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Physicochemical characteristics of *Terminalia catappa* (Combretaceae) almond flour harvested in the Plateau district of Côte d'Ivoire

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Abstract

This work was initiated to highlight the physicochemical characteristics of *Terminalia catappa* almond flour. The standard methods (AOAC) were used to determine the physicochemical composition. The physicochemical analysis of 100 g of almond flour from *Terminalia catappa* revealed a high protein (24.22%), high fat (55.65%), ash (4.1%), fibre (6.5%) and low carbohydrate (10.36%) content with an energy value of 639.1 Kcal/100 g. The amino acid profile of *Terminalia catappa* almond meal indicated a total essential amino acid level of 15.58 mg/100g protein and non-essential amino acids were 16.45 mg/100g protein. The fatty acid profile was composed of eight (8) saturated fatty acids, three (3) unsaturated fatty acids and one polyunsaturated. Statistical analysis reveals that the calcium (552.54 ± 0.03 mg/100g), potassium (675.65 ± 0.02 mg/100g), zinc (5.24 ± 0.02 mg/100g), magnesium (401.15 ± 0.05 mg/100g), iron (7.12±0.04 mg/100g) and manganese (10.21 ± 0.03 mg/100g) contents of *Terminalia catappa* flour were significantly ($p < 0.05$) different. The molar ratios of Phytates/Iron, Phytates/Zinc and Oxalate/Calcium show that the flour of the almond of *Terminalia catappa* could not interfere with the assimilation of iron and zinc. Therefore, the substitution of flour from *Terminalia catappa* almond to wheat for experimentation in nutrition and food technology would be an alternative in the fight against protein-energy malnutrition.

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Introduction

Human communities in Africa benefit from multi-purpose woody species because of their contribution to meeting food, health, energy and other aspects of human health Tourey *et al.* (2021). Some of these species are known for their fruits, which have great potential in many sectors, while others remain discreet Aboudou *et al.* (2017). Among the latter, the tree of *Terminalia catappa* stands out because of its considerable productivity in almost unexploited fruits.

Terminalia catappa is a species of plant in the family Combretaceae, native to South Asia and cultivated in tropical regions. In Côte d'Ivoire, this culture was introduced through urban ornamentation during the colonial period. This tree (*Terminalia catappa*) can reach a height of 8 meters when adult, presenting a spiral phyllotaxy. Fruits consist of a pulp that covers the shell of a nut containing an edible almond (Etienne *et al.*, 2017). Green when not ripe and yellow or red when ripe (Udotong *et al.*, 2015).

Extensive research has shown that this almond contains a large amount of nutrients such as protein (18.39-40.9%) and lipids (43.36-63.65%), followed by 9.97% dietary fibre, 7.68% carbohydrates, 6.23% moisture and 3.78% ash (Monnet *et al.*, 2012; Adepoju *et al.*, 2014; Ng *et al.*, 2015; Ladele *et al.*, 2016; Santos *et al.*, 2020).

According to some authors, the nutrient compound determined are of major interest for human health. However, despite its many nutritional and health benefits, *Terminalia catappa* is not commonly processed and its consumption is limited to a few fruits collected by children under this tropical tree (Etienne *et al.*, 2017).

Consequently, a substitution of *Terminalia catappa* almond flour for other widely consumed flours such as wheat could serve as an alternative to treat malnutrition. This study therefore aims to promote the consumption of *Terminalia catappa* almond in the treatment of protein-energy malnutrition. This study will enable us to determine the physico-chemical and specific composition of *Terminalia catappa* almond flour, in order to obtain more information on its benefits and nutritional content, with a view to enhancing its value.

Materials and methods

Biological material

Terminalia catappa fruits were collected from under trees in the Plateau commune (Abidjan, Côte d'Ivoire) during the month of November 2021 to January 2022. Wheat flour type 45 (Wheat flour Doucine) was purchased commercially in Abidjan, Côte d'Ivoire.

Terminalia catappa flour production

Terminalia catappa fruits are dried for three weeks in the sun, then crushed to obtain the kernels. Once extracted, the almonds were dried using the method used by Etienne *et al.* (2017) at 50°C for 48 hours in the oven (MEMMERT, Germany). After ambient cooling, they were ground using a blender (BINATONE Brender with grinder), kept in sealed polyethylene bags and stored in a dry place (dryer) until analysis.

Determination of the physico-chemical composition of Terminalia catappa almond flour and wheat

Moisture content was determined by drying at 105°C for 24 h AOAC (2004). The dry matter content is obtained by subtracting the moisture content of 100%. The method used to determine lipid content is that of Soxhlet AOAC (2004). The Kjeldahl method is used to calculate the amount of protein considered as total nitrogen in each flour sample. The carbohydrate content is assessed using the difference method. Ash content was determined by incinerating a capsule containing the sample in a muffle furnace at a temperature of 550°C for 12 hours (AOAC, 2004). Crude fiber content, total energy value, pH and titratable acidity were also determined using the AOAC (2004) method.

The total sugar content is determined by the phenol-sulfuric method described by Dubois *et al.* (1956), and the quantification of reducing sugars by the method of Bernfeld (1955).

Determination of specific chemical composition

Determining amino acid profile

Amino acids are determined by high-performance liquid chromatography (HPLC). One (1) g of flour delipidated with 10 ml of HCl (6N), was dried at 110°C in an oven for 24 h, then under nitrogen flow. The dry residue was taken up in 10 ml of 0.2 N sodium citrate at pH 2.3. The homogenized mixture was centrifuged at 3,000 rpm for 25 min at 0°C. The collected supernatant was filtered through Whatman n°4 paper and then through a 0.45 µm millipore filter (Sartorius AG, Goëttingen, Germany). Treated supernatants were stored at -20°C prior to analysis. The amino acid composition of the samples was determined after hydrolysis with 6 M HCl with phenol (1%) at 150° C for 60 minutes. Analyses were performed in triplicate.

The identification of amino acids in the various samples was carried out by comparing the retention times of the eluted compounds with the retention times of the reference solutions.

Amino acid concentrations in the flour samples studied were determined from the average of the peak areas of the reference (control) solutions. The chemical index is the lowest percentage of an essential amino acid in relation to the reference protein (1998), and the calculated biological value is the difference between 100% and the chemical index.

Determination of fatty acid profile

Free and total fatty acid methyl esters were analyzed with a GC system using an HP 6890 gas chromatograph. Representative methyl ester peaks were identified using reference substances (methyl esters) and this was achieved by comparing the retention times of each peak in the chromatogram with those obtained for the standards. The volume of esterified sample injected was one microliter (1 µL).

Physicochemical characteristics of fats

The iodine index, which corresponds to the number of grams of iodine fixed per 100 g of oily fat, was calculated using the standard analytical method ISO 3596 (1996). Standard analytical method ISO 3960 (2016) was used to assess the peroxide value, which corresponds to the amount of peroxidized active oxygen present in 1 kg of fat. The saponification index was assessed using the ISO 3657 (2016) analysis method. Standard analytical method ISO 660 (2016) was used to determine the acid number. A multi-scale refractometer RFM 81 (Automatic Refractometer) was used to measure refractive index, in accordance with standard analysis method ISO 6320 (2000). Color measurements were carried out using a colorimeter (Lovibond RT Color Measurement Kit V2.28) with a 10° viewing window and a typical D65 light source.

Determination of mineral elements

The minerals calcium, potassium, zinc, magnesium, sodium, copper, iron, manganese and phosphorus were determined using a Perkin Elmer AAS 800 atomic absorption spectrophotometer (Groegaert, 1958).

Determining anti-nutritional factors

Flavonoids were quantified spectrophotometrically as described by Gorinstein *et al.* (2007). The methods described by Belem-Kabré *et al.* (2020) were used to determine tannins. Phytates are quantified by the method of Latta *et al.* (1980), based on the decoloration of Wade's reagent by phytates. Oxalates are quantified according to the method of Day *et al.* (1986) using potassium permanganate ($KMnO_4$).

Calculation of molar ratios and assimilation index

Phytate/iron molar ratio

The Phytate/Fer molar ratio was calculated according to the formula of Harland *et al.* (2004).

Phytate/iron molar ratio = (PC / MMP) / (IC / AMI)

PC : Phytate content; MMP : Molar mass of phytic acid (660,04 g/mol) ;

IC : Iron content ; AMI : Atomic mass of iron (55,84 g/mol).

Phytate/Zinc molar ratio

The Phytate/Zinc molar ratio was determined using the equation of Harland *et al.* (2004)

Phytate/Zinc molar ratio = (PC / MMP) / (ZnC / AMZn)

PC : Phytate content; MMP : Molar mass of phytic acid (660,04 g/mol) ;

ZnC : Zinc content ; AMZn : Zinc atomic mass (65,38 g/mol).

Calcium assimilation index

Calcium assimilation index (CI/CaC) was determined by calculation of Tchiégang *et al.* (2004).

Calcium assimilation index = OC / CaC

OC : Oxalate content;

CaC : Calcium content

Statistical analysis

The results obtained were processed with GRAPH PAD Prism 8.0 software and an analysis of variance was performed using ANOVA. Statistical analysis of differences between means was performed using the Newman-Keuls Test. Differences were considered significant for $p < 0.05$.

Results

Physico-chemical composition of Terminalia catappa almond flour

The results of the analyses show a significant difference ($p<0.05$) between the values of the parameters analyzed (Table 1).

Table 1. Physico-chemical composition of *Terminalia catappa* almond flour

Parameters	*Terminalia catappa* almond flour
Humidity (g/100 g)	5,67 ± 0,07[a]
Dry matter (g/100 g)	94,33 ± 0,07[a]
Protein (g/100 g)	24,22 ± 0,01[a]
Fat (g/100 g)	55,65 ± 0,05[a]
Ash (g/100 g)	4,10 ± 0,10[a]
Fibers (g/100 g)	6,50 ± 0,05[a]
Total sugars (g/100 g)	3,39 ± 0,18[a]
Reducing sugars (g/100 g)	1,60 ± 0,04[a]
Carbohydrate (g/100 g)	10,36 ± 0,01[a]
Energy values (Kcal/100 g)	639,10 ± 1,06[a]
Acidity (meq/100 g)	0,50 ± 0,01[a]
pH	5,76 ± 0,01[a]

Each value is the mean standard deviation of three determinations. a: there is no significant difference (p> 0.05) between two values of the same line surmounted by the same letter.

High dry matter content and low moisture content were observed at 94.33 ± 0.07 g/100g and 5.67 ± 0.07 g/100g respectively. *Terminalia catappa* almond flour contained considerable protein and fat content, with 24.22 ± 0.01 g/100g and 55.65 ± 0.05 g/100g respectively. On the other hand, it had a low total carbohydrate content (10.36 ± 0.01 g/100g). *Terminalia catappa* almond flour had an energy value of 639.1 ± 1.06 Kcal/100g. Terminalia catappa almond flour was slightly acidic, with a pH of 5.76.

Specific chemical composition of Terminalia catappa almond flour

Amino acid profile of Terminalia catappa almond flour

The amino acid profile of *Terminalia catappa* almond flour revealed the presence of 14 amino acids, including six (6) essential and eight (8) non-essential amino acids (Table 2).

Table 2. Amino acid profile of *Terminalia catappa* almond flour

Amino acids	*Terminalia catappa* flour (mg/100g protein)	Reference protein FAO (1998)
Leucine	5,02 ± 0,02	77
Lysine	2,89 ± 0,02	58
Isoleucine	2,99 ± 0,02	28
Methionine	0,85 ± 0,02	25
Threonine	2,00 ± 0,01	34
Histidine	1,83 ± 0,03	19
Essential amino acids	15,58	
Valine	2,73 ± 0,02	
Phenyle	4,22 ± 0,02	
Tyrosine	1,65 ± 0,03	
Proline	1,91 ± 0,02	
Alanine	1,73 ± 0,03	
Serine	2,35 ± 0,02	
Arginine	1,24 ± 0,01	
Cysteine	0,62 ± 001	
Total non-essential amino acids (%)	16,45	
Total amino acids (%)	32,03	
Chemical index (%)	3,4	
Biological value (%)	96,6	

Values are the mean ± standard deviation of three determinations.

Total essential amino acids were 15.58 mg/100g protein. The level of non-essential amino acids was 16.45

mg/100g protein. Among the essential amino acids, methionine was the lowest at 0.85 ± 0.02 mg/100g protein, while leucine was the highest at 5.02 ± 0.02 mg/100g protein. The chemical index of Terminalia catappa almond flour was 3.40%, while the biological value was 96.60%.

Fatty acid profile of Terminalia catappa almond flour

The fatty acid profile of *Terminalia catappa* almond meal revealed eleven (11) fatty acids of varying proportions. This fatty acid profile was made up of eight (8) saturated fatty acids: caproic acid, lauric acid, capric acid, myristic acid, margaric acid, arachidic acid, palmitic acid and stearic acid. There were three (3) unsaturated fatty acids, including a monounsaturated one (oleic acid) and a polyunsaturated one (linoleic acid). The degree of saturation indicated that this fat was composed of 34.54% saturated fatty acids and 64.07% unsaturated fatty acids, including 31.30% monounsaturated fatty acids and 32.36% polyunsaturated fatty acids (Table 3).

Table 3. Fatty acid profile of *Terminalia catappa* almond meal

Fatty acids	*Terminalia catappa* almond flour
Lauric acids (C12)	0,17 ± 0,01
Capric acids (C10)	0,06 ± 0,01
Myristic acids (C14)	0,18 ± 0,01
Margaric acids (C17)	0,08 ± 0,01
Arachidic Acids (C20)	0,42 ± 0,01
Palmitic acids (C16 :0)	30,48 ± 0,68
Stearic Acids (C18 :0)	3,95 ± 0,01
Total saturated fatty acids	35,43 %
Palmitoleic acids (16 :1 n-7)	0,41 ± 0,02
Oleic Acids (cis 18 :1)	31,30 ± 0,57
Linoleic Acids (18 :2 n-6)	32,36 ± 0,33
Unsaturated fatty acids (%)	64,07
Monounsaturated fatty acids (%)	31,30
Polyunsaturated fatty acids (%)	32,36

Fatty acid values are the mean ± standard deviation of three determinations. (-) : Not detected

Physico-chemical characteristics of almond flour fat

The physico-chemical characteristics of *Terminalia catappa* almond meal fat are presented in Table 4. The fat derived from *Terminalia catappa* almond flour was gray in color, with a semi-solid appearance. This fat had a refractive index of 1.10 ± 0.01, an acid value of 3.35 ± 0.02 mg KOH/g fat and an oleic acidity of 1.68 ± 0.01%. The saponification value was 179.6 ± 0.02 mg KOH/g fat and the unsaponifiable matter content was 1.81 ± 0.01%. The iodine and peroxide indices of *Terminalia catappa* almond meal fat were 10.08 ± 0.01 g iodine/100 g fat and 1.35 ± 0.02 meq oxygen/kg fat respectively.

Table 4. Physico-chemical characteristics of *Terminalia catappa* almond meal fat

Physico-chemical characteristics	Parameter qualities & values
Color	Grey-orange
Aspect	Semi-solid
Refractive index	1,10 ± 0,01
Acid value (mg KOH/g fat)	3,35 ± 0,02
Oleic acidity (%)	1,68 ± 0,01
Saponification index (mg KOH/g fat)	179,60 ± 0,02[a]
Unsaponifiable matter content (%)	1,81 ± 0,01
Iodine index (g iodine/100 g fat)	10,08 ± 0,01
Peroxide value (meq oxygen/fat)	1,35 ± 0,02

Each value is the mean ± standard deviation of three determinations.

Mineral composition of Terminalia catappa almond flour

The mineral composition of *Terminalia catappa* flour is shown in Table 5. The various analyses revealed minerals such as calcium, potassium, zinc, magnesium, sodium, copper, iron, manganese and phosphorus. The highest content was observed in potassium, at 675.65 ± 0.02 mg/100g, and the lowest in sodium (1.37 ± 0.03 mg/100g). The results of the statistical analysis reveal a significant difference ($p < 0.05$) between mineral contents.

Table 5. Mineral content of *Terminalia catappa* almond meal

Parameters	*Terminalia catappa* almond flour (mg/100g)
Calcium	552,54 ± 0,03[a]
Potassium	675,65 ± 0,02[a]
Zinc	5,24 ± 0,02[a]
Magnésium	401,15 ± 0,05[a]
Sodium	1,37 ± 0,03[a]
Copper	2,15 ± 0,04[a]
Iron	7,12 ± 0,04[a]
Manganese	10,21 ± 0,03[a]

Each value is the mean ± standard deviation of three determinations. a : there is a significant difference ($p > 0.05$) between two values in the same column surmounted by the same letter.

Composition of anti-nutritional factors

The composition of anti-nutritional factors in *Terminalia catappa* almond flour revealed levels of total polyphenols, flavonoids, tannins and phytates. A significant difference ($p < 0.05$) was observed between these different levels through statistical analysis (Table 6).

Table 6. Composition of anti-nutritional factors in *Terminalia catappa* almond flour

Parameters (mg/100g MS)	Terminalia catappa almond flour (mg/100g)
Flavonoids	69,76 ± 0,006[a]
Tannins	15,85 ± 0,015[a]
Phytate	29,48 ± 0,007[a]
Oxalates	116,22 ± 0,007[a]

Each value is the mean ± standard deviation of three determinations. a : there is no significant difference ($p > 0.05$) between two values on the same line surmounted by the same letter.

Molar ratios of Terminalia catappa almond flour powder

The molar ratios of Phytate to Iron, Phytate/Zinc and Oxalate/Calcium in *Terminalia catappa* almond flour are shown in Table VII. The molar ratios of Phytate/Iron, Phytate/Zinc and Oxalate/Calcium in *Terminalia catappa* almond flour are shown in Table 7. *Terminalia catappa* almond flour showed molar ratios of Phytate/Fe (4.14 ± 0.01), Phytate/Zn (5.63 ± 0.02) and Oxalate/Ca (0.21 ± 0.01). The results of the statistical analysis showed a significant difference ($p<0.05$) between these values.

Table 7. Molar ratios of *Terminalia catappa* almond flour

Samples	Parameters		
	Phytate/Fe	Phytate/Zn	Oxalate/Ca
Terminalia catappa almond flour	4,14 ± 0,01[a]	5,63 ± 0,02[a]	0,21 ± 0,02[a]

Each value is the mean ± standard deviation of three determinations. a: there is no significant difference ($p < 0.05$) between two values in the same column surmounted by the same letter.

Discussion

Terminalia catappa almond flour was found to contain a wide range of rich macronutrients and micronutrients. Thus, the moisture content which was 5.67%, lower than those obtained by Aboudou *et al.* (2017) ranging between 6.80 and 15.69% investigating the physical and mechanical properties of almonds of two morphotypes of *Terminalia catappa* collected on three types of soils. According to Mabossy-Mobouna *et al.* (2017) a low moisture content allows good physical preservation of food while avoiding decomposition. However, the moisture content obtained in the present work is below the maximum reference value (12%) set by the RDA for dry food preservation (Fofana *et al.*, 2017).

The dry matter content of *Terminalia catappa* almond flour was estimated at 94.33 ± 0.07%. These results are close to those of Bamba *et al.* (2023) (90.77%) on mango almonds. These authors suggested that a high dry matter content would be synonymous with a high nutrient content.

The protein content obtained in the present study was 24.22%, this content was similar to those of Camara *et al.* (2021) (24.74%) and lower than that of Etienne *et al.* (2017) (31.21%), on the same species. Since protein is one of the most important nutrients required in weaning feeds, *Terminalia catpppa* almond flour could be used to formulate high-protein supplementary feeds. Taking into account FAO/WHO recommendations, a protein content of 11-12% is required for maximum amino acid supplementation of feed (FAO/WHO, 2009). Thus, the protein content of *Terminalia catappa* almond flour will be of nutritional importance in most developing countries.

The fat content of *Terminalia catappa* almond flour was 55.65%. This content was higher than that obtained by Etienne *et al.* (2017) (54.76%) and lower than that obtained by Ladele *et al.* (2016) (61.76%). These results show a variation in fat content. According to, variations in fat content can be due to different factors such as plant variety, climate, location, harvesting period and extraction methods (Almas *et al.*, 2019; Qarnifa *et al.*, 2019). Thus, the fat percentage obtained in the present study was found to be higher than that of conventional oils such as corn oil (15.8%), various soybean cultivars (18.3-21.5%), Moringa oleifera seed oil (19-47%), palm kernel oil (36%), peanut oil (42%) and cottonseed oil (35%) (Ng *et al.*, 2015; Ladele *et al.*, 2016; Chen *et al.*, 2019). As a result, it is more suited to being used as an alternative to conventional oilseeds as a great source of oils.

As for the chemical properties of *Terminalia catappa* almond meal fat, an acid value (3.35 ± 0.02%) higher than that reported by Olatidoye *et al.* (2011) was observed, as well as the value recorded for cashew nuts (2.48%) (Idah *et al.*, 2014). It is also lower than the standard free acid value (4%) required by the Codex Alimentarius (Codex, 1999) for virgin oils, suggesting good quality *Terminalia catappa* almond oil. It is also clear that the peroxide value (1.35 ± 0.02 g meq oxygen/kg fat) is also lower than the maximum 15 g mEq O2/kg recommended for fat quality. The saponification value was 179.6 mg KOH/g fat, higher than that obtained by (Olatidoye *et al.* 2011) (128 mg KOH/g fat); but lower than the values obtained for some vegetable oils ranging from 188 to 196 mg KOH/g fat (Olatidoye *et al.* 2011). Unsaponifiables (1.81%) are present in minute quantities in the fat of this almond. Since they are made up of bio-active substances including tocopherols and tocotrienols, which are natural antioxidants, biological hydrocarbons, sterols and terpene alcohols (Pioch *et al.*, 2018); they give the fat in *Terminalia catappa* almonds a capacity for immune defense, cancer prevention and atherosclerosis.

The ash content of *Terminalia catappa* almond flour was 4.1%. This content was close to that obtained by Jahurul *et al.* (2022) (4.6%) in a nutritional characterization study of *Terminalia catappa* almonds. According to Bamba *et al.* (2023), ash is the total mineral content of a sample. As a result, this flour could be a good source of minerals essential to the body's proper functioning. Mineral analysis of *Terminalia catappa* almond flours showed a high presence of minerals such as calcium, potassium, magnesium, sodium and copper, with significantly different levels ($p< 0.05$). These minerals are virtually essential to the body's functioning, through their various roles. Le fer et le zinc sont tellement importants que leur déficit peut engendrer de véritables problèmes de santé publique. According to Djossinou (2019), iron deficiency anemia is responsible for 10% of maternal mortality, where 800,000 deaths represent 2.4% of annual mortality due to iron deficiency. Zinc is an antioxidant that stimulates the immune system, it is involved in the metabolism of proteins required for normal fetal development, insulin synthesis and sperm production (El-Hadjela, 2016). What's more, a sodium/potassium ratio of less than 1 is good for the body's proper functioning. Copper is an essential element with beneficial effects on the immune system (Bost *et al.*, 2022). Manganese helps slow down the aging process by opposing the formation of free radicals (Cohen-Letessier, 2009).

Terminalia catappa almond flour also contains carbohydrates and fiber: 10.36% total carbohydrates and 6.50% fiber. These characteristics are also more important in *Terminalia catappa* almond flour as in cashews and peanuts (Diomande *et al.*, 2017). Carbohydrates are easily digested and provide the body with energy. Conversely, fibers are not digested but contribute to the biodigestion of nutrient macromolecules, prior to their physiological use, and possess beneficial effects on intestinal muscles (Udotong *et al.*, 2015).

Terminalia catappa almond flour may be beneficial for digestion and energy requirements. Consuming 100g of these almonds provides the body with 639.1 Kcal of energy. This value was slightly higher than that obtained by Etienne *et al.* (2017) who obtained a value of 596.92 Kcal/100g from the same almond. In fact, this energy could be used by the body for its daily needs. However, this rate is higher than that of FAO (2004) (413 Kcal), which noted the high energy content of edible flours and consequently encouraged their incorporation into infant flours.

The total and reducing sugar contents of *Terminalia catappa* almond flour evaluated in the present study were 3.39% and 1.60% respectively. These results are slightly higher than those of Camara *et al.* (2021), who obtained total and reducing sugar contents of 2.37% and 1.39% respectively in the physicochemical and biochemical characterization of the fruit and oil of three oleaginous plants including *Terminalia catappa*. These low levels could be highly beneficial to the body, helping to prevent metabolic diseases linked to variations in blood sugar levels, such as diabetes mellitus (Foua Bi *et al.*, 2015).

The amino acid profile of *Terminalia catappa* almond flour showed a total amino acid content of 32.03 mg/g protein, including 15.58 mg/g protein for essential amino acids and 16.45 mg/g protein for non-essential amino acids. The levels of essential and non-essential amino acids in *Terminalia catappa* almond meal were low and below those of the FAO (1998) reference proteins. This deficiency could affect protein synthesis and cause illnesses such as depression, behavioral disorders, hypertension, kidney problems and the maintenance of cell membrane fluidity (WHO, 1985). The concentration of essential amino acids present was very low compared to that recommended by the FAO, WHO and UN for children aged 2 to 5 in the reference protein (Foidl *et al.*, 2001). Incorporating *Terminalia catappa* almond flour and other cereal products rich in amino acids could optimize its amino acid nutritional value.

The fatty acid profile of Terminalia catappa almond flour also revealed 64.07% unsaturated compounds, this result is in line with the 65.85% unsaturated fatty acids found by Etienne *et al.* (2017) and higher than the value obtained by Dos Santos *et al.* (2008) (60%). Unsaturated fatty acids, also known as bio-functional molecules, play an important role in reducing blood LDL cholesterol, blood pressure and cardiovascular diseases (Ajayi *et al.*, 2008). The presence of unsaturated fatty acid is encouraging, as it is a desirable element in the human diet (Vijayakumari *et al.*, 1997). Polyunsaturated fatty acids make a major contribution to these physiological roles, and the high linoleic acid content (32.36%) in *Terminalia catappa* almonds is said to help reduce blood cholesterol. This result confirms that of Etienne *et al.* (2017) who obtained 33.29% linoleic acid content. According to Ouldamara (2020), cardiovascular disorders such as coronary heart disease, atherosclerosis and high blood pressure are prevented by dietary fats rich in linoleic acid. The present study indicated 31.30% oleic acid, a result similar to that of Monnet *et al.* (2012) who obtained 32.40%. This fatty acid plays an important role in reducing blood pressure by increasing HDL cholesterol levels in the blood (Amar, 2020). The saturated fatty acid content of almond oil was 35.43%, making it a valuable source of energy for the body.

Conclusion

A study of the physicochemical characteristics of *Terminalia catappa* almond flour has revealed the high nutritional value of this almond. These values highlight its protein quality, making this almond a good source of protein. Satisfactory levels of minerals such as potassium, sodium, calcium, magnesium and iron were observed. Although *Terminalia catappa* almond flour is lower in carbohydrates, it has a high fat content. In addition to its high protein content, its considerable fat content makes it a good source of energy. It therefore makes sense to use this flour as a complement to other carbohydrate-rich cereal flours, in order to improve people's diets. This alternative could contribute to the treatment of protein-energy malnutrition worldwide, and particularly in African households.

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