

Assessment of Physicochemical and Nutritional Characteristics of *Sclerocarya birrea* A. Almonds and Oil from Burkina Faso

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Abstract

Sclerocarya birrea fruits and almonds are used in human nutrition and are a source of income for the rural population of Burkina Faso. The aim of this study was to evaluate the physico-chemical and nutritional characteristics of *Sclerocarya birrea* A. rich (*Anacardiaceae*) almonds from Burkina Faso. Fresh ripe fruits of *Sclerocarya birrea* were collected in three regions of Burkina Faso: the *North*, the *Mouhoun loop* and the *Hauts-Bassins*. The physico-chemical parameters of almonds and oil extracted from almonds were determined using AOAC methods. Amino acids were measured by HPLC and minerals by atomic absorption spectrometry. The results show that *Sclerocarya birrea* almonds have a moisture of $4.16\% \pm 0.40\%$ with $4.47\% \pm 0.20\%$ total ash; $28.89\% \pm 2.08\%$ protein; $56.46\% \pm 2.36\%$ total fat and $10.18\% \pm 2.14\%$ carbohydrates. Amino acid profile showed that almonds contain all the essential amino acids, with high levels of histidine and phenylalanine. Total ash analyzed consists mainly of calcium (192.85 ± 169.17 mg/100g), potassium (806.71 ± 324.48 mg/100g), magnesium (386.57 ± 176.03 mg/100g) and sodium (28.68 ± 20.55 mg/100g), with a Na/K ratio of 0.03 ± 0.01 . Almonds also contain iron (3.33 ± 1.50 mg/100g) and zinc (6.46 ± 3.06 mg/100g). *Sclerocarya birrea* oil has a refractive index at 20°C of 1.46 ± 0.00 , an iodine value of 25.40 ± 3.18 g I₂/100g and a saponification value of 190.29 ± 10.25 mg KOH/g. *S. birrea* almonds of Burkina Faso are a source of protein, lipids, carbohydrates, minerals and essential amino acids for the diet and deserve to be developed.

Keywords

Sclerocarya birrea, Nutritional Composition, Physico-Chemical Parameters,

Burkina Faso

1. Introduction

In 2014, Burkina Faso's production of fixed vegetable oils was estimated at around 86,086 tons, including 76,894 tons from cotton, 9104 tons from groundnuts and the rest (88 tons), sesame and shea. However, this production is still insufficient to meet the national demand of more than 150,000 tons per year [1]. This shortfall can be explained by the fact that cultivation areas have shrunk as a result of climate change and urbanization, but also by the decline in the number of shea trees [2]. In order to satisfy the oil demand of local consumers, other oilseed plants such as *Adansonia digitata*, *Lannea microcarpa*, *Sclerocarya birrea* and *Balanites aegyptiaca* have been identified as alternative resources [3].

The species *Sclerocarya birrea*, also called *morula*, are an anacardiaceous plant found in arid and semi-arid areas of Africa [4]. The roots, bark and leaves of the plant are used to treat malaria, gastroenteritis, haemorrhoids, diabetes, tumours and wounds, etc. [5]. In Burkina Faso, our research shows direct consumption of the fresh pulp, which is also processed into fermented or non-fermented beverages in certain regions, such as *Mouhoun loop*. The almond is sold and consumed raw or cooked in several towns in Burkina Faso.

The almond is said to be a source of protein and lipids, as well as minerals such as potassium, calcium, magnesium and iron [6]. Almond oil is edible and has moisturizing, healing, emollient and antiperspirant cosmetic properties [5] and is rich in essential fatty acids [7].

The socio-economic interest of this plant has led national researchers to select ecotypes adapted to the agro-ecological conditions of Burkina Faso to popularize its consumption. Very little data are available on the physico-chemical characteristics and nutritional value of the almond and almond oil of the *Sclerocarya birrea* ecotypes found in Burkina Faso.

This study contributes to scientific research by determining the physico-chemical and nutritional characteristics of *Sclerocarya birrea* almond. Specifically, it presents the proximal composition, amino acid profile and mineral elements of *Sclerocarya birrea* almonds, as well as some characteristics of the oil from these almonds.

2. Material and Methods

2.1. Study Area

The locations from which *Sclerocarya birrea* fruits were collected for this study were:

- Northern region, located in the Sahelian climatic zone, with a rainy season lasting 3 to 4 months on average and rainfall of less than 600 mm per year. The vegetation is a steppe consisting of shrubs, robust and thick trees or groves The

villages such as You and Yarsi, with GPS coordinates of $02^{\circ}09'24''\text{W}$, $13^{\circ}41'51''\text{N}$ and $02^{\circ}03'07''\text{W}$, $12^{\circ}52'25''\text{N}$ respectively, have large stands of *S. birrea* trees, often used as animal fodder (Figure 1).

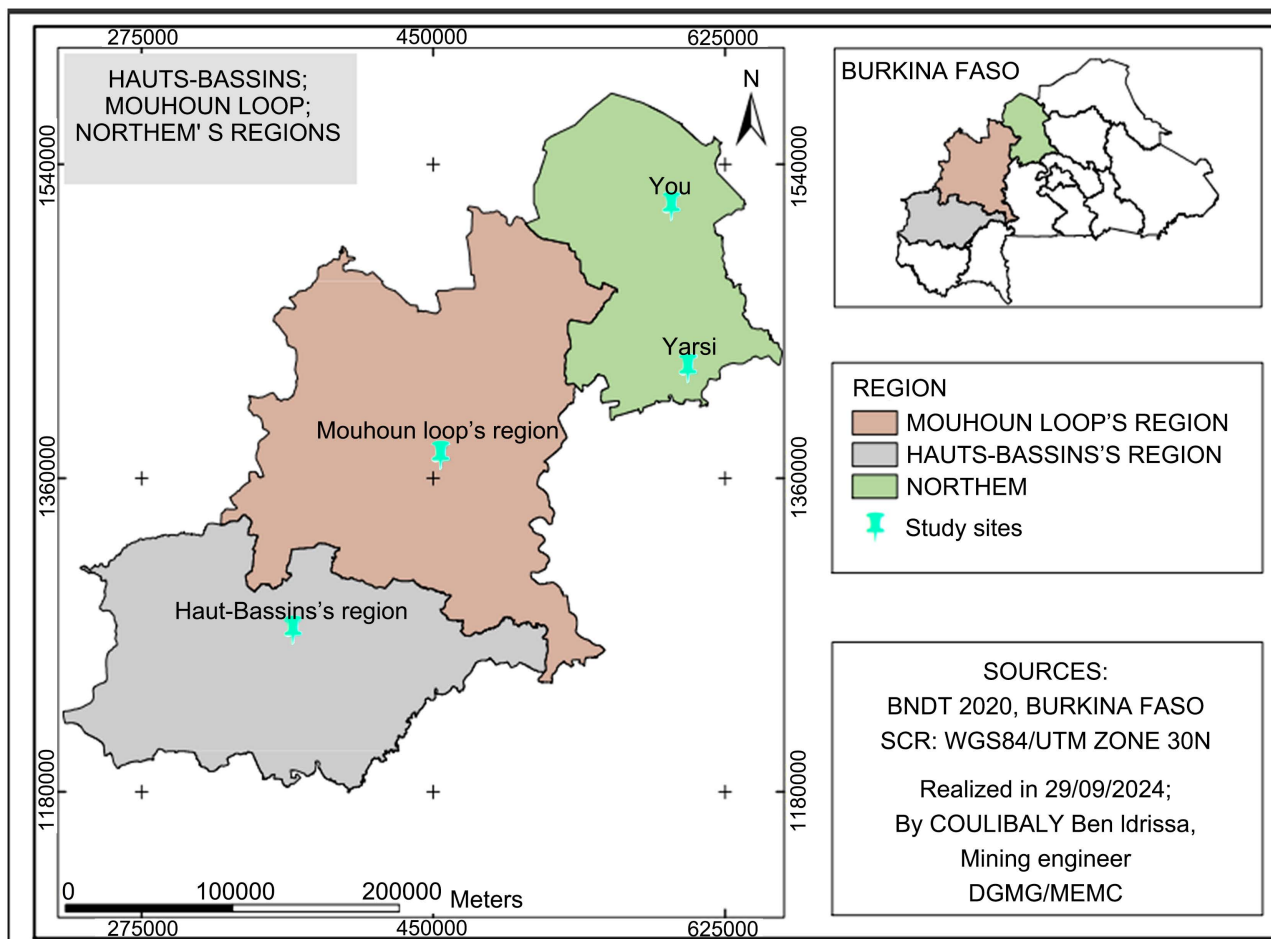


Figure 1. Map of the study area.

- *Mouhoun loop's* region (GPS coordinates $12^{\circ}24'59.76''\text{N}$, $3^{\circ}25'10.391''\text{W}$), is mainly located in the Sudano-Sahelian zone, with a rainy season lasting between 4 and 5 months, with average annual rainfall of between 600 and 1000 mm. The woody cover is more or less dense and the herbaceous cover becomes increasingly continuous towards the south. In the villages of *Lokindé*, *Bomborokuy*, *Yabana* and *Simbadougou* of this region, women use the fruits of the species as a source of economic income. A fermented drink of the fruit and the kernels almonds are sold in the village markets, like Bomborokuy.
- *Haut-Bassins's* region (GPS coordinates $11^{\circ}29'39.12''\text{N}$, $4^{\circ}14'0.01''\text{W}$), is located between Sudanian and Sudano-Sahelian climatic zones. Recorded rainfall ranges from 900 mm to 1200 mm per year, with a rainy season lasting around 6 months. This region is characterized by the presence of gallery forests. In Bobo-Dioulasso, Union-Yanta, a group of women's associations works to protect environment and promotes non-timber forest products.

This association is involved in the processing of *S. birrea* fruit. The study covered the villages of Nasso, Dinderesso, Wolokoto, Tolotama and Sara in this region (**Figure 1**).

Pre-treatment of the samples and determination of the physicochemical and nutritional parameters were carried out in the laboratory of food technology department of IRSAT/CNRST laboratory in Burkina Faso.

2.2. Vegetable Material

Sclerocarya birrea ripe fruits were collected in the North (ND), *Hauts-Bassins's* (HB) and *Mouhoun loop's* (ML) regions of Burkina Faso between May and July, 2018.

In total, eleven (11) batches of ripe fruit samples, of two (02) kilograms each, were collected in the three (03) regions. They were collected directly from the feet of the trees, put in plastic baskets with lids, labeled and then transported to the laboratory where they were thoroughly washed in tap water and left to dry in a plastic basket. Using a mortar and strainer, the nuts were collected and dry in the shade before the kernels were extracted by manual crushing. The kernels obtained were crushed using a porcelain mortar, packed in plastic jars, coded and kept in the refrigerator at 4°C before analysis. The oil samples were obtained in the laboratory by extraction with organic solvent (n-hexane) and by direct sampling during the hydraulic press extraction sessions at the *Union-Yanta* center. **Figures 2-5** show the fruit, nuts, kernels and oil of *Sclerocarya birrea* during sample pre-treatment, respectively.



Figure 2. *Sclerocarya birrea* fruit being washed and drained.



Figure 3. *Sclerocarya birrea* nuts being dried in the IRSAT/DTA pilot workshop.



Figure 4. *Sclerocarya birrea* almonds.



Figure 5. *Sclerocarya birrea* oil sample.

2.3. Methods of Analysis

2.3.1. Determination of Proximal Composition

Moisture, total ash, total fat, protein, total sugars and energy of *Sclerocarya birrea* kernels were determined using the official methods of analysis described by AOAC International, 16th edition [8].

2.3.2. Determination of Amino Acids and Mineral Elements in *Sclerocarya birrea* Kernels

Total amino acid profiles were determined by reverse phase HPLC using the Waters Pico-Tag method [9] and amino acid values were calculated [10]. Minerals in *Sclerocarya birrea* kernel samples were determined by flame atomic absorption spectrometry using the international AOAC method [11].

2.3.3. Determination of Physicochemical Parameters of *Sclerocarya birrea* Oil Samples

The Abbe refractometer was used to determine the refractive index of *S. birrea* oils according to the official methods of the American Oils Chemists' Society [12], which were used to determine the saponification and iodine indices.

2.4. Statistical Analysis

The data were analyzed with XLSTAT2014.5.03 software. The calculation of the means and standard deviations of the various physicochemical and nutritional characteristics carried out in triplicate was done with the “mean” and “standard deviation” functions of the XLSTAT2014.5.03 software. The analysis of variance (ANOVA), was used to test the significant differences between the means of the parameters determined from the different sample. For $P < 0.05$, the difference was considered significant.

3. Results and Discussion

3.1. Proximal Composition of the Kernel of *Sclerocarya birrea*

The proximate composition of *S. birrea* kernel is given in **Table 1**. The results of analysis of dried nut kernels showed $4.02\% \pm 0.47\%$ moisture with 4.47 ± 0.18 g ash; 29.50 ± 2.19 g protein; 55.78 ± 2.62 g fat; 10.25 ± 1.02 g carbohydrates and 661.02 ± 12.85 Kcal energy value per 100 g dry matter (DM). *ML* and *HB* samples showed the highest fat and moisture contents with high energy values, while the highest protein and carbohydrate contents were obtained with seeds from *ND* samples. total ash content of *S. birrea* kernels was relatively similar in the three regions (**Table 1**).

Table 1. Proximal composition of *Sclerocarya birrea* fruit kernel by collection region.

locality	Moisture (%)	Total ash (% DM)	Proteins (% DM)	Total fat (% DM)	Carbohydrates (% DM)	Energy value (kcal/100g DM)
Mouhoun loop	4.19 ± 0.33	4.67 ± 0.10	28.87 ± 0.54	57.39 ± 2.29	9.08 ± 1.88	668.24 ± 11.34
Haut-Bassins	4.39 ± 0.22	4.34 ± 0.10	27.69 ± 2.07	57.20 ± 1.12	10.77 ± 2.45	668.62 ± 5.35
Nord	3.49 ± 0.01	4.40 ± 0.08	31.94 ± 1.06	52.76 ± 0.43	10.91 ± 0.55	646.19 ± 1.87
Mean	4.02 ± 0.47	4.47 ± 0.18	29.50 ± 2.19	55.78 ± 2.62	10.25 ± 1.02	661.02 ± 12.85
P value	0.151	0.646	0.545	0.801	0.180	0.939

DM = Dry Mater. P-value > $\alpha = 5\%$, so no significant difference between proximal parameter values in the same column.

Analysis of variance (ANOVA) at the significance level $\alpha = 5\%$ showed that there was no significant difference between *S. birrea* kernels from the three regions in terms of proximate composition and energy value (P-value > α).

Moisture contents in the present study are lower than those obtained by [6] ($10.47\% \pm 0.33\%$) in Nigeria, but similar to those obtained by [13] ($4.17\% \pm 0.23\%$) in Ghana. These authors obtained lower carbohydrate contents ($9.76\% \pm 0.06\%$) than in the present study. The different drying methods for fresh *S. birrea* nuts and agroclimatic conditions in different study areas could explain the difference in moisture content. The ash contents were similar to those obtained by [6] and [13] ($4.67\% \pm 0.15\%$ and $4.63\% \pm 0.08\%$, respectively), but lower than those obtained by [14] (5.43%) using kernels of the same species. The protein and fat contents obtained by [6] ($30.97\% \pm 1.17\%$ and $58.88\% \pm 0.59\%$, respectively) are higher than those obtained in the present study. Another study carried out in Niger by [15] showed higher average protein (35.23%) and carbohydrate (14.77%) contents with lower average fat content (46.03%) than in the present study. This difference could be explained by differences in agro-climatic conditions. It could also be explained by variability of genetic factors of plant. Our results for fat content are similar to those obtained ($51.30\% - 56.23\%$) for almonds of the same species from the Centre and Cascades regions [16]. They are higher than those obtained (47.5%) by [17] from almond oils of *S. birrea* subsp. *Caffra* from different

countries in South Africa (Malawi, Mozambique, Zambia and Zimbabwe). This shows that *S. birrea* subsp. *Caffra* is less rich in fat than the *S. birrea* subsp. *birrea* subspecies of the present study.

Protein contents of *Lannea kerstingii* (26.39%), and *Lannea microcarpa* (21.14%) kernels [18] [19] are lower than *S. birrea* kernel of the present study. On the other hand, fat content is lower than that of *Lannea kerstingii* (57.85%) and *Lannea microcarpa* (64.90%) kernels [18] [19]. Another study on *Balanites aegyptiaca* seed showed lower protein (28.28%) and fat (55.78%) contents than the present study [20]. These results show that *S. birrea* kernel is a potential source of protein, lipids and calories. It is also a potential raw material for the oil industry, the production of energy bars and ingredients for seasoning sauces like peanut powders and pastes.

3.2. Amino Acid Composition of *Sclerocarya birrea* Kernel Proteins

Table 2 shows amino acid content of *S. birrea* seeds. A total of seventeen (17) alpha-amino acids were detected. *S. birrea* seeds contain mainly glutamic acid (16.88 ± 1.55 g/100g), arginine (7.47 ± 0.86 g/100g) and proline (6.88 ± 0.72 g/100g). These values are lower than those found in Nigeria by [6] who reported that glutamic acid (28.09%), arginine (14.99%) and aspartic acid (13.35%) were the major amino acids in *S. birrea* seeds. They are higher than the values obtained by [14], who also confirmed the predominance of glutamic acid, arginine and aspartic acid in *S. birrea* kernels compared to the other amino acids. The differences observed could be explained by the differences in agro-climatic conditions in study areas or by genetic variability of plants.

Table 2. Amino acid composition and essential amino acid scores of *Sclerocarya birrea* kernels from Burkina Faso.

Amino acids	Content (g/100g de proteins)	Adult content according to FAO (g/100g de proteins)	Essential amino acid score (%)
<i>Essential amino acid</i>			
His	1.61 ± 0.20	1.5	107.33
Thr	1.76 ± 0.21	2.3	76.52
Val	3.17 ± 0.29	3.9	81.28
Ile	2.16 ± 0.26	3.0	72
Leu	3.16 ± 0.34	5.9	53.56
Lys	1.85 ± 0.18	4.5	41.11
Met + Cys	1.99 ± 0.16	2.2	90.45
Phe + Tyr	4.28 ± 0.24	3.0	142.67
<i>Non-essential amino acids</i>			
Asp	4.53 ± 0.50		

Continued

Glu	16.88 ± 1.55
Ser	2.65 ± 0.27
Gly	2.72 ± 0.25
Arg	7.47 ± 0.86
Cys	0.85 ± 0.16
Ala	2.03 ± 0.21
Pro	6.88 ± 0.73
<i>Total essential amino acids</i>	<i>19.98 ± 0.24</i>
<i>Total non-essential amino acids</i>	<i>44.01 ± 0.57</i>

These results show that *S. birrea* kernel is a potential source of glutamate, which is often used to enhance the flavour of foods. In nutritional terms, this molecule is one of the most important neurotransmitters in the brain and aids memory and learning [21] [22]. It would be advisable for students to consume *S. birrea* almonds on a regular basis.

An estimate of essential amino acid content shows that the protein of *S. birrea* consists of 19.98% ± 0.24% essential amino acids. This percentage is lower than that obtained by [6] (35.01%). These differences could be due to the agro-climatic conditions of the study areas or to the genetic variability of the plants. Essential amino acid values in relation to the FAO recommendations show that 100 g of *S. birrea* almond protein is likely to meet the nutritional requirements for the aromatic amino acids, Phe + Tyr (value = 142.67%) as well as for histidine (value = 107.33%). The other essential amino acids are present in limited amounts in 100 g of *S. birrea* almond protein [10].

3.3. Mineral Composition of *Sclerocarya birrea* Kernels

Mineral composition of *S. birrea* seeds in the three regions of Burkina Faso is given in **Table 3**. The values obtained show that *S. birrea* kernels contain an average of 259.64 mg calcium, 911.30 mg potassium, 443.96 mg magnesium and 35.38 mg sodium per 100 g dry matter as major minerals, with an Na/K ratio of 0.04. The highest values were found from ND fruit kernels, while the lowest values were obtained from *ML* and *HB* fruit kernels, which showed almost similar values of major mineral elements (**Table 3**).

Table 3. Mineral composition of *Sclerocarya Birrea* fruit kernels.

Location	Ca (mg/100g)	K (mg/100g)	Mg (mg/100g)	Na (mg/100g)	Fe (mg/100g)	Zn (mg/100g)	Ratio Na/K
Mouhoun loop	138.65	653.99	299.14	18.44	3.34	5.58	0.03
Haut-Bassins	132.21	645.69	301.84	18.80	2.23	4.42	0.03

Continued

Nord	508.05	1434.22	730.91	68.91	5.50	12.28	0.05
Means	259.64	911.30	443.96	35.38	3.69	7.43	0.04
P value	0.003	<0.0001	<0.0001	<0.0001	0.048	0.007	0.034

P-value < $\alpha = 5\%$, so the difference between the mineral values in the same column is significant.

The kernels of the collected *S. birrea* fruits also contained minor mineral elements such as iron (3.69 mg/100g DM) and zinc (7.43 mg/100g DM). The highest values were found in the kernels of ND fruits, while the lowest values were found in those of HB fruits (Table 3).

Analysis of variance (ANOVA) at $\alpha = 5\%$ significance level showed a significant difference between the mineral contents of *S. birrea* kernels from the three regions (P-value < α).

Calcium and Fe contents in *S. birrea* kernels from the present study are lower than those obtained from the same species in Nigeria by [6] (403.08 ± 1.97 mg/100g DM and 27.49 ± 0.11 mg/100g DM, respectively). These authors reported lower levels of K (366.00 ± 2.00 mg/100g), Mg (206.14 ± 3.14 mg/100g), Na (4.76 ± 0.47 mg/100g) and Zn (3.29 ± 0.12 mg/100g DM). This difference in mineral content could be explained by the different agro-climatic conditions in the study areas. The calcium, potassium, magnesium, sodium, iron and zinc contents of the present study are higher than those of *Lannea kerstingii* (78.33 mg/100g; 674.18 mg/100g; 317.15 mg/100g; 2.48 mg/100g; 4.46 mg/100g and 6.34 mg/100g, respectively) according to [18]. *S. birrea* seeds are therefore a potential source of major and minor mineral elements. This is a great advantage for the consumer, especially for the strengthening of bones and teeth in children by Ca, respiration and cellular energy metabolism with Fe, heart rate regulation and insulin production by Mg. The low Na/K ratio (< 1) shows that the consumption of *Sclerocarya birrea* kernels could be an asset in reducing blood pressure and contributing to the reduction of the risk of cardiovascular diseases [23]-[25].

3.4. Physico-Chemical Characteristics of *Sclerocarya birrea* Oil

The results of physico-chemical parameters of *S. birrea* oil are given in Table 4. *S. birrea* oil gave an average refractive index of 1.47; saponification value 192.25 mg KOH/g oil and iodine value 24.97 g I₂/100g oil. All the refractive indices are almost similar in the almond oils from the three locations. The highest iodine and saponification indices (28.02 g I₂/100g, 200.86 mg KOH/g oil) were found with the *S. birrea* kernel oils from HB and ND respectively, while the lowest indices (23.26 g I₂/100g, 183.89 mg KOH/g oil) were found with the oil sampled from Union-Yanta and that from kernels from BM (Table 4).

Analysis of variance (ANOVA) at the significance level $\alpha = 5\%$ showed that there was no significant difference between the oils from *S. birrea* seeds from the three regions in terms of refractive index and iodine value (P-value > α).

Table 4. Physico-chemical characteristics of *Sclerocarya birrea* oil by region.

Location	Refractive index (n ₂₀)	Saponification index (mg of KOH/g)	Iodine index (g de I ₂ /100g of oil)
Mouhoun loop	1.46	183.89	24.26
Haut-Bassins	1.46	187.05	28.02
Nord	1.47	200.86	24.35
Centre Union-Yanta	1.47	197.19	23.26
Mean	1.47	192.25	24.97
P value	0.065	0.031	0.410

P-value > $\alpha = 5\%$ (no significant differences between values in the same column) and P-value < $\alpha = 5\%$, (significant differences between values in the same column).

The refractive indices are similar to the specifications of the Codex Alimentarius [26] for palm oil (n₂₀ = 1.46 to 1.47). They are also similar to those reported in Nigeria by [27] (n₂₀ = 1.46), but higher than those found in Ghana by [13] for raw almond oil (n₂₀ = 1.37) and roasted almond oil (n₂₀ = 1.38). The difference with the refractive index values of these authors could be explained by the variation in agro-climatic conditions and whether the samples were pretreated or not.

The saponification index values are close to the Codex Alimentarius specifications [26] for palm oil (I_s = 190 to 209 mg KOH/g oil). They are higher than the values published in Nigeria by [27] (178.60 mg KOH/g). This difference could be explained by the variation in agro-climatic conditions, but also by the genetic variability of the species. These saponification index values show that *S. birrea* oil has good saponification power and is mainly composed of fatty acids (FAs) with relatively low molecular weights [28]-[30].

The iodine index values are all higher than those published in Ghana (19.56 ± 0.02 g I₂/g oil) by [13] for raw *S. birrea* almond oils. However, they are lower than the Codex Alimentarius specifications [26] for palm oil (I_i = 50.0 to 55.0 g I₂/g oil). These iodine index values obtained in the present study are higher than specifications for palm kernel oil (I_i = 14.1 to 21.0 d'I₂/g oil) according to [26]. The iodine indices show that the fatty acid molecules of *S. birrea* oil in the present study have little unsaturation. As a result, this oil is stable at room temperature [29].

4. Conclusions

The aim of this study was to evaluate physico-chemical and nutritional characteristics of *Sclerocarya birrea* A. rich (*Anacardiaceae*) kernels from Burkina Faso.

The results showed that *Sclerocarya birrea* kernels from different regions contain considerable amounts of proteins, fat, carbohydrates, minerals and essential amino acids. *Sclerocarya birrea* kernels from ND region had the highest protein and mineral contents. Those from HB and *ML* regions had the highest

carbohydrate and fat contents. *S. birrea* kernels from HB and *M L* regions are more suitable for formulation of energy bars and as an ingredient in sauces and pastries due to their high glutamate content, which is also one of the most important neurotransmitters in the brain. Almonds have a low Na/K mineral ratio. They can be recommended to people suffering from high blood pressure. The high lipid content of *Sclerocarya birrea* seeds makes them a potential raw material for the oil industry. *Sclerocarya birrea* oil has low unsaturation and a high saponification index. It is therefore stable at room temperature and could be used in cooking to flavour dishes and in the cosmetics industry.

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Authors' Contributions

All authors contributed to the study's conception and design. Mamadou SANOU wrote the first draft of the manuscript, and all authors reviewed and edited it. All authors read and approved the final version of the manuscript.

Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose.

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