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Research Article

Comparative Analysis of Proximate Compositions, Physical Properties, and Sensory Attributes of Kersting's Groundnut (*Macrotyloma geocarpum* (Harms) Maréchal & Baudet) Accessions

Finagnon Toyi Kevin Fassinou[1,2] **Eric Etchikinto Agoyi**[3] **Marius Affonfere**[1,2] **Edmond Sacla Aide**[4,5] **Achille Ephrem Assogbadjo**[3,4] **and Flora Josiane Chadare**[1,2]

[1]*Université Nationale d'Agriculture, Laboratoire de Sciences et Technologie des Aliments et Bioressources et de Nutrition Humaine, Ecole des Sciences et Techniques de Conservation et de Transformation des Produits Agricoles, Centre Universitaire de Sakété, Porto-Novo, Benin*
[2]*Université d'Abomey-Calavi, Laboratoire de Sciences des Aliments, Faculté des Sciences Agronomiques, Cotonou, Benin*
[3]*Université d'Abomey-Calavi, Laboratory of Applied Ecology, Faculty of Agronomic Sciences, Cotonou, Benin*
[4]*Université d'Abomey-Calavi, Laboratoire de Biomathématiques et d'Estimation Forestière, Faculty of Agronomic Sciences, Cotonou, Benin*
[5]*Hasselt University, Interuniversity Institute for Biostatistics and Statistical Bioinformatics, Data Science Institute, Hasselt, Belgium*

Correspondence should be addressed to Flora Josiane Chadare; fchadare@gmail.com

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Kersting's groundnut (*Macrotyloma geocarpum*, Harms) is a legume crop with nutritional potential in West Africa where it is widely consumed due to its palatability. The present study investigated the physical characteristics, nutritional composition, and organoleptic properties of five Kersting's groundnut accessions selected based on their yield performance, stability, and seed color. Physical characteristics (seed size, length, and thickness) were determined using a Vernier Caliper while a laboratory weighing scale was used to determine 100-seed weight. Protein and fat contents were analyzed using micro-Kjeldahl and Soxhlet systems, respectively. Dietary fiber content was determined using the AOAC method while carbohydrate content was determined using the method of difference. Amino acids were hydrolyzed and determined using the liquid chromatography method. Ten trained panelists participated in testing the cookability of the samples while 30 untrained panelists were involved in the acceptability test. Results showed that accessions ranged between 8.1 ± 0.1 and 9.3 ± 0.2 mm for seed length, 5.7 ± 0.4 and 6.0 ± 0.2 mm for the width, and 4.0 ± 0.0 and 4.9 ± 0.4 mm for thickness. The 100-seed weight ranged from 11.7 ± 0.8 to 16.7 ± 1.6 g. Protein, fat, and carbohydrate contents ranged from 20.5 ± 0.2 to 22.0 ± 0.2, 1.2 ± 0.0 to 2.3 ± 0.0, and 56.5 ± 0.0 to 59.4 ± 0.1 (g/100 g dw), respectively. The lowest and highest cooking times were 78 and 124 minutes, respectively. All accessions recorded good sensory acceptability (>50%) except the accession BUR 16 which was liked only by 23.3%. Overall, accession OUA had the highest protein, medium cooking time, and highest overall acceptability score (>70%), hence recommended for wide production. Future studies need to be performed on the antinutritional content of this accession and to find out the effect of cooking on the nutritional value of derived meals and starch modification.

1. Introduction

Protein-energy malnutrition (PEM) remains a public health problem, especially in the African countries [1]. In these countries, legumes are the main source of dietary protein because of the prohibitive cost of animal protein that makes it unaffordable to most rural populations [2]. Legumes are vital protein sources, containing up to 20–40 grams of dietary proteins per 100 grams of dry matter. In tropical African countries, the most commonly consumed legumes include cowpea (*Vigna unguiculata* (L.) Walp.), bambara groundnut (*Vigna subterranea* (L.) Verdc.), grass pea (*Lathyrus sativus* L.), and Kersting's groundnut (*Macrotyloma geocarpum* (Harms) Maréchal & Baudet) [3, 4]. They provide essential proteins, vitamins, and dietary fiber for consumers. Kersting's groundnut is an important African indigenous leguminous crop grown on a small scale in West Africa [5]. It originated in West Africa and is widely consumed in Benin, Burkina Faso, Ghana, Mali, Niger, Nigeria, and Togo [6]. The seed coat color is the main criterion used to distinguish landraces of Kersting's groundnut [7]. In West Africa, based on the seed coat color, Agoyi et al. [8] reported 17 different morphotypes. In Benin, based on the seed coat colors, three landraces are commonly observed via the white or cream landrace, locally named as "doyiwe" the black landrace "doyi wiwi" and the brown/red landrace "doyi vovo" [6]. Although cowpea and bambara groundnut seeds are widely consumed, Kersting's groundnut seeds are preferred to them because of their palatable taste [9]. It has a high economic value with a significant contribution to the income and livelihood of resource-limited farmers [3, 4]. The monthly quantity of seeds sold per woman varies from 51.25 to 400 kg (125 kg on average) producing in average a profit of 20–160 $ in Dantokpa market in Benin [6, 10]. Nevertheless, the nutritional value of Kersting's groundnut is poorly documented and the few available reports indicate that Kersting's groundnut grains contain 21.3% of protein, 6.2% of fiber, 61.53–73.3% of carbohydrates, and 3.2% of ash [11]. Arginine, an amino acid for pediatric growth, is the most concentrated amino acid in the seed (9.3 g/100 g of protein) followed by phenylalanine (3.2 g/100 g) and histidine (2.1 g/100 g) of protein [12]. These essential amino acids are necessary for maintaining body muscle and growth. Despite the high income generated from the sale of Kersting's groundnut and its nutritional values as well as its well appreciated organoleptic characteristics, it remains a neglected and underutilized crop species in Benin [3, 4, 8]. The underlying reasons include its low yield, high labor requirement, long cooking time, and nonavailability of improved varieties [8, 13] and the lack of information on its nutritional values. Accordingly, the legume-breeding program at the Laboratory of Applied Ecology, University of Abomey-Calavi, conducted research to assess yield performances and stability across the major growing areas of Benin. Following these trials, five (5) landraces were selected based on their yield performance, seed coat color, and stability across environments from the breeding program. However, in order to achieve a sustainable breeding program with high yielding cultivars, genetic resistance to major biotic and abiotic stress [14], the good quality of grains regarding their nutritional and technological quality [15], and sensorial characteristics [16] are important elements that need to be considered. Sensory evaluation of accessions provided valuable information to support adoption and marketability, in the sense of desirable product characteristics for which consumers would be willing to pay more [16]. The nutritional content allowed the selection of health-promoting accessions [17]. In this regard, the present study investigated the nutritional composition and physical and organoleptic characteristics of five Kersting's groundnut accessions. This study contributed to the promotion of Kersting's groundnut accessions with better nutritional contents and easy cooking technology.

2. Materials and Methods

2.1. Selected Kersting's Groundnut Seeds. The five Kersting's groundnut seed lots used in this study were accessions BUR 7, BUR 14, BUR 16 collected in Burkina Faso, ADC, and OUA collected in Benin. These accessions were selected based on yield performance and stability, from a wide germplasm collection followed by multilocation evaluations across growing areas in Benin. BUR 14 and BUR 7 have cream seed coat with a black eye, BUR 16 has black seed coat while ADC and OUA have cream seed coat and eye (Figure 1) [18]. After harvesting and sun drying, the pods were shelled and seeds packaged in sealed paper bags and stored at room temperature until analyses.

2.2. Determination of Physical Seed Characteristics

2.2.1. Length, Width, and Thickness of Seeds. Hundred randomly selected seeds from each accession were used to measure the three main dimensions that are in the three mutually perpendicular directions: the length (L), the width (W), and the thickness (T). They were measured using a Vernier Caliper reading to 0.01 mm, as applied by Wani et al. [19]. The geometric mean diameter (Dm) of each accession was calculated using the approach of Mohsenin [20].

$$Dm = (\mathrm{LWT})^{1/3}. \quad (1)$$

2.2.2. Hundred Seed Weight and Hundred Seed Volume. Three seed lots, each of one hundred seeds, were manually counted from each accession; these samples were weighed on a digital weighing balance with accuracy up to 0.001 mg and recorded as 100-seed weights. The seeds volume (Vm) was calculated using the formula of Mohsenin [20].

$$Vm = \frac{\pi B^2 L^2}{6(2L-3)}, \quad (2)$$

where $B = (WT)^{1/2}$ with width (W) and thickness (T).

2.2.3. Hydration Capacity and Hydration Index. One hundred grams of each accession were weighed and transferred to a measuring cylinder, along with 100 ml of water. The cylinder was covered with aluminum foil and left

Figure 1: Seed of selected Kersting's groundnut accessions.

at room temperature (28 ± 2°C). The seeds were left to soak for 24 hours and drained, and their superfluous water was removed using a tissue paper. Thereafter, the swollen seeds were weighed. Hydration capacity per seed and hydration index were calculated using the following formulae applied by Adebowale and Oshodi [21]:

$$\text{hydration capacity per seed} = \frac{(\text{weight after soaking} - \text{weight before soaking})}{\text{number of seed}},$$
$$\text{hydr ation index} = \frac{\text{hydration capacity per seed}}{\text{weightof one seed}}. \quad (3)$$

2.2.4. Cookability of Kersting's Groundnut Seed. The cookability of the accessions was determined with selected panelists who were previously trained on the evaluation of the texture of cooked Kersting's groundnut seeds.

2.2.5. Panelists Selection and Training on Evaluation of Cooked Seed Texture. The cooking time of each Kersting's groundnut accession was determined using the subjective finger pressing method, as applied by Kinyanjui et al. [22] with some modifications. As this method is subjective and then requires trained panel to obtain reliable results [23], a quantitative descriptive analysis (QDA) was used for this purpose [24]. Ten (10) consumers of Kersting's groundnut seed were selected and trained on the evaluation of cooked seeds texture. Six men and four women from four ethnic groups (Fon, Idatcha, Nago, and Mahi) were selected. They were students aged 24.8 ± 2.3 years old and had participated at least once in a sensory evaluation in the past. During the training, they defined the cooked Kersting's groundnut seed as follows: "A seed that can break under a gentle pressure using fingers and thumb and no hard material will be found in the cotyledon." To prevent bias and to consider the means of panelists, unstructured line scales were used to define the score of texture intensity, as recommended by Murray et al. [25]. The panel was trained over eight (08) hours to master the scoring scheme. The lowest and highest scores were defined for the uncooked and well-cooked Kersting's groundnut seed. The lowest score 0 was "dry Kersting's groundnut seed" and the highest score 10 was "soft seed." The middle (score 5) corresponds to the state where the cooked seed may be acceptable and the texture value 6 is a state where the cooking is acceptable for consumption. During the training, the cooked seeds were subjected to sensory triangle tests and intensity scales to make sure that the panelists were able to detect a difference.

2.2.6. Cooking Time Determination for Cooked Kersting's Groundnut Seed. Cooking test was done weighing one hundred (100) grams of seeds of each accession. Each seed lot was put in an aluminum sauce pan with two liters of distilled water. This was placed to boil on a gas cooker. Boiling was continued for ninety minutes after which little samples were picked using a spatula every 10 min and tested for softness by pressing between fingers and thumb by the panelists. Each panelist received 10 boiled seeds, and the test was duplicated during two consecutive days for each accession. Cooking was said complete when the panelists scored at least 5 for the pressure exerted on the cooked seed. Thereafter, the cooking time was defined as the period of time the seeds achieved the desirable softness. Cooking time was reported in minutes.

2.3. Nutritional Characteristics of Kersting's Groundnut Seed. Seed lot of each Kersting's groundnut accession was cleaned, which involved removal of foreign matter, broken seeds, and immature seeds. There were ground in laboratory condition using the laboratory mill 3600 and sieved with 500 μm sieve. Flour obtained was packaged in polyethylene bag and stored at 4°C until analysis.

2.3.1. Seed Dry Matter. Dry matter was determined according to the AOAC [26] method. Five grams of samples were used for the determination of dry matter by weighing in a crucible and drying in an oven at 105°C for 72 hours. The dry matter content was calculated using the following formulae:

$$TMS = \frac{(P_2 - P_1)}{Pe} * 100, \quad (4)$$

where TMS is the dry matter content, P_1 is the crucible weight, P_2 is the weight (sample + crucible) after drying, and P_e is the weight of sample.

2.3.2. Ash Content of Kersting's Groundnut Seeds. The ash content was determined according to the AOAC [26] method. A clean porcelain crucible was oven-dried at 105°C for 1 hour and weighed. Kersting's groundnut seeds were ground using the laboratory mill 3600. Five grams' samples were weighed and placed in a muffle furnace at 550°C for 8 hours. It was cooled in a desiccator before recording the weight of the porcelain crucible. The ash content was computed using the following formulae:

$$ASH = \frac{(P_2 - P_1)}{P_0} * 100, \quad (5)$$

where ASH is the ash content, P_1 is the porcelain weight, P_2 is the weight (sample + crucible) after drying in the furnace at 550°C for 8 hours, and P_0 is the weight of the sample.

2.3.3. Protein Content of Kersting's Groundnut Seed. The micro-Kjeldahl method applied by Akintomide and Antai [27] was used for protein content determination. Five grams' samples were placed into the micro-Kjeldahl flask, and one Kjeldahl catalyst tablet with 10 ml of concentrated H_2SO_4 was added. Digestion was performed for 4 hours after which a clear colorless solution was found in the tube. The digest was carefully transferred into a 100 ml volumetric flask, thoroughly rinsing the digestion tube with distilled water, and the volume of the flask was made up to the mark with distilled water. Five-millimeter portion of the digest was then pipetted to Kjeldahl apparatus, and 5 ml of 40% (w/v) NaOH was added. The mixture was then steam-distilled, and the released ammonia was collected into a 50 ml conical flask containing 10 ml of 2% boric acid plus mixed methyl red-methylene blue indicator solution. The green colored solution was then titrated using 0.01 N HCl solution. At the endpoint, the green color turns to a wine color, which indicates that all the nitrogen trapped as ammonium borate has been removed as ammonium chloride. The percentage of nitrogen was calculated using % N = (Titre value ∗ atomic mass of nitrogen ∗ normality of HCl used ∗ 4) where % N is the percentage of nitrogen. The protein is determined by multiplying the percentage of nitrogen by a constant factor of 6.25 [28].

2.3.4. Fat Content of Kersting's Groundnut Seed. Fat content was determined using the Soxhlet system according to the AOAC [28] method as applied by Akintomide and Antai [27]. Samples of 1 g were placed into a fat-free extraction thimble, which was plugged lightly with cotton wool. The thimble was placed in the extractor and fitted up with a reflux condenser and a 250 ml Soxhlet flask, which had been previously dried in an oven, cooled in the desiccator, and weighed. The Soxhlet flask was then filled to ¾ of its capacity with petroleum ether and the Soxhlet flask extractor and condenser set was placed on the heater. The heater was put on for six hours with constant running water from the tap for condensation of ether vapor. The ether was left to siphon over several times at least 10–12 times until it was short of siphoning. After this, the remaining ether content of the extractor was carefully drained into the ether stock bottle. The thimble-containing the sample was then removed and dried on a clock glass on the benchtop. The extractor flask with condenser was replaced, and the distillation continued until the flask was practically dried. The flask, which now contained the fat or oil, was detached; it was dried to a constant weight in the oven [28]. The fat content was determined using FAT content = [(W1 − Wo)/Weight of sample taken] where the initial weight of the dry Soxhlet flask is Wo and the final weight of the oven-dried flask + oil/fat is W1.

2.3.5. Dietary Fiber and Carbohydrate Contents of Kersting's Groundnut Seed. The dietary fiber content was assessed according to the AOAC [26] method, while the carbohydrate content was determined by the difference method. Percentages of moisture, fat, protein, ash, and dietary fiber content were subtracted from 100% as applied by Ijarotimi and Keshinro [29].

2.3.6. Determination of Amino Acid Profile. Amino acid profile of Kersting's groundnut seed was determined using liquid chromatography method as applied by Imbuhila [30]. A sample of 100 mg was weighed in duplicate from each accession. Each was transferred into a 5 ml vial tube and 2 ml of 6 N HCl was added and the content was completely closed. The samples were hydrolyzed for 24 hours at 110°C. The hydrolysates were evaporated to dryness under a vacuum. Thereafter, the hydrolysates were reconstituted in 1 ml 90 : 10 water : acetonitrile solution. There were vortexed for 30 seconds and then centrifuged at 14,000 rpm, and the supernatant was transferred to another vial. Serial dilutions of the authentic standards amino acids (1–105 μg/µl) were analyzed using liquid chromatography to generate linear calibration curves (peak area vs. concentration) used for external quantification. The samples were analyzed using liquid chromatography to determine the amino acids and their concentration in each sample. ACE5 C-18 column (250 × 108 4.6 mm, 5 μm particle size) was used at 40°C. The flow rate and injection volume were 0.5 mL/min and 3 μL, respectively. The solvent system used as mobile phase consisted of two eluents: water and 0.01% acetonitrile acid. The amino acids were identified and quantified by comparing with the retention times and peak areas of standards.

2.4. Acceptability Test of Cooked Kersting's Groundnut Seed. Thirty students from the University of Abomey-Calavi who were willing to taste and assess Kersting's groundnut were selected on a voluntary basis for the acceptability test. This test was performed at the "Laboratoire de Physico-Chimie et d'Evaluation Sensorielle (LAPESA)" at the Faculty of Agronomic Sciences (FSA) using individually partitioned booth. The acceptability of each accession was assessed after their cooking times have been determined. Each panelist received 25 g of the cooked Kersting's groundnut on a white tray, with a glass of water for rinsing the mouth between two samples. The cooked samples were coded and submitted to evaluation using a 7 hedonic scale test as follows: 7 = liked extremely, 6 = liked very much, 5 = liked, 4 = neither liked nor disliked, 3 = disliked, 2 = disliked very much, and 1 = disliked extremely. The firmness, taste, Kersting's groundnut aroma, color intensity, and overall acceptability were evaluated for each accession [31, 32]. Since aroma is lost over time [31, 33] and legume texture becomes hard over time after cooking, these were evaluated immediately after cooking when samples were still warm.

2.5. Statistical Analysis. All statistical analyses were performed in R Statistical Software [34] at 5% significance level. Descriptive statistics (means and standard deviations) were used to summarize physical and physicochemical characteristics of Kersting's groundnut. Analysis of variance (ANOVA) was used to test whether there was a significant difference between accessions for their physical characteristics, proximate parameters, and amino acid contents. The Anova linear model is presented as follows:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}\,; \quad i = 1, \ldots, t;\ j = 1, \ldots, n_{ij}, \tag{6}$$

here Error term $\varepsilon_{ij} \sim$ i.i.d N $(0, \sigma^2)$ with σ^2 the residual variance, τ_i is the effect of accession i, n_{ij} is the number of replicates in accession group (i, j), and Y_{ij} is the response variable (physical and physicochemical characteristics)

The Kruskal–Wallis test was used to test the effect of accession on the physical and physicochemical characteristics where the assumptions for normality were not met. When a significant difference ($p < 0.05$) was detected, Tukey's multiple comparison test was used to evaluate the difference between pairs of accessions. Prediction of cooking time to textural intensity scale 6 (acceptable texture for consumption) was carried out using a linear regression (Table 1). Pearson correlation test was performed in the packages Harrell [35] and Wei and Simko [36] to highlight the relationship between accession's cooking time, physical parameters (length, width, thickness, and hundred seed weight), and proximate parameters (carbohydrate, fat, protein, ash, dietary fiber, and dry matter).

3. Results

3.1. Physical Characteristics of Kersting's Groundnut Accessions. Generally, there was no significant difference among accessions for width, thickness, seed volume, geometric mean diameter, and hydration index ($p > 0.05$) (Table 2). However, significant differences were found in accessions regarding their seed length, 100-seed weight, and hydration capacity. The accessions BUR 14, BUR 7, OUA, and ADC have the lowest seed length (from 8.1 ± 0.1 to 8.6 ± 0.3 mm) while the accession BUR 16 had the highest seed length (9.3 ± 0.2 m). BUR 14 had the highest 100-seed weight (16.7 ± 1.6 g) while ADC exhibited the lowest 100-seed weight (11.7 ± 0.8 g). Accessions BUR 14, BUR 16, and BUR 7 had 0.14 ± 0.00 g/seed while ADC and OUA had 0.10 ± 0.00 g/seed as hydration capacities (Table 2).

3.2. Cooking Time of Kersting's Groundnut Accessions. The texture of the selected Kersting's groundnut accessions varied across the accessions and according to the cooking time (Figure 2). Accession BUR 7 had the lowest trend of texture change in function of the cooking time, which means that it had high texture than the other accessions. The accessions BUR 16 following by BUR 14 had the highest trend of texture change in function of the cooking time. At ninety minutes cooking time, the texture of the accession BUR 16 was 6.27, which is higher than the acceptable texture (score 6) for consumption according to the panelists. These values indicate that BUR 16 cooks in less than 90 minutes. Accessions BUR 7, ADC, OUA, and BUR 14 after being cooked for 90 minutes had texture scores of 4.33, 5.59, 5.58, and 5.40, respectively, values lower than 6. Using the linear regression equation of texture for each accession as a function of the cooking time (Table 1), the cooking times needed for accessions BUR 16, BUR 14, ADC, OUA, and BUR 7 to reach an acceptable texture for consumption (score 6) were 78.0, 100.5, 104.5, 105.3, and 124.0 minutes, respectively.

3.3. Proximate Composition of Kersting's Groundnut Accessions. There was a significant difference among accessions for all proximate parameters (Table 3). The protein content ranged from 20.5 ± 0.2 g/100 g dw (ADC) to 22.0 ± 0.2 g/100 g dw (OUA). Accession BUR 16 had the highest fat content (2.3 ± 0.0 g/100 g dw), and the accession ADC had the lowest fat content (1.2 ± 0.0 g/100 g dw). The carbohydrate contents varied from 56.5 ± 0.0 g/100 g dw (BUR 7) to 59.4 ± 0.1 g/100 g dw (BUR 14). The accession ADC had the highest dietary fiber content (7.6 ± 0.4 g/100 g dw) while OUA had the lowest dietary fiber content (4.3 ± 1.0 g/100 g dw). The highest ash content was 3.9 ± 0.0 g/100 g dw for BUR 7 while the lowest ash content was 3.1 ± 0.1 g/100 g dw for OUA.

3.4. Amino Acids Composition of Kersting's Groundnut Accessions. Amino acids composition varied significantly among accessions (Table 4). Concentration of methionine ranged between 0.19 ± 0.00 and 0.41 ± 0.02 g/100 g dw of protein. Concentrations of valine and histidine ranged between 0.92 ± 0.01–1.32 ± 0.03 g/100 g dw protein and 0.38 ± 0.01–0.64 ± 0.0103 g/100 g dw protein, respectively, while phenylalanine varied between 0.73 ± 0.02 and 1.91 ± 0.02 g/100 g dw protein. ADC had the highest leucine content but generally poor in other amino acids. BUR 7 had the highest methionine and valine contents while OUA had the highest lysine and phenylalanine contents. Overall, the accession OUA had the best amino acid profile, ranking top in 6 out of 8 essential amino acids analyzed. Across accessions leucine was in higher concentration (1.84 ± 0.02 g/100 g dw of protein) followed by lysine (1.64 ± 0.02 g/100 g dw of protein), while arginine had the lowest concentration (0.24 ± 0.03 g/100 g dw of protein).

Table 1: Parameters of linear regression equations of the five accessions texture according to the cooking time.

Accessions	Linear regression equations	Adjusted R-squared
BUR 16	$y = 3.33571 + 0.03414$ cooking time	0.9635
BUR 14	$y = 0.47000 + 0.05504$ cooking time	0.9931
BUR 7	$y = -0.09143 + 0.04914$ cooking time	0.9799
ADC	$y = 3.05143 + 0.02821$ cooking time	0.9873
OUA	$y = 3.11714 + 0.02739$ cooking time	0.9891

with y = Kersting's groundnut seed texture.

Table 2: Physical characteristics of Kersting's groundnut seeds.

Selected accessions	Width (mm)	Thickness (mm)	Length (mm)	Hundred seed weight (g)	Seed volume (mm^3)	Geometric mean diameter (mm)	Hydration capacity (g/seed)	Hydration index
ADC	5.8 ± 0.1^{a}	4.4 ± 0.5^{a}	8.1 ± 0.1^{a}	11.7 ± 0.8^{a}	67.3 ± 10.4^{a}	5.9 ± 0.3^{a}	0.10 ± 0.00^{a}	0.82 ± 0.00^{a}
OUA	5.9 ± 0.1^{a}	4.5 ± 0.5^{a}	8.1 ± 0.3^{a}	13.2 ± 0.4^{ab}	69.5 ± 6.2^{a}	6.0 ± 0.1^{a}	0.10 ± 0.00^{a}	0.83 ± 0.00^{a}
BUR 14	5.7 ± 0.4^{a}	4.9 ± 0.0^{a}	8.6 ± 0.3^{a}	16.7 ± 1.6^{c}	78.6 ± 8.64^{a}	6.2 ± 0.2^{a}	0.15 ± 0.01^{b}	0.96 ± 0.09^{a}
BUR 16	6.0 ± 0.2^{a}	4.0 ± 0.0^{a}	9.3 ± 0.2^{b}	15.1 ± 0.7^{bc}	71.8 ± 4.4^{a}	6.1 ± 0.1^{a}	0.14 ± 0.00^{b}	0.96 ± 0.00^{a}
BUR 7	5.5 ± 0.3^{a}	4.6 ± 0.5^{a}	8.2 ± 0.4^{a}	15.4 ± 1.3^{bc}	68.3 ± 13.6^{a}	5.9 ± 0.4^{a}	0.15 ± 0.00^{b}	1.01 ± 0.05^{a}
Significance levels	0.366	0.187	0.004	0.002	0.594	0.542	0.003	0.038

The mean ± standard deviation is presented and values having different superscript letters in a given column are significantly different at 5% significance level.

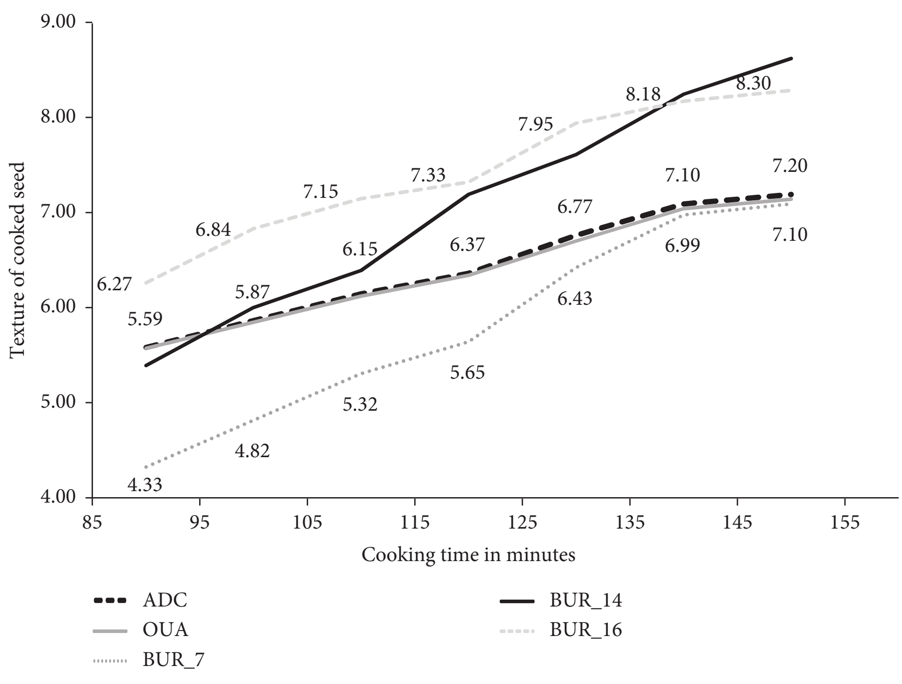

Figure 2: Cooking time- and accession-based changing trend of Kersting's groundnut seed texture.

Table 3: Proximate composition of selected Kersting's groundnut seed.

Selected accessions	Dry matter (g/100 g)	Ash (g/100 g dw)	Protein (g/100 g dw)	Fat (g/100 g dw)	Carbohydrate (g/100 g dw)	Dietary fiber (g/100 g dw)
ADC	88.9 ± 0.1^{a}	3.5 ± 0.0^{a}	20.5 ± 0.2^{a}	0.5 ± 0.0^{a}	56.8 ± 0.0^{a}	7.6 ± 0.4^{a}
OUA	88.7 ± 0.1^{a}	3.1 ± 0.1^{b}	22.0 ± 0.2^{b}	1.2 ± 0.0^{b}	58.3 ± 0.0^{b}	4.3 ± 1.0^{bc}
BUR 14	88.9 ± 0.1^{a}	3.6 ± 0.0^{a}	21.8 ± 0.2^{b}	0.4 ± 0.0^{c}	59.4 ± 0.1^{c}	3.7 ± 0.2^{c}
BUR 16	88.9 ± 0.1^{a}	3.5 ± 0.1^{a}	21.2 ± 0.3^{bc}	2.3 ± 0.0^{d}	56.9 ± 0.0^{a}	5.6 ± 1.3^{b}
BUR 7	89.2 ± 0.0^{b}	3.9 ± 0.0^{c}	20.8 ± 0.4^{ac}	1.1 ± 0.0^{e}	56.5 ± 0.0^{d}	7.2 ± 0.4^{a}
Significance levels	0.008	0.001	0.001	<0.001	<0.001	0.001

The mean ± standard deviation is presented and values having different superscript letters in a given column are significantly different at 5% significance level.

Table 4: Amino acids composition of Kersting's groundnut seed (g) per 100 g protein dry weight.

Accessions	Methionine (g/100 g dw)	Lysine (g/100 g dw)	Valine (g/100 g dw)	Histidine (g/100 g dw)	Phénylalanine (g/100 g dw)	Tryptophane (g/100 g dw)	Leucine (g/100 g dw)	Arginine (g/100 g dw)
ADC	0.19 ± 0.00^{a}	0.36 ± 0.02^{a}	0.92 ± 0.01^{a}	0.38 ± 0.01^{a}	0.73 ± 0.02^{a}	0.63 ± 0.00^{a}	1.80 ± 0.04^{a}	0.12 ± 0.00^{a}
OUA	0.41 ± 0.02^{b}	1.64 ± 0.02^{b}	1.30 ± 0.01^{b}	0.56 ± 0.01^{b}	1.09 ± 0.02^{b}	0.82 ± 0.01^{b}	1.84 ± 0.02^{a}	0.24 ± 0.03^{b}
BUR 14	0.29 ± 0.00^{c}	1.29 ± 0.03^{c}	1.16 ± 0.02^{c}	0.64 ± 0.01^{c}	0.82 ± 0.03^{c}	0.73 ± 0.01^{c}	1.03 ± 0.01^{b}	0.18 ± 0.03^{c}
BUR 16	0.35 ± 0.00^{d}	1.24 ± 0.02^{d}	1.25 ± 0.03^{d}	0.61 ± 0.00^{d}	0.76 ± 0.00^{a}	0.91 ± 0.02^{d}	1.03 ± 0.01^{b}	0.24 ± 0.03^{b}
BUR 7	0.39 ± 0.03^{b}	1.23 ± 0.03^{d}	1.32 ± 0.03^{b}	0.52 ± 0.01^{e}	0.87 ± 0.03^{d}	0.85 ± 0.02^{e}	1.21 ± 0.02^{c}	0.17 ± 0.01^{c}
Significance levels	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

The mean ± standard deviation is presented and values having different superscript letters in a given column are significantly different at 5% significance level.

Table 5: p value of correlation matrices.

	Width	Thickness	Length	100-seed weight	Ash	Dry matter	Protein	Fat	CHO	Dietary fiber
Width										
Thickness	0.203									
Length	0.395	0.361								
100-seed weight	0.581	0.545	0.382							
Ash	0.134	0.724	0.883	0.401						
Dry matter	0.116	0.827	0.979	0.526	0.007					
Protein	0.627	0.587	0.853	0.530	0.303	0.259				
Fat	0.339	0.085	0.188	0.845	0.839	0.953	0.947			
CHO	0.895	0.241	0.993	0.506	0.527	0.357	0.074	0.487		
Dietary fiber	0.610	0.561	0.667	0.404	0.404	0.290	0.008	1.000	0.034	
Cooking time	0.061	0.261	0.077	0.911	0.520	0.389	0.731	0.305	0.847	0.574

3.5. Relationship between Kersting's Groundnut Accessions, Cooking Time, and Their Physical and Nutritional Proprieties. There was no significant correlation between the cooking time and the physical and nutritional composition of Kersting's groundnut seed at 5% (Table 5). Otherwise, at 10% significance level, the cooking time was negatively correlated with seed width and length. Although there were not significant, cooking time was also positively correlated with the thickness, ash, dry matter, and dietary fiber content of Kersting's groundnut and negatively correlated with its fat and protein content (Table 6). These results indicate that accessions with high thickness and high dietary fiber content could take longer to cook whereas the accessions with high width, length, fat, and protein content could cook faster.

3.6. Acceptability of Selected Kersting's Groundnut Accessions. Thirty students aged of 28 ± 5.6 years old evaluated the acceptability of Kersting's groundnut seeds. Sixty percent were man and forty percent were women. They are from six ethnic groups mainly Fon, Idatcha, Nago, Mahi, Minan, and Adja. In general, more than 50% of the panelists liked the accessions ADC, OUA, BUR 7, and BUR 14 for their texture, aroma, color, and taste after cooking (Table 7). Texture after cooking of the accession BUR 14 was the most appreciated (76.7% of the panelists). The texture after cooking of OUA was appreciated by 63.3% of the panelists. Based on aroma and taste, the accessions OUA and BUR 7 were the most appreciated while color intensity of ADC (66.7%) and OUA (66.7%) appeared to be more appreciated than that of BUR 14 (63.3%) and BUR 7 (53.3%). Overall, up to 50% of the panelist appreciated the accessions ADC, OUA, BUR 7, and BUR 14 (Figure 3). BUR 7 was the most appreciated accession (70%) followed by OUA (66.7%), BUR 14 (60%), and ADC (56.7%). Accession BUR 16 appeared the most disliked. It was disliked by 46.7% of the panelists, 30% were indifferent and only 23.3% liked it (Figure 3). The black seed color appeared to be the main reason for its rejection (63%), followed by the aroma (53.3%) and taste (40%).

4. Discussion

4.1. Physical Characteristics and Correlation with Nutritional Composition and Cookability of the Seeds. The width, thickness, and length of the five selected accessions varied from 5.8 to 6.0 mm, 4.4 to 4.9 mm, and 8.1 to 9.3 mm, respectively. These values are within the range reported on 297 accessions of Kersting's groundnut by Akohoue et al. [37]. The authors found that the width, thickness, and length of the accessions varied from 4.7 to 8.80 mm, 3.5 to 6.23 mm, and 6.9 to 9.3 mm, respectively. Otherwise, the 100-seed weight of the five selected accessions ranged from 11.7 to 16.7 g while the seed grains found by the aforementioned authors ranged between 7.10 and 16.3 g. The seed weight of the accessions used in the present study especially BUR_14 is much heavier than that investigated by Akohoue et al. [37]. It comes out that the physical characteristics mainly width and thickness, length, and 100-seed weight of these selected

Table 6: Correlation matrices between Kersting's groundnut physical characteristics and proximate composition.

	Width	Thickness	Length	100-seed weight	Ash	Dry matter	Protein	Fat	Carbohydrates	Dietary fiber
Width	1.00									
Thickness	−0.68	1.00								
Length	0.50	−0.53	1.00							
100-seed weight	−0.34	0.37	0.51	1.00						
Ash	−0.76	0.22	0.09	0.49	1.00					
Dry matter	−0.78	0.14	−0.02	0.38	0.97	1.00				
Protein	0.30	0.33	0.12	0.38	−0.58	−0.63	1.00			
Fat	0.55	−0.83	0.70	0.12	−0.13	−0.04	0.04	1.00		
Carbohydrates	0.08	0.64	−0.01	0.40	−0.38	−0.53	0.84	−0.41	1.00	
Dietary fiber	−0.31	−0.35	−0.26	−0.49	0.49	0.59	−0.97	0.00	−0.91	1.00
Cooking time	−0.86	0.62	−0.84	−0.07	0.39	0.50	−0.21	−0.58	−0.12	0.34

Table 7: Acceptability level of cooked Kersting's groundnut accessions.

Sensorial attributes	Acceptability levels	ADC	OUA	BUR 7	BUR 14	BUR 16
Texture	Disliked	33.3	3.3	3.3	6.7	36.7
	Neither liked nor disliked	16.7	33.3	40.0	16.7	23.3
	Liked	50.0	63.3	56.7	76.7	40.0
Kersting's groundnut aroma	Disliked	13.3	0.0	3.3	10.0	53.3
	Neither liked nor disliked	23.3	20.0	30.0	26.7	20.0
	Liked	63.3	80.0	66.7	63.3	20.0
Color intensity	Disliked	13.3	0.0	16.7	10.0	63.3
	Neither liked nor disliked	20.0	33.3	30.0	26.7	20.0
	Liked	66.7	66.7	53.3	63.3	16.7
Taste	Disliked	16.7	3.3	10.0	6.7	40.0
	Neither liked nor disliked	23.3	23.3	16.7	33.3	30.0
	Liked	60.0	73.3	73.3	60.0	30.0

The results are presented as proportion (%) of panelists who like, neither liked nor disliked, or disliked. Liked: Proportion of panelists who liked extremely + liked very much + liked. Disliked: Proportion of panelists who disliked extremely + disliked very much + disliked.

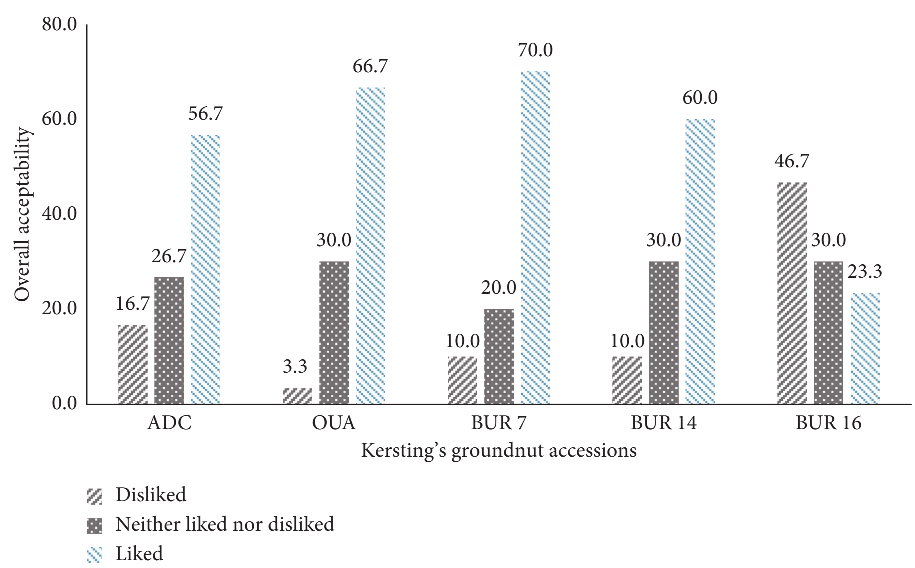

Figure 3: Overall acceptability of Kersting's groundnut accessions. Legend: Liked: proportion of panelists who liked extremely + liked very much + liked. Disliked: proportion of panelists who disliked extremely + disliked very much + disliked.

accessions are similar to those already consumed across climatic areas of Benin and Togo. Consequently, the physical characteristics will not be a challenge for the acceptability of these accessions.

Even though there was no significant correlation between the physical characteristic, proximate composition, and cookability of the accessions at 5%, some results are in line with the studies of Kaur et al. [38] and Singh et al. [39]. Accession BUR_14 had the highest seed volume, indicating that it has a higher carbohydrate content and lowest dietary fiber content correlation also reported by Kaur et al. [38]. Carbohydrate content of seed is negatively correlated with protein, dietary fiber, and fat content, and this is consistent with results reported by Singh et al. [39]. Thickness is positively correlated with cooking time, indicating that thicker grains require a longer cooking time. Similar results were found by Erkskine et al. [40]. In opposite, accession BUR_7 which had the highest hydration capacity (0.15 g/seed) and hydration index (1.01) should have a higher permeability of the seed coat and softer cotyledons than lower cooking time [39]. These results mean that they may have a strong correlation between physical characteristics, proximate composition, and cookability of Kersting's groundnut. However, correlation was not significant in this study.

4.2. Nutritional Potential of Kersting's Groundnut Accessions and Implication for Their Promotion. The protein content found in the present study ranged from 20.5 ± 0.2 to 22.0 ± 0.2 g/100 g dw. These values are consistent with observations made by Ajayi and Oyetayo [12] and Adu-gyamfi et al. [13]. However, the accessions used in our study exhibit higher protein content than those analyzed by Abiola and Oyetayo, [41]. As for carbohydrate contents, they ranged between 56.5 ± 0.0 to 59.4 ± 0.1 g/100 g dw, values that are higher than those observed by Adu-gyamfi et al. [13] which is 49.6 g/100 g dw and lower than those of Ajayi and Oyetayo [12], 61.53–73.3 g/100 g dw. These discrepancies could be explained by the genetic background of each accession and the environmental conditions where they were grown [42–45]. However, taking into account protein and carbohydrate contents of the five Kersting's groundnut accessions, they can be consumed as alternative legume protein sources as cowpea grains which have similar protein and carbohydrate contents (22.2 g/100 g and 59.3 ± 2.3 g/100 g, respectively) [46]. Protein content of these Kersting's groundnut accessions can be used to enhance the protein content of the diet to address the protein malnutrition that remains a challenge in rural areas among the low-income groups [47]. Therefore, the production of these accessions could be promoted in the areas where the population cannot afford the animal protein source.

Similar to organisms that have different amino acids, Kersting's groundnuts have several amino acids arranged in different sequence and combinations. Of the 20 amino acids that are the basic components of the body's proteins, ten are considered to be essential, as they cannot be synthesized endogenously via metabolic pathways and thus must be provided by dietary sources [48]. Eight of these essential amino acids were analyzed and found in the accessions used in the present study (arginine, histidine, leucine, lysine, methionine, tryptophan, phenylalanine, and valine). These essential amino acids have a growing interest in the medical field for use in preventing or even treating chronic metabolic disorders [49]. The accession OUA had the highest amino acid contents compared to other accessions. The amino acid contents of the five accessions were lower than those found in Kersting's groundnut accessions by Adu-gyamfi et al. [13]. These amino acid contents were lower than the required amount for legume (in g/100 g protein 5.0 for valine, 7.0 for leucine, 5.5 for lysine, and 1.0 for tryptophan) according to data reported by Hussain and Basahy [50]. Overall, the accession OUA had higher protein content and amino acid profile compared to the other accessions and therefore could be promoted as alternative nutritious accessions. However, further breeding efforts are needed to improve the nutritional value of this accession. However, the nutritional value of legumes grains is not only the key parameter in term of plant breeding; their technological is also of interest.

Cooking is the most widely used processing method for legumes. In this process, the legume seeds are boiled in hot water until they become soft. This improves protein and amino acid digestibility [51]; it causes considerable losses of them and modifies the starch structure of legume. Protein and amino acid solubilities significantly decreased (up to 50%) during cooking due to thermal modification and loss of soluble fractions in the cooking water [52]. Future studies are needed to access the effective protein and amino acid contents of accessions as consumed by consumers for their better selection. Moreover, cooking legume seeds causes a significant decrease in resistant starch (RS) (by 61–71%) and slowly digestible starch (SDS) (by 56–84%) [53] and this reduction increases with cooking time. RS in the diet has been shown to exert positive effects on a human body as it stimulates the growth of beneficial microflora and reduces postprandial blood level of glucose and blood level of cholesterol [54]. The SDS is used for the treatment of type II diabetes because it affects the sensation of satiety through the metabolic response, namely, the postprandial low level of glucose and insulin in blood [55]. Therefore, the decrease in SR and SDS may have an impact on consumer's health, and the phenomenon is strongly correlated with the amylose content of legumes [56]. It will be important to conduct future studies in order to investigate the starch quality of the accessions. Furthermore, since the solids reduction of legumes increases with cooking time and a long cooking time is a limitation for legume selection, their cookability appears important.

4.3. Cookability of Kersting's Groundnut Accessions. Cooking time is an important and key quality parameter in food legumes. First, the cooking softens the grains and facilitates palatability, increases protein digestibility and bioavailability in grain legumes, and destroys antinutritional factors [57]. The cooking time varied across accessions, and the lowest and highest cooking times recorded were 78.0 and

124.0 minutes for the accessions BUR 16 and BUR 7, respectively. However, to the best of our knowledge, only one study assessed the cooking time of Kersting's groundnut [58]. This study reported that the cream Kersting's groundnut seed usually consumed in Benin has a cooking time of 392.25 ± 18.82 minutes using similar cooking equipment. Comparing this value with the range of 78–124 minutes found in this study, it turns out that the accessions used in the present study have shorter cooking times and probably could be more acceptable by the consumers. Accordingly, using BUR 16, BUR 14, ADC, OUA, and BUR 7 accessions, consumers will reduce their usual cooking time by 80.11%, 74.38%, 73.36%, 73.15%, and 68.38%, respectively. In addition, these cooking times are lower than the cooking time of bambara groundnuts (3-4 hours) and cowpea bean (2.4 hours) reported by Mubaiwa et al. [59], two commonly consumed legumes in Africa. Although cooking improves the nutritional quality of the legume seed, prolonged cooking results in a decrease in protein quality and digestibility and loss of nutrients such as vitamins and minerals [60, 61]. Therefore, a short cooking time is then desirable as it preserves the protein quality and digestibility of nutrients but also reduces energy used in cooking and saves labor cost [42]. In this context, soft cooking cultivars of Kersting's groundnut could make them preferable by the consumers. Otherwise, the cooking time has a negative correlation with their width, length, fat, and protein content. Thus, Kersting's groundnut accessions with high width and length (accessions BUR 16 and BUR 14) and fat and protein content (accessions OUA and BUR 16) could be interesting in the case of cooking time reduction. Accordingly, about the modern trend towards convenience foods with reduced cooking time [42], these accessions BUR 16 and BUR 14 could be interesting for their high length and width while the accession OUA and BUR 16 could be interesting for their protein and fat content. This result indicates that the black Kersting's groundnut seed (BUR 16) would be the first preference of consumers, as it would involve lesser fuel and time consumption. Nevertheless, these correlations are not significant and need to be investigated by future studies because cooking time is not the only parameter, which makes the product acceptable to consumers.

4.4. Acceptability of Kersting's Groundnut Accessions. The accession BUR 16 suggested as the best in terms of cooking time has recorded the lowest overall acceptability. This result is due to its black color disliked by 63% of the panelists. Assogba et al. [6] found that the color after cooking is the most sensitive sensorial attribute that influences Kersting's groundnut acceptability. Color plays a major role in the initial acceptability of a product [62, 63]. According to Barbut [64], the visual appearance and color are important factors in consumer selection of food, and if the color does not meet expectations, they react negatively to the product. Consequently, Kersting's groundnut black-seeded landraces are scare and produced only by a few households particularly for its contribution to dietary diversity and medicinal purposes, and it is used for cultural rituals [10]. Apart from the color of accession BUR 16 that was much disliked, its texture, aroma, and taste were also disliked by the panelists. This result underlined that the BUR 16 color influences negatively the acceptability of other sensorial attributes [6]. In this study, we recommend a paradigm change, toward research of new processing schemes for the black and red Kersting's accessions, in order to optimize their consumption while reducing on refusal due to color and aroma. Otherwise, the accessions OUA and BUR 7 were the most accepted due certainly to their taste, liked by up to 70% of the panelists and aroma liked by up to 60% of the panelists, which are important influential attributes for food acceptability [65]. In addition, according to the panelists, the accession OUA has similar characteristics with the local Kersting's groundnut usually consumed while the accession BUR 7 is very similar to cowpea grain especially due to it black eyes. Thereby, the consumers could promote the accessions OUA and BUR 7 for crops production as they have the best acceptability. Nevertheless, given that Kersting's groundnut got much higher market value than cowpea, it would be useful for breeding efforts to give priority to varieties with cream seed coat without black eyes, as these later would be seen as cowpea and thus would fail to fetch true price.

5. Conclusion and Perspectives

The present study explored physical, nutritional, and organoleptic characteristics of five selected Kersting's groundnut accessions. The cooking time of these accessions was lower than the cooking time of the cream Kersting's groundnut seed usually consumed in Benin and the accessions BUR 16 and BUR 14 recorded the lowest cooking time. The accessions BUR 7 and OUA recorded the best acceptability level. It is worth noting that the accessions BUR 16 and BUR 14, which recorded the short cooking times, were not the most accepted probably due to their color. The accession OUA could be promoted for production based on its higher protein content, best amino acid profiles, its medium cooking time, and good acceptability level. However, further studies need to be conducted on the improvement of protein content especially the amino acid profiles as well as the profiling of their antinutritional composition.

Appendix

Table 1 presents the linear regression equations for the five accessions' textures according to cooking time. The normality of the model was determined and all these equation' residuals were normally distributed (p˃0.05). In addition, all the adjusted R-squared were higher than 95%, indicating that these equations explain more than 95% of the variability in Kersting's groundnut seed texture.

Data Availability

The dataset used to support the findings of this article are available upon request from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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