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Physicochemical characteristics and nutritional composition of the seeds and oils of *Hannoa undulata* (Guill. & Perr.) Planch

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Abstract

Hannoa undulata kernels are a potential source of nutrients. However, the nutritional potential of the species remains under-utilised in Burkina Faso. The aim of this study was to determine the nutritional composition of the seeds and oil of *H. undulata*, a neglected species, with a view to improving their utilization. Proximal composition and physicochemical parameters were determined using standard AOAC and AOCS methods. The composition of fatty acids, triglycerides, tocopherols, minerals and amino acids was determined by gas chromatography, HPLC, inductively coupled plasma-atomic emission spectrometry (ICP-AES) and liquid chromatography coupled to a tandem mass spectrometer (LC-MS/MS), respectively. The results showed that the oil, protein, carbohydrate and mineral contents of the almonds were (50.6±0.5 %), (33±0.2 %), (13.9 %) and (2.9±0.2 %) respectively. Oleic acid (147792.55 mg/kg), stearic acid (46762.08 mg/kg), palmitic acid (18778.2 mg/kg) and linoleic acid (14004.91 mg/kg) were the dominant fatty acids. Triglycerides are in the majority, with very little hydrolysis. Stearodiolein (SOO) accounts for 50.6 % of triglycerides, while triolein (OOO) makes up 10.8 %. Cysteine (453305.1 mg/kg) and glutamine (69624.84 mg/kg) are the main amino acids in almonds. They contain all the essential amino acids except tryptophan. The total mineral content is 1242.977 mg/100g, including 1237 mg/100g for macronutrients and 5.977 mg/100g for trace elements. This analytical study shows that *H. undulata* kernels and seed oil are an important source of nutrients for the diet.

Key words: *H. undulata;* Fatty acids; Amino acids and mineral composition; Triglycerides

1. Introduction

In Burkina Faso, the most widely exploited non-timber forest products include shea, used for its butter, néré, the seeds of which are used to produce soumbala (a local ingredient), and tamarind, whose seeds are used as a drink. (FAO, 2001). Some of these species remain little-known and neglected, such as *Hannoa undulata* (Guill. & Perr.) Planchon (Simaroubaceae), locally known as Yerting among the Sénoufos. Although it is exploited for its wood (Traore et al., 2011), its medicinal properties and honey production (Lykke et al., 2021), this species is not widely recognised by the local population. The seeds of *H. undulata* are a potential source of tocopherols, fatty acids and sterols (Firestone, 2013; Iko and Oscar, 2015), which opens up interesting prospects for the development of a new oil (Lykke et al., 2021) as well as for applications in the cosmetics and industrial sectors. However, studies on the physicochemical parameters of this species in Burkina Faso are rare. Despite its nutritional potential, questions remain about how to use this resource while guaranteeing its quality and sustainability. By identifying the factors influencing the quality of the extracted oil, this

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research could promote its optimal use and its development in local food systems. In addition, commercially, the seed oil could be exported to other West African countries, where demand for alternative, nutritious vegetable oils is growing rapidly. If properly processed, *H. undulata* oil could gain a foothold on international markets, particularly in the organic and fair-trade segments, and be incorporated into industrial formulations, including food products and nutritional supplements, thanks to its health benefits. The aim of this study is to assess the physicochemical composition of almonds and the physicochemical properties of *H. undulata* oil.

2. Materials and methods

2.1. Collection site and sampling

Ripe fruits of *H. undulata* were collected in the Cascades region (see Figure 1) in southern Burkina Faso in April 2024. This region was chosen because of the strong presence of the species. Five localities - Mondon, Toumousséni, Wolonkoto, Djanga and Bérégadougou - were randomly selected for fruit collection. Around 10 kg of fruit were collected from 20 randomly selected plants per village.

After collection, the fruit was transported to the laboratory, where it was sorted to remove any damaged fruit. The ripe, infection-free fruit was then pulped and dried at room temperature (between 28 and 30°C) for three weeks. After drying, 1 kg of seeds per village were collected and pooled to obtain a mixture representative of the region. Finally, the seeds obtained were dehulled and the kernels were ground using a Moulinex-type grinder for biochemical analysis.

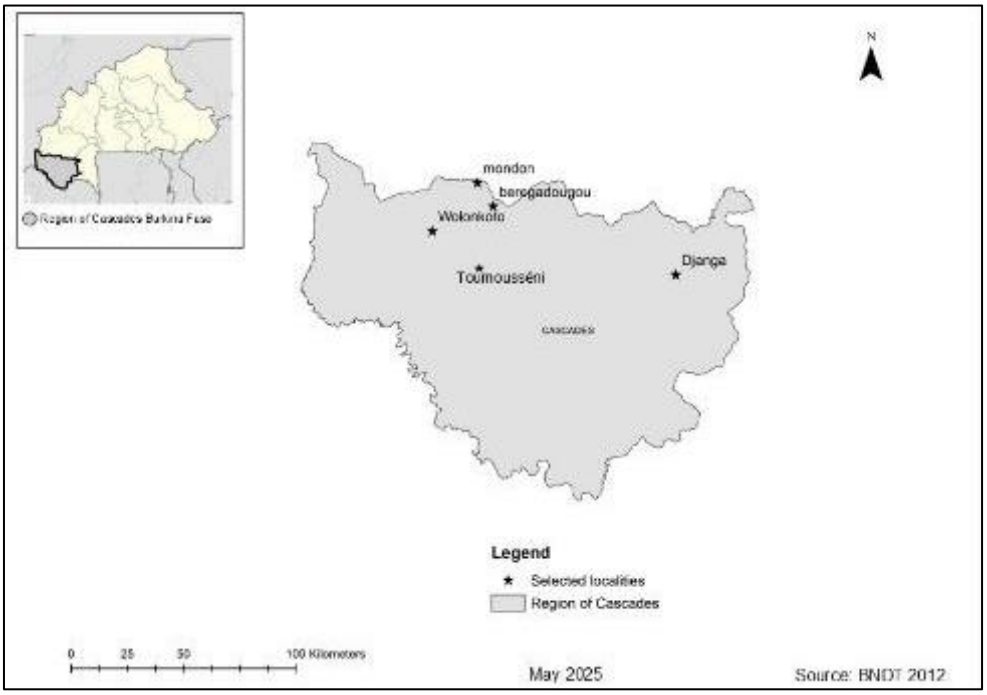

Figure 1 Collection site

2.2. Determination the proximal composition of kernels

The biochemical composition of the seeds was determined from crushed kernels using the (AOAC, 2002) method. The moisture content of the kernels was determined by differential weighing after oven drying at 105°C using AOAC method 925.10. The crude ash content was determined by incineration of the sample in a muffle furnace at a temperature of 550°C using the AOAC 923.03 method. The total protein content of the almond samples was determined by mineralization of the organic nitrogen in liquid ammonia, followed by acidimetry, using the Kjeldahl AOAC 979 method. At the same time, the total fat content of ground almond meal was determined by semi-continuous extraction of the fat until exhaustion using Soxhlet, in accordance with AOAC method 960.39. The total carbohydrate content was estimated using the differential method (Barminas, 1999).

The theoretical energy value was calculated using the formula :

$$E=(P\times4)+(G\times4)+(L\times9)$$

where :

- E is the total energy value in kilocalories (kcal),
- P is the quantity of protein in grams (g),
- G is the amount of carbohydrate in grams (g),
- L is the amount of fat in grams (g). Analyses were carried out in triplicate.

2.3. Determination of the physico-chemical parameters of oils

The saponification index was determined using the AOCS Cd 3-25 method (AOCS, 1990), the oils were first saponified under heat using excess alcoholic potash solution. The excess potash was then titrated. The difference is used to obtain the saponification index. The iodine value was calculated as a function of the fatty acid composition of the oil using the AOCS Cd 1c-85 method (AOCS, 1990). The peroxide value was determined by titration of the iodine released by the reaction of hydroperoxides in the presence of iodide ions using the AOCS Cd 8-53 method (AOCS, 1990). 5 g of oil was dissolved in a 30 ml acetic acid/chloroform mixture (3/2, v/v). Using a propette, 0.5 mL of saturated KI was added and the mixture was left to stand for one minute. Then 30 mL of distilled water was added and the iodine liberated was determined by a solution of sodium thiosulphate (0.1N) in the presence of starch starch. The acid number was determined by titration of the free fatty acids present in the oil using the AOCS Ca 3a-63 method (AOCS, 1990). The oxidative stability of the oils was determined using the automated Rancimat method. 3 g of oil were weighed into a reaction tube and introduced into the Rancimat 743 (Metrohm, Switzerland). Induced oxidation was carried out at 120°C with a purified air flow rate of 20 l/h. The time taken for total oxidation of the oil was then measured.

2.4. Determination of fatty acid composition

Fatty acid composition according to methods 2.301 and 2.304 of the International Union of Pure and Applied Chemistry (IUPAC (1979) with a slight modification as described in our previous work (Bazongo, et al., 2023) . The almond lipids were first extracted with petroleum ether. The fatty acids were then derivatised to the corresponding methyl esters using a 15% boron trifluoride methanoic solution. The methyl esters were then extracted with 30 mL of n-heptane. Finally, the methyl esters were analysed by gas-liquid chromatography (GLC) using the Shimadzu GC-2010 Pro. The column used was a 100 m long SH-Rt-2560 column with a film thickness of 0.20 µm and an internal diameter of 0.25 mm. The column temperature was initially 100°C, maintained for 8min, then raised to 240°C at 3°C/min for 15 min. The injector temperature was 240°C, the injection volume was 1 µL and the flow rate was 1 mL/min. The detector temperature was 245°C. Analysis was performed in triplicate.

2.5. Determination of amino acid composition

Amino acid composition was determined by liquid chromatography coupled to a tandem mass spectrometer (LC-MS/MS) as described in our previous work (Bazongo, et al., 2023). The samples were first digested under heat (110˚C), with a 1‰ hydrochloric acid solution of phenol/water in the proportions (V/V). Then the operation was followed by filtration on a 0.22 µm pore membrane. The amino acid composition was then determined using a Shimadzu 8050 LC-MS/MS instrument. The column was an Endeavor-sil C18 type measuring 100*2.1mm 1.8um and the flow rate was 0.2 ml/min. The column temperature was 40˚C and the collection time was 15 min. The mobile phase was 0.1% formic acid and acetonitrile as shown in the table below. Mass conditions for electrospray ionisation were as follows: interface temperature: 300˚C, desolvation temperature: 526˚C, DL temperature: 250˚C, atomising gas flow rates: 3.00 L/min, heating air flow rate: 10.00 L/min, heating block temperature: 400˚C, drying air flow rate: 10.00 L/min. Quantification was performed using combined MRM and SIM methods for direct quantitative determination of amino acids in various samples on LC/MS/MS.

2.6. Determination of mineral composition

Mineral composition was determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) according to Selmi (2021) with slight modifications as described in our external work (Bazongo et al., 2023) . The samples were first digested with a mixed solution of nitric acid and perchloric acid on an electric hot plate. The minerals were analysed by gas-liquid chromatography (GLC) using the PerkinElmer (PE) AVIO200 model. Parameters were adjusted as follows: Instrumental analysis conditions: argon; Plasma gas flow rate: 12 L/min; Auxiliary gas flow rate: 0.2 L/min; Atomising gas flow rate: 0.6 L/min; Power output: 1300 W; Pump flow rate: 1.5 mL/min; Carrier gas (greater

than 99.996% argon: 0.6 - 0.8 MPa); Purge gas (greater than 99.999% argon or nitrogen: 0.3 - 0.8 MPa); Air compressor (0.6 - 0.8 Pa); Cooling water circulator (20˚C).

2.7. Determination glyceride content

Glyceride levels were determined by high-performance exclusion chromatography (HPSEC) using the method described by (Shukla and Perkins, 1991). The extracted oil was dissolved in tetrahydrofuran (THF) at a concentration of 1% by weight of oil. This solution was then filtered using a filter (Millipore

® FH SJFHL05NS) and directly analysed using HPSEC, the parameters of which are described below. The dissolved and filtered samples were injected into the columns in a 20 µl loop. THF was used as the mobile phase. The mobile phase flow rate was 1.0 ml/min. Three PLgel columns were used as follows: the first had a pore size of 500 Å, combined with two other columns with a pore size of 100 Å. All columns were 300mm x 7.5mm stainless steel (Polymer Laboratories Ltd). The columns were maintained at room temperature (22-23°C). A refractive index detector was used and maintained at 37°C. Glyceride and glyceride polymer peaks were identified using the retention time of the glyceride and polymer standards.

2.8. Determination of triglyceride composition

Triglycerides were analysed using a combination of two different HPLC methods depending on the type of columns and solvents used (Shukla and Blicher-Mathiesen, 1993). The first phase involved the extraction of triglycerides. The oil samples were individually mixed in hexane at a concentration of 20% (V/V or M/V), followed by extraction of the triglycerides. The HPLC system used for this separation was an SP 800 chromatograph coupled to an LC-UV 3100 detector and fitted with an injector. The stationary phase was a silica gel column (Kromasil® premium silica-based HPLC columns). The mobile phase consisted of isopropanol and hexane (2.5:100, v/v). The flow rate was 1.0 mL/min. Triglycerides were detected at 206 nm, collected and then dissolved in THF at a concentration of 5%, after evaporation of the extraction solvent under nitrogen.

The second phase consisted of separating and quantifying the triglyceride molecules. The HPLC system described above was used, with variations as follows. The columns used for the separations consisted of 3 silica columns (two 150 mm x 4.5 mm ID and one 120 mm x 4.5 mm ID, Spherisorb S3 ODS 2) arranged in series. The columns were maintained at 20°C by coupling the column oven to a cooling system. The mobile phase consisted of acetonitrile and THF (70:30, v/v). The mobile phase flow rate was 1.0 mL/min. The air compressed in the solvents was first extracted by ultrasound. The detector was calibrated at 220 nm. An SP 8000 electronic integrator was used to obtain accurate retention times at a running speed of 0.25 cm/min. Triglyceride isomers were identified by comparison with the retention times of cocoa butter triglycerides used as standards.

2.9. Determination of tocopherol content

The tocopherol (vitamin E) composition of the samples was determined by HPLC using the standard AOCS method (Ce 8-89) with slight modifications (AOCS, 1990; Shukla and Jensen, 1996). The HPLC system used was a Perkin Elmer Fluorescence (excitation wavelength = 290 nm, emission wavelength= 330 nm) 200 series equipped with an automatic injector (Rheodyne 7125) with a 20 µL loop. External tocopherol standards (α-, β-, γ- and δ-tocopherols Sigma-Aldrich, Inc., St. Louis, MO) were used for individual identification and quantification of tocopherol isomers present in each oil sample. The solvent system used consisted of water-saturated hexane, hexane and propane-2-ol in the proportions (49.55/49.55/0.9) (v/v/v) respectively. The stationary phase consisted of 2 columns (150 mm x 4.6 mm I.D.) packed with 3µm CN particles. After preparation, the sample was injected directly into the column and eluted at an isocratic flow rate of 1.0 mL/min.

2.10. Data analysis

The data were processed using Excel 2019. Means and standard deviations for triplicate analyses were calculated.

3. Results and discussion

Table 1 Proximal composition of kernels and physicochemical parameters of *H. undulata* oil

Parameters	Value
Moisture (%)	2.9±0.2
Protein (%)	33±0.2
Lipid (%)	50.6±0.5
Carbohydrate (%)	13.9±0.1
Ash (%)	2.5±0.2
Saponification value (mg KOH/ g oil)	186.82±0.12
Iodine value (g of iodine/100 g of oil)	73.29±0.1
Acid value (mg of KOH/g of oil)	0.22±0.4
Peroxid value (meq of O2/kg of oil)	12.00±0.01
Melting point (°C)	24.5±0.08
Refractive index (25°C)	1.47±0.01
Color index	3.37±0.04
Oil stability (h) at 120°C	0.22± .00
Triglycerides (%)	95.20±0.13
Diglycerides (%)	3.80±0.08
Monoglycerides (%)	0
Free Faty Acids (%)	1
Polymers %	0
Total tocopherols (mg/kg)	0

The proximal composition of the kernels and the physicochemical parameters of the *H. undulata* oil are given in Table 1. The water content of the seeds was 2.9 ± 0.2 %. This is relatively low and lower than that melon (4.12 %) (Onyeike and Acheru, 2002), baobab (4.3 %) and *Balanites aegyptiaca* Del. (Zygophyllaceae) (3.70 ± 0.1 %) (Bazongo, et al., 2023). This shows that they have good keeping qualities. The kernels are rich in lipids (50.6 ± 0.5 %) and protein (33 ± 0.2%). They are therefore an oleo-proteaginous species. The protein content of almonds is higher than that of sesame (25.77 ± 1.02%) (Elleuch et al., 2007), melons (29.90 %) (Mian-hao and Yansong, 2007) and groundnuts 26.5 % (Onyeike and Acheru, 2002) but slightly lower than that of soya. The oil content of almonds is higher than that of several local oilseeds used as a source of oil, such as *B. aegyptica*, *Azadirachta indica* A. Juss (Meliaceae), and *Lophira lanceolata* Tiegh. ex Keay (Ochnaceae). However, it is lower than that of *Carapa procera DC* (Meliaceae) and *Lannea microcrocarpa* Engl. & Krause (Anacardiaceae) (Bazongo, et al., 2023; Djenontin et al., 2012; Lohlum, 2010). The oil content found in this study is slightly different from that found in the seeds of *Hannoa undulata,* which is 55.6 % (Mirailles et al., 1988). The lipid and protein contents found are lower than those reported by Seyni et al., (2022) in Senegal. This could be explained by differences in climatic and edaphic factors. The total carbohydrate and ash contents were 13.9 % and 2.5 ± 0.2 % respectively.

The acid number, which gives an idea of the quantity of free fatty acid present in the oil, was very low (0.22 mg of KOH/g of oil). This indicates good preservation of the seeds and low hydrolysis of the triglycerides. These results are confirmed by the high triglyceride content of the oil (95.2 %) and the low levels of diglycerides (3.8 %) and free fatty acids (1 %), as well as the total absence of monoglycerides. There was also a total absence of polymers in the oil studied. This indicates the good quality of the extracted oil. However, the peroxide value was high (12 meq of 02/kg of oil). This could be explained by the relatively high iodine value of 73.29 g of iodine/100 g of oil. A high level of unsaturation in the oil could facilitate the attachment of oxygen molecules to the double bonds, thus favouring the formation of hydroperoxides.

The iodine value found in our study is much higher than that found for the species by Seyni (2022) which is (21.5 - 38.11 meq of O2/kg oil). The oxidative stability of the oil is 0.22 h. This is relatively low compared with other oils. This is relatively low compared with so-called stable oils such as moringa oil, olive oil and marula oil whose induction period at 120 °C is between 8 and 43 h (Anwar, 2007; Mariod et al., 2006) . This oil is therefore not recommended for frying. This value could be explained by the zero value of tocopherol and its isomers found in this study. Tocopherols are one of the powerful antioxidants in vegetable oils. The saponification index, colour index, refractive index and melting point of *H. undulata* oil were 186.82 mg KOH/ g of oil, 3.366, 1.472 and 24.5 °C respectively. The relatively high value of the saponification index justifies its use in saponification. The oil is liquid at room temperature.

Table 2 Proximal composition of kernels and physicochemical parameters of *H. undulata* oil

Fatty acids	**Value (mg/kg)**	**Value (%)**
Capric acid C10:0	108.55	0.05
Mirtic acid (14:0)	119.37	0.05
Cis-9-tetradocarenoic acid (14:1 ω-5)	39.07	0.02
Pentadecanoic acid (15:0)	57.66	0.02
Palmitic acid (16:0)	18778.2	8.09
Heptadecanoic acid (17:0)	339.76	0.15
Stearic acid (18:0)	46762.08	20.13
Oleic acid (18:1 ω-9)	147792.55	63.63
Cis-9,12-linoleic acid (18:2 ω-6)	14004.91	6.03
Cis-6-9-12-γ-linolenic acid (18:3 ω-6)	1391.69	0.60
Cis-9,12,15-linolenic acid (18:3 ω-3)	1040.48	0.45
Cis-11,14,17-eicosanotrienoic acid (20:3 ω-9)	643.22	0.28
Eicosapentaenoic acid (EPA) (C20:5 ω-3)	938.61	0.40
Lignoceric acid C24:0	236.84	0.10
Saturated Fatty Acids (AGS)	66402.46	28.59
Monounsaturated Fatty Acids (AGMI)	147831.62	63.65
Polyunsaturated Fatty Acids (PUFA)	18018.91	7.76

The fatty acid composition of the oil is shown in Table 2. Indeed, 14 fatty acids were detected in the oil, including 4 major fatty acids: oleic acid (147792.55 mg/kg), stearic acid (46762.08 mg/kg), palmitic acid (18778.2 mg/kg) and linoleic acid (14004.91 mg/kg). These fatty acids represent 97.88 % of the fatty acids in the oil. It is a so-called monounsaturated oil because the Insaturated Monounsaturated Fatty Acids content 63.65 % of the fatty acids in the oil. It is comparable to olive oil, rapeseed oil, neem oil, *X. americana* oil, *S. birrea* oil and *M. oleifera* oil (Abdulkarim et al., 2007; Eromosele and Eromosele, 2002; Mariod et al., 2004). Oleic acid is as effective as linoleic acid in lowering LDL cholesterol levels in normotriglyceridaemic patients (Mattson and Grundy, 1985). Oleic acid also plays an important role in nerve cell construction. In the body, it can be transformed into a series of compounds similar to prostaglandins, which play an important role in blood vessels and blood coagulation (Nehdi, 2011). Oleic acid-rich oils are mostly used as table oils because of the stability and nutritional value of oleic acid. The polyunsaturated fatty acid content (7.76%) is not negligible and could explain the fairly high peroxide value found above. The presence of these acids improves the nutritional value but may require the oil to be well preserved against pro- oxidant factors. Among saturated fatty acids, stearic acid is in the majority (20.13%). Previous studies have shown that stearic acid does not have a significant impact on blood lipid levels because it is poorly absorbed from the intestine (Dubois et al., 2007). This fatty acid enhances the softness of food formulations. Our results are different from those found by Iko and Oscar, (2015) but similar to those of Mirailles (1988) who found the same majority fatty acids but with different proportions.

The triglyceride composition of *H. undulata* oil is presented in Table 3. The oil is composed mainly of di-unsaturated triglycerides (59%), poly-unsaturated triglycerides (23.9 %) and mono-unsaturated triglycerides (17.1%).

Stearodiolein (SOO) (50.6 %) and triolein (OOO) (10.8 %) are the main triglycerides in the oil. There is also a distribution of polyunsaturated fatty acids in the various triglycerides, preferably esterified in the Sn2 position. This considerably reduces the number of unsaturations per triglyceride. This distribution of IFAs in the triglyceride structure helps to stabilize the oils better during oxidation. In fact, in the case of oils containing a fairly large quantity of unsaturated fatty acids, the structure of the triglycerides influences the stability of these oils (Wijesundera, 2008). Palmitic acid has a positive effect on the increase in bad blood cholesterol levels, and this effect is all the greater when it is esterified in the SN2 position of the triglyceride (Dubois et al., 2007). It can be seen that palmitic acid is preferentially esterified in the SN1 and SN3 positions of triglycerides.

Table 3 Triglyceride composition of *H. undulata* oil

Triglycerides	**Value (%)**
Monounsaturated	
POP	2.1
POS	3.4
SOS	8.2
SOA	3.4
Total	17.1
Di-unsaturated	
PLP	2.2
OOP	5.5
SOO	50.6
SLS	-
AOO	0.7
Total	59
Polyunsaturated	
LLL	-
LLO	3.1
SLnL	1.7
PLL	-
PLnO	-
LOO	5.1
SLL	-
PLO	3.2
OOO	10.8
SLO	-
Total	23.9

POP: dipalmitolein; POS: palmitoleostearin; SOS: distearolein; SOA: stearoleoarachidin; PLP: dipalmitolinolein; POO: palmitodiolein; SOO: stearodiolein; SLS: distearolinolein; AOO: arachidodiolein; LLL: trilinolein, LLO: dilinolein; SLnL: stearolinolenolinolein; PLL: palmitoyl dilinolein; PLnO: palmitolinolenoolein; LOO: dioleolinolein; SLL: stearodilinolein; PLO: palmitolinolein, OOO: triolein; SLO: stearolinolein.

The amino acid composition of almonds is presented in table 3. A total of 19 of the 20 amino acids found in the human body were detected in almonds. Non-essential amino acids were in the majority with 89.06 % corresponding to a content of 616463.57 mg/kg of almonds. Essential amino acids were in the minority with 10.94 % corresponding to a content of 75725.58 mg/kg. However, it should be noted that almonds of this species contain all the essential amino acids for

humans, with the exception of tryptophan. The main amino acids in almonds are cysteine (453305.1 mg/kg) representing 65.49 % of amino acids, followed by glutamine (69624.84 mg/kg) corresponding to 10.06 %. With regard to the essential amino acid requirements of children and adults, *H. undulata*ta kernels could cover all daily requirements with the exception of tryptophan. *H. undulata*ta kernels could therefore be a good source of both essential and non-essential amino acids such as cysteine and glutamine.

Table 4 Amino acid composition of *H. undulata* kernels

Amino acids	Value (mg/kg)	Value (%)	Adult	Children
	Essential amino acids			
Threonine	6578.75	0.95	15	24
Lysine	4074.42	0.59	30	44
Histidine	3268.92	0.47	10	15
Valine	16350.98	2.36	26	36
Methionine	2641.72	0.38	10	22
Isoleucine	14919.26	2.16	20	27
Leucine	14825.93	2.14	39	54
Phenylalanine	13065.6	1.89	25	40
Tryptophan	ND	ND	4	6
Non-essential amino acids				
Alanine	6735.12	0.97		
Glycine	8172.1	1.18		
Serine	6583.62	0.95		
Arginine	30276.65	4.37		
Glutamine	69624.84	10.06		
Proline	11014.14	1.59		
Aspartic acid	22371.45	3.23		
Tyrosine	8380.55	1.21		
Cystine	453305.1	65.49		
TAAE	75725.58	10.94		
TAANE	616463.57	89.06		

*Essential amino acid requirements for adults over 18 and children aged 1-2 (Millward, 2012) ; TAAE: total essential amino acids; TAANE: total non-essential amino acids.

The mineral content of *H. undulata* kernels is presented in Table 5. The total mineral content is 1242.977 mg/100g, of which 1237 mg/100g are macroelements and 5.977 mg/100g are trace elements. The main minerals are potassium (512,434 mg/100g), followed by phosphorus (354,182 mg/100g) and magnesium (240,769 mg/100g), accounting for 89.09% of minerals. Minerals play an important role in the diet and their deficiency is associated with serious illnesses. Potassium, for example, is an essential nutrient needed to maintain total body fluid volume, acid and electrolyte balance and normal cell function. Insufficient potassium intake has been associated with hypertension and cardiovascular disease, and appropriate intake levels may be protective against these diseases (World Health Organization, 2012) . Given the dietary requirements for these minerals, *H. undulata* seeds could help to cover the needs of adults and children for these 3 minerals (FAO/WHO, 1998). Three trace elements were found: boron, iron and zinc, with respective concentrations of 2.035 mg/100g, 2.216 mg/100g and 1.726 mg/100g. The potassium, phosphorus and magnesium contents are much higher than those of baobab kernels (Nkafamiya et al., 2007) . Our results are similar to those found by (Seyni et al., 2022) who found the same major minerals but with slightly different values.

Table 5 Mineral composition of *H. undulata* kernels

Minerals	Value (mg/100g)	Value (%)
	Macronutrients	
Ca	119.819	9.64
K	512.434	41.23
Mg	240.769	19.37
Na	9.796	0.79
P	354.182	28.49
	Trace elements	
B	2.035	0.16
Fe	2.216	0.18
Zn	1.726	0.14

4. Conclusion

The physico-chemical composition of *H. undulata* almonds reveals a wealth of beneficial fatty acids, particularly oleic acid, which could contribute to cardiovascular health and nutrition. These almonds have good keeping qualities, making them particularly suited to the climatic conditions of the country. What's more, their nutritional potential is enhanced by the presence of a variety of essential and non- essential amino acids, as well as important minerals. By promoting the use of this species, it is possible not only to meet the growing demand for alternative vegetable oils in Burkina Faso and even in West Africa, but also to promote sustainable practices that guarantee the quality and sustainability of this resource. In this way, *H. undulata* oil could establish itself on international markets, particularly in the organic and fair-trade segments, while contributing to food security and the health of local populations.

Compliance of ethical approval

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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