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Biochemical Analysis of *Lannea microcarpa* Engl. & K. Krause (Anacardiaceae) Seed and Seed Oil

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Abstract *Lannea microcarpa* called also African grape is a fruit species known to the entire population but very little valued for the nutritional richness of its seeds. This study aims to conduct a biochemical characterization of *L. microcarpa* seeds and seed oil. Samples were collected from South Central Burkina Faso. Phytochemical screening was carried out using AOAC official method and biochemical analysis of the seeds and seed oil was performed using LC-MS/MS. Antioxidant activity was assessed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical assay for both methanolic and n-hexane extracts of the seed oil. The phytochemical screening revealed that the seeds contain alkaloids, polyphenols, saponins, tannins, and triterpene sterols. The physicochemical parameters showed moisture values of 2.54%, ash (2.84 ± 0.00%), crude fat (60.95 ± 1.24%), acid number (5.24 ±0.00 mg KOH/g), oleic acid (2.62 ± 0.19%), carbohydrate (15.11 ± 0.04%) and crude protein (18.55 ± 0.35%). The content of monounsaturated and polyunsaturated fatty acids (55.64%) exceeds the quantity of saturated fatty acids. The seeds contain approximately 6% essential amino acids, with leucine being the most abundant at a concentration of 12,532.01 ± 0.08 mg/kg. The seeds have five main minerals and 17 trace elements, with phosphorus being the most prevalent (36.40%). The ratio of phosphocalcic (Ca/P) was less by 0.3 compared to the suggested values of 1.5 and 2 for animal nutrition. The Ca/Mg ratio (0.7) was nearly at the recommended value of 1. The Na/K ratio (0.4) was within the limit of 1 not being exceeded. The seed exhibits significant antioxidant activity, with the methanol extract (220 ± 25 µg/mL) showing a higher effect than the n-hexane extract (1001.4 ± 42 µg/mL). The composition of the seed and its oil could have potential nutritional and medicinal benefits.

Keywords *Lannea microcarpa*, Phytochemical, Fatty Acid, Amino Acids, Minerals

1. Introduction

Lannea microcarpa Engl. & K. Krause also called the African grape belongs to the family of Anacardiaceae. It is a woody species found in the savannahs and particularly very frequent in southern of Burkina Faso [1]. It is a local plant whose tree is commonly called “Sabga” and the fruit “Siba” in the local language (Mooré).

The species is used in pharmacopoeia, food, agriculture

and crafts [2]. Research indicates that extracts derived from the trunk bark of *L. microcarpa* prevent Angiotensin II-induced hypertension and vascular dysfunction by reducing oxidative stress pathways and inhibiting calcium entry [3]. Notably, the consumption of the fruits of this species is common during periods of scarcity. Furthermore, both the fruits and seeds of this species boast a high nutritional content, particularly in terms of carbohydrates and polyunsaturated fatty acids, fat-soluble vitamins [4] and mineral salts. The species' fruits also contain tannins and anthocyanins (around 1300 mg per 100 g of dry pulp for the anthocyanin content). Minerals such as calcium, magnesium, iron and phosphorus have been highlighted in the pulp of the fruit and seeds [5]. The richness of the fruits and seeds of this species in mineral elements and vitamins could help fight against several diseases. Thus, in the pharmacopoeia the fruits are employed in the treatment of rickets and scurvy, wounds, inflammations, conjunctivitis [6] and gastroenteritis [7]. The kernel of the seed is used as a laxative. On the food front, a local drink is made from the fruit of *L. microcarpa*. Industrially, seed oil can be used as a table oil and in the manufacture of soap [8]. The cakes can be used as a condiment (called *Soumbala;* local: food).

However, the observation is that *L. microcarpa* is a fruit species known to the entire population but very little valued for the nutritional richness of its seeds. The seeds can be better exploited and valorized through medicinal (potion, powder, ointment, food supplement), food (juice, jam, biscuit, syrup, vanilla, *etc*.), agricultural (oil as a biopesticide and seed residues can be used) and industry (as a biofertilizer). For example, iron deficiency in the body can cause fatigue or lead to anemia [9]. A protein deficiency would influence the microbiota and could expose one to the risk of infection [10]. This would justify the use of the seeds in the pharmacopoeia for domestic care.

This study aims to conduct a biochemical characterization of *Lannea microcarpa* seeds and seed oil. Specifically, it will involve carrying out a phytochemical characterization then determining the physicochemical properties of the seeds, the content of fatty acids, minerals and amino acids and determining the antioxidant activity of the seeds. The outcomes of this research can offer significant insights that can inform the development of novel medicinal applications and food applications for *L. microcarpa* seed or seed oil.

The uniqueness of this study stems from the limited research on the species. Additionally, the analysis of fatty acids, amino acids, and minerals adds value to utilizing *L. microcarpa* seeds and oil, highlighting their nutraceutical richness.

2. Materials and Methods

2.1. Sampling and Seed Preparation

Mature fruits of *L. microcarapa* were collected in the fields randomly from several trees from Manga, Guiba, Gogo and Bind éin June 2022 in the Zoundweogo province in Burkina Faso (Figure 1). The fruits were collected randomly over 10 individuals per site (approximately 1, 5 kg per site). The trees were located in agricultural fields and forests. This sampling was carried out to have a representative sample.

The fruits were sorted by hand to remove damaged fruits before being sent to the laboratory. They were then mixed to create a homogeneous mixture. 1.5 kg of ripe fruits were selected from the sample for the remainder of the study. The samples were thoroughly cleaned with distilled water on a glass surface, then drained and left to air dry in a controlled laboratory environment (22-23 ℃) for a period of two weeks. Approximately 500 g of the dried outer tissue surrounding the pith of the fruit was removed, and the nuts (seeds) were shelled and finely ground with a grinder before being packed in an airtight container and stored at -18 ℃ until analysis.

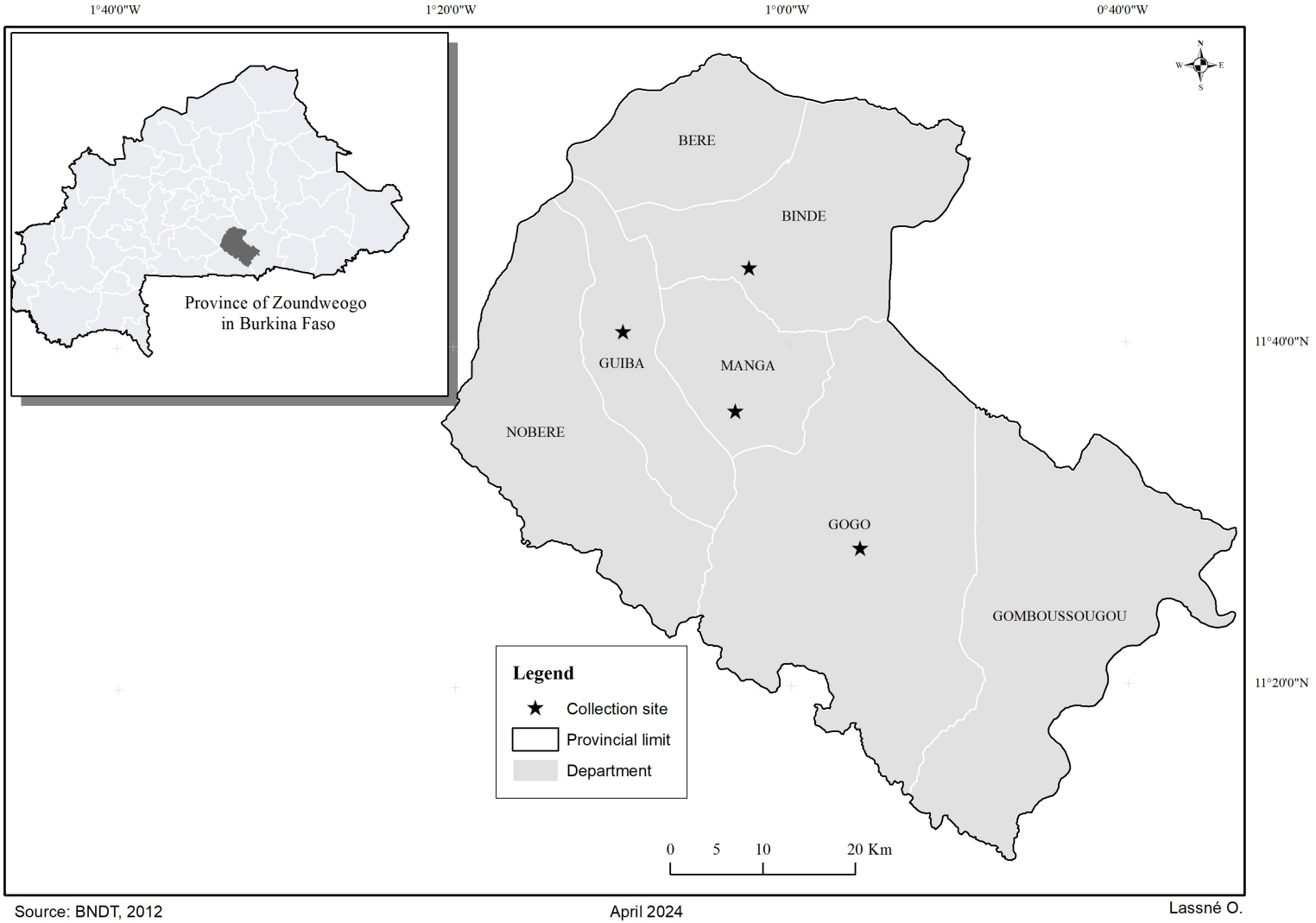

Figure 1. Collection site

2.2. Phytochemical Screening

The phytochemical screening of secondary metabolites, including alkaloids, saponins, flavonoids, triterpene sterols, tannins, and total polyphenols, was conducted using established methods. Specifically, saponins were analysed according to the protocol outlined by Odebiyi O and Sofowora [11], while alkaloids, tannins, and flavonoids were evaluated using the method described by Kancherla *et al.* [12]. Additionally, steroids and/or triterpenoids were identified using the technique developed by Maria *et al.* [13]. Total polyphenols were quantified using the Folin-Ciocalteu reagent and gallic acid (GA) as the reference standard [14]. The absorbance of the final solution was read at a wavelength of 760 nm against a control sample. The concentration was expressed as mg GAE/g of extract.

2.3. Physicochemical Characterization

The AOAC official method [15] was employed for determination of moisture, protein, ash and lipid contents. Experimentation was replicated 3 times.

2.4. Anti-radical Activity (DPPH)

The evaluation of the anti-radical activity by the use of DPPH (2,2-diphenyl-1-picrylhydrazyl) as described by Velazquez et al. [16] was used.

The control sample consisted of a mixture of 100 µL of methanol or distilled water and 200 µL of DPPH. The percentage of inhibition of the DPPH radical by the extracts was calculated using the following formula:

$$\text{Inhibition} = (\text{Absorbance of blank-Absorbance of the sample})/\text{Absorbance x100} \quad (1)$$

The inhibition concentration (IC) was expressed in µg/mL, and the standard used was acid ascorbic at a concentration of 4±0.15 µg/mL, acid ascorbic [13].

2.5. Characterization of Fatty Acids

Fatty acid analysis was conducted using the method outlined by Bazongo *et al.* [17]. The extraction process involved adding approximately 5 g of sample to a Soxhlet extractor, followed by the addition of petroleum ether for a 3h extraction period. Subsequently, an 8 mL quantity of a 2% sodium hydroxide methanol solution was added to the extracted fat.

All system components were connected to the reflux condenser, and the mixture underwent reflux in a water bath at 80 ℃ until the oil droplets disappeared. After that, a 15% solution of boron trifluoride in methanol (7 mL) was introduced at the upper end of the reflux condenser, and reflux continued for 2 min. Afterward, the reflux condenser was rinsed with a small amount of water. The flask was removed from the water bath, allowed to cool to room temperature (25±2 ℃), and then 10 to 30 mL of n-heptane was added and stirred for 2 min. The extraction process was completed by adding a saturated sodium chloride solution, after which around 5 mL of the upper n-heptane layer was carefully transferred. The extracted n-heptane layer was combined with around 3-5 g of anhydrous sodium sulfate in a 25 mL test tube. The mixture was shaken for 1 min and then allowed to stand for 5 min before the supernatant was collected into a sample vial for analysis. The fatty acid composition was determined using gas-liquid chromatography on a Shimadzu GC-2010 Pro instrument. The separation was performed on a SH-Rt-2560 column, which had a length of 100 m, a film thickness of 0.20 µm, and an inner diameter of 0.25 mL. The column temperature started at 100 ℃ and remained constant for 8 min. Afterward, it was raised to 240 ℃ at a rate of 3 ℃ per min and held at that temperature for 15 min. The injector temperature was set to 240 ℃, the injection volume was 1 µL and the flow rate was 1 mL per min using high-purity argon as the carrier gas at a pressure of 0.6-0.8 MPa. The detector temperature was maintained at 245 ℃. The analysis was replicated three times.

2.6. Characterization of Amino Acids

Amino acids were determined using the non-derivatization liquid chromatography-tandem mass spectrometry (LC-MS/MS) method as described by Bazongo *et al.*[17] and DeArmond and Bunch [18]. The quantification of amino acids in different samples was performed by combining MRM and SIM methods and using LC/MS/MS [19].

Samples were first digested. The digestion solution consisted of 1:1 hydrochloric acid containing 1‰ of phenol, hydrochloric acid and water were mixed 1 to 1. Then phenol (1/1000 of the weight) was added according to the volume of the mixture. A suitable quantity of uniform sample was combined with 10 mL of digestion solution. The whole is sealed by injecting nitrogen into the digestion tube to replace the air. It was dissolved at 110 ℃ for 24 h, after cooling and filtering, 1 mL of the filtrate was dried at 110 ℃, redissolved with 1 mL of diluted hydrochloric acid (0.1 mol/L) then put on the machine after a 0.22 µm filtration membrane.

The Shimadzu 8050 LC-MS/MS apparatus was used to analyse amino acids according to the procedure outlined below. The column utilized was an Endeavorsil type C18, 1.8 µm, 100 mm x 2.1 mm, with a flow rate of 0.2 mL/min and a split ratio of 1:100. The overall run time was 43 min, with a column temperature program that began at 100 ℃ for 8 min, ramped at 3 ℃/min to 240 ℃, and remained at 240 ℃ for 15 min (Table 1). The mobile phase included 0.1% formic acid and acetonitrile, with a 1 µL injection volume. The mass conditions for electrospray ionization included an interface temperature of 300 ℃, desolvation temperature of 250 ℃, DL temperature of 250 ℃, atomizing gas flow of 3.00 L/min, air flow heating of 10.00 L/min, and heating block temperature.

Table 1. Gradient elution conditions: Flow rate 0.2 mL/min

Time/min	Phase A %	B phase %
0	98.0	2.0
5.00	40.0	60.0
10.10	98.0	2.0
15.00	98.0	2.0

The injector temperature was set at 240 ℃, injection volume was 1 μL, and flow rate was 1 mL/min. The carrier gas was more than 99.996% argon at a pressure of 0.6-0.8 MPa, while the detector temperature was kept at 245 ℃. The experiment was repeated three times.

2.7. Characterization of Minerals

Mineral and trace element analyses were performed using inductively coupled plasma emission spectrometry (ICP-OES) as described by Bazongo et al.[17].

The samples had been acid-digested. A glass or polytetrafluoroethylene digestion vessel was used to weigh approximately 0.5 g of each sample. Nitric acid mixture of 10 mL and perchloric acid (10:1) was added and dissolved on an electric hotplate. If the digestion solution became brown and black throughout the digestion process, a small amount of mixed acid was added till white smoke was produced. When the solution became colorless, transparent, or slightly yellow, it was cooled and filled with water up to 25 mL. A blank test was run concurrently.

The PerkinElmer (PE) AVIO200 model was used for ICP-OES. Parameters were altered as follows: Instrumental analysis conditions included an argon plasma gas flow rate of 12 L/min, an auxiliary gas flow of 0.2 L/min, an atomizer gas flow rate of 0.6 L/min, 1300W output power, a pump flow rate of 1.5 mL/min, a carrier gas (more than 99.996% argon) at a pressure of 0.6-0.8 MPa, a purge gas (more than 99.999% argon or nitrogen) at a pressure of 0.3-0.8 MPa, an air compressor at 0.6-0.8 Pa, and a 20 ℃ cooling water circulator. The experiment included roughly 63 typical reference minerals. The experiment was repeated three times.

2.8. Data Analysis

The Excel 2021 spreadsheet allowed the entry and processing of data was done using Minitab 19.1. The percentage, Ca/P, Ca/Mg and Na/K ratios were calculated. The results were presented as means (± SD, n = 3).

3. Results and Discussions

3.1. Phytochemical Screening

The chemical groups detected in the n-hexane and methanolic extracts were alkaloids, polyphenols, saponins and catechetical tannins (Table 2). Except for gallic tannins and triterpene sterols which were detected in the methanolic extracts. This proves that *L. microcarpa* seeds are full of several secondary metabolites. The works of Hilou *et al.* [7] on the seeds of local species including L. microcarpa demonstrated the presence of saponins, sterols/triterpenes, catechin tannins and total polyphenols. This confirms our results in the richness of seed oil of *L. microcarpa* studied in secondary metabolites.

Table 2. Chemical groups in *L. microcarpa* seed

Secondary metabolites	Methanolic extract	Hexanic extract
Alkaloids	+	+
Total polyphenols	+	+
Gallic tannins	+	-
Catechetical tannins	+	+
Saponins	+	+
Triterpene sterols	-	+

+ : Present; -: Not detected

3.2. Physicochemical Properties

The physicochemical properties and antioxidant indexes of the *L. microcarpa* seeds are summarized in Table 3. The moisture content was 2.54%, ash (2.84 ±0.00%), crude fat (60.95 ±1.24%), acid number (5.24 ±0.00 mg KOH/g), oleic acid (2.62 ±0.19%), carbohydrate (15.11 ±0.04%) and crude protein (18.55 ±0.35%). The ash and moisture content were lower than the value found by Bazongo *et al*. [20]. The moisture content: 2.54%, which indicates good potential for storage as lower moisture content can help prevent the spoiling of the seeds.

Table 3. Physicochemical parameters of *L. microcarpa* seed and seed oil

Properties	Values
Moisture	2.54% ±0.13
Ash	2.84 ±0.00%
Crude fat	60.95 ±1.24%
Acid number	5.24 ±0.00 mg KOH/g
Oleic acid	2.62 ±0.19%
Carbohydrate	15.11 ±0.04%
Crude protein	18.55 ±0.35%

In cotton, the moisture content of peanut and soybeans was more than 5, and the ash content was about 2 for peanuts and more than 4 for cotton and soybeans [21].

The seed of *L. microcarpa* moisture content was low, which means a good storage quality, which results in good quality of the oils extracted. Kabutey *et al*. [22], reported that low moisture in seeds leads to high rate pressure, indicating that the collected seeds were well preserved and of good quality.

Crude fat content: 60.95±1.24%, which is quite high, suggesting that the seeds are a rich source of oil. The acid number was about 5.24±0.00 mg KOH/g superior to the one of 1.50 found by Sirajo [4].

However, the WHO standard value recommended for domestic oil is 0.6 mg KOH/g. This high acid number could mean that the oil of the African grape studied had a higher level of free fatty acid which could cause rancidity and off-flavors. Some authors showed that most of domestic oil, exposed to environmental oxygen undergoes oxidation because of high levels of unsaturated fatty acids [23].

3.3. Antioxidant Activity in Seed Oil

The antioxidant capacity is specified in Table 4. The reducing capacity of the seed oil, as determined by the Folin-Ciocalteau assay, was 20±0.34 mg GAE/g for the methanol extract and 6±0.13 µg/mL for the n-hexane extract. DPPH activity was 220±25 µg/mL (methanol extract) and 1001.4±42 µg/mL (n-hexane extract).

Table 4. Antioxidant indexes of *L. microcarpa* seed oil extracts

Folin-Ciocalteau (mg GAE/g)	Methanol extract	20±0.34
	n-hexane extract	6±0.13
DPPH radical activity (IC_5; µg/mL) Standard (4±0.15 µg/mL, acid ascorbic)	Methanol extract	220±25
	n-hexane extract	1001.4±42

Free fatty expressed in oleic acid content was about of 2.62± 0.19% higher than sesame oil (1.84%) [24]. Oleic acid is important monounsaturated fat associated with several health benefits.

Carbohydrate content was higher than the value of 10.85% found by Bazongo *et al*. [20] in the Southwest of Burkina Faso. The sampling collection site can then explain this difference. The carbohydrate content was lower than the value found in peanuts [25]. This carbohydrate content indicates that *L. microcarpa* seeds are energy-yielding nutrients present.

The value of crude protein represented almost twice that was found in *L. microcarpa* fruits regarding the work of Yalcin *et al*. [26] in *Vitis vinifera* L. grape seeds. We can note that the seed of *L. microcarpa* is a notable amount of protein for a seed.

The DPPH activity (IC50) value of methanol and n-hexane extract was 220±25 µg/mL and 1001.4±42 µg/mL respectively. The highest antiradical activities were from methanol extract. Our results are similar to those of Hilou *et al*. [22] who found that polar extracts had a strong antiradical activity. The lower the IC50 value in the DPPH assay, the stronger the antioxidant activity of the substance being tested. Therefore, the methanolic extract has a significantly stronger antioxidant activity, which is potentially valuable for nutritional and medicinal applications due to the protective effect of antioxidants against oxidative stress and related diseases. This confirms the work of Bazongo *et al.* [27] which is a significant oxidative stability.

3.4. Biochemical Parameters

3.4.1. Fatty Acids in Seed Oil

In *L. microcarpa* seed oil, fatty acid profile included a total of 20 individual fatty acids, comprising 14 saturated fatty acids, 2 monounsaturated fatty acids, and 4 polyunsaturated fatty acids (as detailed in Table 5). Notably, the proportions of monounsaturated and polyunsaturated fatty acids (55.63%) exceeded those of saturated fatty acids. Furthermore, the number of fatty acids found in L. microcarpa seed oils surpassed the 10 fatty acids reported in Sirajo's work [4].

Table 5. Fatty acid profile in *L. microcarpa seed oil*

Fatty acid	Value (mg/kg)	Percentage (%)
Saturated fatty acid		
Arachidic acid 20:0	6757.92±0.05	1.21
Behenic acid 22:0	101.39±0.00	0.02
Decanoic acid 10:0	102.85±0.4	0.02
Heptadecanoic acid 17:0	865.4±0.02	0.16
Lauric acid 12:0	83.02±0.00	0.01
Myristic acid 14:0	1411.07±0.23	0.25
Palmitic acid 16:0	178502.97±0.1	32.04
Pentadecanoic acid 15:0	139.66±0.05	0.03
Stearic acid 18:0	59171.78±0.68	10.62
Mono-unsaturated fatty acid		
Cis-9-oleic acid 18:1 n-9	209991.54±1.05	37.69
Cis-9-tetracosenoic acid 24:1 n-9	19.06±0.02	0.00
Palmitoleic acid 16:1 n-7	995.95±0.89	0.18
Poly-unsaturated fatty acid		
Arachidonic acid 20: 4 n-6	135.06±0.07	0.02
Cis-6-9-12-γ-linolenic acid 18:3 n-3	114.72±0.8	0.02
Cis-9,12-linoleic acid 18:2 n-6	95595.76±0.01	17.16
Cis-9,12,15-α-linolenic acid 18:3 n-3	1965.1±0.84	0.35
Cis-11-arachidonic acid 20:4 n-6	1133.6±0.5	0.20
SFA	247136.06±1.53	44.36
MUFA	211006.55±1.96	37.87
PUFA	98944.24±2.22	17.76

SFA: Saturated Fatty Acid; MUFA: Mono-Unsaturated Fatty Acid; PUFA: Poly-Unsaturated Fatty Acid

Palmitic acid, cis-9-oleic acid and cis-9,12-linoleic ω6 were identified as the predominant fatty acids in *L. microcarpa* oil comprising over 85% of its fatty acid composition. This combination of fatty acids characterizes the oil as a palmitic-oleic-linoleic oil comparable to oils from pili nuts and palm [28]. Furthermore *L. microcarpa* oil is noted for its favorable texture and softness, making it suitable for industrial applications [29]. Rich in omega-6 and omega-3 essential fatty acids, this oil can offer potential health benefits. Specifically, linoleic acid and linolenic acid present in the oil can positively impact blood lipid levels by reducing LDL cholesterol. Moreover, these fatty acids serve as precursors for various hormones that are important for human immunity [29].

3.4.2. Amino Acids in Seed

Table 6. Amino acids profile of *L. microcarpa* seed

Amino acids	Value (mg/kg)	Percentage (%)
Alanine	6996.17 ±0.02	2.14
Arginine	27135.96 ±0.00	8.29
Aspartic acid	13579.25 ±0.00	4.15
Cystine	174898.03 ±0.1	53.45
Glutamic acid	33825.12 ±0.04	10.34
Glycine	8051.11 ±0.00	2.46
Histidine*	3612.07 ±0.06	1.10
Isoleucine*	9070.23 ±0.20	2.77
Leucine*	12532.01 ±0.08	3.83
Lysine*	4819.19 ±0.50	1.47
Methionine*	401.33 ±0.42	0.12
Phenylalanine*	9108.64 ±0.01	2.78
Proline	1868.02 ±0.00	0.57
Serine	7982.68 ±0.02	2.44
Threonine*	4971.85 ±0.70	1.52
Tryptophane*	96.57 ±0.00	0.03
Tyrosine	5629.63 ±0.10	1.72
Valine acid*	2624.93 ±0.03	0.80
TNEAA	279965.97 ±0.03	85.56
TEAA	47236.82 ±0.22	14.44

TNEAA: Total non-essential amino acids, TEAA: Total essential amino acids

Table 6 shows that eighteen (18) amino acids were found in *L. microcarpa* seed. Of which, nine non-essential amino acids represented 85.56% of the seed. Essential amino acids represent approximately 6% of the seed. Essential amino acids are vital since the human body cannot synthesize them and they must be obtained through diet. Cystine was the most predominant amino acid (53.45%), followed by glutamic acid (10.34%). The cystine value was 174,898.03 ± 0.1 mg/kg, which is more significant than the value of 12,500 mg/kg reported by Sirajo [4] in *L. microcarpa* seeds. This difference may be attributed to the geographical location of the species. Furthermore, in Sirajo's works [4], the total amount of non-essential amino acids and essential amino acids was almost similar, which contrasts with our study. Cystine and glutamic acid were the predominant proteins; these two proteins serve as precursors of glutathione (GSH) [30]. This suggests that the seed of *L. microcarpa* from Burkina Faso could act as a precursor of GSH.

The most predominant essential amino acids were leucine (12532.01 ±0.08 mg/kg) followed by phenylalanine (9108.64 ±0.01 mg/kg) and isoleucine (9070.23 ±0.2 mg/kg). The essential amino acid with the low value was tryptophane (96.57 ±0.00 mg/kg). The recommended value of the three most essential amino acids; leucine, phenylalanine, and isoleucine are 10.7-15.7 mg/kg, 12.1-15.7 mg/kg and 7.8-10.1 mg/kg respectively [31]. The recommended value of all essential amino acids is deficient [31] regarding those found in *L. microcarpa* seed.

This demonstrates that the seed of *L. microcarpa* is a potential source of essential amino acids and can be used as a supplement in the food or medicinal industry. Essential amino acids are required for various metabolic processes and are building blocks for protein synthesis.

3.4.3. Minerals of *L. microcarpa* Seed

In *L. microcrapa* seed twenty-two minerals were determined of which five major minerals (calcium, potassium, magnesium, sodium and phosphorus) and eighteen trace minerals (aluminum, barium, boron, chromium, cobalt, copper, iron, lead, lutetium, manganese, nickel, rubidium, selenium, silicon, strontium and zinc) (Table 7). The most predominant major minerals were phosphorus (36.40%) and potassium (33.30%). The most trace minerals were rubidium (0.40%) and boron (0.29%).

The seed of *L. microcarpa* is a source of phosphorus and potassium and can supplement the lack of phosphorus and potassium.

The five major minerals found are necessary for bone health, cardiovascular function, nerve transmission, and many other physiological processes.

In general trace minerals were very low in the seed of *L. microcarpa* and represented 2.23%.

The calcium (Ca) concentration was 1915.53 ±0.00 mg/kg, whereas the recommended calcium dietary intake for an adult around 50 years old is 1000 mg per day [32]. *L. microcarpa* seed can be a source of calcium for the body.

L. microcarpa seed had a magnesium (Mg) concentration of 2746.03 mg/kg. Magnesium participates in bone formation and many enzymatic reactions.

Phosphorus and sodium content in seed was about 6350.99 ±0.06 mg/kg and 215.63 ±0.10 mg/kg close respectively to phosphorus found in sunflower seed and sodium content in soybean seed [32].

The seed of *L. microcarpa* had a potassium (K) value of 5809.31 mg/kg. This oilseed can serve as a supplement for potassium deficiencies. Potassium plays a crucial role in muscle function. The recommended potassium intake for adults is around 3000 mg [33]. With its high potassium

content, this oilseed could potentially address deficiencies in this essential mineral. Furthermore, the significance of potassium in the seed may elucidate why the seed cake of *L. microcarpa* is utilized as a condiment (called *Soumbala*).

Table 7. Minerals profile of *L. microcarpa* seed

Element name	Symbol of Element	Value (mg/kg)	Percentage (%)
Major minerals			
Calcium	Ca	1915.53±0.00	10.98
Potassium	K	5809.31±0.01	33.30
Magnesium	Mg	2746.03±0.05	15.74
Sodium	Na	215.63±0.10	1.24
Phosphorus	P	6350.99±0.06	36.41
Trace minerals			
Aluminum	Al	35.51±0.00	0.20
Barium	Ba	48.85±0.00	0.28
Boron	B	51.26±0.02	0.29
Chromium	Cr	8.39±0.00	0.048
Cobalt	Co	0.30±0.01	0.00
Copper	Cu	19.43±0.03	0.11
Iron	Fe	19.14±0.04	0.11
Lead	Pb	0.12±0.00	0.00
Manganese	Mn	12.10±0.4	0.07
Nickel	Ni	6.02±0.00	0.03
Rubidium	Rb	69.93±0.03	0.40
Selenium	Se	2.44±0.00	0.01
Silicon	Si	41.59±0.01	0.24
Strontium	Sr	28.32±0.08	0.16
Zinc	Zn	44.66±0.05	0.26
Zirconium	Zr	0.20±0.00	0.00
Total major minerals	-	17037.49±0.04	97.77
Total trace minerals	-	388.26±0.03	2.23
Ratios			
Calcium:Phosphorus	Ca:P	1:3.31	-
Calcium:Magnesium	Ca:Mg	1:1.43	-
Sodium:Potassium	Na:K	1:26.94	-

The quantity of aluminum (Al) in the seed was 35.51± 0.00 mg/kg. While the tolerable biological value for aluminum is 200 µg/L [34]. To be consumed, the oil must have a large part of its aluminum removed.

The concentration of barium (Ba) was 48.85±0.00 mg/kg, while the dietary intake of barium in some foods like potatoes and nuts was about 0.30 mg and 1.80 mg [35]. The lethal dose in the human body is comprised between 1 to 30 g and an ingestion of 0.2 g can be toxic [35]. It is important to avoid consuming seeds with high concentrations of barium to prevent potential health risks.

The boron (B) content was about 51.26±0.02 mg/kg. The recommended daily intake amount for boron is 1-13 mg. Boron enters into the metabolism of minerals, lipids and proteins [36,37].

The quantity of chromium (Cr) was 8.39±0.00 mg/kg. Chromium participates in the regulation of insulin and blood sugar. Its recommended daily value is 50 µg to 200 µg [38].

The cobalt concentration was 0.30±0.01 mg/kg. Cobalt is a constituent of vitamin B12 and participates in the metabolism of digestive flora [39].

The copper (Cu) concentration was 19.43±0.03 mg/kg. Yet the daily intake of copper in animals such as pigs is approximately 5 to 10 mg/kg but this value can be about 75 mg/kg to 250 mg /kg for pig weaning and growth [40].

Iron (Fe) content was 19.14±0.04 mg/kg. The daily intake of iron is 0.13 mg/kg, while the limit maximum residual for this element is of between 8 and 18 mg/kg [41,42]. The approved concentration in edible oil of Fe is comprised between 1 and 1.5 mg/kg [43]. Regarding this concentration, our value is high. Iron participates in the formation of red blood cells; it is an important element for energy metabolism and helps reduce fatigue. Excess iron in the body has an antioxidant effect.

Lead (Pb) concentration of 0.12±0.00 mg/kg was found in the seed of *L. microcarpa*. This value is close to the Pb limit maximum residual in edible oil of 0.10 mg/kg [44,42]. The accumulation of lead in the body can cause serious damage.

The quantity of manganese (Mn) was about 12.10±0.4 mg/kg. The daily intake ranged from 2 to 3 mg for an adult and around 1 and 2 mg for children. Manganese is essential for bone formation and is involved in the production of insulin. That said, the oil of our seed can act as a dietary supplement for diabetics. Manganese is also involved in the metabolism of carbohydrates, lipids and proteins. *L. microcarpa* seed can contribute to the supply of manganese to the body and helps to avoid bone problems and oxidative stress. Manganese helps synthesize certain enzymes such as superoxide dismutase, which allows the body to fight against oxidative stress.

The nickel (Ni) concentration found was 6.016±0.00 mg/kg. The recommended content of Ni in edible oils is 0.2 mg/kg [43] lower than the present results.

The rubidium (Rb) content found in the oilseed was 69.9344±0.03 mg/kg. The Rb content in this study was very high compared to the daily intake of this element, which is about 3 mg. In fact, the body treats rubidium like a potassium ion [45].

The selenium (Se) content determined in this study was approximately 2.44 mg/kg. For adults, the recommended daily intake of selenium is between 0.05 mg and 0.25 mg per day. Selenium participates in the enzymes synthesis in the body [46].

The concentration of silicon (Si) measured in this study was approximately 41.60 mg/kg. Silicon occurs naturally in various foods, including cereals, milk and beverages.

Notably, the recommended daily intake of silicon in China is around 139 mg/kg per day [47]. Silicon plays a role in several physiological processes and maintaining an appropriate intake level is believed to be essential to overall health.

The strontium (Sr) content of the oil was measured at 28.3192 ±0.08 mg/kg. Furthermore, the daily intake of strontium is 4 mg [48]. The sample's zinc (Zn) content was estimated at 44.6631 ±0.05 mg/kg. As for the recommended daily intake of zinc for adults, it can be up to 11 mg for men and 9 mg for women [49]. Zinc helps boost the immune system of older adults and may help reduce the duration and severity of colds [50]. Zinc is necessary for several enzymatic processes. It participates in the synthesis of DNA, RNA and proteins. The seed of *L. microcarpa* serves as a valuable zinc source for dietary supplementation and medicinal purposes. The zirconium content was measured at 0.1968 ±0.00 mg/kg. Notably, the recommended daily dose of zirconium does not exceed 125 mg and it finds diverse applications within the pharmaceutical industry [51].

The phosphocalcic ratio (Ca:P) must be between 1.5 (for the maintenance of reproduction) and 2 (for growth and work) for animal feed [52], while in our study this ratio is low and is located at 1:3.31, which is less than the recommended values for animal feed, implying that if used as animal feed, it may need to be balanced with other sources of calcium.

The Ca:Mg ratio was 1:1.43. The calcium-to-magnesium ratio differs for human and animals, it depends on the age for the humans and the weight for the animals [53]. In this study, Ca:Mg was inferior to the recommended value of 2:1 to maintain physiological health [54].

The Na:K ratio was 1:26.94 similar to the value found in the seed of *Balanites aegyptiaca* L. Delile from Burkina Faso [17].

Na to K ratio indicates a favorable balance, as high sodium diets are often associated with health risks, and a lower Na:K ratio is generally considered healthier.

The seed of *L. microcarpa* contains some heavy metals. But it should be noted that in edible oils heavy metals such as cadmium, lead, copper and iron have been determined in olive oil, corn oil, rapeseed oil and sunflower [42].

Beyond all these minerals, note that the maximum residual value for heavy metals is set at a limit of 100 µg for edible oils [55]. Thus, *L. microcarpa* seed oil would need some processing to be safe for consumption.

4. Conclusions

L. microcarpa seed and seed oil have promising nutritional and medicinal potential due to their rich biochemical composition. They contain secondary metabolites like alkaloids, polyphenols, saponins, and tannins. The seed quality is indicated by its high content of fatty acids and proteins, good moisture and ash content. Over half of the seed oil composition is made up of essential monounsaturated and polyunsaturated fatty acids, including omega-6 and omega-3, which are crucial for heart health and cellular function. The seed's richness in essential amino acids and its mineral content, with major minerals making up over 97% of the total, suggest its value as a dietary supplement and mineral source. The seed oil's antioxidant capacity, evident from the DPPH assay, suggests it may help mitigate oxidative stress linked to chronic diseases and aging. Thus, *L. microcarpa* seed oil could be beneficial in the food industry for health-promoting products and in the medicinal industry for its therapeutic properties.

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