sides, with fibrous and fleshy pericarp and hard endocarp. Studies have indicated that the leaves of *Terminalia catappa* are rich in tannins and a host of organic compounds that help condition the culture water, resulting in improved survival, growth, and health of cultured aquatic species" [15]. It turns from green to purplish-yellow on ripening, containing a hard shell or nut covering the delicate edible seed. The ripe mesocarp of the fruit is mainly consumed by children who neglect the seed. The branches are arranged in obvious tiers, forming canopy layers, giving the tree a pagoda-like shape.

"Despite being classified mainly as a nut, an almond is a seed from the fruit of an almond tree. *Terminalia catappa* oil is considered a high-quality edible because of its high percentage of linoleic and oleic fatty acids. Its high oil content also qualifies it for industrial use, especially biodiesel production. The world's production of *Terminalia catappa* fruit is estimated at 700,000 tons annually" [16].

"Almond oil, a rich source of macronutrients and micronutrients, is extracted for food flavorings and cosmetics" [17]. It is used as edible oil, mainly as a salad dressing and in vegetable dips. It is also used in the cosmetic industry, especially in hair, dry skin creams, anti-wrinkle, and anti-aging products. It is also used in aromatherapy and massage therapy since it suits any skin type. Bitter almond oil limits its uses to external applications.

"In contrast, sweet almond oil is safe to ingest internally. It contains many vitamins, including E and K, that help skin regeneration and maintain elasticity, which is why the oil is used in many cosmetic products" [18]. Almond oil is transparent, light yellow, fragrant, and can resist temperatures under 200°C.

1.2 Traditional Medicinal Uses of Almond Oil

"Almond oil is regularly mentioned in the writings of famous herbalists throughout the ages. Historically, almond oil has been used for its numerous health and beauty benefits in ancient Chinese, Ayurvedic, and Greco-Persian schools of medicine" [18]. John Gerard (the eclectic herbalist Gerard) indicates that almond oil is a huge source of relief from pain on the outside through massage.

"Dioscorides (author of Materia Medica) mentioned several recipes for ointments made using almond oil. Culpeper mentions the request for almond oil to massage the temples, believed to improve brain function and relieve stress. Almond has been used traditionally for curing wounds, anemia, insomnia, headache, sore throat, brain infections, kidney disorders, urinary infections, arthralgia, pityriasis, and hysteria" [19].

1.3 Therapeutic Properties of Almond Oil

- Anti-Inflammatory- It reduces inflammation when ingested.
- Antioxidant- Almond oil possesses mild antioxidant ability.
- Immune Booster -The topical as well as internal function of sweet almond oil boosts immunity and provides robust protection from various diseases
- Anti-hepatotoxic—Almond oil is recognized to aid the liver in eliminating toxins, which is performed by castor oil.
- Emollient- The excellent moisturizing property. It is used to remove excess dry skin.
- Sclerosant- Used to treat vascular issues like spider veins, hemorrhoids, and varicose veins.
- Laxative- Promotes defecation and relieves constipation. This laxative action is mild compared to more potent laxatives like castor oil.
- Analgesic-almond oil is a soft pain reliever.
- Muscle Relaxation- Massage with almond oil soothes stressed and sore muscles.
- Cicatrizant helps wounds heal faster.
- Anti-dandruff- It dissolves, leaving dandruff on the scalp.
  [20,21]

Fig. 2. Morphology of the plant

1.4 Importance of *Terminalia catappa*

“Almonds may be small food, but they pack an enormous nutritional punch. They contain several vital vitamins and minerals, as well as healthy fats. Some of their excellent health benefits include lowering blood pressure, controlling blood sugar and cholesterol levels, and alleviating constipation, respiratory disorders, and anemia. Almonds are also great for hair, skin (psoriasis), and dental care. Almonds and almond oil have anti-inflammatory, immunity-boosting, and anti-hepatotoxic effects” [10].

“Further associations between almond oil and improved bowel transit have been made, reducing irritable bowel syndrome symptoms. Further, some studies show a reduced incidence of colonic cancer. Moreover, cardiovascular benefits have also been identified with almond oil elevating the levels of so-called "good cholesterol," high-density lipoproteins (HDL). At the same time, it reduces low-density lipoproteins (LDL)” [22].

2. ALMOND OIL OBTAINING PROCESS

“The almond oil-obtaining process is very similar to obtaining other nut oils. The nut is harvested before the autumn rains (August- September). After harvesting, the next step is de-hulling, which consists of removing the mesocarp that appears to have adhered to the nut and has not been lost by falling from the tree. After de-hulling, the nuts are typically exposed to the sun for two or three days (drying), as a general rule, or they are subjected to hot air ventilation to finish their drying. The humidity content is considerably reduced by up to 5-8% by drying. After that, cracking occurs, which consists of separating the shell and the seed. Finally, oil extraction takes place, generating a solid edible by-product. Some extraction systems will require previous grinding of the seeds. The most critical operations in almond oil extraction, which would need to be optimized to obtain a better quality final product, are drying and extraction” [22].

2.1 Almond Drying

Almond drying is a fundamental operation from a commercial point of view (deficient drying reduces the operational profitability and the shelf life of nuts susceptible to rancidity) and a sanitary point of view (adequate drying prevents the growth and spread of fungus). Almond drying can be done in different ways: direct sun exposure, in a hot air oven, using a fan, in a hot air dryer, etc.

2.2 Almond oil Extraction

Different extraction methods can be used for almond oil extraction, although, as with other seeds, solvent extraction will provide the highest industrial yield. Traditional equipment uses high temperatures and chemical products, reducing the quality of the oil due to the appearance of undesirable flavors and the inactivation of vitamins and active substances that appear in the raw material, forcing the posterior necessity of refining the oils so they could not be defined as virgin oils. Matos and Acua 2010 evaluated “three main influence parameters: extraction temperature, size of the almond particle, and solid/ solvent proportion regarding yield, and defined the optimal conditions as 90 C, 0.5 mm, and 1:3 proportion, respectively, reaching an oil yield of 44.59%. This yield can be improved if samples are irradiated with ultrasounds of 42 kHz”.

In recent years, supercritical fluid extraction (CO) has improved its conception of alternatives to conventional solvent extraction methods. Femenia et al., in 2001, used pressures of 330 bar and temperatures of 50 °C to extract the oil contained in raw almonds, raw peeled almonds, and roasted almonds, obtaining oil percentages of 15-16%, 27- 33%, 49-64%, respectively. Leo et al., 2005 also extracted almond oil using this system, but using pressures of 350 to 550 bar, temperatures of 35 to 50 °C and solvent rates of 10 to 30 kg-1, and observed that the increase in extraction pressure and temperature caused an increase in oil yield. It was also observed that equal flow and pressure rate and the temperature increase caused an increase in yield of almost four times higher. An explanation for this phenomenon is that it increased oil solubility in CO2.

“Experimental results were used to deduct that oil production, the initial stage of extraction, increased with an increase in the CO, flow rate of 10 to 30 kg-1, constant pressure, and temperature. Thus, oil production increased with pressure, temperature, and flow rate increments. Later on, Ma et al., in 2007, studied the factors that influence bitter almond oil extraction, finding optimal extraction conditions: extraction pressure (35 MPa), extraction temperature (50 °C), CO, flow rate (24 h), almond particle size (0.6 mm) and extraction time (2 hours). The factor sequence that affects extraction is almond particle size > extraction time > extraction pressure > CO, flow rate > extraction

temperature. Under these conditions, almond oil yield reaches 53%.

An alternative to solvent use is the use of pressing with both hydraulic and Screw presses" [22].

2.3 Characterization of Extracted Oil

The fatty glycerides of plant origin form an essential class of organic compounds: out of these, those that are solids at ordinary temperature are called fats, and those that are liquids are known as oils. Both of these categories are referred to as saponifiable oils. These are used in foods, the manufacture of soap and medicine, etc. Most fats and oils comprise glycerides of fatty acids containing 16 to 18 carbon atoms, such as oleic, stearic, and palmitic acid. The oil sample is filtered to remove suspended matter.

2.4 Proximate Composition

2.4.1 Proximate analysis

Proximate analysis, also known as Weende analysis, was developed in 1866 by Hennberg and Stohmann; it is a chemical method of assessing and expressing the nutritional value of a feed, which reports the moisture content, ash content (minerals), crude fiber, crude fat, and crude protein present in a food as a percentage of dry weight. The proximate analysis gives the overall nutritional composition of a sample. According to an industry standard, the proximate analysis consists of five constituents: ash, moisture, proteins, fat, and carbohydrates. Proximate plant analysis gives valuable information and helps assess the sample's quality.

These methods evolved from thorough studies of the inherent properties of the component of interest and exploration of the unique advantage such properties have over others, thus allowing the component to be isolated or eliminated.

3. MATERIALS AND METHODS

3.1 Materials

Chemicals/Reagents

i. Carbon tetrachloride
ii. Chloroform
iii. Ethanol
iv. Hydrochloric acid
v. Kjedahl catalyst
vi. Petroleum ether
vii. Petroleum ether (40-60°C)
viii. Potassium hydroxide
ix. Potassium iodate
x. Potassium iodide
xi. Sodium hydroxide
xii. Sodium thiosulphate
xiii. Tetraoxosulphate (VI) acid

Apparatus/Equipment

i. Crucible tong
ii. Heating mantle
iii. Kjedahl flask
iv. Muffle furnace
v. Oven
vi. Soxhlet apparatus
vii. Specific gravity bottle
viii. Thermometer
ix. Water bath
x. Weighing balance

3.2 Methods

3.2.1 Sample collection, identification, and preparation

Freshly matured *Terminalia catappa* fruits were collected from the Faculty of Social Science at Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. The fruits were identified using online sources which include the Missouri Botanical Garden(St. Louis, U.S.A.) and the E-Flora of Gandhinagar (Gujarat Forestry Foundation, Gujarat, India). The fruits were transported to the laboratory in a polyethene bag. The flesh of the fruits was removed, air-dried, milled into a fine powder, sieved, and stored in an airtight polyethene bag. The seeds were oven-dried, cracked open, milled into a fine powder, and stored in an airtight polyethene bag for further analysis.

3.2.2 Proximate analysis

3.2.2.1 Determination of Moisture Content [23]

Method:

A crucible was cleaned, dried in an oven, and cooled in a desiccator. Two grams of the sample were weighed into the crucible. The sample was dried in an oven at 70-80°C for 2 hours and then at 105°C for 4 hours until the weight remained constant. The crucible was cooled in a desiccator, and the final weight was recorded.

Calculation:

Moisture content (%) = W2−W3 x 100/ W2−W1

Where:

- *W*1 = Initial Weight of empty crucible
- *W*2 = Weight of crucible + sample before drying
- *W*3 = Final weight of crucible + sample after drying

3.2.2.2 Determination of Ash Content [23]

Method:

Two grams of the sample were weighed into a crucible, charred, and ashed in a muffle furnace at 550°C for 2 hours. The ash content was calculated as:

Ash content (%) = Weight of ash x100 / Weight of sample

$$\frac{W_3 - W_1}{W_2 - W_1} \times 100$$

Where:

- *W*1 = Weight of empty crucible
- *W*2 = Weight of crucible + food before ashing
- *W*3 = Weight of crucible + ash

3.2.2.3 Determination of Crude Fibre [23]

Method:

Two grams of the sample were defatted, boiled with H2SO4 solution, filtered, washed, boiled with NaOH solution, filtered, washed, oven-dried, and ignited in a furnace at 550°C. The fibre content was calculated as:

Crude fiber (%) = loss in weight after ignition x 100 / Weight of Sample

3.2.2.4 Determination of Lipid Content [23]

Method:

Using a Soxhlet extractor: A clean boiling flask was dried in an oven at 105-110°C for about 30 minutes, 1U was transferred to a desiccator, and allowed to cool. 2g of the sample was weighed into a filter paper and moved into the Soxhlet apparatus. 300ml of petroleum ether was weighed into the boiling flask of known Weight and placed on the heating mantle. The Soxhlet extractor was connected and allowed to reflux for about 4 hours. After a clear colourless solution was obtained, the petroleum ether was collected. The flask containing the extracted oil was dried in the oven at 110°C for an hour, transferred into a desiccator to cool, and then weighed.

Calculation:

Lipid content % Weight of fat x 100 / Weight of sample

3.2.2.5 Determination of Protein Content [23]

Method:

Two grams of the sample were weighed into a digestion flask. 5g of Kjedahl catalyst was added, 8.0 g of K,SO, and 1g CuSO,(catalyst) were added, followed by 25 ml of concentrated sulphuric acid and five glass beads to prevent bumping during heating. The flask was heated until frothing ceased and the solution cleared. It was cooled, and black particles that appeared at the mouth and neck of the flask were washed with distilled water. The flask was reheated and allowed to cool again. The digest was then transferred with several washings into a 250 ml volumetric flask containing 30 ml boric acid and indicators (0.1% bromocresol green solution and 0.1% methyl red solution). It was made up to the mark with distilled water. The solution was distilled until 150 ml of distillate was obtained. The boric acid-receiving solution was titrated with 0.1 M HCl to a purplish-pink color.

Calculation:

Protein (%) = Nitrogen (%) x 6.25
Nitrogen (%) = (Vs−Vb)×M×14.01 / W

Where:

- *Vs* = Volume of acid used to titrate the sample
- *Vb* = Volume of acid used to titrate the blank
- *M* = Molarity of HCl used
- *W* = Weight of sample
- 14.01 = Atomic Weight of nitrogen
- *F* = Protein-nitrogen conversion factor (6.25)

3.2.2.6 Determination of Carbohydrate Content

Calculation:

Carbohydrate (%) = 100 - (% protein + % fat + % moisture + % ash + % crude fibre)

3.3 Extraction of Oil

3.3.1 Extraction by cold maceration

The crushed almond flesh and nuts were weighed and soaked in 1000 ml of N-hexane. After 48 hours, the mixture was filtered and evaporated to dryness. The oils were then characterized accordingly.

3.3.2 Determination of the percentage of oil from *T. Catappa* seed

Petroleum ether (300 ml) was poured into a round bottom flask. Ten grams of the sample were placed in a thimble and then inserted in the center of the extractor. The Soxhlet apparatus was heated to 40-60°C. As the solvent boiled, the vapor rose through the vertical tube into the condenser at the top. The liquid condensate dripped into the filter paper thimble containing the solid sample to be extracted. The extract seeped through the pores of the thimble, filled the siphon tube, and flowed back down into the round bottom flask. This process continued until the extraction was completed, as indicated by the decolorization of the oil-solvent mixture in the extractor. The thimble was then removed from the tube, dried in an oven, cooled in a desiccator, and weighed to determine the amount of oil extracted.

3.3.3 Determination of the percentage of Oil from *T. catappa* mesocarp

30g of the sample were placed in the thimble and inserted in the center of the extractor. Approximately 150 ml of petroleum ether was poured into the round bottom flask. The apparatus was heated to 40-60°C and allowed to run for 3 hours of continuous extraction using the Soxhlet apparatus. Finally, the solvent was distilled, and the percentage of oil extracted was determined.

The percentage yield of the oils was calculated as follows:

% yield = Weight of oil x 100 / Weight of sample

3.4 Characterization of the Extracted Oil

3.4.1 Physical properties

The analysis was conducted using AOAC [23] methods.

1. **Color Determination**

The oil sample in a glass tube was viewed and matched against a standard color and recorded.

2. **Specific Gravity Test**

A clean and dried gravity bottle was weighed, and its weight was recorded. The bottle was then filled with oil, weighed, and its weight recorded. The weight of the bottle when filled with distilled water was also recorded.

Specific gravity = weight of oil / Weight of equal volume of water

3.4.2 Chemical properties

1. **Determination of acid value**

25ml of diethyl ether and 25 ml of ethanol were mixed in a 250 ml beaker. The resulting mixture was added to 10 g of oil in a 25 ml conical flask, and a few drops of phenolphthalein were added. The mixture was titrated with 0.1 M NaOH with consistent shaking until a dark pink color was observed. The volume of 0.1 M NaOH used was noted.

Free fatty acid = Titre value x M x 5.61 / Weight of sample

Where M = Normality of KOH

Acid value = 2 x free fatty acid

2. **Determination of saponification value**

2g of the sample were weighed into a conical flask, and 25 ml of 0.1 M potassium hydroxide was added. The content, which was constantly stirred, was allowed to boil gently for 60 minutes. A reflux condenser was placed on the flask containing the mixture, and a few drops of phenolphthalein indicator were added to the warm solution. The mixture was then titrated with 0.5 M HCl to the endpoint until the pink color of the indicator disappeared. The same procedure was used for other samples and a blank.

The expression for saponification value (SV) is given by:

SV= 56.1 x N x (Vo-Vi)

Where:

- *Vo* = the volume of the solution used for the blank test
- *Vi* = the volume of the solution used for the determination
- *N* = normality of HCl used (0.5)
- *m* = mass of the sample

3. Determination of iodine value

0.4g of the sample was weighed into a conical flask, and 20 ml of carbon tetrachloride was added to dissolve the oil. 25ml of Dam reagent were added to the flask using a safety pipette in a fume chamber. The flask was vigorously swirled and placed in the dark for 2 hours and 30 minutes. After this period, 20 ml of 10% aqueous potassium iodide and 125 ml of water were added using a measuring cylinder. The content was titrated with 0.1 M sodium thiosulphate solution until the yellow color almost disappeared. A few drops of 1% starch indicator were added, and titration continued by adding thiosulphate drop-wise until the blue coloration disappeared after vigorous shaking. The same procedure was used for the blank test and other samples.

The iodine value ([V) is given by the expression:

$$\text{Iodine Value} = 12.69 \times (V1-V2) \times N / M$$

Where:

- *N* = molarity of sodium thiosulphate used
- *V*1 = volume of sodium thiosulphate used for the blank
- *V*2 = volume of sodium thiosulphate used for determination
- *m* = mass of the sample

4. Determination of peroxide value

The peroxide value was calculated as:

$$PV=S \times M \times 1000 / W$$

Where:

- *S* = volume of sodium thiosulphate used
- *M* = molarity of sodium thiosulphate used
- *W* = weight of the sample

4. RESULTS AND DISCUSSION

4.1 Proximate Composition

The proximate composition analysis of *Terminalia catappa* seeds demonstrates a notable nutrient profile. The moisture content of 23.24% is significantly higher than the 5.50% observed in cashew nuts [24] and 5.10% in African oil beans [25]. This high moisture content suggests that the almond seed is unsuitable for long-term preservation without drying or other moisture-reduction processes.

Table 1. Proximate composition of *T. catappa* seed

Parameters	Composition (%)
Moisture	23.24
Ash	5.50
Fat	16.51
Crude Protein	21.22
Crude Fibre	12.30
Carbohydrate	39.99

Table 2. Physicochemical properties of *T. catappa* seed Oil

Properties	Composition
Saponification (mg KOH/g)	162
Acid value (mg KOH/g)	1.68
Iodine value	89
Specific gravity	0.95
% yield	46
Colour	Yellow
Peroxide value (mg Iodine/g)	1.40

The high carbohydrate content of 39.99% underscores the seeds' potential as an energy-rich food source, aligning with the finding that carbohydrates are essential for providing necessary calories in human diets. Given the easily digestible nature of carbohydrates, *T. catappa* seeds could be particularly beneficial in regions where high-calorie foods are needed [26].

The ash content, at 5.50%, indicates a substantial presence of minerals. Minerals play crucial roles in various physiological functions and in maintaining overall health (King et al., 2015). The crude protein content, measured at 21.22%, suggests that *T. catappa* seeds are a valuable source of dietary protein, vital for growth and maintaining a positive nitrogen balance. This is especially significant for developing nations, where plant-based proteins are often the primary protein source [27].

Additionally, the crude fibre content of 12.30% highlights the seeds' potential benefits for digestive health. Dietary fibre aids in appetite satisfaction facilitates the movement of food

through the digestive system, and helps prevent constipation [28,29]. Soluble fibre, in particular, has been shown to reduce levels of low-density lipoprotein (cholesterol) in the blood, which is advantageous for cardiovascular health [30].

The fat content of 16.51% and high oil yield indicate that *T. catappa* seeds could be an economical source of edible oil, comparable to other conventional oil seeds such as palm oil, groundnut oil, and soybean oil [31].

The physicochemical analysis of *T. catappa* seed oil reveals several noteworthy properties. The acid value of 1.68 is low compared to 2.15 for melon seed oil [32] and 4.30 for camphor seed oil [33], indicating its suitability for consumption and use in the paint industry.

The iodine value of 89 classifies *T. catappa* oil as a non-drying oil, making it inappropriate for paint manufacturing but suitable for the cosmetic industry [34]. Non-drying oils, characterized by their low iodine values, are less likely to form films upon exposure to air, which is a desired property in cosmetic formulations.

The peroxide value of 1.40 suggests a low susceptibility to oxidative rancidity, indicating the presence of antioxidants that enhance the oil's shelf life [34]. The specific gravity of 0.95 confirms that the oil is less dense than water, a common characteristic of vegetable oils.

5. CONCLUSION AND RECOMMENDATION

The results of this study confirm that *Terminalia catappa* seeds are rich in essential nutrients and bioactive compounds, making them a valuable resource for both dietary and industrial applications. The seeds' high protein content and low levels of anti-nutrients suggest their potential as a dietary supplement and an ingredient in animal and poultry feed.

The chemical properties of *T. catappa* seed oil, including its high saponification value and low iodine value, indicate its suitability for use in cosmetics rather than the paint industry. Its low acid and peroxide values further support its stability and edibility, making it a promising alternative to conventional edible oils.

Based on these findings, we recommend the incorporation of *T. catappa* seeds and oil into food supplements and cosmetic products due to their high nutritional value and favourable physicochemical properties. Further research should explore sustainable cultivation practices and optimized extraction methods to fully harness the potential of this versatile plant.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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https://www.sdiarticle5.com/review-history/118829