Nutritive Components in the *Terminalia catappa* L. (Combretaceae) Almonds Cultivated in Côte d’Ivoire

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Authors’ contributions

This work was carried out in collaboration between all authors. Author DTE designed the study, wrote the protocol, fitted the data and wrote the first draft of the manuscript. Author KNY performed the statistical analysis, checked the first draft of the manuscript for submission and revised the manuscript. Authors CA and SD managed the literature and assisted the experiments implementation. Author BGHM expertized the results interpretations. All authors read and approved the submitted manuscript.

Article Information

DOI: 10.9734/JALSI/2017/33032

Received 28th March 2017
Accepted 18th May 2017
Published 10th June 2017

ABSTRACT

**Aims:** To determine the contents of the main nutrients in almonds derived from fruits of *Terminalia catappa* L. (Combretaceae) cultivated in Côte d’Ivoire.

**Study Design:** The almonds of *T. catappa* were removed from the dried mature fruits harvested in various regions of Côte d’Ivoire. A pool of almonds was drawn at Laboratory and the nutritive components were assessed.

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Place and Duration of Study: Laboratory of Biochemistry and Food Sciences, Biochemistry department of Biosciences Unit, Félix Houphouet-Boigny University, between October and December 2015.

Methodology: The dry fruits of *T. catappa* were opened using nutcracker. The extracted almonds were oven dried, crushed, put into polyethylene bags, and then kept into a desiccator till analyses. The nutritive traits assessed were moisture, ash, proteins, carbohydrates, fibers, lipids and fat properties including fatty acid profile. The caloric energy value of almonds was also estimated.

Results: The results showed an extraction yield of 1.95%, a moisture percent of 3.58% and 5.48% ash content. The samples also revealed means of 5.12% crude fibers, 31.21% proteins, 4.97% carbohydrates, and 54.76% lipids. The oil properties resulted in mean trends of 1.34%, 6.27 g mEq O₂/kg, 87 g/100 g, 122.21 mg KOH/g, and 1.46 for respective acid, peroxide, iodine, saponification, and refractive values. The fatty acids profile showed more unsaturated fatty acids (65.85%) against 34.83% saturated fatty acids. The major unsaturated fatty acid molecules were oleic and linoleic acids with respective rates of 31.20% and 33.29%, whereas the main saturated fatty acids were palmitic acid (30.12%) and stearic acid (4.52%).

Conclusion: The almonds of *T. catappa* display highly good nutritive properties and can be considered as bio-functional food.

Keywords: *Terminalia catappa*; almonds; nutritive components; fatty acids; Côte d'Ivoire.

1. INTRODUCTION

Belonging to the plant family of Combretaceae, *Terminalia catappa* is originated from the Southern Asia and thrives in the tropical ecosystems. This crop was introduced in Côte d'Ivoire through urban ornamentation at the colonial era [1]. *T. catappa* can reach 8 m of height at the adult stage, with spiral phylloaxis.

Regarding the leaves of *T. catappa*, therapeutic properties are observed resulting from their phytochemical agents. Indeed, Masuda et al. [2] reported that the leaves' extracts of *T. catappa* record obvious anti-carcinogenic and antioxidant activities. Lin et al. [3] and Wang et al. [4] showed their antioxidant and anti-inflammatory activities, whereas Teotia and Singh [5] and Nagappa et al. [6] revealed their inhibitory action against the elevation in blood glucose levels.

This crop produces several fruits, locally known as ‘côcôman’ in Côte d’Ivoire, with earlier green colour but turning to yellow colour when they ripen. The ripe fruits of *T. catappa* have sweet fibrous pulp and are edible matter enjoyed by children. Besides, the fruits record white almond so richer in nutrients that *T. catappa* is considered as a legume tree that could have significant contribution against the malnutrition usually caused by lower proteins foods [7]. Indeed, Kimbonguila et al. [8] showed that the almonds contain higher levels of proteins (23.78%) and fats (51.80%). In addition, the proteins in these almonds are good source of essential amino acids [9]. These fruits also have various pharmacological properties and are used as traditional medicine in the treatment of leprosy, headaches, intestinal parasites, and wounds [10].

From the fresh almonds, other edible uses are stated by authors. Biego et al. [11] indicated that they can be eaten as an aperitif in various recipes. They are richer in unsaturated fatty acids, specifically oleic acid and linoleic accounting respective contents of 31.48% and 28.93% [12,13]. Works on the nutrients contents of *T. catappa* fruits almonds are not exhaustive since various phytonutrients are found in such a raw food material.

In Côte d’Ivoire, fewer studies have been achieved for the nutritional interests of the almonds deriving from *T. catappa*, whereas this crop is strongly adopted and grows in many regions. As almonds are currently comprising high value in diets, this study focuses the nutritive value of almonds of *T. catappa* growing in the Ivorian environment.

2. MATERIALS AND METHODS

2.1 Vegetable Material

The vegetable material consisted of dried ripe fruits from *T. catappa* collected from suppliers in different regions of Côte d’Ivoire.
2.2 Sampling

The ripe dried fruits of *T. catappa* were collected between October and December from farmers in two regions of Côte d'Ivoire, namely Tonkpi region (Man and Danané cities) and Guemon region (Duékoué city), where this crop is cultivated. Per location, 3 suppliers were considered, from each of them 60 kg of dried fruits of *T. catappa* were collected. Thus, a total volume of 540 kg of dried fruits were collected, convoyed in the laboratory for analyses.

2.3 Extraction Yield of Almonds

The ripe dried fruits of *T. catappa* were weighed (MF) using a two digits electronic scale (TIGER SOREF). They were then opened using iron nutcracker tools to remove the almonds. The resulting almonds were also weighed (MA), and the yield of almonds extraction was determined by the equation below:

\[ \text{AEY} \, (\%) = \frac{M_A \times 100}{M_F} \]  
\[(1)\]

With AEY, almond extraction yield; \(M_A\), mass of almond (g); MF, mass of the raw fruit (g).

2.4 Processing of the *Terminalia catappa* Dry Fruits

The treatment of the *T. catappa* dry fruits is illustrated by the flow chart shown in Fig. 1. Once extracted, the almonds were dried at 50°C for 48 h in an oven (MEMMERT, Germany). After ambient cooling, they were crushed (Magimix Crusher), kept into sealed polyethylene bags, and then stored into a dry place (desiccator) till analysis.

2.5 Determination of the Almond Moisture

The moisture was determined by drying 5 g of raw almond in an oven at 105°C till constant weight measured using a two-digit scale. The weight loss resulting from the almond's ovening allowed deduction of the water content [14].

2.6 Determination of Nutritive Features in Almonds of *T. catappa*

The nutritive assessment included the determination of the contents in proteins, carbohydrates, ash, fibers, and lipids according to standard methods. The oil properties and the fatty acid profile were also worked and the caloric energy value of almonds was calculated.

![Fig. 1. Flow chart showing the process from dry fruits of *T. catappa* to almond powder](image-url)
2.6.1 Proteins content

The determination of the proteins content regarded the total nitrogen in each almond sample according to Kjeldhal method. Thus, 1 g of almond powder was mineralized at 400°C for 2 h using concentrated sulfuric acid and potassium sulfate catalyst. The resulting solution was diluted with distilled water, mixed with sodium hydroxide, and then distilled for ten min. The distillate was collected into a flask containing boric acid and methylene bromocresol reagents, and the total nitrogen was titrated against a 0.01 N sulfuric acid solution.

The total nitrogen content was converted into proteins content [14] according to the equation mentioned hereafter.

\[ \text{PRC (g/100 g)} = \text{TNC} \times 6.25 \]  

With: PRC, proteins content; TNC, total nitrogen content (g/100 g).

2.6.2 Ash content

The ash content was measured by incineration of 5 g of almond powder in an electric muffle oven. The sample was beforehand carbonized on a Bunsen burner, and then placed into the oven at 550°C for 12 h. The ash consisting of the resulted white residue was weighed and expressed in percentage [14].

2.6.3 Crude fibers content

The determination of the crude fibers percentage consisted in treatment of 2 g of almonds with 50 mL of 0.25 N sulfuric acid and 50 mL of 0.31 N sodium hydroxide, and filtration of the mixture upon a Whatman paper. The residue was dried for 8 h at 105°C then incinerated at 550°C for 3 h into oven [14]. The crude fibers content was calculated according to the following formula:

\[ \text{Crude fibers contents (g) = } \frac{(m_1 - m_2) \times 100}{m_e} \]  

With: \( m_1 \), mass of oven dried residue (g); \( m_2 \), mass of the ash after incineration (g); \( m_e \), Mass of the test sample (g).

2.6.4 Fat content

The lipids were measured after solvent extraction using hexane and Soxhlet device for 7 h [14]. The hexan-oil mixture resulted from the extraction was separated with a rotavapor apparatus and the sample's weight difference before and after the process revealed the lipids content.

2.6.5 Carbohydrates contents

The total carbohydrates content was calculated according to the following formula provided by the FAO [15].

\[ \text{TCC (\%)} = 100 - [\text{PC+ LC + MC + AC+FC}] \]  

With: TCC, total carbohydrates content; PC, LC, MC FC, respective contents in proteins, lipid, moisture, and fibers.

Afterwards, the total ethanosoible carbohydrates were extracted according to the method of Agbo et al. [16]. Thus, 1 g of almond powder was treated with ethanol, zinc acetate, and oxalic acid solutions at respective concentrations of 80% (v/v), 10% (w/v), and 10% (m/v). The extract was centrifuged at 3,000 rpm for 10 min, and the ethanol residue was evaporated from the extract upon a hot sand bath. Then, the extracted total soluble sugars were measured out using phenol and sulfuric acid reagents [17] and spectrophotometer (PG instruments). The reducing carbohydrates content was also determined from the extract with 3, 5- dinitro-salycilic acid reagent [18] and spectrophotometer.

Prior to both total soluble and reducing carbohydrates contents determinations, calibrations were performed with standard solutions of glucose and sucrose.

2.6.6 Energy value

The caloric energy value of the almond samples was calculated using relating coefficients of the main macronutrients, namely proteins, carbohydrates, and oil [19] as stated below:

\[ \text{CEV (kcal/100 g)} = 4 \times \text{PR} + 4 \times \text{TCC} + 9 \times \text{OIC} \]  

With: CEV, caloric energy value; PRC, TCC, OIC, the respective contents in proteins, total carbohydrates, and oil.

2.7 Assessment of the Almond Oil Properties

2.7.1 Determination of acid, peroxide, iodine, saponification, and refractive values

The acid value was determined using raw almond oil treated with chloroform and ethanol
The deriving mixture was titrated with 0.05N sodium hydroxide [20], against a blank solution, and the acid value was calculated according to the following equation:

\[
FAV (%) = \frac{(Ve-Vo)*282*100}{1000M} \quad (6)
\]

With: \( FAV \), free acid value; \( Ve \), volume of the sodium hydroxide solution used to titrate the sample essay (mL); \( Vo \), volume of the sodium hydroxide solution used to titrate the blank solution (mL); \( N \), normality of sodium hydroxide solution (0.05N); 282, Molecular weight of oleic acid taken as standard acid; \( M \), mass of the sample (1 g).

Regarding the peroxide value, 0.94 g of almond oil was dissolved into acetic acid/chloroform solvents (2:1, v:v) mixture. To this solution, 1 mL of saturated potassium iodide, 35 mL of distilled water and 3 drops of 1% starch were added, and then titrated using 0.01N thiosulfate solution [21]. The derived peroxide value is given below.

\[
I_p = \frac{(Ve – Vo)*N*1000}{M} \quad (7)
\]

With: \( I_p \), peroxide value (g mEq \( O_2 \)/kg); \( Ve \), volume of the thiosulfate solution used to titrate the sample essay (mL); \( Vo \), volume of the thiosulfate solution used to titrate the blank sample (mL); \( N \), normality of the thiosulfate solution (Na\( _2 \)SO\( _3 \)); \( M \), mass of the sample (g).

For the iodine value, 0.6 g almond oil was dissolved into 15 mL chloroform, and then treated with 25 mL Wijs reagent and kept in darkness for 2 h. Thereafter, 20 mL of distilled water and few drops of starch were added, and the deriving mixture was titrated using 0.1N thiosulfate solution, against a blank essay [22]. The derived iodine value is given as below.

\[
I_i = 126.9 \times \frac{(Vo-Ve)*N*100}{1000M} \quad (8)
\]

With: \( I_i \), iodine value; 126.9 molar weight of iodine (g/mol); \( Vo \), volume of the thiosulfate solution used to titrate the blank sample (mL); \( Ve \), volume of the thiosulfate solution used to titrate the sample essay (mL); \( N \), normality of the thiosulfate solution (Na\( _2 \)SO\( _3 \)); \( M \), mass of the sample (g).

The determination of the saponification value was achieved with use of 0.8 g of almond oil dissolved into 10 mL of 0.5 N alcoholic potassium hydroxide, and then heated on a boiling water bath for 45 min. Afterwards, 5 mL of distilled water and 3 drops of 1% phenolphthalein were added, and the final mixture was titrated with 0.5 N hydrochloride acid against a blank sample [23]. The resulted saponification value is given by the following equation:

\[
I_s = \frac{(Vo – Ve)*N*40}{M} \quad (9)
\]

With: \( I_s \), saponification value (mg KOH/g); \( Vo \), volume of the hydrochloride acid solution used for titration of the blank sample (mL); \( Ve \), volume of hydrochloride acid solution used for titration of the sample essay (mL); \( N \), normality of hydrochloride acid solution (N=0.5); 40, molecular weight of KOH (g/mole); \( M \), mass of the sample (g).

The refractive index was also measured, using a refractometer (ABBE refractometer). A drop of oil was put on the planar section of the glass prism and then the apparatus was lightened with diverse-directed light rays. The refractive index of the oil resulted in the difference between two ranges (clear and dark) observed from the screen of the refractometer.

2.7.2 Fatty acids profile

The fatty acids profile was revealed by gas chromatography. Prior to analysis, the acid molecules were converted into methyl esters using a sodium-methanol mixture [24]. The chromatography analysis permitted to get graphs which peaks were identified compared to those of standard fatty acid methyl esters.

2.8 Statistical Analysis

The data were recorded on Excel software and statistically treated with Statistical Program for Social Sciences (SPSS 22.0 for Windows). Means and standard deviations of overall parameters were determined. The homogeneity of the values provided was estimated on the coefficient of variation (relative standard deviation) basis.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Traits of the \( T. \) catappa Fruits Almonds

The almonds extraction yield from the \( T. \) catappa fruits records mean of 1.95% with a little variation from experiments (RSD = 2.69%). These almonds display mean moisture value of 3.58%, whereas they’re also provided with 5.48% ash (Fig. 2).
3.2 Nutritive Compounds of the *T. catappa* Fruits Almonds

The main nutritive parameters of the *T. catappa* almonds are filled in Table 1. The results of the macromolecule nutrients analysis from the dry almond powder show main proteins content of 31.21%, while the fats account for 54.76%, and the total carbohydrates represent 3.81%. The carbohydrates are involved by 3.19% total soluble sugars content and 0.11% reducing carbohydrates content as shown in Table 1. Besides, 5.12% fibers are enclosed in the *T. catappa* almonds. On the main macromolecules basis, the studied almonds record a total caloric energy value of 596.92 Kcal/100 g.

The data from overall nutrients traits seem homogenous, since the relative standard deviations are between 0.20% and 5.09% (Table 1).

Table 1. Contents of nutritive compounds in the almonds of *T. catappa* fruits

| Parameters                  | Means ±SD  | RSD (%) |
|-----------------------------|------------|---------|
| Fat (%)                     | 54.76±0.28 | 0.53    |
| Proteins (%)                | 31.21±0.13 | 0.42    |
| Fibers (%)                  | 5.12±0.08  | 1.67    |
| Total carbohydrates (%)     | 3.81±0.33  | 2.37    |
| Total soluble carbohydrates (%) | 3.19±0.03 | 1.19    |
| Reducing carbohydrates (%)  | 0.11±0.00  | 5.09    |
| Caloric energy value (Kcal/100 g) | 596.92±1.32 | 0.20    |

With: SD: Standard deviation; RSD: Relative standard deviation

3.3 Chemical Properties of the Oil Derived from the *T. catappa* Fruits Almonds

The results from the oil properties analysis are displayed in Table 2. This caption reveals mean of 1.34% for the free acid value, while the saponification value records 122.21 mg KOH/g. From the peroxide, iodine, and refraction indexes, respective mean value of 6.27 g mEqO₂/kg oil, 87.00±0.21 g I₂/100 g oil, and 1.46 are also provided (Table 2).

Table 2. Main properties in oil of *T. catappa* almonds fruits

| Parameters                        | Means±SD   | RSD (%) |
|-----------------------------------|------------|---------|
| Acid value (%)                    | 1.34±0.15  | 1.32    |
| Saponification value (mg KOH/g oil) | 122.21±3.50 | 3.50    |
| Peroxide value (g mEqO₂/kg oil)   | 6.27±0.20  | 1.87    |
| Iodine value (g I₂/100 g oil)     | 87.00±0.21 | 2.12    |
| Refraction index                  | 1.46±0.02  | 0.98    |

With: SD: Standard deviation; RSD: Relative standard deviation

Regarding the unsaturated fatty acids, predominance of linoleic acid and oleic acid are evidenced with respective mean contents of 33.29% and 31.20%, whereas linolenic acid and palmitoleic acid record lower amounts (0.91% and 0.45%, respectively).

From the saturated fatty acids, the palmitic acid is more abundant (30.12%). Stearic acid and myristic acid account for 4.52% and 0.19% total fatty acids (Table 3).

3.4 Fatty Acids Profile of the Oil Derived from the *T. catappa* Fruits Almonds

The fatty acids of the oil extracted from the almonds studied are shown in Table 3. The profile reveals higher amount of unsaturated fatty acids (65.85%) compared to saturated fatty acids (34.83%).

3.5 Discussion

The moisture of the almonds studied (3.58%) is lower than the rate of 9.3% reported by Olatidoye et al. [25] from South-Western Nigeria. But, it’s comparable to that of 2.84% reported by Agatemor et al. [26] in India. Environmental relative humidity from various climates could result in different moisture contents of the crops.

However, the moisture found in the current work is below the maximal reference value (12%) set by the RDA [27] for the dry foods preservation. Hence, the dry almonds of *T. catappa* could be successfully preserved over months in Ivorian conditions.

These almonds are provided with 5.48% ash comparable to the respective 4.8% and 5.19% reported by Omeje et al. [28] and Udotong et al. [29]. Such ash values seem more significant than the 1.7% to 3.9% ash content from peanuts and cashew nuts [30,31] and [32], forecasting great minerals richness in almonds of *T. catappa* fruits.
Table 3. Fatty acids composition deriving from almond oil of *T. catappa* fruits

| Fatty acids            | Means±SD | RSD (%) |
|------------------------|----------|---------|
| Saturated fatty acids  |          |         |
| Lauric acid            | < LOQ    |         |
| Myristic acid [C14:0]  | 0.19±0.01| 7.90    |
| Palmitic acid [C16:0]  | 30.12±0.95| 3.16    |
| Stearic acid [C18:0]   | 4.52±0.16| 3.57    |
| Total saturated fatty  | 34.83±0.90| 2.60    |
| acids (%)              |          |         |
| Unsaturated fatty acids|          |         |
| Mono unsaturated fatty | 0.45±0.10| 22.22   |
| acids [C16:1 (n7)]     |          |         |
| Oleic acid [C18:1 (n9)]| 31.20±0.85| 2.73    |
| Total                  | 31.65±0.95| 3.01    |
| Poly unsaturated fatty | 33.29±0.70| 2.13    |
| acids [C18:2 (n6)]     |          |         |
| Linolenic acid [C18:3 (n3)]| 0.91±0.07| 7.93    |
| Total                  | 34.20±0.68| 2.00    |
| Total unsaturated fatty| 65.50±0.81| 2.50    |
| acids (%)              |          |         |

LOQ: Limit of quantification; SD: Standard deviation; RSD: Relative standard deviation

The proteins content found in our study (31.21%) corroborates the 32.6% of proteins reported by Olatidoye et al. [25]. Thus, the investigated almonds are more provided with proteins compared to the results (14%-23%) reported by M’bah et al. [33] from raw *T. catappa* almonds in Nigeria. They have also more proteins than cashew nuts and peanuts [31,32], and could therefore be better source of proteins since daily proteins intakes between 23 g and 36 g, and between 44 g and 56 g are recommended for respective children and adults persons [34] to fit the body needs such as the cellular structure maintenance and the growth [35].

Glucides are also found in the *T. catappa* almonds; accounting 5.12% fibers and 3.81% total carbohydrates. These traits are also more significant from *T. catappa* compared to the cashew nut and peanut [31,36]. Carbohydrates are easily digested to provide the organism with energy. Oppositely, the fibers are not digested but have due contribution for the bio-digestion of the macromolecule nutrients, prior to their physiological uses [37]. The almonds of *T. catappa* could be beneficial for digestion and energy needs. The consumption of 100g of these almonds provides the body with 596.92 kcal energy. Comparable energy values have been reported by Guillermo-Arrázola et al. [38] and Omeje et al. [28] from the same raw material.

Regarding the fat, content of 54.76% is recorded, compared to the 44.64% from study of Udotong et al. [29] and the 63.65% found by Monnet et al. [39] with the same raw material. Thus, these almonds are as richer in lipids as the cashew nuts [31] but more provided than soybeans [40]. Fats are important macromolecules since they strengthen the foods sensory traits and the bio-absorption of lipo-soluble vitamins [41]. The chemical properties of these almonds oil reveal the same free acid value (1.34±0.15%) reported by Olatidoye et al. [25], but lower than the 2.48% recorded from the cashew nuts [42]. It’s also below the standard free acid value (4%) requested by the codex alimentarius [43] for virgin oils; forecasting good quality for the oil of *T. catappa* fruits almonds. This statement is as obvious as the peroxide value (6.27 g mEq O₂/kg) is also lower than the maximal amount of 15 g mEq O₂/kg recommended for the oil quality.
According to the iodine value resulted from our work (87 g I₂/100 g oil), the oil extracted from the T. catappa almonds is classified as a non-drying oil since such oils display I<100 and refractive index within 1.467 and 1.478; whereas semi-drying oils have 100 < I<130, and drying oils have I>130 [44]. Thanks to this aspect, the almond oil can be recommended in the edible cream industries and as raw vegetable oil. This oil showed also lower saponification value (122.21 mg KOH/g) compared to other usual oils, namely the palm oil (196-205 mg KOH/g), the groundnut oil (188-196 mg KOH/g) and the coconut kernel oil (253 mg KOH/g) worked by authors [40,45] and [46] and which often have valorizations for the cosmetic industry. So, the almond oil of T. catappa is more suitable edible foodstuff than cosmetic raw material.

For the fatty acids profile, the study reveals 65.85% of unsaturated compounds, corroborating the 60% unsaturated fatty acids found by Dos Santos et al. [47] from the same raw material. Thus, the almonds oil is provided in unsaturated fatty acid over the palm oil (50%) but lower than the 85% mentioned from the soya oil by Campbel [48]. Unsaturated fatty acids are known as bio-functional molecule due to their role in the reduction of the blood LDL-cholesterol, the blood pressure, and the cardiovascular diseases [49]. These physiological roles are more fitted with the polyunsaturated fatty acid, especially the linoleic acid really represented in the almond oil studied (33.29%), accordingly to reports from previous attempts [12,47]. In addition, the oleic acid stated at 31.20% has importance in the blood pressure reduction by increasing the blood HDL cholesterol ratio [50]. The 34.83% of saturated fatty acids found in the almond oil are valuable energy sources for the body.

Otherwise, the differences observed between the nutritive parameters from other studied are related to various factors, as the plant crop, the agro-climatic conditions and the crop harvesting period [38].

4. CONCLUSION

The study of the physicochemical and nutritive properties of T. catappa L. almonds revealed 35.12% fibers, 5.48% ash, 3.81% total carbohydrates, and higher proteins content (31.21%) and oil content (50.76%). This oil records good physicochemical properties as edible oil. It contains 65.85% unsaturated fatty acids, especially linoleic acid (33.29%) and oleic acid (31.20%) that are significant traits of good quality edible oil.

The almonds deriving from fruits of T. catappa could therefore be recommended for nutritional purposes in order to improve populations’ diet and such uses could provide producers with significant incomes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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