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Physicochemical and Biochemical Composition of *Balanites aegyptiaca* Seed and Seed Oil from Burkina Faso

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Abstract

In Burkina Faso, the seeds of *Balanites aegyptiaca* have been considered to be potentially high lipid, protein and mineral sources but seem to be neglected and sometimes unknown by communities. This study aims to complete data on seed oil and detail on amino acids and minerals composition of the seed of *B. aegyptiaca* for better use. Physicochemical parameters such as moisture and ash content, saponification index, iodine, acid value, peroxide value and the melting point were determined. Seed oil triglycerides, fatty acids and amino acids have been estimated throughout this study. The moisture and ash content were 3.70% ± 0.1% and 2.90% ± 0.2%, respectively. The saponification and iodine values were respectively 181.96 ± 0.4 mg KOH/g of oil and 104.86 ± 0.6 g of iodine/100 g of oil. Polyunsaturated fatty acid content (50.94%) was the most important. Triglyceride (LLO, 22.4%) was the major triglyceride. 9 essential amino acids and 9 non-essential amino acids were identified. Phenylalanine (11697.82 ± 0.00 mg/kg) was the most important essential amino acid. The content of 21 minerals was determined and the most important was potassium (9323.13 ± 0.01 mg/kg). Ca/P, Ca/Mg, Ca/Mg and Na/K ratios were 0.34; 1.18; 0.04 and 0.19 respectively. *B. aegyptiaca* seed oil is a source of multiple nutritional values and can be used by the population for multipurpose.

Keywords

Seed, Seed Oil, Fatty Acids, Amino Acids, Minerals, *Balanites aegyptiaca*, Burkina Faso

1. Introduction

Native oilseed trees are widely used in West Africa for daily consumption and income generation. They are used as sources of specific nutrients (lipids, proteins, vitamins, minerals…) and natural molecules for food, medicine, body care and hair care. The oleaginous plants are invaluable reservoirs for food use, but also industrial [1]. In fact, *Balanites aegyptiaca* (L.) Del. (Zygophyllaceae) called also desert date is well represented in West Africa, particularly in Burkina Faso. It is a multipurpose species employed for a variety of indigenous medical, food and cosmetic purposes. It is used especially as a source of oil and proteins. For example in Burkina Faso, *B. aegyptica* leaves and fruits are used as medicine and food [2]. In Uganda, leaves and seeds are used as complementary food [3].

The fruits are edible and known as desert dates. The pulp is bitter sweet and contains galactose, mannose, arabinose, xylose, rhamnose and glucuronic acid [4]. Crude oil (49.0%) and crude protein (32.4%) were the two major constituents of the kernels [5]. Yet, according to the same source, the oil is edible and characterized by a content of 75.1% unsaturated fatty acid. Linoleic acid (47.1%) followed by oleic acid (28%) and palmitic acid (15.3%) were the predominant fatty acids according to Bazongo *et al.* [6] and Deshmukh and Bhuyar [7]. The fatty acid content of the oil from the seeds was about 41.3% and the triglycerides were a value of 98.6% [6]. The physicochemical parameters of *B. aegyptiaca* oil indicate a pale yellow with a density of 0.910 g/cm3; a refractive index of 1.458 and a viscosity of 19.68 [8]. The acid value, free fatty acid, peroxide, saponification value and iodine value were 3.06 mgKOH/g; 1.27; 3.71 mEq/Kg; 198 mg/KOH/g; and 98.73 100/g respectively [3] [8]. Fruits, seed and seed oil of *B. aegyptiaca* contain saponin compounds which have numerous biological and pharmacological properties (antimicrobial, antifungal larvicidal) including anticarcinogenic activity [9] [10] and antioxidant activities [11].

Literature has reported much data on lipids [6] [12], proteins, and minerals in *B. aegyptiaca* seeds oil [13] [14]. However, Lykke *et al.* [15] in their work carried out on unconventional oils taking into account *B. aegyptiaca* seed oils in West Africa showed that the work published on these seed oils must be taken with caution. In addition, in Burkina Faso, the data about the species of seed and seed oil is not well documented. The species is sometimes neglected and its nutritional values are unknown.

Thus, the sustainable exploitation of these natural resources could constitute a palliative solution to undernourishment and malnutrition in Burkina Faso. Moreover, in recent years, particular attention has been paid to these species of

oilseeds to better promote them. Research therefore on the composition of seeds and seed oil of *B. aegyptiaca* could provide details on the physicochemical and biochemical composition as well as more information on the nutritional and therapeutic aspects of this species.

The objective of the present study is to complete the data on seed oil and to detail the amino acid and mineral composition of *B. aegyptiaca* seed for better use of this species.

2. Material and Methods

2.1. Fruits Sampling

Fruits of *B. aegyptica* (2 kg) at the same maturity stage were collected in November 2022 in South Central Burkina Faso. Before their transport to the laboratory, the fruits were hand sorted to eliminate damaged ones. Before any analysis, fruit samples were washed with glass-distilled water, drained, and air dried under laboratory conditions (22˚C - 23˚C) for one week. The dried seeds were milled with a Moulinex grinder (GT550, Zurich, Switzerland) then sieved using a 1 mm mesh sieve and stored at 18˚C until analyses.

2.2. Physicochemical Analysis of Seed and Oil Seed

Moisture and ash contents in seeds were determined according to the protocols established by the Association of Official Analytical Chemists [16]. Moisture was determined gravimetrically after drying the sample overnight at 105˚C. Ash was quantified after incinerating the sample overnight at 550˚C. The total protein content (% total nitrogen × 6.25) in seed was established by the Kjeldahl method [17]. Total lipids on the seed were determined by Soxhlet extraction with petroleum ether for 6 h, after which the solvent was removed using a rotary vacuum evaporator. Carbohydrate content (on a dry weight basis) in seed was estimated by the difference of mean values: 100 − (sum of percentages of ash, protein and lipids) [18]. The saponification value was determined according to AOCS official method Cd 3-25 [19]. The oil sample (5 g) was saponified using alcoholic potassium hydroxide (40 g of KOH dissolved in 1000 ml of ethanol). The unreacted KOH was back titrated with HCl (1 M) using phenolphthalein as an indicator. The iodine value was directly determined from the fatty acid composition according to the AOCS method Cd 1-25 [19]. Peroxide value was determined according to the AOCS official method Cd 8-53 [19]. The oil (5 g) was placed in 30 ml glacial acetic acid: chloroform (3:2 v/v %) and a saturated solution of potassium iodide (0.5 ml) was added to liberate iodine by reacting with the peroxide. The resulting solution was titrated against sodium thiosulphate (0.01 M) using starch solution (1%) as an indicator. The acid value of seed oil was determined according to the AOCS official method Ca 3a-63 [19]. To a liquid fat sample, neutralized 95% ethanol and phenolphthalein indicator were added and titrated with NaOH. The melting point was determined by the capillary tube method according to AOCS official method Cc 1-25 [19].

2.3. Biochemical Analysis of Seed and Seed Oil

2.3.1. Triglyceride Analysis

Triglyceride compositions were determined using the adapted method of Bazongo *et al.* [20]. The sample size was 5 - 10 µL of ca. 10% solutions of triglycerides. Triglyceride isomers were identified by comparison of their retention time to those of cocoa butter obtained under similar analytical conditions [20] [21]. The analysis was done in triplicate.

2.3.2. Determination of Fatty Acids

Fatty acids were determined according to IUPAC Standards Methods with a few modifications [22]. A certain amount of sample was weighed into the fiber filter, put into the Soxhlet extractor, and petroleum ether was added to extract for 3 hours. 8 mL of 2% sodium hydroxide methanol solution was added into the fat extract, connected to the reflux condenser and was refluxed on the water bath at 80˚C until the oil droplets disappeared. 7 mL 15% boron trifluoride methanol solution was added from the upper end of the reflux condenser, and the reflux was continued in the water bath at 80˚C for 2 min. The reflux condenser was flushed with a small amount of water. The heating was stopped, the flask was removed from the water bath, and quickly cooled to room temperature. Accurately 10 mL - 30 mL n-heptane was added and shaken for 2 min, then saturated sodium chloride solution was added, stand stratification. About 5 mL of the upper n-heptane extraction solution was absorbed, mixed with 3 g - 5 g anhydrous sodium sulfate into a 25 mL test tube, shaken for 1min; left for 5min and the upper solution was absorbed into the sample bottle to be determined. Gas Liquid Chromatography (GLC) was performed using Shimadzu GC-2010 Pro. The column was SH-Rt-2560, length 100 m, film thickness 0.20 µm, and inner diameter 0.25 mm. Column temperature was initially 100˚C, maintained for 8 min, and the temperature raised to 240˚C at 3˚C /min for 15 min. the temperature of the injector was 240˚C, the injection volume was 1 µL and the flow rate was 1 mL/min. The temperature of the detector was 245˚C. The analysis was done in triplicate.

2.3.3. Determination of Amino Acids

The amino acids were determined using the non-derivatization liquid chromatography-tandem mass spectrometry (LC-MS/MS) method as described by Dearmond and Bunch [23]. First all the samples were digested. The digestion solution was 1 + 1 hydrochloric acid containing 1‰ phenol, hydrochloric acid and water are mixed by 1 to 1, and then one-thousandth of the weight of phenol is added according to the volume of the mixture. An appropriate amount of uniform sample was taken, mixed it with a digestion solution of 10 mL, and then sealed by injecting nitrogen into the digestion tube to replace air. It was dissolved at 110˚C for 24 hours, cooled and filtered, and 1 mL of filtrate was dried at 110˚C, redissolved with 1 mL 0.1 mol/L hydrochloric acid, diluted, and then put on the machine after 0.22 µm filtration membrane. Amino acids analysis was

performed using the Shimadzu 8050 LC-MS/MS instrument. The column was Endeavorsil C18 1.8 µm 100 × 2.1 mm and the flow rate was 0.2 ml/min. The column temperature was 40˚C and collection time was 15 min (Table 1). The mobile phase was 0.1% formic acid and acetonitrile as indicated in the table below. The mass conditions of electrospray ionization were as follows: Interface temperature: 300˚C, desolvation temperature: 526˚C, DL temperature: 250˚C, atomization gas flows: 3.00 L/min, air flow heating: 10.00 L/min, heating block temperature: 400˚C, drying air flow: 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 was used [24].

2.3.4. Determination of Minerals

Mineral and trace element analyses were achieved using inductively coupled plasma optical emission spectrometry (ICP-OES) as described by Selmy *et al.* [25] with a few modifications. Before conducting the experiments, the sample was acid digested. Accurately 0.5 g (accurate to 0.001 g) of samples were weighed in a glass or polytetrafluoroethylene digestion vessel. 10 mL of nitric acid-perchloric acid (10 + 1) mixed solution was added and then dissolved on the electric heating plate. If the digestion solution turns brown and black during digestion, a small amount of mixed acid is added appropriately until white smoke is emitted. When the digestion solution became colorless and transparent or slightly yellow, it was cooled and was filled with water to 25 mL. A blank test was done at the same time. The ICP-OES Instrument was PerkinElmer (PE) ICP-OES Model AVIO200. The parameters were adjusted as follows: Instrumental analysis conditions: argon; Plasma gas flow rate: 12 L/min; Auxiliary gas flow: 0.2 L/min; Atomizer gas flow rate: 0.6 L/min; Power output: 1300 W; Pump flow rate: 1.5 mL/min; Carrier gas (more than 99.996% argon: 0.6 - 0.8 MPa); Purge gas (more than 99.999% argon or nitrogen: 0.3 - 0.8 MPa); Air compressor (0.6 - 0.8 Pa); Cooling water circulator (20˚C). The analysis was done in triplicate.

2.4. Statistical Analysis

The software Minitab 19.1 was used to analyze data. The data were presented as the mean with standard deviation (mean ± SD) and each experiment was performed in a set of three separate replicates (n = 3).

Table 1. Gradient elution.

Time/min	Flow Rate (mL/min)	Phase A %	B phase %
0	0.200	98.0	2.0
5.00	0.200	40.0	60.0
10.10	0.200	98.0	2.0
15.00	0.200	98.0	2.0

3. Results and Discussion

3.1. Physicochemical Composition

The physicochemical parameters of the seed are summarized in Table 2.

The moisture and ash content was of 3.14% ± 0.11% and 3.72%, respectively. While crude fat, protein and carbohydrate were of 39.33%, 28.28% and 25.53%, respectively.

The value of moisture content was close of to the value of 3.19% and 3.27% mentioned by Datti *et al.* [8] and Ali *et al.* [12]. All these values were higher than the values of 0.114% and 0.10% found respectively by Zang *et al.* [26] and Khadra *et al.* [27].

This difference can be explained by the geographical position of the desert date or the nature of the raw material.

Ash content value was higher compared to the value of Datti *et al.* [8] about the kernel oil. This ash content would indicate a richness of *B. aegyptiaca* seed in minerals [28].

The physicochemical composition of *B. aegyptiaca* seed oil is recorded in the Table 3.

Saponification value of 181.96 mg KOH/g of oil found was close to 186 mg KOH/g of oil recorded by Kabo *et al.* [29].

The iodine value was about of 104.86 g of iodine/100 g of oil close to the value of 104.39 mentioned by Zang *et al.* [26]. While iodine value found in the work of Ogala *et al.* [30] in Nigeria was about 98.74 g of iodine/100 g of oil. Yet, the saponification value is ranged between 172 and 199.32 mg KOH/g with an iodine value ranged between 65 to 68.56 g of iodine/100 g of oil [31]. This indicates that the seed oil of desert date from Burkina Faso has a good saponification value and a higher iodine value.

Table 2. Physicochemical composition of *B. aegyptiaca* seed.

Properties	Value (%)
Moisture	3.14 ± 0.11
Ash	3.72 ± 0.12
Crude fat	39.33 ± 0.42
Crude protein	28.28 ± 0.17
Carbohydrate	25.53 ± 0.03

Data are expressed as mean ± SD (n = 3).

Table 3. Physicochemical parameter of *B. aegyptiaca* seed oil.

Properties	Value
Saponification value (mg KOH/g of oil)	181.96 ± 0.4
Iodine value (g of iodine/100 g of oil)	104.86 ± 0.6
Acid value (mg of KOH/g of oil)	0.4 ± 0.00
Peroxide value (meq of O_2/kg of oil)	4 ± 0.1
Melting point (˚C)	4.4 ± 0.00

Data are expressed as mean ± SD (n = 3).

The acid value was of 0.4 mg of KOH/g of oil lower than 0.6 mg of KOH/g of oil corresponding to the standard value of acid given by FAO for the refined edible oils [32]. This shows the good quality of the seed oil from *B. aegyptiaca*. Peroxide value (4 meq of O_2/kg of oil) was ranged in the value of the Joint FAO/WHO Codex Alimentarius commission [32] which recommends a value of up to 10 meq of O_2/kg of oil for refined oils.

3.2. Biochemical Composition

3.2.1. Fatty acid Composition

Fatty acids in *B. aegyptiaca* seed oil are recorded in **Table 4**.

Polyunsaturated fatty acid content (50.93%) was higher than monounsaturated fatty acid (25.61%) and saturated fatty acid (23.46%). The main fatty acid was Cis-9.12-linoleic *ω*6 acid (284354.32 mg/kg or 50.85%) followed by Cis-9-oleique acid (142443.35 mg/kg or 25.47%).

Linoleic acid sounds to be the major fatty acid in *B. aegyptiaca* seed oil. In fact, in the work of Diedhiou *et al.* [33] linoleic acid was the most predominant (about 37%) in the *B. aegyptiaca* seed oil. This confirms our results on the importance of linoleic acid in *B. aegyptiaca* seed oil.

The richness of *B. aegyptiaca* seed oil in linoleic acid would be an asset for this oil in the field of child malnutrition. This oil could therefore be integrated as an ingredient in the preparation of food for malnourished children and certain adults in a situation of nutritional imbalance.

Table 4. *B. aegyptiaca* composition in fatty acids in seed oil.

Fatty acids	Value (mg/kg)	Value (%)
Lauric acid	29.71 ± 0.00	0.01
Myristic acid	320.87 ± 0.00	0.06
Palmitic acid	71576.3 ± 0.01	12.8
Stearic acid	57526.82 ± 0.3	10.29
Arachidic acid	1652.01 ± 0.02	0.3
Palmitoleic acid	762.75 ± 0.00	0.14
Cis-9-oleique acid	142443.35 ± 0.07	25.47
Cis-9.12-linoleic *ω*6 acid	284354.32 ± 0.00	50.85
Cis-9.12.15-linolenic *ω*3 acid	464.12 ± 0.00	0.08
Arachidonique *ω*6 acid	72.8 ± 0.00	0.01
SFA	131105.71 ± 0.06	23.46
MUFA	142443.35 ± 0.07	25.61
PUFA	284891.24 ± 0.00	50.93

Data are expressed as mean ± SD (n = 3). SFA = saturated fatty acid; MUFA = monounsaturated fatty acid; PUFA = polyunsaturated fatty acid.

3.2.2. Triglycerides Composition

In this study, 12 triglycerides were found (Table 5) in *B. aegyptiaca* seed oil. Triglycerides were composed of mainly by polyunsaturated (76.1%) followed by saturated (22.4%) and monounsaturated (1.5%). The importance of polyunsaturated fat means that the seed oil of *B. aegyptiaca* can participate to the decreasing of bad cholesterol in the body and in addition polyunsaturated fat can't be biosynthetized by the body [34]. Kris-Etherton and Yu [35] established a positive correlation between the administration of SFA and the increase in blood cholesterol (LDL). This correlation factor depends on the type of SFA and their position in the triglyceride skeleton. This activity is more important when SFA is in the Sn2 position of the triglyceride [36] [37]. The triglyceride composition of *B. aegyptiaca* oil showed that there are no SFA esterified in the SN2 position. This result therefore indicates that the consumption of this oil can help improve the health of those who have diseases linked to bad cholesterol.

Table 5. Triglycerides profile of *Balanites aegyptiaca* seed oil.

Triglycerides	Value (Mole%)
Mono-unsaturated	
POP	-
POS	1.5 ± 0.00
SOS	-
SOA	-
Total	1.5 ± 0.00
Diunsaturated	
PLP	3.9 ± 00
POO	8 ± 0.01
SOO	6 ± 0.00
SLS	4.5 ± 0.02
AOO	-
Total	22.4 ± 0.00
Poly-unsaturated	
LLL	15.3 ± 0.00
LLO	22.5 ± 0.00
SLnL	-
PLL	8.3 ± 0.05
PLnO	-
LOO	2.2 ± 0.01
SLL	14.4 ± 0.00
PLO	8.4 ± 0.00
OOO	5 ± 0.01
SLO	-
Total	76.1 ± 0.01

Data are expressed as mean ± SD (n = 3). Ln = Linolenic Acid 18:3. L = Linolic Acid C18:2. O = Oleic Acid C18:0. P = Palmitic Acid C16:0. A = Arachidic Acid C20:0. S = Stearic acid.

Trilgyceride (LLO, 22.4%) was the major triglyceride follow by triglyceride (LLL, 15.3%) and triglyceride (SLL, 14.4%). Diedhiou *et al.* [33] was studied *B. aegyptiaca* triglycerides and found triglycerides (PPIL, POL, SOL) different from our results. This difference can be due to the geographical position of the species. The triglyceride composition of *B. aegyptiaca* oil is similar to that of corn oil in which the majority triglycerides are dilinoleoolein (LLO) (20.1%) and trilinolein (LLL) (20.1%) [38].

3.2.3. Amino Acid Composition

Table 6 highlights the amino acid profile encountered in *B. aegyptiaca* seed.

18 amino acids were determined including 9 essential amino acids and 9 non-essential amino acids. The total amino acid content was 652113.73 mg/g and the essential amino acid content was 52333.77 mg/g. The most important essential amino acid was phenylalanine with a value of 11697.82 mg/kg. For the non-essential amino acid, the most important was cystine with a value of 476919.42 mg/kg. As a reminder, the body cannot synthesize essential amino acids and their source always comes from food. *B. aegyptiaca* seed oil can be used as a food supplement to fill the deficit of essential amino acids due to its richness in essential amino acids. Moreover, work by Okia [3] showed that *B. aegyptiaca* almonds were used as a food supplement and this reinforces our idea.

Table 6. Amino acid profile of *B. aegyptiaca* seed.

Amino acid	Value (mg/kg)
Alanine	7226.66 ± 0.01
Threonine*	5241.50 ± 0.00
Glycine	13815.16 ± 0.02
Lysine*	6401.96 ± 0.00
Serine	6278.42 ± 0.00
Histidine *	2762.09 ± 0.04
Arginine	38051.35 ± 0.00
Cystine	476919.42 ± 0.02
acide Glutamique	38450.70 ± 0.05
Proline	1894.50 ± 0.00
Aspartic acid	17143.75 ± 0.00
Valine*	2271.33 ± 0.02
Methionine*	552.80 ± 0.01
Isoleucine*	7064.75 ± 0.01
Leucine*	11221.28 ± 0.00
Tyrosine	4979.11 ± 0.03
Phenylalanine*	11697.82 ± 0.00
Tryptophane*	141.13 ± 0.01
TAA	652113.73 ± 0.01
TEAA	52333.77 ± 0.01

Data are expressed as mean ± SD (n = 3). * Essential Amino Acid. TAA = Total Amino Acid. TEAA = Total Essential Amino Acid.

The amount of phenylalanine was lower than the amount of 4.23 mg/100g found by Muhammad *et al.* [39] in the oilseeds of *B. aegyptiaca* from Nigeria. The phenylalanine content in *B. aegyptiaca* oilseeds was high and this indicates that the oil can help improve the diet of children and adults.

In our work 9 essential amino acids were determined then in the work of Sagna *et al.* [40] on the biochemical composition of the fruit of *B. aegyptiaca* in Senegal this number was reduced to 8. This proves the richness of seed oil of *B. aegyptiaca* from Burkina Faso in essential amino acids.

Sulfur-containing amino acids such as cysteines (476919.42 mg/kg) have a very high content compared to that of methionine (552.80 mg/kg). The importance of the oil in essential amino acids would give this oil nutritional and therapeutic quality.

3.2.4. Mineral Composition

Table 7 represents the minerals profile of *Balanites aegyptiaca* seed. The content of 21 minerals was determined.

Table 7. Mineral profile of *B. aegyptiaca* seed.

Element Name	Symbol of element	Composition (mg/kg)
Calcium	Ca	2056.92 ± 0.00
Potassium	K	9323.13 ± 0.01
Magnesium	Mg	1743.99 ± 0.00
Sodium	Na	327.92 ± 0.01
Phosphorus	P	6055.44 ± 0.00
Copper	Cu	11.39 ± 0.01
Iron	Fe	19.83 ± 0.00
Zinc	Zn	31.81 ± 0.00
Manganese	Mn	16.54 ± 00
Selenium	Se	10.58 ± 0.02
Aluminum	Al	55.46 ± 0.03
Boron	B	67.12 ± 0.00
Barium	Ba	27.40 ± 0.00
Cobalt	Co	0.07 ± 0.00
Chromium	Cr	7.77 ± 0.02
Nickel	Ni	3.58 ± 0.00
Lead	Pb	0.56 ± 0.00
Rubidium	Rb	20.74 ± 0.01
Silicon	Si	54.42 ± 0.001
Strontium	Sr	39.90 ± 0.005
Zirconium	Zr	0.30 ± 0.001
Ca/P		0.34
Ca/Mg		1.18
Na/K		0.04
Na/Mg		0.19

Data are expressed as mean ± SD (n = 3). Ca/P: Calcium to phosphorus ratio; Ca/Mg: Calcium to magnesium ratio. Na/K: Sodium to potassium ratio; Na/Mg: Sodium to magnesium ratio.

There were 5 major minerals including potassium, phosphorus, calcium, magnesium and sodium with respective values of 9323.1306 mg/kg; 6055.4437 mg/kg; 2056.9204 mg/kg; 1743.9925 mg/kg and 327.9191 mg/g. There were 16 trace elements, the most important of which were boron (67.12 mg/kg) and aluminum (55.46 mg/kg). The potassium in *B. aegyptiaca* was higher than those of peanut (6035.9 mg/kg), sunflower (8753.8 mg/kg) and sesame (4295.7 mg/kg) according to the work of Özcan [41]. While calcium content was close to that of Pistachio oil (1998.09 mg/kg). Phosphorus content was higher than that of olive seed oil (745.5 mg/kg) mentioned by Maestri *et al.* [42]. In fact, phosphorus is an essential element in the care of malnourished children [43]. The oil contains zinc (31.81 mg/kg) and iron (19.83 mg/kg) which can contribute to a good diet.

The calcium/phosphorus ratio (0.34) was below the normal Ca/P range of 1 to 2:1 which corresponds to the recommended intake for infant feeding [44]. Yet, calcium is favorable when the Ca/P ratio is ranged between 0.5 - 0.8 [45]. From there our results are close to these values.

The Ca/Mg ratio was 1.18 almost similar to the recommended value of 1.0 [46] lower than the range of 1.70 - 2.5 recommended to reduce the risk of cancer [47] and associated with greater inflammation [48]. This allows us to say that *B. aegyptiaca* seed oil would reduce the risk of inflammation.

The Na/K ratio value was about 0.04 lower than 1 which indicates a good quality of oil to fight against cardiovascular diseases [49].

These minerals identified in the seeds of *B. aegyptiaca* show the richness of the seed in minerals or even that of the oil which comes from the seed. The importance of these minerals gives B. *aegyptiaca* oil nutritional and therapeutic properties. The oil could therefore play the role of a nutraceutical.

4. Conclusions

Physicochemical parameters analysis of *B. aegyptiaca* from Burkina Faso shows that the seed oil has good saponification, acid and peroxide values. The seed and seed oil are rich in minerals, fatty acids and amino acids. Thus, seed and seed oil from *B. aegyptiaca* have significant nutritional value and can be used as food/nutraceuticals or can be useful for preparing soaps values.

These data could contribute to the knowledge and valorization of *B. aegyptiaca* seed and seed oil from Burkina Faso.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Merrien, A., Carre, P. and Quinsac, A. (2012) Des ressources oléagineuses variées

potentiellement au service du développement de la chimie verte. *OCL*, **19**, 6-9. https://doi.org/10.1051/ocl.2012.0425

[2] Ouédraogo, S., Bondé, L., Ouédraogo, O., Thiombiano, A., Boussim, I.J., Ouédraogo, S., *et al.* (2020) To What Extent Do Tree Size , Climate and Land Use Influence the Fruit Production of *Balanites aegyptiaca* (L) Delile in Tropical Areas (Burkina Faso)? *International Journal of Fruit Science*, **20**, 282-299. https://doi.org/10.1080/15538362.2019.1619216

[3] Okia, C.A. (2010) *Balanites aegyptiaca*: A Resource for Improving Nutrition and Income of Dryland Communities in Uganda. Ph.D. Thesis, Bangor University, Bangor.

[4] Beka, R.G., Guiama, V.D., Delmont, A., Donn, P., Slomianny, M., Libouga, D.G., *et al.* (2011) Glycosyl Part Identified within *Balanites aegyptiaca* Fruit Protease. *International Journal of Biological Macromolecules*, **49**, 397-401. https://doi.org/10.1016/j.ijbiomac.2011.05.019

[5] Mohamed, A.M. and Wolf, W. (2002) Physical, Morphological and Chemical Characteristics, Oil Recovery and Fatty Acid Composition of *Balanites aegyptiaca* Del. Kernels. *Plants Foods for Human Nutrition*, **57**, 179-189. https://doi.org/10.1023/A:1015237612018

[6] Bazongo, P., Henri, I., Bassole, N., Nielsen, S., Dick,o M.H. and Shukla, V.K.S. (2014) Studies in the Evaluation of Unconventional Oils from Burkina Faso Rich in Linoleic Acid, Oleic Acid or Other Unusual Fatty Acids. *Journal of Food Processing and Technology*, **5**, 2-5.

[7] Deshmukh, S.J.Ã. and Bhuyar, L.B. (2009) Transesterified Hingan (*Balanites*) Oil as a Fuel for Compression Ignition Engines. *Biomass and Bioenergy*, **33**, 108-112. https://doi.org/10.1016/j.biombioe.2008.04.017

[8] Datti, Y., Yahya, A.T., Koki, I.B., Lado, U.A., Musbahu, L., Shuaibu, M.M., *et al.* (2020) Determination of the Proximate and Mineral Contents of Desert Date Kernel (*Balanites aegyptiaca* Linn.) and the Physical and Chemical Characteristics of the Kernel Oil Available in Kano State, Nigeria. *FUDMA Journal of Sciences*, **4**, 250-259. https://doi.org/10.33003/fjs-2020-0402-217

[9] Chapagain, B.P., Yehoshua, Y. and Wiesman, Z. (2009) Desert Date (*Balanites aegyptiaca*) as an Arid Lands Sustainable Bioresource for Biodiesel. *Bioresource and Technology*, **100**, 1221-1226. https://doi.org/10.1016/j.biortech.2008.09.005

[10] Beit-yannai, E., Ben-Shabat, S., Goldschmidt, N. and Chapagain, B.P. (2011) Antiproliferative Activity of Steroidal Saponins from *Balanites aegyptiaca*—An *in vitro* Study. *Phytochemistry*, **4**, 43-47. https://doi.org/10.1016/j.phytol.2010.11.004

[11] Nitiema, L.W., Sombié, P.A.E.D., Koala, M. and Del Fiore, A. (2020) Phytochemical Composition and Antioxidant Activity of *Balanites aegyptiaca*, *Securidaca longepedunculata* and *Acacia gourmaensis* Used against Seed-Borne Fungi in Burkina Faso. *Current Journal of Applied Science and Technology*, **39**, 79-87. https://doi.org/10.9734/cjast/2020/v39i130483

[12] Ali, A.E., Mohammed, B., Abd, H., Mahmoud, A., Omer, I., Malik, M., *et al.* (2021) Biochemical Properties and Nutritional Value of *Balanites aegyptiaca* (Laloub) Seed Oil. *EAS Journal of Nutrition and Food Sciences*, **3**, 100-103.

[13] Elbadawi, S.M.A., Ahmad, E.E.M., Mariod, A.A. and Mathäus, B. (2017) Effects of Thermal Processing on Physicochemical Properties and Oxidative Stabilities of *Balanities aegyptiaca* Kernels and Extracted Oils. *Grasas Y Aceites*, **68**, e184. https://doi.org/10.3989/gya.1048162

[14] Murthy, H.N., Yadav, G.G., Dewir, Y.H. and Ibrahim, A. (2021) Phytochemicals

and Biological Activity of Desert Date (*Balanites aegyptiaca* (L.) Delile). *Plants*, **10**, Article 32. https://doi.org/10.3390/plants10010032

[15] Ouédraogo, A. and Lykke, A.M. (2013) Potentials for Promoting Oil Products Identified from Traditional Knowledge of Native Trees in Burkina Faso. *Ethnobotanical Ressources and Applications*, **11**, 71-83.

[16] Horwitz, W. (2002) Official Methods of Analysis of AOAC International. 17th edition, AOAC International, Gaithersburg.

[17] Kjeldahl, J. (1983) A New Method for the Determination of Nitrogen in Organic Matter. *Zitschrift für Analytische Chemie*, **22**, 366-382. https://doi.org/10.1007/BF01338151

[18] Yeo, H., Youn, K., Kim, M., Yun, E., Hwang, J., Jeong, W., *et al.* (2013) Fatty Acid Composition and Volatile Constituents of *Protaetia brevitarsis* Larvae. *Preventive Nutrition and Food Science*, **18**, 150-156. https://doi.org/10.3746/pnf.2013.18.2.150

[19] American Oil Chemist's Society (1998) Official Methods and Recommended Practice of the American Oil Chemist's Society. 5th Edition, American Oil Chemist's Society, Champaign.

[20] Bazongo, P., Bassolé, I.H.N., Nielsen, S., Hilou, A., Dicko, M.H. and Shukla, V.K.S. (2014) Characteristics, Composition and Oxidative Stability of *Lannea microcarpa* Seed and Seed Oil. *Molecules*, **19**, 2684-2693. https://doi.org/10.3390/molecules19022684

[21] Shukla, V.K.S., Nielsen, S.W. and Batsberg, W. (1983) A Simple and Direct Procedure for the Evaluation of Triglyceride Composition of Cocoa Butters by High Performance Liquid Chromatography—A Comparison with the Existing TLC-GC Method. *Fette*, *Seifen*, *Anstrichmittel*, **85**, 274-278. https://doi.org/10.1002/lipi.19830850705

[22] IUPAC (1979) Standard Methods for the Analysis of Oils, Fats and Derivatives. *Pure and Applied Chemistry*, **51**, 2503-2525. https://doi.org/10.1351/pac197951122503

[23] Dearmond, P.D. and Bunch, D.R. (2022) Quantitation of Non-Derivatized Free Amino Acids for Detecting Inborn Errors of Metabolism by Incorporating Mixed-Mode Chromatography with Tandem Mass Spectrometry. *Journal of Mass Spectrometry and Advances in the Clinical Lab*, **25**, 1-11. https://doi.org/10.1016/j.jmsacl.2022.05.002

[24] Sun, Z., Xing, J., Khoo, Y. and Zhan, Z. (2016) A Combined MRM and SIM Method for Direct Quantitative Determination of Amino Acids in Various Samples on LC/MS/MS. ASMS, TP 740.

[25] Selmi, A., Khiari, R., Snoussi, A. and Bouzouita, N. (2020) Analysis of Minerals and Heavy Metals Using ICP-OES and FTIR Techniques in Two Red Seaweeds (*Gymnogongrus griffithsiae* and *Asparagopsis taxiformis*) from Tunisia. *Biological Trace Element Research*, **199**, 2342-2350. https://doi.org/10.1007/s12011-020-02335-0

[26] Zang, C.U., Jock, A.A., Garba, H.I. and Chindo, Y.I. (2018) Application of Desert Date (*Balanites aegyptiaca*) Seed Oil as Potential Raw Material in the Formulation of Soap and Lotion. *American Journal of Analytical Chemistry*, **9**, 423-437. https://doi.org/10.4236/ajac.2018.99033

[27] Khadra, B., Ahmed, M., Somia, B., Ahmed, B., Nafissa, B. and Nassima, F. (2022) Physicochemical Properties of *Balanites aegyptiaca*'s Seeds and Seed Oil from Southern Algeria. *Egyptian Journal of Chemistry*, **65**, 39-45.

[28] Uzoukwu, A.E., Ubbaonu, C.N., Nwosu, J.N., Ogueke, C.C. and Chukwu, M.N. (2020) The Anti-Nutritional and Proximate Composition of Rain Tree (*Samanea*

saman) Pod Samples. *Agriculture and Food Sciences Research*, **7**, 28-37. https://doi.org/10.20448/journal.512.2020.71.28.37

[29] Kabo, K.S., Ali, T. and Ogbesejana, A. (2020) Extraction and Physico-Chemical Parameter Analysis of Desert Date (*Balanite aegyptiaca*) Oil from Dutsin-Ma. *FUDMA Journal of Sciences*, **4**, 409-413. https://doi.org/10.33003/fjs-2020-0402-225

[30] Ogala, H., Elinge, C., Wawata, I.G., Adegoke, A., Muhammad, A. and Ige, A. (2018) Extraction and Physicochemical Analysis of Desert Date (*Balanites aegyptiaca*) Seed Oil. *International Journal of Advanced Academic Research*, **4**, 1-12.

[31] Cheikhyoussef, N., Kandawa-Schulz, M., Bock, R. and Cheikhyoussef, A. (2020) Cold Pressed *Moringa oleifera* Seed Oil. In: Ramadan, M.F., Ed., *Cold Press Oils*, Academy Press, Cambridge, 467-475. https://doi.org/10.1016/B978-0-12-818188-1.00042-6

[32] Joint FAO/WHO Codex Alimentarius Commission (2001) Fats, Oils and Related Products. World Health Organization, Rome.

[33] Diedhiou, D., Faye, M., Candy, L., Vandenbossche, V., Diedhiou, D., Faye, M., *et al.* (2022) Composition and Balance of the Analytical Fractionation of Desert Date (*Balanites aegyptiaca* L.) Seeds Harvested in Senegal. *African Journal of Biotechnology*, **20**, 150-158.

[34] Elhardallou, S.B., Elawad, A.M., Khairi, N.A., Gobouri, A.A. and Dhahawi, H.O. (2014) A Review on ω-3 and ω-6 Essential Fatty Acids: Uses, Benefits and Their Availability in Pumpkins (*Curcurbita maxima*) Seed and Desert Dates (*Balanites aegyptiaca*) Seed Kernel Oils. *Pakistan Journal of Biological Science*, **17**, 1195-1208. https://doi.org/10.3923/pjbs.2014.1195.1208

[35] Kris-Etherton, P.M. and Yu, S. (1997) Individual Fatty Acid Effects on Plasma Lipid Sand Lipoproteins: Human. *American Journal of Clinical Nutrition*, **65**, 1628S-1644S. https://doi.org/10.1093/ajcn/65.5.1628S

[36] Dabadie, H., Peuchant, E., Bernard, M., Leruyet, P. and Mendy, F. (2005) Moderate Intake of Myristic Acid in Sn-2 Position Has Beneficial Lipidic Effects and Enhances DHA of Cholesteryl Esters in an Interventional Study. *Journal of Nutritional Biochemistry*, **16**, 375-382. https://doi.org/10.1016/j.jnutbio.2005.01.010

[37] Kubow, S. (1996) The Influence of Positional Distribution of Fatty Acids in Native, Interesterified and Structure-Specific Lipids on Lipoprotein Metabolism and Atherogenesis. *Nutritional Biochemistry*, **7**, 530-541. https://doi.org/10.1016/S0955-2863(96)00106-4

[38] Kamal-Eldin, A. (2006) Effect of Fatty Acids and Tocopherols on the Oxidative Stability of Vegetable Oils. *European Journal of Lipid and Science Technology*, **58**, 1051-1061. https://doi.org/10.1002/ejlt.200600090

[39] Muhammad, I.U., Alhassan, A.J., Ramatu, Y., Mohammad, A., Nasir, A., Yaradua, A.I., *et al.* (2018) Amino Acid Profile and Mineral Content of *Balanites aegyptiaca* Kernel. *Asian Journal of Applied Chemistry Research*, **1**, 1-7. https://doi.org/10.9734/ajacr/2018/v1i49683

[40] Sagna, M.B., Diallo, A., Sarr, P.S., Ndiaye, O. and Guisse, A. (2014) Biochemical Composition and Nutritional Value of *Balanites aegyptiaca* (L.) Del Fruit Pulps from Northern Ferlo in Senegal. *African Journal of Biotechnology*, **13**, 336-342. https://doi.org/10.5897/AJB2013.12395

[41] Özcan, M.M. (2006) Determination of the Mineral Compositions of Some Selected Oil-Bearing Seeds and Kernels Using Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES). *Grasas Y Aceites*, **57**, 211-218. https://doi.org/10.3989/gya.2006.v57.i2.39

[42] Maestri, D., Barrionuevo, D., Bodoira, R., Zafra, A., Jiménez-López, J. and de Dios Alché, J. (2019) Nutritional Profile and Nutraceutical Components of Olive (*Olea europaea* L.) Seeds. *Journal of Food Science and Technology*, **56**, 4359-4370. https://doi.org/10.1007/s13197-019-03904-5

[43] Yoshimatsu, S., Chisti, M.J., Hossain, I., Islam, M., Fukushima, T. and Wagatsuma, Y. (2012) Hypophosphataemia among Severely-Malnourished Children : Case Series. *Health Population and Nutrition*, **30**, 491-494. https://doi.org/10.3329/jhpn.v30i4.13419

[44] Loughrill, E., Wray, D. and Christides, T. (2017) Calcium to Phosphorus Ratio, Essential Elements and Vitamin D Content of Infant Foods in the UK : Possible Implications for Bone Health. *Maternal and Child Nutrition*, **13**, e12368. https://doi.org/10.1111/mcn.12368

[45] Novidzro, K.M., Wokpor, K., Fagla, B.A., Koudouvo, K., Dotse, K., Osseyi, E., *et al.* (2019) Study of Some Physicochemical Parameters and Analysis of Mineral Elements, Chlorophyll Pigments and Carotenoids of *Griffonia simplicifolia* Seed Oil. *International Journal of Biological and Chemical Science*, **13**, 2360-2373. https://doi.org/10.4314/ijbcs.v13i4.38

[46] Adeyeye, E.I., Orisakeye, O.T. and Oyarekua, M.A. (2012) Composition, Mineral Safety Index, Calcium, Zinc and Phytate Interrelationships in Four Fast-Foods Consumed in Nigeria. *Bulletin of Chemical Society of Ethiopia*, **26**, 43-54. https://doi.org/10.4314/bcse.v26i1.5

[47] Zhao, J., Giri, A., Zhu, X., Shrubsole, M.J., Jiang, Y., Guo, X., *et al.* (2019) Calcium : Magnesium Intake Ratio and Colorectal Carcinogenesis, Results from the Prostate, Lung, Colorectal, and Ovarian Cancer Screening Trial. *British Journal of Cancer*, **121**, 796-804. https://doi.org/10.1038/s41416-019-0579-2

[48] Deluccia, R., Cheung, M., Ng, T. and Ramadoss, R. (2019) Calcium to Magnesium Ratio Higher than Optimal across Age Groups (P10-100-19). *Current Developments in Nutrition*, **3**, nzz034.P10-100-19. https://doi.org/10.1093/cdn/nzz034.P10-100-19

[49] He, F.J. and Macgregor, G.A. (2008) Beneficial Effects of Potassium on Human Health. *Physiologia Plantarum*, **133**, 725-735. https://doi.org/10.1111/j.1399-3054.2007.01033.x