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Antioxidants Contents of *Terminalia catappa* (*Combretaceae*) Almonds Grown 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 KKAC, NY, KC, 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.

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ABSTRACT

Aims: To determine the antioxidants contents of almonds from fruits of *Terminalia catappa* L. (Combretaceae) grown in Côte d'Ivoire.
Study Design: The almonds of *T. catappa* were removed from the dried mature fruits harvested in different regions of Côte d'Ivoire. A pool of almonds was drawn at Laboratory and the antioxidants

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components were determined.
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 antioxidant component assessed were phenolic compounds (polyphenol, flavonoid), vitamins (ß-carotene and E), minerals (Fe, Zn, Mn and Cu) and polyunsatured fatty acids (linoleic and linolenic acids). The antioxidant activity was also determined.
Results: The results showed that the content of total polyphenol and total flavonoid varies from 1.05 to 7.28 g EAG/l, 0.25 to 0.5g EQ/l. Vitamins ß-carotene and vitamin E were revealed with 1.25±0.06 ER/100g and 1.19±0.12 µg/100g respectively. The sample also revealed means of 7.66±0.21 mg/100g Fe, 0.96±0.32 mg/100g Zn, 13.6±0.5 mg/100g Cu, 0.05±0.002 mg/100g Se and 6.84±0.17 mg/100g Mn. The unsaturated fatty acids profile showed linoleic and linolenic acids with respective rates of 33.29±0.7% and 0.91±0.07%. Finally the antioxidant activity was 2.22 mg/l.
Conclusion: The almonds of *T. catappa* and their unsaturated oil are very good sources of phenolic compounds and interesting mineral and vitamin nutrients for human body as useful dietary supplements and good health.

Keywords: Antioxidants; almonds; Terminalia catappa; Côte d'Ivoire.

1. INTRODUCTION

Natural antioxidants are increasingly appreciated by consumers due to both their inherent positive effects and to the possibility of using them as a source of natural additives to replace synthetic ones [1,2]. The main dietary sources of antioxidants compounds are fruits, beverages, cereals, chocolate, and dry legumes [3,4]. Antioxidant activity of fruits and vegetables is generally positively correlated with their content of polyphenols [4]. The total dietary intake of polyphenols is about 1 g/day [4,5]. It is much higher than that of all other known dietary antioxidants, about 10 times higher than that of vitamin C and 100 times higher than those of vitamin E and carotenoids [6].

Antioxidants are radical scavengers which protect the human body against free radicals that may cause pathological conditions such as ischemia, asthma, arthritis, inflammation, neurodegeneration [7]. According to Momo et al. [8], the new strategies for alleviating the oxidative damage in diseases, interest has grown in the usage of natural antioxidants. It has been postulated that supplementation with antioxidants such as vitamin A, E, C and other no-nutrient antioxidant such as plant derived natural antioxidants have been shown to reduce the oxidative stress [9,10]. Some essential minerals such as Selenium (Se), Manganese (Mn) and iron (Fe) and unsaturated fatty acids show recognized antioxidant properties [11]. Thus, there is high demand for natural antioxidants in the food, cosmetic and therapeutic industries, due to their low cost, high stability, high compatibility with dietary intake and no harmful effect to the human body.

Plants like *Terminalia catappa* are used by tradomedical practitioner in African country for the management of a lot of diseases such as diabetes, sexual inadequacies, cancer [12,13]. *Terminalia catappa* is a tropical tree of the *Combretaceae* family encountered in many tropical regions [14,15]. Different parts of this plant have long been used as folk medicine in India, Philippines, Malaysia, Indonesia, Benin for antidiarrhoetic, antipyretic, anti-inflammatory, anti-carcinogenic and haemostatic purposes [16,14,13]. Various studies on the chemical composition and nutritional value have been carried out. The results of various investigations revealed the presence of flavonoids, alkaloids, anthraquinones, terpenoids and steroids [17,18,19, 20]. According to some authors, the nutritive compounds and mineral profile determined are very interesting for human health [21,22,13]. However, despite its many nutritional benefits and its beneficial effects on health, processing of *Terminalia catappa* is not widespread and its consumption is limited to a few fruits picked up by children under this tropical tree, mostly used for ornamentation purposes [23]. This has enabled recent studies in Côte d'Ivoire in order to enhance *Terminalia catappa* almonds.

Thus, only few reports exist in Côte d'Ivoire concerning the chemical compositions and antioxidant capacity of *T. catappa* almonds. Indeed, Biego et al. [14] studied the Physicochemical Quality of kernels from *Terminalia catappa* L. and sensory evaluation of the Concocted kernels. As for Douati et al. [24], they showed that *Terminalia catappa* kernels and oil extracted there from contained saturated fatty acids (34.83%) and unsaturated fatty acids (65.50%), nutritive compounds such as proteins (31.21%), fibers (5.12%), total carbohydrates (3.81%) and fat (54.76%). According the literature, data concerning the antioxidant capacity of *Terminalia catappa* extracts from Côte d'Ivoire are not available. This study was therefore undertaken to screening different extracts of *T. catappa* almonds and quantifies their antioxidant capacity.

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 dried fruits of *T. catappa* were collected October to December in the regions of tonkpi (Man, Danané) and Guemon (Duékoué) of the Côte d'Ivoire from producers. In each city, 3 suppliers were considered. At these last, 60 kg of dried fruits were collected. Thus, a total of 540 kg of dried fruit of *T. catappa* was collected and crushed in the laboratory for analysis.

2.3 Treatment of Dried Fruits of *T. catappa*

The treatment diagram of the fruits of *T. catappa* is detailed in Fig. 1. The dried fruits of *T. catappa* were opened using nutcracker. The extracted almonds were dried at 50℃. for 48 h in an oven (MEMMERT, Germany). After cooling, they were crushed (Magimix Crusher) before being stored in sealed polyethylene bags and then stored in a desiccator before analysis.

2.4 Determination of Minerals

Minerals were determined by acid digestion method [25]. The minerals were analyzed by dry ashing the samples at 550℃ to constant weight in an oven for 24 h. After cooling at room temperature, 5 ml of hydrochloric acid (0.1 M) was added and the mixture was returned to the oven at 400℃ for 30 minutes. The residue was recovered with 30 mL of a solution of 1 M hydrochloric acid and then up to 50 ml with distillated water. The contents of minerals were determined by an Energy dispersive spectrophotometer (EDS) coupled to a scanning electron microscope (SEM) with an X-ray detector (Oxford instruments) connected to a platform of micro-analysts (Inca cool dry, without liquid nitrogen). Absorbance was measured at 213.9 nm, 324.8 nm, 248.3 nm and 279.9 nm for Zn, Cu, Fe and Mn, respectively. All chemical used were of analytical grade and analysis were carried out at least in triplicate.

2.5 Determination of Vitamins

HPLC-DAD analyses were performed according to the method described by NFV03-110 [26]. The samples (20 µL) were injected on a reverse phase column Kromasil C_{18}, 30 x4 mm (CIL CUZEAV) with a manual injector. Experiments were conducted on a High Performance Liquid Chromatographic (HPLC, Mark Water Alliance) system equipped with an UV/PDA detector. Vitamins (A and E) were separated at room temperature with a mobile phase of acetonitrile and methanol (80/20, v/v), isocratic elution system. The flow rate was set at 1.0 $mL.min^{-1}$ and the detection wavelength was carried out at 445 nm and 245 nm for vitamin A and vitamin E, respectively. A total time required for the analysis was 35 min. External standard linear calibration plots were performed with each standard at different concentrations (0-125 µg/ml). The chromatograms were identified and confirmed by quantitative result were expressed as. All analyses were achieved in triplicate.

2.6 Fatty Acids

The fatty acids profiles were obtained by gas-liquid chromatography of the fatty acid methyl ester derivatives. Firstly, *T. catappa* almonds powder was extracted with hexane in a Soxhlet apparatus, by the method described by AOAC (1975) [27], to give the oil. Fatty acid profiles were obtained by gas liquid chromatography of the fatty acid methyl ester derivatives. Fatty acids from the oil extract were firstly methylated and the fatty acid methyl esters obtained were separated and quantified with a gas liquid chromatography (6890 N, Agilent Technologies, USA) equipped with a flame ionization detector, an automatic injector (Agilent 7683, USA) and a supelcowax column (60 m x 0,25 mm x 0,2 µm).

The system used H_2 as the carrier gas and operated at a constant pressure of 200 kPa. The column temperature was fixed and maintained at 180℃, while the temperature of the injector and the detector were at 260℃ and 250℃, respectively. Hydrogen flow to the detector was 30 ml/min and a calibration mixture of fatty acid standards was processed in parallel. The data were analyzed by using the Chemstations (USA) software. Each peak was identified and quantified by comparison of retention times with pure fatty acids methyl esters standards. Fatty acids are expressed as the percent of fatty acid quantified within individual sample.

2.7 Extraction and Determination of Phenolic Compounds

2.7.1 Extraction procedure

The extracts of almonds powder were prepared using different solvents (water, acidified water and ethanol). 10 g of sample was mixed with 50 ml of solvent with stirring (100 trs/min) at laboratory room temperature (22±2℃) for 30 min. The mixture was then centrifuged for 2 min at 2000 trs/min. Extracts obtained were filtered through a filter paper (Whatman No.1) and stored at 4℃ in refrigerator for subsequent determination.

2.7.2 Screening phytochemical

The phytochemical analysis of *T. catappa* almond extracts were carried out according to the standard method of Harborne [28] with slight modifications.

2.7.2.1 Test for polyphenols

A drop of a solution of 2% aqueous ferric chloride was added to 2 ml of the plant extract. The appearance of a darker or darker blue color indicates the presence of phenolic compounds.

2.7.2.2 Test for flavonoids

A small piece of magnesium ribbon was added to extract of the plant material, this was followed by the drop wise addition of concentrated hydrochloric acid. Colors varying from orange to red indicated flavones, red to crimson indicated flavonols, crimson to magenta indicated flavonones.

2.7.2.3 Test for alkaloids

6 mL of plant extract were dried on a sand bath. The residue was then taken up in 6 ml of ethanol at 60℃. Finally, 2 drops of dragendorff reagent

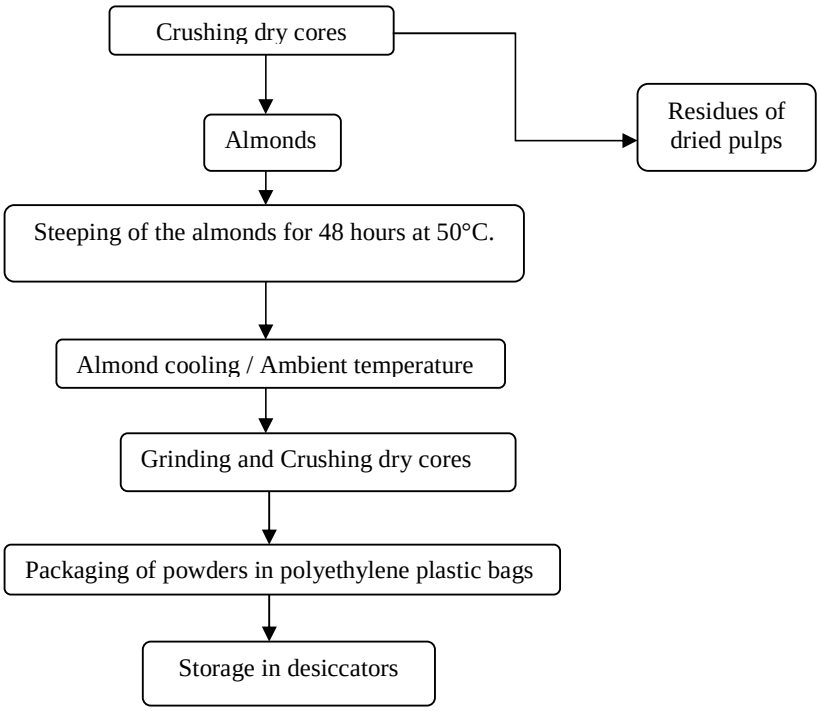

Fig. 1. Diagram for obtaining almond powder from *Terminalia catappa*

were added to the resulting solution. The appearance of a precipitate or an orange color indicated the presence of alkaloids.

2.7.2.4 Test for tannins

2.7.2.4.1 Tannins catechic

1 ml of freshly prepared 10% KOH was added to 1 ml of the extract. A dirty white precipitate indicated the presence of tannins.

2.7.2.4.2 Tannins gallic

Powdered of the test plant (1.0 g) was weighed into a beaker and 10 ml of distilled water added. Mixture was boiled for five minutes. Two drops of 5% FeCl3 were added. Production of greenish precipate indicated the presence of tannins.

2.7.2.5 Test for leucoanthocyanins

5 mL of hydrochloric acid and 1 mL of isoamyl alcohol were added to a test tube containing 2 mL of the evaporated plant extract. The mixture was then heated for 15 minutes in a water bath at 80℃ for 30 minutes. Production of a red-cherry or purplish coloration indicated the presence of leucoanthocyanins.

2.7.2.6 Test for saponin

Extract of the plant test was ground into powder and 0.5 g of the powder was introduced into a tube containing 5.0 ml of distilled water. The mixture was vigorously shaken for 2 min and the formation of froth indicated the presence of saponins.

2.7.3 Determination of phenolic compounds

2.7.3.1 Total polyphenols

Total polyphenols were determined by colorimetry, using the Singleton and Rossi method [29] modified by Wood *et al* [30]. Diluted Folin-Ciocalteu reagent (1/10, v/v, 2.5 mL) was added to 30 µL of sample. After 2 min of incubation in the dark at room temperature, 2 mL of aqueous sodium carbonate (75 g/L) was added. After gentle stirring, the mixture was incubated in a water bath at 50℃ for 15 min and rapidly cooled down to stop the reaction. The absorbance was measured at 760 nm with distilled water as blank. A calibration curve was performed with gallic acid at different concentrations (0-1 g/L). Analyses were performed in triplicate and polyphenols level was expressed in grams of gallic acid equivalent per liter of extract (g EAG /L).

2.7.3.2 Total flavonoids

Total flavonoids were determined by the method of Marinova et al. [31]. A volume of 0.75 mL of sodium nitrite ($NaNO_2$) to 5% (w/v) was added to 2.5 ml of extract in a 25 mL flask. The mixture was added 0.75 mL of aluminum chloride ($AlCl_3$) to 10% (m/v) and incubated for 6 minutes in the dark. After incubation, 5 ml of sodium hydroxide (NaOH 1N) were added and the volume made up to 25 mL. The mixture was stirred vigorously before being dosed with UV-Visible spectrophotometer. The reading was taken at 510 nm with distilled water as a blank. A calibration curve was performed with quercetin (0-1.5 g.L-1) at different concentrations (0, 0.15, 0.3, 0.9, 1.2, 1.5 g.L-1). The tests were performed in triplicate and the flavonoids content was expressed in g quercetin equivalents of extract (g QE/l).

2.8 Determination of Antioxidant Activity

ABTS radical activity of *T. catappa* almonds extracts were determined according to the method described by Teow et al. [32] with slight modification. $ABTS^{\bullet+}$ solution was freshly prepared by mixing equal volume of 8 mM ABTS solution and 3 mM potassium persulfate solution and the resulting solution was kept for 16 h in dark at room temperature (27±2℃). This solution was diluted with methanol to yield an absorbance of 0.700±0.02 at 734 nm and the same solution was used for the antioxidant activity. A sample volume of 0.1ml was mixed with 3.9ml of diluted $ABTS^{\bullet+}$ stock solution and the mixture was incubated for 6 min exactly, in the dark at 27±2℃. Absorbance was measured at 734 nm, and had to be higher than 20% of the absorbance of the diluted $ABTS^{\bullet+}$ stock solution itself, otherwise the sample solution had to be diluted accordingly. Pure methanol was used as a blank solution. Trolox solutions with concentrations ranging from 0 to 500 µmol/l were used as the standard. TEAC was expressed as µmol/l TE (trolox equivalent). Samples were analyzed in triplicate.

2.9 Contributions Estimated in Anti-oxidants at the Ivorian Adult

The contributions in antioxidants have been estimated according to the method of the Codex Alimentarius that takes into account the concentrations in antioxidant recovered in the

food and the daily consumption of an adult individual of 70 kg of this food [33]. These quantities of foods are given by World Health organization studies [33]. The contribution of this food in daily requirement has been calculated also from the values of daily recommended intakes [34].

Estimated Daily Intake (EDI) = C × Q

Contribution (%) = (EDI × 100)/DRI

C: antioxidant concentration measured

Q: food daily consumption

DRI: Daily Recommended Intake

2.10 Statistical Analysis

All experiments were done in triplicate and data in tables and figures represent mean values ± standard deviation (n= 3). The statistical analyses were performed by MS Excel 2007 software. Comparison of mean values of measured parameters was performed by a one-way ANOVA (STATISTICA, version 7.1) using LSD test, for the level of significance P=0.05.

3. RESULTS

3.1 Minerals Contents

The results indicate the minerals (Cu, Fe, Mn, Zn and Se) with statistically different grades in the samples ($p < 0.001$). The contents vary from 0.05±0.002 to 13.60 ±10.74 mg/100 g. Copper provides the highest concentration (average at 13.60±10.74 mg/100 g), iron , manganese and Zinc have respective concentrations of 7.66 ±0.22 and 6.84±0.20 mg/100g and 0.96±0.06 mg/100 g, whereas selenium is only 0.05±0.002 mg/100 g (Table 1).

3.2 Vitamins Contents

Analysis of the vitamin concentration in *Terminalia catappa* almonds powder reveals the ß-carotene and vitamin E with 1.25±0.06 ER/100g and 1.19±0.12 mg/100g respectively (Table 1).

3.3 Fatty Acids Contents

The polyunsaturated fatty acids (linoleic and linolenic) extract from *T. catappa* oil are obtained with 33.29±0.70 and 0.91±7.93 respectively (Table 2).

3.4 Phytochemical constituents

Table 3 shows the different compounds in the various extracts. Results indicate that all extract characterized contained total phenols, total flavonoids and alkaloids with a lack of saponins**.** The aqueous and acidified water extracts contained additionally leucoanthocyanins, gallic and catechic tannins.

3.5 Phenolic Compounds

Contents in total polyphenols and total flavonoids in different extract almonds are statistically different ($p < 0.001$). The total polyphenol content were in the order of acidified water (7.28±0.06 $g.l^{-1}$eqag) > water (2.88±0.11 $g.l^{-1}$ eqag) > ethanol (1.05±0.06 $g.l^{-1}$ eqag). For total flavonoids, content are 0.50±0.06, 0.25±0.01 and 0.25±0.01 $g.l^{-1}$ eq, for acidified water, water and ethanol extract, respectively (Table 4). Content obtained with acidified water are at least 2 fold higher than that obtained with the other solvent.

Table 1. Mineral and vitamin contents of *T. catappa* almonds

Minerals	Contents	RSD (%)	F	P
Copper (Cu) (mg/100g)	13.60±10.47[a]	78.97		
Iron (Fe) (mg/100g)	7.66 ±0.22[b]	82.81		
Zinc (Zn) (mg/100g)	0.96±0.06[d]	86.81	4483.54	<0.001
Manganese (Mn) (mg/100g)	6.84±0.20[c]	86.51		
Selenium (Se) (mg/100g)	0.05±0.002[e]	90.22		
Vitamins				
ß-carotene (ER /100g)	1.25±0.06[a]	86.81	1109.6	<0.001
Vit E (µg/100g)	1.19±0.12[b]	86.51		

Means ± standard deviations with the same lowercase letters are statistically identical at 5% significance. F, value of the statistical Ficher test, P, probability value of the statistical test; RSD, relative standard deviation

3.6 Antioxidant Activity

Table 4 shows antioxidant activity in the different extract. This activity is high in acidified water (2.22 mg/L TE) but decrease respectively in aqueous (1.8 mg/L TE) and ethanol (1 mg/L TE).

The intakes of antioxidants estimated for the average daily consumption of 1 g of almond of *T. catappa* for an adult Ivorian is presented in table 5. Estimated intake of antioxidants minerals fluctuate between 0.0005±0.01 (Se) and 0.13±0.01 mg (Cu). However, vitamins ß-caroten and E, have respective low estimated intakes of 0.012 ± 0.2ER/d and 0.012 ± 0.03µg/d. Estimated intakes of phenolics compounds fluctuate between 0.07±0.01 $g.L^{-1}$EQAG/d (polyphenols) and 0.005 ±0.1 $g.L^{-1}$EqQuerc/d (flavonoids). linoleic acid and linolenic acid have respective estimated intake of 0.33±0.03 mg/day and 0.01±0.02 mg/d.

The determined contributions are presented in table 5. These values indicate that with the exception of zinc (0, 1%), of ß-caroten (0.0015±0.01%) and vitamin E (with 0, 1%) the contributions are all superior to the 0, 1% of the almonds of *T. catappa* in the daily general food. Also, the cover of the needs to copper even culminates to 13%.

4. DISCUSSION

In this work, the values detected for minerals (Cu, Fe, Zn, Se and Mn), were generally higher than those obtained by some authors [18,35,22,13]. The results of the estimation of the mineral elements indicated that the level of the elements were as follow Cu > Fe > Mn > Zn>Se

Table 2. Polyunsatured fatty acids contents of oil from *T. catappa* almonds

Polyunsatured fatty acids	Means±SD	RSD (%)
linoleic acid [c18:2 (n6)]	33.29±0.70	2.13
linolenic acid [c18:3 (n3)]	0.91±0.07	7.93
Total	34.20±0.68	2.00

With SD: standard deviation; RSD: relative standard deviation

Table 3. Phytochemical screening of *Terminalia catappa* almonds

Constituents	Ethanol extract	Aqueous extract	Acidified water extract
Total phénol	+	++	+++
Total flavonoids	+	++	+++
Tannins gallic	-	+	++
Tannins catechic	-	+	+
Leucoanthocyanins	-	+	++
Saponins	-	-	-
Alkaloids	+	+	+

+++: most abundant, ++: abundant, +: present, -: absent

Table 4. Polyphenols, flavonoids contents and antioxidants activity of extracts of *T. catappa* almonds

Parameters	Different extracts			Statistical parameters	
	Acidified water extract	Aqueous extract	Ethanol extract	F	p
Totals Polyphénols ($g.L^{-1}$EQAG)	7,28±0,06[a]	2,88±0,11[b]	1,05±0,06[c]	1015,21	<0,001
Totals Flavonoids (g.L^{-1}EqQuerc)	0,50±0,06[a]	0,25±0,01[b]	0,25±0,01[b]	396,12	<0,001
Antioxidants activity (mg/LTE)	2,22±0,10[a]	1,8±0,3[b]	1±0,1[c]	597,16	<0,001

Means ± standard deviations with the same lowercase letters are statistically identical at 5% significance. F, value of the statistical Ficher test, P, probability value of the statistical test.

Table 5. Antioxidants (Minerals, vitamins, phenolic compounds and polyunsatured fatty acids) intake recommendations (mg / day) and contribution of *T. catappa* almonds (%) in their recovery

Parameters	Estimated intake	RDI	Contribution (%)
Cu (mg/d)	0.13±0.01	1	13±10
Fe (mg/d)	0.07±0.01	14	0.5±0.01
Zn (mg/d)	0.01±0.01	10	0.1±0.01
Mn (mg/d)	0.07±0.01	2	3.5±0.01
Se (mg/d)	0.0005±0.01	0.07	0,71±0.01
ß-caroten(ER/d)	0.012±0.2	800	0.0015±0.01
Vit E (µg/d)	0.012±0.03	2	0.1±0.01
Polyphenols (g.L-1EQAG/d)	0.07±0.01	1	7±0.01
Flavonoids (g.L-1EqQuerc/d)	0.005±0.1	0.181	2.76±0.05
linoleic acid [c18:2 (n6)]	0.33±0.03	10	3.3±0.3
linolenic acid [c18:3 (n3)]	0.01±0.02	2	0.5±0.1

RDI: Recommended daily intake

with values of 13.6, 7.66, 6.84, 0.96 and 0.05 mg/100 g, respectively. According to Mc Dowell et al. [11], several metalloenzymes which include glutathione peroxidase (Se), catalase (Fe), and superoxide dismutase (Cu, Zn, and Mn) are also critical in protecting the internal cellular constituents from oxidative damage. *Terminalia catappa almonds could be recommended as a* dietary supplement for people who need iron and those dwelling in the rural areas that live in poverty and even urban dwellers. This shows that these seeds are very rich in iron; and iron is very important for the formation of haemoglobin and normal functioning of the central nervous system [22].

The content of β-carotene in this study is higher than those obtained by Udotong and Bassey [35] and Dau et al. [22]. According to Oruch and Pryme [36], vitamin A plays key role in visual processes. It promotes growth and differentiation of cellular epithelium. While, the content of vitamin E is much lower than that obtained by Dau et al. [22]. According to Baldi et al. [37] and McDowell et al. [11], vitamin E functions as a membrane bound antioxidant, trapping lipid peroxyl free radicals produced from unsaturated fatty acids under conditions of oxidative stress. The presence of these vitamins could thus positively influence the antioxidant power of the extracts obtained from the almonds.

Polyunsaturated fatty acids (PUFAs) are essential for survival of humans and other mammals and they cannot be synthesized in the body and hence, have to be obtained in our diet and thus, are essential [38]. Essential fatty acids form an important constituent of all cell membranes, and confer on membranes properties of fluidity and thus, determine and influence the behaviour of membrane-bound enzymes and receptors [39]. There are two types of naturally occurring essential fatty acids in the body, the ω-6 series derived from linoleic acid [C18:2, (n6)] and the ω-3 series derived from α-linolenic acid [C18:3, (n3)] [39]. In our study, the values detected for these two essentials fatty acids are 33.29 and 0.91 g/100g for linoleic and linolenic acid, respectively. These data are more 2 folds higher than those obtained by Ladele et al. [13]. The high level of the PUFAs makes this oil consumption beneficial for health. It is noted that these molecules have a similar action to that of hormones and regulate physiological functions as fundamental as smooth muscle contraction, reproduction, blood coagulation, inflammation, neuronal activity [40]. PUFAs and their oxygenated derivatives also regulate multiple metabolic pathways by modulating certain intracellular signaling processes, as well as the expression of target genes via specific activation of transcription factors [41].

The phytochemical constituents in *Terminalia catappa* almonds have been reported to several biological activities [19]. The phytochemical results observed are similar to those observed by Krishnaveni et al. [20] and Ladele et al. [13]. These families of identified molecules are responsible for most of the antioxidant properties attributed to *Terminalia catappa* almonds. According to the literature, polyphenolics compounds (flavonoids and tannins) are anti-cancergenics, anti-ulcerous, anti-inflammatory, analgesics, vasodilators, antiviral activities [20]. The majority of alkaloids have biologically active

and heterocyclic chemical compound which contains nitrogen and may some pharmacological activity and, in many cases, medicinal or ecological use [42]. Many synthetic and semi-synthetic drugs are structural modifications of the alkaloids, which were designed to enhance or change the primary effect of the drug and reduce unwanted side-effects [43]. According to Hesse [44] and Anizweski [42], alkaloids are stimulant, analgesic, anticholinergic, vasodilator, muscle relaxant, aphrodisiac. Thus, *Teminalia catappa* could be considered as source of antioxidants compounds [35,13], and its consumption could allow the maintenance of the organism in a good state of health.

Three solvents were used to extract secondary metabolites from *Teminalia catappa* almonds: Water, Water/ citric acid (0.01 N) and ethanol. Results showed that content obtained with acidified water are at least 2 fold higher than that obtained with the other solvents. According to Naczk and Shahidi [45], Jerez et al. [46] and Koffi et al. [47], the extraction of phenolic compounds in plant material is influenced by the extraction solvent: chemical composition, polarity, organic concentration, etc. The use of alcoholic solution provides satisfactory results [48,47], but sometimes, the acidification of the extraction solution would result in a greater embrittlement of the cell membranes and therefore the substantial release of the compounds into the extraction medium [49,47].

The antioxidant capacities determined are ranked in the same order as previously. Indeed, this is explain by the fact that the phenolic compounds represent the most active fraction of plant metabolites [4,50,51].

Although there is much research in human nutrition, bibliographic data on the estimation of antioxidants nutrient intakes are still very scarce. According to OMS [33], the daily consumption of almonds of *Terminalia catappa* is around 1 g for an average food intake of 1018.1 g. In this case, almonds represent a proportion of 0.1% of the daily diet of the populations. With the exception of zinc (0.1%), of ß-caroten (0.0015±0.01%) and vitamin E (with 0.1%) these contributions are all higher than 0.1% of the almonds of *T. catappa* in the daily general diet. Coverage of copper, polyphenols and flavonoids requirements are even at 13%, 7% and 2.76%. This testifies to the antioxidants richness of *T. catappa* almonds.

5. CONCLUSION

Terminalia catappa almonds, very appreciated by African children, possess good nutritional properties similar to other groundnut. In this study, results obtained reveal that *T. catappa* almonds contains substantially large proportion of active compounds such as polyphenols (flavonoids in particular), essential minerals (Cu, Zn, Fe and Mn), essential fatty acids and alkaloids which possess recognized antioxidant properties. These compounds therefore contribute to the fight against specific diseases associated with oxidative stress and able to satisfy nutrient needs provided that the daily consumption is much more important. *Terminalia catappa* are thus significant source of antioxidant for human health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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