Original Research Article

NUTRITIONAL AND ANTINUTRITIONAL EVALUATION OF THE PULP AND SEED OF Terminalia catappa (TROPICAL ALMOND) FRUIT AND PHYSICOCHEMICAL PROPERTIES OF ITS SEED OIL

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ABSTRACT

Aims: This study aimed at determining the nutritional and antinutritional composition of the pulp and seeds as well as physicochemical characteristics of the seed oilof *Terminalia catappa* (tropical almond).
Study design: The experimental design was employed
Place and Duration of Study: Agroecology and life science laboratory of the University of Buea between June 2023 and May 2024.
Methodology: Oil was extracted using soxhlet method. UV-visible spectrophotometer was used for nutritional and antinutritinal analyses; while gas chromatography and titrimetry were used to analyse the fatty acid profile andphysicochemicalproperties of the seed oil respectively.
Results: Results revealed that the seeds recorded more concentrated energy (596.28 Kcal/100g) than the pulps (403.42 Kcal/100g).Total phenolic (133.70 ± 0.15 mg/100g), tannin (77.90 ± 0.01 mg/g), oxalate (15.01 ± 0.01 mg/100g) and phytic acid (2.81 ± 0.06 mg/100g) contents were displayed by the pulp and 29.70 ± 0.25, 18.00 ± 0.07, 20.92 ± 0.07 and 1.88 ± 0.01 mg/100g, respectively for seeds.The abundant minerals in the pulp were K, Ca, Na, and P, those in the seeds were Mg, K, P and Fe. The Acid value, Saponification value, Iodine value, Peroxide value and P-anisdine value of the seed oil were 2.24 ± 1.16 mgKOH/g, 222.2 ± 3.11 mgKOH/g, 78.50 ± 0.54 gI2/100g, 5.50 ± 0.71 mEq/kg and 3.65 ± 0.23, respectively. Fatty acid profiling showed 66.68% unsaturated fatty acids of which 19.86% and 9.81% were linoleic and linolenic, respectively and 33.32% saturated.
Conclusion: The pulps and seeds of *T. catappa*have a significantly high content of macro and micronutrients that can meet up the nutritional needs of a population and the quality assessment of the oil suggests that it can be recommended as suitable for industrial usage.

Keywords: Pulp, Seed, oil, fatty acid profile, Terminalia catappa, nutritional composition, physicochemical properties, fatty acid profile.

1. INTRODUCTION

Indigenous fruit trees are fruit-bearing tree native to a specific region or ecosystem and are sometimes traditionally cultivated or utilized by indigenous communities within the area. These plant species are known for their leaves consumed as vegetables with high nutritive values as well medicinal properties. Their fruits are edible and sometimes contain seeds, classified as oilseeds [1] of high nutritional and economic importance as they Fruits not only offer easily available energy, but also micronutrients necessary to sustain and support human growth and activity [2]. Ahmad and Pieroni [3], stipulated that edible indigenous fruit species have been used as an alternative to naturalized species, during dry periods and times of food crises and in this way bridge the 'hunger gap' during times of food shortage [4]. However, in the last two decades, research efforts have been channelled toward harnessing the nutrient potentials of both conventional and unconventional fruits as a way of enhancing food security. While a few research studies have focused on quite a number of these indigenous fruit plants [5-7].

Terminalia catappa also known as country almond, Indian almond, Malabar almond, sea almond, tropical almond, and beach almond, is an endemic tropical fruit tree species from the Combretaceae family. In Cameroon, it is known by a common appellation ¨Banga school¨. *Terminalia catappa* tree has leaves and stem barks whose nutritional and medicinal importance has been revealed. Although it also produces fruits and nuts which are edible, it is still among the non-conventional fruit trees that have been under-exploited in Cameroon despite its wide distribution in the communities of Cameroon [8-10], Contrary to leaves and stem bark, whose nutritional and medicinal importance has been revealed by several authors, very little or no studies have been done on the fruits and their seeds, especially in Cameroon. Meanwhile studies conducted in D.R. Congo, an African country revealed that *T. catappa* fruit contained a higher coil content (51.80%) compared to the oil yield reported for some commercial plant oils such as cotton seed (36%), olive (17%), sunflower (44%), soybeans (18%) and corn 3.4% [11, 12].

However, the consumption and utilization of the fruits of *Terminalia catappa* in Cameroon are limited to the immediate localities. To the best of our knowledge, no data has been published concerning the nutritional potentials of either the fruits or kernel oil from Cameroonian *Terminalia catappa* despite the abundance of these plant species in it forest. Still, there is no scientific report about the proximate analysis of seeds and characteristics of oil produced from *T. catappa* seed. Therefore, the main objective of this study was to determine the nutritional characteristics of seeds as well as the physicochemical characteristics of *Terminalia catappa* seed oil.

2. MATERIAL AND METHODS

2.1. Sample collection

Ripe fruits of *Terminalia catappa* were harvested from seaside and beaches in Limbe and Idenau, localities found in the Southwest region of Cameroon in June 2023. The fruits were transported in ice cold box to the life science laboratory of the University of Buea for preparation and analyses.

2.2. Samples Preparation

Terminalia catappa fruits were washed, pulp removed and the seeds dehulled to obtain the kernel and dried in an oven at 50 °C for 48 h. The freshly pooled pulps were crushed using a mortar and pestle and dried in a vacuum oven at 50 °C for 48 h and later crushed into fine powder using an electric blender. Similarly, the dried seeds were de-husked manually cracking with a stone to remove the kernels which were further dried for another 48 hours until moisture content was less than 12%. The dry kernels were then ground using an electric grinder to obtain fine powder. The fine powder (Fig. 1) obtained from the seed was divided into two portions, the first potion (1kg) was used for proximate and nutritional analysis while the second portion (4kg) was used for oil extraction..

2.3 Oil Extraction

Extraction of *Terminalia catappa* seed oil was by the Soxhlet method. The oil was extracted from the seed powder in a Soxhlet extractor for 8 h to maximize the total oil yield using n-hexane as a solvent. The solvent was evaporated and recovered with the help of Rota vapor (Buchi, Switzerland) at 100 rpm, and dried in an oven at 45 °C for 2 h [13]. The extracted oil (Fig. 1) was then allowed to be collected, weighed and stored at 4 ^{o}C for further analysis. The total oil yield expressed as a percentage was calculated on dry weight basis as:

$$\% \text{ Oil yield} = \frac{Weight\ in\ gram\ of\ extracted\ oil}{Weight\ in\ gram\ of\ extracted\ seed\ powder\ sample}$$

A **B** **C**

D **E** **F**

G **H**

Fig. 1. The process of harvesting of seeds and oil extraction from *Terminaliacatappa*. *A= a typical tropical almond tree with fruits, B=Fresh fruits with seeds, C= dried fruits with seeds, D = fresh dehulled seeds, E = oven dried seeds, F= powdered seeds prior to extraction of oil, G = Extracted oil, H = defatted flour*

2.3. Nutritional Analyses of pulp and seed flour

2.3.1 Proximate analysis of pulp and seed flour

The methods used for sample treatment and analysis were carried out based on the standard procedures recommended by AOAC [14], The moisture content of both pulp and defatted seed powder was determined gravimetrically by heating at 105 °C for 24 h in an oven by the procedure described by AOAC [14], Proximate analysis (crude fat, ash, total carbohydrates, fiber, and proteins) was determined according to AOAC [14]. Total oil was quantified gravimetrically and calculated as a percentage of oil using a soxhlet extractor. Protein (N × 6.25) was determined by the Kjeldahl method. To determine the ash content of the sample, 5 g of the sample was incinerated at 550 °C in a muffle furnace. The crude fiber content of the samples was determined by treating the both samples with 1.25% sulfuric acid and 1.25% sodium hydroxide solutions under specific conditions and the dried residue remaining after digestion of the samples was considered as crude fiber. Digestive carbohydrate content was determined by difference method according to AOAC [14].

2.3.2. Determination of mineral composition of pulp and seed flour

Minerals were assayed by atomic absorption spectroscopy [14]. The principle is based on the fact that when atoms of an element are in contact with a flame, they emit wavelengths of radiation whose intensity can be measured. The concentration of the cation to be determined was calculated from the absorbance values by linear regression equations. To determine the mineral content of both samples, 5 g of sample was incinerated in a furnace at 550 °C and

the ashes dissolved in 50 ml of 2.5% HNO_3 solution. The concentrations of Na, Ca, Mg, Fe, P, K, Zn, and Fe were determined using atomic absorption spectrophotometer (Buck Science). A calibration curve was prepared using standard metal solutions.

2.3.3. Estimation of vitamin A content of pulp and seed flour

The vitamin A content was estimated after determining the β-carotene content of the samples. β-carotene content was determined as described by Ranganna [15]. A mass of 1 g of the sample was extracted in 5 ml of methanol for 2 h at room temperature under dark conditions. The β-carotene layer was separated using hexane through a separating funnel. The volume was made up to 10 ml with hexane and then this layer was again passed through sodium sulphonate through a funnel to remove any moisture from the layer. The absorbance of the β-carotene layer was measured at 436 nm using hexane as a blank. The beta carotene was calculated using the formula:

Beta-carotene content (µg/100g) = Absorbance (436 nm) x V x D x100 x 100/W x Y

Where: V = Total volume of extract; D = Dilution factor; W Sample weight; Y = Percentage dry matter content of the sample.

Vitamin A content was estimated using the 1 µg retinol = 1 RE method.

1 µg β-carotene = 0.167 µg RE as defined by Codex Alimentarius [16].

2.3.4. Determination of vitamin C content of pulp and seed flour

Vitamin C was determined by the titration method using the protocol described by AOAC [14]. A volume of 1 mL of both samples and 90% acetic acid was titrated with a solution of 50 µM DCIP. The endpoint titration was determined when the blue colour changes to a pale pink colour. A blank titration was performed against 90% acetic acid while a standard titration was performed against 40 mg/L pure L-ascorbic acid. The amount of Vitamin C was expressed in mg/100ml of sample.

2.3.5 Anti-nutritional factors of pulp and seed flour

2.3.5.1 Determination of Total Phenolics Content (TPC).

The total phenolics content of the pulp and seed was determined using the Folin-Ciocalteu colorimetric method described by Chlopicka et al. [17].

2.3.5.2. Estimation of tannins content

The content of Tannins was estimated by the Vanillin-HCl method of Price et al. [18]. Defatted *T. catappa* flour and pulp flour (5 g) were treated with acidic methanol for extra et al. ction of tannins. From the diluted extract, 1 ml was mixed with 5 ml of freshly prepared vanillin-HCl reagent, and the optical density was determined at 500 nm by using a spectrophotometer. The results were expressed mg/100 g dm using catechin as standard.

2.3.5.*3. Determination of phytates content*

Phytates content was determined according to Wheeler and Ferrel [19]. The amount of phytate phosphorus content was calculated from the standard curve by assuming that 4:6 iron-to-phosphorus molar ratio.

2.3.5.4 Determination of oxalates content

To determine oxalates content in *T. catappa* seed flour and pulp, 2 g of flour were extracted with 100 ml of boiling distilled water for 30 min, filtered, and adjusted to 200 ml. The hot water extract residue was further extracted with 150 ml of boiling 1 M HCl for 30 min, adjusted to 200 ml, and filtered. The two filtrates were combined and titrated with potassium permanganate [14].

2.4 Seed oil analysis

2.4.1 Determination of oil quality indices

After extraction of the *Terminalia catappa*seed oil, it was filtered to remove non-oil materials. Sodium sulfate crystals was added to the crude oil to remove any trace water. The dry agent was separated by decanting and filtration. The physicochemical analyses of the oil for free fatty acid, iodine, peroxide, saponification, and P-anisidine values were carried out according to the methods of AOAC [14]. Total Oxidation (TOTOX) value was determined according to Holm [20] based on the obtained peroxide and P-Anisidine values using the formula;

$$TOTOX = 2PV + AV$$

2.4.2. Determination of Fatty acids composition

The fatty acid composition was determined by conversion of oil to fatty acid methyl esters prepared by adding 950µl of n-hexane to 50mg of oil followed by 50µl of sodium methoxide using the method of AOAC [14]. The mixtures were vortexed for 5s and allowed to settle for 5 min. A volume of 1µl of the top layer was injected into a gas chromatograph (Model GC-14A, Shimadzu Corporation, Kyoto, Japan) equipped with a flame-ionization detector and a polar capillary column (B PX 70 0 .25), 0.32 mm internal diameter, 60 m length and 0.25µm film thickness (SGE Incorporated, USA) . The detector temperature was 240 °C and the column temperature was 110 °C held for one minute and increased at the rate of 8 ºC.min^{-1} to 220 ºC and held for one minute. The run time was 32 min. The fatty acid Methyl ester peaks were identified by comparing their retention time with those of standards. Percent relative fatty acid was calculated based on the peak area of a fatty acid species to the total peak area of all the fatty acids in the oil sample.

Fatty acid profiling (ΣSFA, ΣMUFA, ΣUFA, ΣPUFa, Σn-3/n-6 ratio, Σ omega-3, Σomega-6, ΣPUFA/ΣSFA ratio was done by summing different classes of fatty acids.

The atherogenicity index (AI) and the thrombogenicity index (TI) were obtained using the formulas of Ulbricht & Southgate [21].

$$AI = \frac{[(C12{:}0+(4\times C14{:}0)+C16{:}0)]}{(\sum MUFA+\sum \omega 6+\sum \omega 3)}$$

$$TI = \frac{(C14{:}0+C16{:}0+C18{:}0)}{[(0.5\times\sum AGMI)+(0{,}5\times\sum \omega 6+(3\times\sum \omega 3)+(\sum \omega 3/\sum \omega 6)]}$$

The ratio of hypocholesterolemic and hypercholesterolemic (H/H) by the method of Santos-Silva et al [22] as;

$$H/H = \frac{(C18{:}1cis9 + C18{:}2\omega6 + 20{:}4\omega6 + C18{:}3\omega3 + C20{:}5\omega3 + C22{:}5\omega3 + C22{:}6\omega3)}{(C14{:}0 + C16{:}0)}$$

2.5. Statistical Analysis

The data were subjected to one-way analysis of variance (ANOVA) to test if the fruit part had an effect on the measured parameters. Since there were more than two levels of the factor for the proximate composition, the significant ANOVA result was followed by Student-Newman-Keuls test. The analyses were conducted in Statgraphics Centurion version XVI and Graphpad-InStat version 3.05 at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Nutritional of T. catappa pulp and seed

3.1.1. Proximate composition

Table 1 presents the results of the chemical composition of *T. catappa* seed and fruit pulp. The moisture content of dried seed in this study was 10.21% while the moisture content for the pulp was 86.53%. The fruit pulp on a dry matter basis recorded a high carbohydrate content (51.81%) as the predominant component, followed by proteins (23.96%) and fat (15.58%).While for the seeds, the predominant was crude fats (49.79%), followed by crude proteins (31.47%).

Table 1. Proximate composition of *T. catappa* fruit pulp, seed and defatted seed

Proximate Composition	Pulps	Seeds	Defatted Seed
Moisture (%)	86.53 ± 0.11^{c}	10.21 ± 0.98^{a}	8.05 ± 2.98^{a}
Crude protein (%)	23.96 ± 2.61^{b}	31.47 ± 0.02^{b}	$70.14. \pm 5.02^{a}$
Crude fat (%)	15.58 ± 2.69^{a}	49.79 ± 0.27^{c}	5.84 ± 0.27^{a}
Total ash (%)	9.66 ± 1.83^{b}	$0.47 \pm .014^{a}$	$0.48 \pm .014^{a}$
Total fiber (%)	9.98 ± 0.45^{c}	2.66 ± 0.09^{b}	2.66 ± 0.09^{b}
Carbohydrate (%)	41.83 ± 0.90^{a}	5.60 ± 0.01^{b}	5.76 ± 0.01^{b}
Total carbohydrate (%)	51.81 ± 4.01^{a}	8.26 ± 0.01^{b}	8.48 ± 0.01^{b}
Energy value (Kcal/100g)	403.42 ± 0.01^{a}	596.28 ± 4.01^{b}	356.16 ± 4.01^{c}

**Moisture content on oven dry weight basis*

Values are mean ± standard deviation, n=3, values with different letters across the rows are significantly different (P ≤ 0.05)

The moisture contents were found to be higher in the edible pulp compared to the seeds. High moisture content reduces the shelf life of fruits since moisture increases microbial activity, implying that both fresh seeds and pulps, cannot be stored for long in the fresh state and therefore need to be preserved by drying techniques, to increase their shelf life as reported by Ojwang et al.[23].

Proteins are important nutrients in the body, as they help in repairing worn-out tissues and are a source of amino acids required for protein synthesis. The findings of this study showed that the protein content of the pulps and seeds were 23.96% and 31.47% respectively, indicating that tropical almond seeds are good sources of protein. When defatted, the seeds had 70.14% protein indicating that it can be used to supplement a protein-deficient diet and as a complementary food to solve protein-energy deficiency [24]. These results are were similar to results obtained for *Terminalia catappa* seeds (28.70%) but higher than the value obtained for the pulps (8.75%) from Nigeria [25]. The protein content obtained for the seeds in this study is very similar to those harvested from Cote D'Ivoire (31.21%) [26], and higher than 20.14% from Benin [27] and 23.78% from Congo [28]. However, the value for the protein content in seeds was slightly lower than 36.3% in cashew nut [29].

Lipids are known to have numerous health benefits in the body such as the synthesis of cell membranes, steroid hormones, and eicosanoids which ensure the integrity of the cell and enable it to carry out several vital body processes. Consumption of lipids is therefore important to ensure the proper functioning of the body [23]. *Terminalia catappa* seeds reported a significantly higher values than those of most conventional seeds such as soybean (14%), palm fruit (20%), palm kernel (36%), groundnut (42%), sunflower (32%), cotton (35%) and unconventional seeds such as mango (12%) and sesame seeds (26%), [30-33]. The high amount of *T. catappa* lipids in the seeds makes it a distinct potential for the oil industry [34]. Generally,the results reveal *T. catappa* seed as an oilseed with the potential of high oil and protein content to satisfy the calorie and protein demands of a population.

For ash content, the pulps recorded the highest ash content (9.66%) relative to the seeds (0.47%). The ash content is a measure of the inorganic materials present in food, which are minerals. *T. catappa* fruits are therefore rich in minerals.The fiber content of the pulp (9.98%) is significantly higher than that of the seeds (2.66%). Fiber is an essential component of a healthy diet as it aids in digestion, promotes satiety and helps maintain bowel movement. A high fiber content in the pulp could be beneficial for overall gut health and may contribute to a feeling of fullness, which can support weight management [35].

The pulp containssignificantly higher quantities of carbohydrate (51.81%) than the seed (8.26%). Carbohydrates, like proteins contribute to more than 10% of the total bio-available energy of the seeds which will make these seeds good sources of energy (Table 1). The calculated metabolizable energy value (403 Kcal/100g for pulp, 596 Kcal/100g and 356 Kcal/100g for defatted *T. catappa*seeds). The result shows that the seed has a higher caloric value than the pulp and this was in line with results obtained for pulps (370 Kcal/100g) and seeds (587 Kcal/100g) of *Terminalia catappa* fruits from Nigeria [25].

3.1.2 Mineral Composition

Table 2 shows the mineral content of *T. catappa* pulps and seeds. The abundant minerals in the pulps were potassium (1989.36 mg/100g), calcium (336 mg/100g) sodium (253.15 mg/100g), and phosphorus (178.46 mg/100g); while in the seeds, abundant minerals were

magnesium (1085 ± 0.04mg/100 g), potassium (1035 ± 4.24 mg/100 g), phosphorus (960.5 ± 4.95), iron (166 ± 1.41 mg/100 g).

Table 2.Mineral composition of *Terminalia catappa* pulp and seed

Mineral content (mg/100g)	Pulps	Seeds
Phosphorus	178.46 ± 0.001[b]	960.5 ± 4.95[a]
Potassium	1989.36 ± 2.38[a]	1035 ± 4.24[b]
Magnesium	58.32 ± 1.37[a]	1085 ± 0.04[b]
Calcium	336 ± 0.74[a]	36 ± 1.41[b]
Zinc	79.33 ± 0.001[a]	6.96 ± 0.05[b]
Sodium	253.15 ± 0.82[a]	53 ± 1.41[b]
Iron	51.24 ± 0.78[b]	166 ± 1.41[a]

**Values are mean ± standard deviation, n=3, values with different letters within rows are significantly different (P ≤ 0.05)*

Mineral analyses revealed that for all the minerals analyzed, the values obtained for the pulp was significantly different (P ≤ 0.05) from that of the seed. The seed contain more proportion of most minerals compared to the pulp of the fruit. Minerals like magnesium play a crucial role as a cofactor of many enzymes [36]. A previous study done by Vibha et al. [37], also recorded that Magnesium (1687.5 mg/kg) was the most abundant mineral among the minerals analyzed in *T. catappa* seeds. Therefore; these seeds have the potential to supply a sufficient amount of minerals for consumers as well as to balance human electrolytes.

3.1.3 Vitamin Composition of *Terminalia catappa* pulp and seed

Fig. 2 demonstrates the results for the vitamin composition of the pulps and seeds of *Terminalia catappa.* From the results obtained in this study, the Vitamin A content of the pulp is 178.46 mg/100g while that for the seed is 960.5 mg/100g. The vitamin C content of the pulp is 1989.36 mg/100g while that for the seeds is 1035 mg/100g.

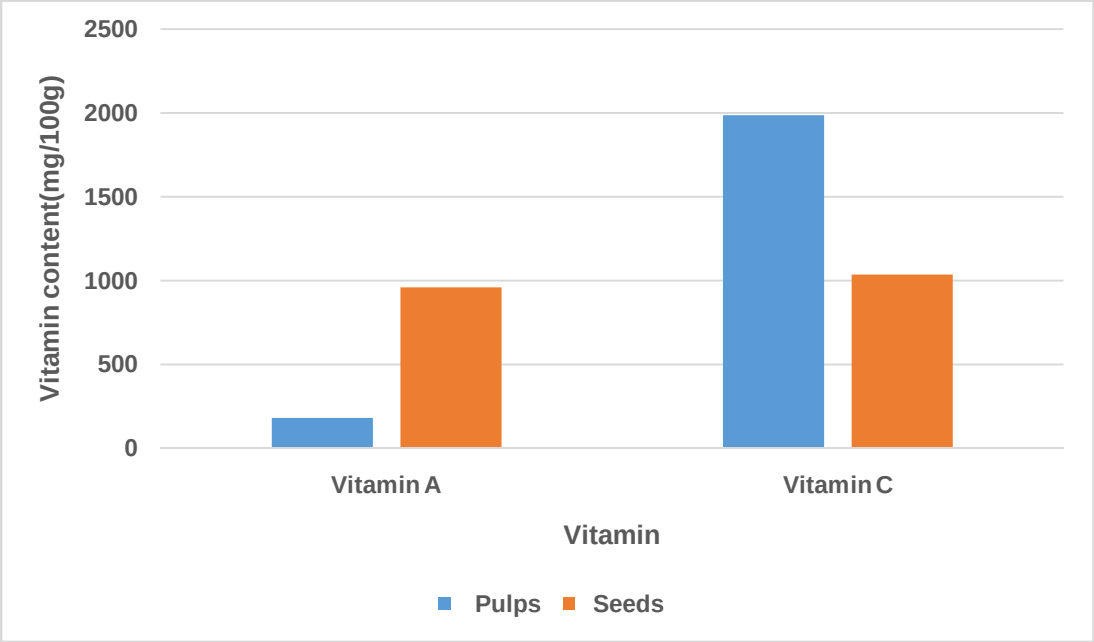

Fig. 2. Vitamin Composition of *Terminalia catappa* pulp and seed

Vitamin A is important for normal vision, gene expression, growth, and immune function through its maintenance of epithelial cell functions [38]. Vitamin C is a potent antioxidant that facilitates the transport and uptake of non-heme iron at the mucosa. Vitamin A was higher in the seed than in the pulp, while vitamin C was higher in the fruit pulp than in the seed. Vitamin C is known to be water-soluble and is found more in fruits than in seeds. Carotene generally is higher in fruits [39] and fat-soluble vitamins are lower than their water-soluble vitamins in fruits. This could also be the reason for the increased pro-vitamin A content in the dry seed.

3.1.4. Antinutrients Composition of pulp and seed of *Terminalia catappa*

Antinutritional components of *T. catappa* fruit pulp and seed are summarized in Table 3. The results show Total phenolic content of pulp and seed to be 133.70 mg/100g and 29.70 mg/100g respectively. Phytate, oxalates and tannins contents is 2.81 mg/100g, 15.01 mg/100g and 77.90 mg/100g respectively for pulps while for seeds the values were 1.88 mg/100g, 20.92 mg/100g and 18.00 mg/100g respectively.

Table 3. Antinutrients Composition of pulp and seed of *Terminalia catappa*

Antinutrients (mg/100g)	Pulp	Seed
TPC	133.70 ± 0.15[a]	29.70 ± 0.25[b]
Phytate	2.81 ± 0.06[b]	1.88 ± 0.01[b]
Oxalate	15.01 ± 0.01[a]	20.92 ± 0.07[a]

Tannin	77.90 ± 0.01[a]	18.00 ± 0.07[b]

Values are mean ± standard deviation, n=3, values with different letters within rows are significantly different (P ≤ 0.05)

Antinutrients are natural or synthetic compounds that interfere with the absorption of nutrients and their presence in any food sample is of significant importance since antinutrients may pose some deleterious effects, depending on the dose present [40]. Phenolic compounds inhibit the activity of digestive enzymes like α -amylase, trypsin, chymotrypsin, and lipase [41] and decrease the digestibility of proteins, carbohydrates, and availability of vitamins and minerals [42]. The pulps exhibit a lower level of phenolics compared to the seeds. The levels of both phenolics and tannins in *T. catappa* appear to be lower than an earlier report for *T.catappa* seeds (35 mg/100g) harvested in Benin [30].

Phytic acid is an antinutrient that inhibits the absorption and utilization of iron and calcium in the body by forming insoluble phytates. Therefore, when present in large amounts, they are known to act as a major inhibition to the absorption of iron. The phytate content for *Terminalia catappa*pulp (2.81 mg/100g) is higher than that for the seeds (1.88 mg/100g). The phytate contents obtained for this study is relatively low compared to 35 mg/100g for almond, 29 mg/100g for cashew nuts; 20 mg/100g for walnut and 23 mg/100g for hazel nut [43], an indication that they may not pose any hindrance to the metabolism of some nutrients in the body when consumed.

Oxalate is a chelating agent, which binds calcium very effectively. Foods with high oxalate content may produce acute metabolic calcium deficiency [44]. The concentration of oxalate (15.01 mg/ 100 g for pulp and 20.92 mg/100g for seed) in this study seems to be low. Tannins are a class of phenolic compounds. High amounts of tannins are well known to form complexes with proteins reducing the solubility of proteins [45]. The tannin level (77.9 and 18.00 mg/100g for pulp and seed respectively) obtained in this study was found to be relatively high in comparison with tannins content found in previous study on *T. catappa* fruits in Nigeria which reported 44 mg/100g for pulp and 35 mg/100g for seeds [25]. Therefore the tannin level in tropical almonds may not be as harmful as expected for consumption.

3.2 Seed Oil Analysis

3.2.1 Physicochemical characterization of oil

In order to know the safety of the oil for consumption, the oil quality indices were analyzed and presented on the table 4. The acid value, free fatty acid, saponification value, iodine value, peroxide value, P-anisidine value and total oxidation value obtained all fell within the recommended Codex Alimentarius commission range for safety. The physicochemical properties of *T. catappa* seed oil are shown on Table 4.

Table 4. Oil quality indices of *T. catappa* seed oil

Quality indices	*T. catappa*oil	Codex safety level *(WHO/FAO)*
Acid index (mgKOH/g)	2.24 ± 1.16	≤ 4.0
FFA (%)	1.54 ± 0.59	≤ 2.5
Saponification value(mgKOH/g)	222.2 ± 3.11	188-194
Iodine value (gI_2/100g)	78.50 ± 0.54	104-120
Peroxide value (mEq/kg)	5.50 ± 0.71	≤ 15
P-anisdine value	3.65 ± 0.23	≤ 20
Totox value	14.65 ± 1.18	≤ 40

Values are mean ± standard deviation, n= 3

The oil under evaluation has a very low acid value of 2.24 mg KOH/g when compared with the safety level of Codex Alimentarius of ≤ 4.0. The acid value obtained for *T. catappa* seed oil in this study is in line with values obtained for *T.cattapa* seed oil from Benin (2.24) and Congo (2.42) [27-28].The acid value in this oil is below the maximum limit (2.50 mg KOH/g) of DIN EN ISO 660 and within the range for reference values estimated for groundnut and palm oils (<4), suggesting that this oil can be stored for long since oil with high FFA level cannot be store for long because they are more prone to oxidation than their esterified ones.The free fatty acid (FFA) content of *T. catappa* seed oil (1.54±0.59%) fell in the safety range of ≤ 2.5% reported by Leung *et al*[46]. The low FFA value in this study suggests that *T. catappa* seed oil may have a long shelf life since oils with low FFA tend to have a long shelf life.

The saponification value of the oil in this study was 222.25 mg KOH/g. This value is closer to values for some common oils like castor seed oil (185.83), palm oil (190-209 mgKOH/g), groundnut oil (187-196 mgKOH/g), and corn oil (187-196 mgKOH/g) [47]. The saponification value of *T. catappa* is within the range of (175–287) specification for oils by the American Society for Testing and Materials [48]. Oils with lower saponification values contain high amount of long chain fatty acids. Therefore, the value obtained for*T. catappa* seed oil contained medium quantity of higher fatty acids, fatty acids ≥ 16 carbon (Table 5).

The iodine value indicates the number of reactive double bonds present in an oil. A high iodine value indicate more double bonds (unsaturation). This value can range from 20-120 for kernel oil and up to 185 for fish oil [49]. The iodine value of *T. catappa*seed oil was 78.50 gI_2/100g which was below the 107-135 gI_2/100 g range recorded for *T. catappa*oil from Malaysia [50], butwithin the range of 77–94 gI_2/100g olive oil, above 8–10 gI_2/ 100 g coconut oil, 12–18 gI_2/100 g palm kernel, 50– 55 gI_2/100 g palm oil and 44.4 gI_2/100 g cashew nut oil [25, 36, 51]. Based on the iodine for *T. catappa*seed oil, the oil can be classified as a non-drying oil since such oils display Ii<100. The seed oil can therefore be recommended in the edible cream industries and as raw vegetable oil.

The peroxide value obtained (5.50±0.71 meqO_2/kg) was within the recommended safety range of ≤ 10 meq of active oxygen/kg of oil by the Codex Alimentarius Committee for all edible oils [16]. The low peroxide value of *T. catappa* oil reported in this study indicates a low level of primary oxidation products, which is characterized by the presence of hydro

peroxides in oil.The P-anisidine value (18.57±0.30) was within the recommended safety range by the Codex Alimentarius Commission (P-anisidine value ≤ 20). Thisvalue suggests that oilmay contain low secondary oxidation products such as aldehydes of α-and β-unsaturation. The total oxidation value (34.24±0.8) was within the recommended Codex Alimentarius Commission safety range (TOTOX ≤ 40) for edible oils indicating high primary hydroperoxides and secondary (aldehydes) oxidative stability for storage [16]. These results overall suggests that *T. catappa seed oil* is good for human consumption but must not be kept exposed on sun.

3.2.2 Fatty acid composition of *Terminalia cattapa*seeds

The fatty acid composition of *T. catappa* seed oil was determined by gas chromatography (Table 5). The major unsaturated fatty acids present in the oil were Linoleic acid, Oleic acid, and Linolenic acid, while the major saturated fatty acids were Lauric, capric, margaric, and arachidic acids. Total saturated fatty acids account for 33.32% of the fat represented mainly by lauric acid (7.32%). Unsaturated fatty acids constitute 66.68% of the total seed fatty acids and 32.47% of these are monounsaturated.

Table 5. Fatty acid profile of *Terminalia catappa* oil

Fatty Acids	Common Name	IUPAC Name (Systematic)	(%)
C10:0	Capric acid	Decanoic acid	5.26
C12:0	Lauric (Dodecanoic) acid	Dodecanoic acid	7.32
C14:0	Myristic (Tetradecanoic) acid	Tetradecanoic acid	2.06
C15:0	Pentadecanoic acid	Pentadecanoic acid	5.26
C15:1	Pentadecenoic acid	14-Pentadecenoic acid	9.09
C16:0	Palmitic acid	Hexadecanoic acid	0.83
C16:1 (9)	Palmitoleic acid	Hexadecenoic acid	9.09
C17:0	Margaric acid	Heptadecanoic acid	5.26
C18:0	Stearic acid	Octadecanoic acid	2.06
C18:1(9)	Oleic acid	Octadecenoic acid	14.30
C18:2(9,12)	Linoleic acid	Octadecadienoic acid	19.86
C18:3(9,12.15)	Linolenic acid	Octadecadienoic acid	9.81
C20:0	Arachidic acid	Eicosanoic acid	5.26
NI	Non Identified		4.54
ΣSFA	Saturated Fatty acids		33.32

ΣMUFA	Monounsaturated fatty acids	32.47
ΣUFA	Unsaturated fatty acids	66.68
ΣPUFA	Polyunsaturated Fatty acids	29.67
Σ (ω-3)	Omega-3	9.81
Σ(ω-6)	Omega-6	19.86
PUFA/SFA	polyunsaturated/saturated ratio	0.89
ω-3/ω-6	omega-3/omega-6 ratio	0.49
AI	Atherogenicity Index	0.26
TI	Thrombogenicity index	0.09
H/H	Hypocholesterolemic and hypercholesterolemic ratio	15.21

Values are mean ± standard deviation, n= 3

Table 5 shows that the tropical almonds oil is greater in unsaturated fatty acid than that for palm oil (50%) but lower than the 85% mentioned for soya oil by Sarwar et al. [52]. Among the unsaturated fatty acids present, polyunsaturated fatty acids, had as values 19.86% and 9.81% for linoleic and linolenic acid respectively. The high level of linoleic acid, which is one of the most important polyunsaturated fatty acids in human food, makes the consumption of this oil beneficial for health. Many studies have positively correlated essential fatty acids with the reduction of cardiovascular morbidity and mortality, hypertension, diabetes mellitus, and neurological/neuropsychiatric disorders [53].

PUFA/SFA is an indicator used to evaluate lipid quality. A PUFA/SFA ratio of 0.2 has been associated with high cholesterol levels and with high risk of coronary heart disorders, while a ratio as high as 0.8 is associated with desirable levels of cholesterol and reduced coronary heart diseases.The minimumrecommended value is 0.45 as reported by the British Department of Health [54]. The levels obtained here were greater than 0.45, indicating that the oil is of good quality oil.

The omega-3/omega-6 (ω-3/ω-6) ratio (0.49) was within the safe limits, since the maximum recommended value of 4 [68]. WHO recommends that the n-6 PUFA/n-3 PUFA ratio should not exceed 10, while the European Nutritional Societies suggest that this ratio should not exceed 5, for the prevention of inflammatory, cardiovascular, and neurological disorders [55]. The oil examined exhibited an n-6/n-3 ratio below 5. The monounsaturated fatty acid (MUFA) content reported in this study was 32.47%. In human nutrition, the MUFAs play an important role, due to their hypocholesterolemic action, reducing the risk of arteriosclerosis. The rich content in MUFAs indicates that *T. catappa* seed oil can be good for cooking processes and seasoning like olive oil if fractionated into oleic fractions.

4. CONCLUSION

From the result of the analysis, it has been shown that the pulp and seed flour of *T. catappa* have higher nutrient composition and calorie value compared to some nuts, especially in terms of crude oil and protein. The amount of protein in the seed is high for un-defatted and defatted seed in comparison with that of most protein-rich crops. T. catappa pulp and defatted kernels contained significant amounts of minerals as well as Vitamin A and C and also chemical compounds like Phenolic compounds, tannins, oxalates and phytates, which were within permissible limits. The percentage oil content of the seed was found to be much more than some conventional oils. The physicochemical properties of the oil produced in this study were within the permissive value of edible oils according to codex standards. The oil was rich in linoleic acids, oleic, linolenic and palmitoleic, composed of unsaturated fatty acids. The high UFA/SFA and PUFA/SFA ratios of this oil indicates its cholesterol-lowering potential and suggests that the seeds of tropical almond fruit have a potential to be used in the dietetic management of certain coronary heart diseases. The fatty acid composition of the seed oil makes it suitable for consumption.

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