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Nutritional and Functional Characterization of Undecorticated Groundnut (*Arachis hypogaea* L.) Seeds from Bosso Market, Minna, Nigeria

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Abstract The undecorticated groundnut (*Arachis hypogaea* L.) seeds were analyzed for proximate compositions, some valuable minerals and functional properties using standard method of analysis. The results showed the seeds samples are within the range of 40.10 to 42.13 % fat, 24.48 to 26.37 % crude protein, 4.24 to 6.30 % carbohydrate, 3.02 to 5.08 % moisture, 17.32 to 22.70 % crude fibre and 1.51 to 2.33 % ash. Minerals content include; sodium, calcium, phosphorus, potassium, manganese, zinc, iron and copper were found to be present in the seeds flours. The dominant macro mineral element (potassium) could be recommended as source of dietary supplement. Functional properties ranged from 198.45 to 201.70 % water absorption capacity, 170.30 to 190.50 % foaming absorption capacity, 25.20 to 31.50 % emulsion capacity, 9.35 to 13.24 % emulsion stability, 3.50 to 4.50 % foaming capacity and 0.62 to 0.80 g/cm^3 bulk density. However, the raw groundnut seed flour had higher values of functional properties than the toasted and sundried groundnut seed flours. The high emulsion stability and activity of the seed flours signify their potential applications in food systems.

Keywords: *groundnut, nutritional properties, functional properties, proximate compositions, minerals*

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1. Introduction

Groundnut, or peanut (*Arachis hypogaea* L.), is a species in the legume family Fabaceae, native to Mexico, South and Central America [1]. In Nigeria, among the leading producing states of groundnut is Niger state [2]. In this Northern part of Nigeria, groundnuts are processed into various products which include groundnut paste popularly known as peanut butter, groundnut cake, salted groundnut and groundnut soup. Groundnut has contributed extremely to the development of the Nigerian economy through the sales of seeds, cakes, oil and haulms [3]. A substantial part is eaten in the cooked form, while fewer people indulge in eating the seeds raw [4]. Therefore, good nutrition is very essential to humans. Healthy population promotes development of the people through the relation between food, nutrition and health which needs to be reinforced in order to satisfy the needs of the increasing population [5].

However, the seeds serve as an important diet in many countries. Owing to its richness in high quality dietary protein and oil it helped to reduce malnutrition in the developing Countries [6] and help to supplement the nutrients of the basic carbohydrate food of the needy who cannot afford enough protein food of animal origin Achu *et al.* [5]. Apart from this, cake made from groundnut could be used in infant food formulations. Groundnut provides considerable amounts of mineral elements like phosphorous, calcium, magnesium and potassium and vitamin E, K, and B group to supplement the dietary requirements of humans and farm animals [7]. Groundnut contained 44 to 56% oil, 22 to 30% protein, and 9.5 to 19.0% total carbohydrates as both soluble and insoluble carbohydrate [8,9,10,11]. According to Aremu *et al.* [12] seed proteins possess the essential functional properties for their successful utilization of some food products. Functional properties are essential physicochemical characteristics which affect the behaviour of proteins in food systems during manufacturing, storage and preparation. Some of these properties can be as a result of the thermodynamically favorable protein water interactions such as wettability, swelling, water retention, solubility, foaming and emulsification [13]. In previous study as reported by Yu *et al.* [14] the functional properties of defatted groundnut flour such as emulsification, bulk density, viscosity, and water and oil absorption were essential in food processing and formulation of food product.

A survey of the literature showed that research had been done on the proximate and mineral analysis of groundnut seeds, but there is little or no information as regards the chemical composition and functional properties of groundnut from a market in Minna, Niger state. It is on this basis that this research was conducted so as to establish the base line data in the chemical compositions, minerals and functional properties of groundnut seeds in this region.

2. Materials and Methods

2.1. Sample Collection and Treatment

Groundnuts (*Arachis hypogaea* L.) seeds were purchased from Mobile markets, Minna, Nigeria and were transported with polythene bag to the laboratory. The seeds were undecorticated, pre-treated by washing with distilled water and then divided into three portions: the first part was air dried, second part sun dried and the third part was toasted in an oven for 3 hours at 105°C. The toasted seeds and the other two portions of sample were grounded into a paste to pass through mesh sieve.

2.2. Proximate Analysis

The standard AOAC [15] methods were used to determine proximate composition of the groundnut samples.

2.3. Analysis of Mineral Elements

The wet-ashing method was employed for the digestion of the seed sample; 1 g of sample was digested with 20 cm^3 of concentrated HNO_3 and perchloric acid (1:1) and thereafter transferred to a 100 cm^3 volumetri flask. It was diluted to volume with distilled water and stored in sample bottle. The mineral element contents were determined using an atomic absorption spectrophotometer (Perkin–Elmer model 703) and a flame photometer as described by Onyeike and Acheru [16].

2.4. Functional Properties

2.4.1. Bulk Density

The weighed sample was transferred into 10 cm^3 graduated. The bottom of the cylinder was gently tapped on a laboratory bench for several times until no further diminution of the sample level was observed after it was filled up to the calibrated mark. Bulk density is expressed as:

$$\text{Bulk density}(\text{g}/\text{cm}^3) = \frac{\text{Weight of the sample(g)}}{\text{Volume of the sample}(\text{cm}^3)}$$

2.4.2. Emulsifying Properties

Emulsifying capacity (EC) was determined according to the method of described by Pedroche *et al*. [17] with little modification. 1.0 g of each sample was homogenized at a speed of 160 rpm for 1 min at room temperature in 25 cm^3 distilled water. The protein solution was mixed with 25 cm^3 of vegetable oil followed by homogenization at 160 rpm for 1 min and finally, the emulsion was centrifuged for 5 min. Emulsifying activity was determined by:

$$\text{Emulsifying capacity}(\%) = \frac{\text{Height of emulsion layer}}{\text{Height of the content in the tube}} \times 100$$

Emulsion stability (ES) was measured by re-centrifugation followed by heating at 80°C for 30 min. Emulsion stability is expressed as follow:

$$\text{Emusifying stability}(\%) = \frac{\text{Height of remaining emulsion layer}}{\text{Height of original emulsified layer}} \times 100$$

2.4.3. Foaming Capacity (FC) and Foam Stability (FS)

Foaming capacity (FC) and stability (FS) were determined by the method described by Sze-Tao and Sathe [18] with certain modification. 1 g of each sample was isolated in 50 cm^3 of distilled water. The solution was stirred at a speed of 160 rpm for 10 min. The blend was immediately transferred into a 100 cm^3 graduated cylinder. The volumes were recorded before and after stirring.

$$\text{Foam capacity}(\%) = \frac{\begin{pmatrix}\text{Volume after whipping}\\ -\text{Volume before whipping}\end{pmatrix}\text{ml}}{(\text{Volume before whipping})\text{ml}} \times 100$$

For the determination of foam stability, foam volume changes in the graduated cylinder were recorded at 25 min of storage.

$$\text{Foam stability}(\%) = \frac{\begin{pmatrix}\text{Volume after standing}\\ -\text{Volume before whipping}\end{pmatrix}\text{ml}}{(\text{Volume before whipping})\text{ml}} \times 100$$

2.4.4. Fat Absorption Capacity (FAC)

Fat absorption capacity was determined using the method described by Lin and Zayas [19] with minor modifications. 1 g of each sample was weighed into 20 cm^3 pre-weighed centrifuge tube and thoroughly mixed with 5 cm^3 vegetable oil. The emulsion was incubated at room temperature for 25 min and then centrifuged for 15 min and the supernatant was carefully removed, and the tube was reweighed. FAC was determined by:

$$\text{Foam absorption capacity} = \frac{F_2 - F_1}{F_0}$$

Where F_o is the weight of the sample (in gram), F_1 is the weight of the tube plus the sample (in gram), and F_2 is the weight of the tube plus the sediment (in gram).

2.4.5. Water Absorption Capacity (WAC)

The modified procedure as described by Rodriguez-Ambriz *et al*. [20] was used to determine the water absorption capacity. 1 g of each sample was weighed into 20 cm^3 pre-weighed centrifuge tube. 10 cm^3 of distilled water was added in to the tube under continuous stirring with a glass rod at room temperature for 25 min. The tube was centrifuged for 20 min and the amount of added distilled water resulting in the supernatant liquid in the test tube was recorded. WAC expressed as grams of water per gram of sample, was calculated by:

$$\text{Water absorption capacity} = \frac{W_2 - W_1}{W_0}$$

Where W_o is the weight of the sample (in gram), W_1 is the weight of the tube plus the sample (in gram), and W_2 is the weight of the tube plus the sediment (in gram).

2.5. Statistical Analysis

Results are expressed as the means and standard deviations of three separate contents. The data were statistically analyzed by 2-way analysis of variance (ANOVA). Standard deviations were compared by Duncan's multiple range tests at 5% level of significance ($P \leq 0.05$).

3. Results and Discussion

3.1. Proximate Composition of Undecorticated Groundnut Seed

Results of the proximate compositions of the groundnut seeds are shown in Table 1.

Table 1. Proximate Composition (%) of Undecorticated Groundnut Seed

Parameter	Raw	CV	Toasted	CV	Sundried	CV
Ash	1.51±0.01[a]	0.66	2.33±0.01[c]	0.43	2.03±0.01[b]	0.43
Moisture	5.08±0.02[b]	0.39	3.02±0.03[a]	0.99	3.05±0.01[a]	0.33
Crude Protein	26.37±0.03[c]	0.11	24.48±0.02[a]	0.08	25.32±0.02[b]	0.08
Crude Fiber	22.70±0.02[c]	0.09	17.32±0.01[a]	0.06	22.06±0.01[b]	0.05
Fat	40.10±0.01[a]	0.03	42.13±0.02[c]	0.05	41.21±0.02[b]	0.05
Carbohydrate	4.24±0.03[a]	0.71	9.16±0.02[c]	0.22	6.30±0.03[b]	0.48
Fatty acid	32.08		33.70		32.95	
Energy(KJ/100g)	1936.27		1984.76		1960.82	

Values are means ± standard deviation of duplicate determination. Calculated fatty acid = 0.8 × crude fat. Calculated soluble energy (KJ/100)= protein × 17 + fat × 37 + carbohydrate.Coefficient of variation (CV)% = $\frac{\text{Standard deviation}}{\text{Mean}} \times 100$.

The moisture content of the raw groundnut seeds was significantly high compared to the toasted and the sundried groundnut since it was not exposed to any heat. The moisture contents of the groundnut seeds were lower when compared to the reported work of Ibeabuchi [21] on the proximate and functional properties of raw and fermented bottle gourd seed (*Lagenaria sicerari*). As a result of this, it would enhance storage stability by preventing mould growth and also suitability and adaptability for further use in food formulation. Ash content is an indicator for mineral elements in seed. The ash contents (1.51-2.33 %) of the groundnut seed flours are higher than 1.38-1.48 % of *Arachis hypogaea* seed flour reported by Ayoola and Adeyeye [22]. The increase in the ash content of toasted groundnut may be as a result of pretreatment since volatile compounds are lost. According to Pomeranz and Clifto [23] ash contents of seeds should be in the range 1.5-3.5 % for suitable consumption. In this study, the ash contents fall within this range thus it can be recommended for human consumption and animal feeds.

The protein contents in both the raw and sun dried groundnuts were low while in the toasted groundnut, the heat applied showed a synergistic effect. The carbohydrate content was higher in the toasted and the sundried than in the raw groundnut. The crude protein contents (24.48-26.37 %) are greater than that of benniseed (16.4–18.1 %) as reported by Yusuf *et al.* [24]. Therefore, the seeds can be used as alternative sources of protein in diets. High fiber content in the samples is an advantage, and hence this may have potential uses as food supplement. The coefficient of variation (CV) % of the groundnut samples range from 0.08 to 0.99 % indicating the results were not critically varied.

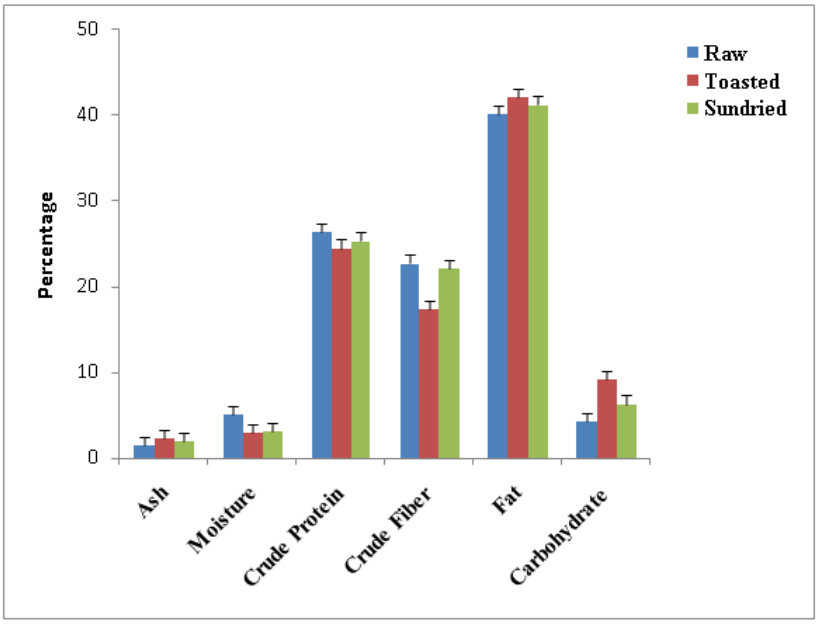

Figure 1. Graphical Representation of Proximate Composition of Groundnut Samples

3.2. Mineral Composition of Undecorticated Groundnut Seed

From "Table 2" and "Figure 2", the toasted groundnut does not lead to reduction in levels of mineral contents but rather increases in the levels since volatile and organic matter are lost by heat which corresponds with the observation of Ayoola and Adeyeye [22]. Therefore, groundnut is a good source of oil protein and minerals which can be used in diets to prevent against some mineral deficiencies

Table 2. Mineral Composition (mg/100g) of Undecorticated Groundnut Seed

Mineral	Raw	Toasted	Sun-dried
Sodium	64.23±0.25[b]	66.13±0.15[c]	62.80±1.06[a]
Potassium	501.00±1.00[c]	535.67±0.11[a]	521.33±0.58[b]
Calcium	90.00±1.00[a]	122.33±1.53[c]	114.80±0.27[b]
Iron	4.53±0.58[a]	5.10±0.10[c]	4.72±0.20[b]
Zinc	4.24±0.06[a]	5.35±0.05[c]	4.81±0.01[a]
Copper	4.61±0.01[a]	5.59±0.80[b]	4.80±0.27[a]
Lead	ND	ND	ND
Manganese	5.50±0.10[a]	6.03±0.15[b]	5.50±0.10[a]
Phosphorus	5.83±0.21[a]	6.80±0.10[b]	6.14±0.15[a]

ND = Not detected. Values are means ± standard deviation of triplicate determination.

Na, K, Cu, Fe and Mn contents were found to be higher than conophor nut, cashew and bean seed [25,26]. Potassium was the highest mineral element. The highest value of potassium agreed with the study that potassium was the most major mineral in Nigerian agricultural products [27]. The Na/K ratios obtained in raw, toasted and sundried samples are 0.12, 0.13 and 0.12 respectively. The values were less than 1 which signifies that the groundnut seeds flour would probably be a good source for electrolyte balance and controls high pressure in the body [28,29]. The raw, sun dried and the toasted seeds contained appreciable amounts of calcium. Calcium is of greater amount when compared to *Abelmoschus esculentus* reported by Ndangui *et al.* [30]. This is very important to health of humans and is required for formation of bones and teeth, formation of blood clot, and body mechanisms [31]. The intake of the seeds flour which contains zinc as a micro element will play a role in the body in the healing of wound. The presence of phosphorous in the samples indicates that the soil nutrient where the samples were planted is rich in the mineral. So therefore, intake of the mineral would help in bone growth, kidney function, cell growth and in maintaining the body's acid-alkaline balance [32]. The absence of lead in the samples indicated that the investigated samples were free from the toxic metal.

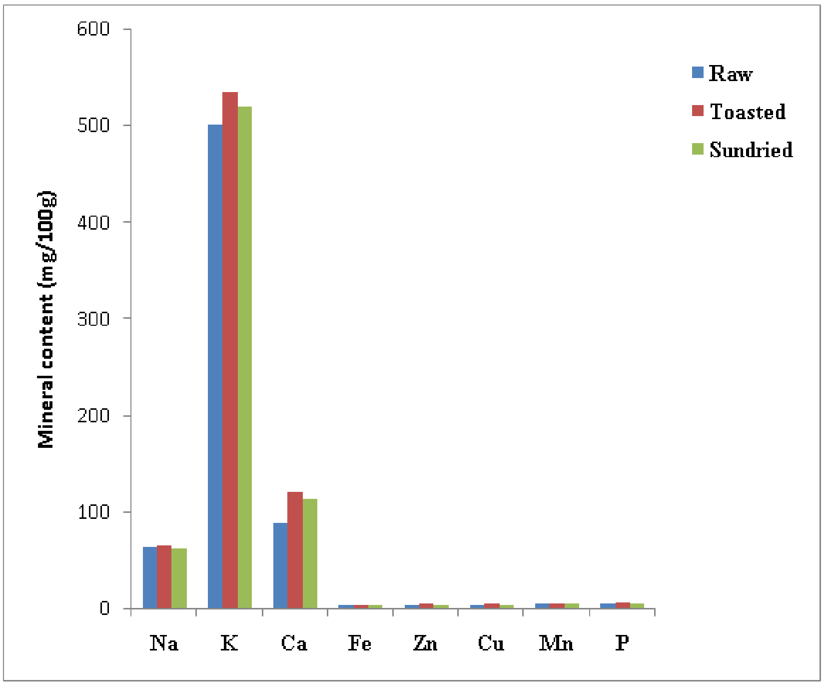

Figure 2. Graphical Representation of Percentage Mineral Content of Groundnut Samples

3.3. Functional Properties of Undecorticated Groundnut Seed

The toasted groundnut showed decrease in its functional properties compared to the raw and sundried seeds (Table 3). The fat absorption capacity (FAC) of raw groundnut was higher than that of toasted and sundried groundnut. This suggests that raw groundnut may have more hydrophobic proteins [33].

The water absorption capacity (WAC) (201.7 %) of raw groundnut seeds was the highest. The high water absorption capacity may be due to the high polar amino acid residues of raw groundnut proteins have strong affinity for water molecules [34]. The foam stability of toasted seeds decreased and other functional properties showed similar trends. Foam stability is dependent on protein content and environmental temperature. The higher the protein content the higher the foam stability [35]. Heat processing diminished the nitrogen solubility of proteins by denaturation and reduced their foaming capacity [36]. High temperature and prolong toasting time would not be desirable for processing the seeds where water or oil absorption are importance. Heat has been reported to inactivate the anti-nutritional factors [37] and also increase the antioxidant activity [38] seed flour. The application of heat during the pretrearment of the toasted and sundried groundnut seeds may contribute to the decreased in their foaming capacity and foaming stability leading to protein denaturation. Similar trends have been reported by Rahma and Mustafa [39] for peanut flour.

Table 3. Functional Properties of Undecorticated Groundnut Seed

Functional property	Raw	Toasted	Sun-dried
Water absorption capacity (%)	201.70	185.20	198.45
Fat absorption capacity (%)	190.50	170.30	183.45
Emulsifying capacity (%)	31.50	25.20	28.72
Emulsifying stability (%)	13.24	9.35	11.30
Foam capacity (%)	4.50	3.50	3.80
Bulk density (g/cm^3)	0.80	0.62	0.72

The emulsion activity shows the ability and capacity of a protein to help in the formation of an emulsion and is related to the protein's ability to absorb to the interfacial area of oil and water in an emulsion [40]. The emulsion stability normally reflects the ability of the proteins to impart strength to an emulsion for resistance to stress and changes [41]. Raw seed flour has the highest emulsion capacity (31.50 %) because the seeds contain low amount of carbohydrate and this may be attributed to the high fat content in the groundnuts. This may be of great important in food emulsion such as yogurt, mayonnaise and ice-creams because of it high emulsion capacity.

The bulk densities of groundnut seed flour of raw, toasted and sundried were found to be in the range of 0.72-0.80 g/cm^3. The bulk density values in this study for the groundnut seed flour are not comparable with 0.54 – 0.57 g/cm^3 for different chickpea varieties as reported by Kaur *et al.* [42]. Higher bulk density is advantageous since it helps to reduce the paste thickness which is an essential factor in child feeding [43,44]. However, the groundnut seed flours could be use as food supplement for children.

4. Conclusion

The undecorticated groundnut seeds contained high level of oil and protein this makes it a potential source of edible oil. The sources of protein and essential minerals can serve as various food and economic purposes. Functional properties of the groundnut seeds flour could be a good replacement in food formulation. This work has helped us know the nutritive values of groundnut from a part of Nigeria which can be considered as a good source of protein and promote the incorporating groundnut to improve protein level in reducing malnutrition in the developing countries. However, more studies should be carried out to investigate the possibility of using the seeds as an ingredient on other food products in order to increase the application of such value added food ingredient.

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