

Research Paper

Effect of dehulling and fermentation on physico-chemical and functional properties of mesquite (*Prosopis africana* Guill. and Perr.) seed flours

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ABSTRACT

Dehulled and fermented flours were produced from mesquite (*Prosopis africana* Guill. and Perr.) seeds and each of the samples was subjected to physico-chemical analysis using standard analytical methods. The results indicated that moisture content of the flours ranged from (2.67 to 9.70%), crude protein (14.23 to 34.24%), crude fat (1.07 to 27.93%), crude fibre (1.20 to 3.87%), Ash (1.33 to 6.33%) and carbohydrate (26.03 to 76.84%). The result of pH ranged from (6.20 to 7.95). Calcium (Ca) ranged from (121.3 to 275.2) in mg/100 g; copper (Cu) ranged from (2.92 to 6.16) mg/100 g; iron (Fe) ranged from (1.35 to 10.05) mg/100 g; zinc (Zn) (2.36 to 6.33) mg/100 g; magnesium (Mg) (58.90 to 78.51) mg/100 g; phosphorus (P) (141.29 to 298.07) mg/100 g; Sodium (Na) (17.51 to 58.90) mg/100 g while potassium (K) ranged from (111.1 to 138.6) mg/100 g. Wettability ranged from (5.0 to 25.0) min; Water absorption capacity in g/ml ranged from (2.2 to 8.0) while the oil absorption capacity in g/ml ranges from (1.87 to 8.09). All the flours produced were within safe limits as stipulated by International Standards. The results showed that flours from dehulled and fermented mesquite seeds can be incorporated to produce condiments of high functional properties.

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INTRODUCTION

Prosopis africana Guill. and Perr. is a leguminous tree and one of the 44 species of the genus *Prosopis*. It is a savannah tree found in the semi-arid and arid regions of tropical Africa (Keay, 1989). The tree is of great economic value to man and animal. It fixes nitrogen to enrich the soil, generates hardy timbers, produce rich leaves and sugary pods used as feed stuffs to ruminants (Annongu and Termeulen, 2004). *P. africana* is known as mesquite seeds in English language, Kirya in Hausa, Ayan in Yoruba, Ubwo in Igbo and Sanchi in Nupe and it is the only species of *Prosopis* that is indigenous to tropical Africa (Ayanwuyi et al., 2010). There is however reports of *Prosopis* spp. existence as native plants in southwestern United States and Mexico where it is used as fodder for animals (Pasiiecznik, 2004).

Mesquite seeds being an oil seed along with other oil seeds such as African locust bean (*Parkia biglobosa*), melon

seed, castor seeds and soybean are fermented to produce condiments locally known as dawadawa in Hausa and nunu among Tiv people of Nigeria. Fermented mesquite (*P. africana*) seed is a well known condiment with a characteristic flavor and aroma used to enhance the taste of traditional soups. It is also known to contribute to the calorie and protein intake of consumers (Annongu and Termeulen, 2004). Traditional fermented condiments (Dawadawa, Iru, Ogiri and Gbaaye etc) are rich in vegetable proteins and consumed by different ethnic groups in Nigeria. It is evident that these products played a major role in the food habit of communities in the rural regions. They serve not only as a nutritive non-meat protein supplements but as functional ingredients in prepared food.

Traditional diets in West Africa often lack variety and consist of large quantities of staple foods (cassava, yam and cereals) supplemented with plantain, cocoyam and cowpea

depending on availability and season (Achi, 1999). Soups eaten with the staples are an essential component of the diets and are derived from a variety of seeds, nuts, pulses and leaves (Campbell-Platt, 1980). The staple foods provide the calories but are poor in other nutrients and minerals. One of the ways to improve the diets has been to improve the nutrient content of the soups. Due to increased population and corresponding increased need for animal food, there is high demand on alternative sources that are close substitutes to high quality animal protein (Odunfa, 1986).

Fermentation markedly improves the digestibility, nutritive value and flavours of the raw seeds. Traditional method of the production of Gbaaye made from mesquite seeds involve subjecting the seeds to 24 h boiling above 100°C followed by dehulling, fermentation, mashing and rolling into balls (Achi, 1992). The fermentation method is uncontrolled solid substrate fermentation, which results to extensive hydrolysis of the protein and carbohydrate components (Fetuga et al., 1973; Eka, 1980). This processing method increases the shelf-life and reduction of the anti nutrition factors (Odunfa, 1985a; Reddy and Pierson, 1999; Barimalaa et al., 1989; Achi and Okereke, 1999).

There are different types of fermentations and examples include: alcoholic fermentation for the production of beer using yeast, lactic acid for yoghurt production using lactic acid bacteria, acetic acid for vinegar production using acetic acid bacteria, propionic acid in blue-eyed cheese using propionic bacteria and alkaline fermentation for Gbaaye, dawadawa and other fermented condiments using *Bacillus*, *Staphylococcus* and *Leuconostoc* species. Moreover, Odunfa (1981) intimated that some microbes are known to hydrolyze proteins into amino acids and peptides releasing ammonia as a by-product in the process; this process is said to increase the protein content of fermented food products. Fermented foods contribute about one-third of the world's diet (Campbell-Platt, 1994). This is because fermentation causes changes in food quality indices including texture, flavour, appearance and nutrition (Odunfa, 1985b; Reddy and Pierson, 1999).

Fermentation markedly improves the digestibility, nutritive value and flavours of the raw seeds. Although, fermented food condiments have constituted a significant proportion of the diet of many people, Nigerians have exhibited an ambivalent attitude in terms of consumer tastes and preferences for such foods (Achi, 2005). The introduction of foreign high technology products especially processed ones due to globalization and liberalization of the economy has radically changed the Nigerian food culture into a mixed grill of both foreign and local dishes.

Many developing countries are still preparing traditional fermented products for human consumption (Campbell-Platt, 1980). Fermented products remain of interest since they do not require refrigeration during distribution and storage. The traditional condiments have not attained

commercial status due to the very short-shelf life, objectionable packaging materials, stickiness and characteristic putrid odour (Arogba et al., 1995).

The production of fermented vegetable proteins for use as food condiments is craft-based. In many areas of Nigeria, they are still made in traditional ways, with success depending upon observance of good manufacturing practices and control of environmental conditions during the manufacturing process. Starter cultures are not normally used and therefore there are variations in the quality and stability of the product (Odunfa, 1981). There is usually rise in pH due to hydrolysis of protein into amino acids and ammonia by predominant micro-organisms *Bacillus* species. As with any other fermentation process the understanding of the microbial ecology of vegetable fermentations requires the knowledge of the fermentation substrates, that is, the seeds of the various plants as well as, the products expected. During fermentation of condiments, amino acids is produced due to protein metabolism which are responsible for the gradual pH increase towards 7.5 to 8.0 (Barimalaa et al., 1989; Achi, 1992; Barber and Achinewhu, 1992; Sarkar et al., 1997). Increase in pH into alkaline range may be physiologically important for tolerance and adaptation of fermenting micro-organisms in the environment.

The use of *Prosopis* leaves and its nutritive value was reported by Lyon et al. (1988). However, information on the physico-chemical properties of the flours produced from dehulled and fermented mesquite seeds (*P. africana*) is very scanty; such information will enhance increased utilization of this inexpensive plant protein to minimize the over dependence on African locust bean (*P. biglobosa*) and soya bean (*Glycine max*) seeds and their allied as condiment. The objective of this study therefore, was to determine the effect of dehulling and fermentation on the chemical and physical properties of mesquite seed flours.

MATERIALS AND METHODS

Procurement of African mesquite seeds

The African mesquite seeds (*P. africana*) used for this study was obtained from North Bank Market in Makurdi, Benue State. So also, the *Gmelina* leaf used for the fermentation process was plucked from the trees within the vicinity of Federal University of Agriculture, Makurdi. Makurdi is situated on Latitude 7.73 and Longitude 8.52 at elevation of 104 m above sea level (World Atlas, 2015).

Procurement of Gbaaye a local condiment

Gbaaye, a local condiment was purchased from Kaduna Central Market in Kaduna State (10°20'N 7°45'E) (Wikipedia, 2017) Nigeria. The purchased Gbaaye

condiment was dried at room temperature (25 to 27°C) for 30 to 60 min and milled into flour using Model RPM 8 Laboratory Mill and packaged in a polythene wrapper and stored at ambient temperature at 25 to 27°C in a plastic jar until ready for use.

Preparations of African mesquite seeds for treatments

Preparation of dehulled and fermented African mesquite seed flour

100 g of cleaned and sorted African mesquite seeds were boiled and dehulled according to the modified method of Achi (2005). The boiling of the seeds was done in an aluminum pot for 12 h using firewood. Loss of water occurring through steaming was topped –up occasionally to compensate for water lost through evaporation after which the seed coats were dehulled manually. The dehulled seeds were washed thoroughly with water, boiled for another 8 h and drained in a plastic sieve ready for fermentation. The dehulled cotyledon seeds were packed into a cleaned wooden basket padded with cleaned *Gmelina* leaves. Additional *Gmelina* leaves were used to cover the cotyledon seeds to enhance anaerobic condition. The wrapped cotyledon seeds were then allowed to ferment at room temperature (25 to 27°C) for 72 h. The fermented dehulled cotyledon seeds were then removed from the leaves, mashed with pestle in a ceramic mortar and rolled into balls. The rolled ball condiments were dried using the hot air oven set at 45°C for 30 to 60 min and then cooled, milled into flour using Model RPM 8 Lab Mill and packaged in a polythene wrapper, stored in a closed plastic jar at ambient temperature of about (25 to 27°C).

Preparation of non-dehulled and fermented African mesquite seed flour

In this method, the same amount of cleaned and sorted African mesquite seeds were treated as earlier described, but the seeds were not dehulled but instead cooked over firewood for 72 h and treated with occasional adding of water as described earlier to compensate for loss of water during cooking. The process of obtaining the non-dehulled and fermented African mesquite seed flour followed the processes as earlier described.

Preparation of dehulled and non-fermented, and non-dehulled and non-fermented African mesquite seed flour

The same amount of African mesquite seeds was treated as earlier described but cooked for 12 h, separately. 100 g of the seeds were dehulled and prepared as non-fermented while another 100 g was prepared as non-dehulled and

non-fermented, respectively. The preparations were spread on a metal tray and dried using the hot air oven at 45°C for 30 to 60 min individually, respectively. The dried seeds were milled and stored individually as earlier described.

Preparation of uncooked, non-dehulled and non-fermented African mesquite seed flour

100 g of the African mesquite seeds were cleaned, sorted and milled with the same machine as described above. The product was sieved using a 2 mm diameter sieve in order to its flour. The flour obtained was packaged in a polythene wrapper and stored in a plastic jar.

Chemical analyses

Dehulled, non-dehulled, fermented and non-fermented African mesquite seed flours were analyzed for proximate composition (moisture content, crude protein, fat content, crude fibre content, crude ash content, carbohydrate and pH) following the standard method as laid down by AOAC (1990), while mineral compositions (Calcium, Copper, Iron, Zinc, Magnesium, Phosphorus and Potassium) were determined by the dry ash procedure of Onwuka (2005). Functional properties of the samples (wettability and water/oil absorption capacity) were determined according to the method of Okaka and Potter (1977).

Statistical analysis

The data obtained was analyzed in one way analysis of variance using Genstat statistical package (2005). Confidence intervals were set at ($p=0.05$) using the studentized maximum modulus (Stoline and Ury, 1979).

RESULTS

Table 1 showed that Sample B had the highest percentage moisture content of 9.70% followed by sample D with 8.66%. Samples A and B were not significantly different ($P\geq 0.05$) from each other but were significantly different ($P\leq 0.05$) from the rest of the samples. Table 1 also showed that Sample A had the highest percentage crude protein (CP) content of 34.24% followed by sample F with 28.19%. The amount of CP between these two samples differed significantly ($P\leq 0.05$) from each other and also from samples B and E (which were not statistically different from each other ($P=0.05$) but were significantly different ($P\leq 0.05$) from samples D and C. The results further showed that Crude fat (CF) percentage varied considerably between the Mesquite seed flours and all the seed flours were significantly different ($P\leq 0.05$) from each other. Sample A

Table 1: Effect of dehulling and fermentation on proximate composition and pH of Mesquite (*Prosopis africana*) seed flours.

Samples*	Parameters in %						
	Moisture	Crude Protein	Crude Fats	Crude fibre	Crude ash	Carbohydrate	pH
A	7.30 ± 0.02 ^b	34.24 ± 0.02 ^a	27.93 ± 0.02 ^a	2.67 ± 0.02 ^c	1.83 ± 0.02 ^e	26.03 ± 0.01 ^d	7.59 ± 0.01 ^a
B	9.70 ± 0.02 ^a	18.48 ± 0.05 ^c	11.07 ± 0.01 ^c	3.67 ± 0.02 ^b	6.33 ± 0.02 ^a	50.73 ± 0.02 ^c	6.49 ± 0.02 ^b
C	5.33 ± 0.02 ^c	14.23 ± 0.01 ^e	1.07 ± 0.01 ^e	1.20 ± 0.02 ^d	1.33 ± 0.02 ^e	76.84 ± 0.02 ^a	6.20 ± 0.01 ^c
D	8.66 ± 0.02 ^a	18.11 ± 0.01 ^d	9.86 ± 0.01 ^c	3.84 ± 0.02 ^a	4.38 ± 0.02 ^c	55.13 ± 0.02 ^c	6.29 ± 0.01 ^d
E	5.17 ± 0.02 ^c	18.91 ± 0.02 ^c	2.73 ± 0.01 ^d	1.66 ± 0.02 ^d	3.17 ± 0.02 ^d	68.36 ± 0.02 ^b	6.43 ± 0.02 ^b
F	2.67 ± 0.02 ^d	28.19 ± 0.02 ^b	21.73 ± 0.02 ^b	3.87 ± 0.02 ^a	5.33 ± 0.02 ^b	28.23 ± 0.02 ^d	7.95 ± 0.01 ^a

Values are means ± standard deviations of triplicate determination. Means with the same superscript within the same column are not significantly different ($P > 0.05$) from each other. *A = Dehulled fermented flour, B = Non-dehulled fermented flour, C = Dehulled-non fermented flour, D = Non-dehulled-non fermented flour, E = Non dehulled non-fermented non boiled flour, F = Commercial purchased flour condiment (control).

Table 2: Effect of Dehulling and Fermentation on Mineral Composition Mesquite (*Prosopis africana*) Seed Flours (mg/100 g).

Samples*	Mineral composition in mg/100 g							
	Calcium	Copper	Iron	Zinc	Magnesium	Phosphorus	Sodium	Potassium
A	152.4 ± 0.00 ^b	6.16 ± 0.00 ^a	3.95 ± 0.01 ^d	2.50 ± 0.02 ^d	76.6 ± 0.00 ^a	272.0 ± 0.01 ^a	14.53 ± 0.05 ^b	111.9 ± 0.05 ^c
B	275.2 ± 0.00 ^a	5.18 ± 0.00 ^b	1.35 ± 0.01 ^e	2.84 ± 0.05 ^c	68.67 ± 0.00 ^b	141.29 ± 0.01 ^d	17.57 ± 0.05 ^a	138.6 ± 0.05 ^a
C	148.3 ± 0.00 ^c	6.03 ± 0.00 ^a	6.47 ± 0.01 ^b	3.07 ± 0.05 ^b	78.51 ± 0.0a	178.39 ± 0.05 ^b	13.58 ± 0.05 ^b	128.4 ± 0.05 ^b
D	174.4 ± 0.00 ^b	5.18 ± 0.00 ^b	10.05 ± 0.00 ^a	6.33 ± 0.01 ^a	72.31 ± 0.00 ^b	167.41 ± 0.05 ^c	12.43 ± 0.05 ^c	111.1 ± 0.05 ^c
E	121.3 ± 0.01 ^c	4.11 ± 0.00 ^c	4.92 ± 0.00 ^c	2.36 ± 0.02 ^e	67.16 ± 0.00 ^c	174.08 ± 0.01 ^b	10.22 ± 0.05 ^d	112.6 ± 0.05 ^d
F	228.2 ± 0.01 ^a	2.92 ± 0.00 ^d	6.74 ± 0.00 ^b	2.61 ± 0.05 ^d	58.90 ± 0.0d ^c	298.0 ± 0.01 ^a	17.42 ± 0.05 ^a	122.1 ± 0.05 ^e

Values are means ± standard deviations of triplicate determination. Means with the same superscript within the same column are not significantly different ($P > 0.05$). *A =Dehulled fermented flour; B = Non-dehulled fermented flour; C = Dehulled-non fermented flour; D=Non-dehulled-non fermented flour; E=Dehulled non-fermented non boiled flour; F = Commercial purchased flour condiment (control).

has the highest percentage CF content of 27.93% followed by sample F, 21.73%. On crude fibre contents, Sample F had the highest percentage crude fibre of 3.87% but this was not statistically different ($P=0.05$) from sample D which had 3.84% and was significantly different ($P\leq 0.05$) from samples B (3.67%), A (2.67%), E (1.66%) and C (1.20%) which were significant different ($p\leq 0.05$) from each other, respectively.

Table 1 also showed that sample B had the highest percentage of Crude Ash content of 6.33% followed by sample F with 5.33%. The Crude Ash contents of the seed flours were all significantly different ($P\leq 0.05$) from each other with the following values recorded in samples A (1.83%) and C (1.33%). The amount of carbohydrate content of the samples showed that sample C had the highest percentage of 76.84% and this was significantly different ($P\leq 0.05$) from the rest of the samples which were in turn significantly different ($P\leq 0.05$) from each other, respectively. The results of the pH determination showed that samples F (7.95%) and A (7.59%) were not statistically different ($P=0.05$) from each other; but were significantly different ($P\leq 0.05$) from the values obtained from samples B and E, C and D, respectively and which were also significantly different from each other.

The effect on dehulling and fermentation on mineral element composition of mesquite seed flour is shown in Table 2. Sample B had the highest calcium concentration of 275.2 ml/100 g followed by Sample F with 228.2 ml/100 g. Sample D had 174.4 ml/100 g; followed by sample A with 152.4 ml/100 g; Sample C had 148.3 ml/100 g while Sample E had the least 121.3 ml/100 g. The results showed that the amount of calcium in samples B and F were significantly different ($P\leq 0.05$) from the rest of the samples and A and D were significantly different from C and E. In terms of proportion of copper concentration in the samples, Sample A had the highest copper concentration of 6.16 ml/100 g followed by sample C with 6.03 ml/100 g which were not significantly different ($P\geq 0.05$) from each other but differs from samples B and D (5.18 ml/100 g, respectively) and these were found to be significantly different from ($P\geq 0.05$) samples E (4.11 ml/100 g) and F (2.92 ml/100 g), respectively. The concentration of iron indicated that samples D contained 10.0 ml/100 g, F (6.74 ml/100 g), C (6.47 ml/100 g), E (4.92 ml/100 g), A (3.95 ml/100 g) and B had the least 1.35 ml/100 g concentration.

The results showed that there were significant differences between ($P\leq 0.05$) the concentrations of iron in the samples (Table 2). The amount of zinc in the samples,

Table 3: Effect of dehulling and fermentation on functional properties of Mesquite seed flours (*Prosopis africana*).

Samples	Wettability (min)	Water absorption capacity (WAC) (g/ml)	Oil absorption capacity (OAC) (g/ml)
A	6.35 ^d	6.23 ± 0.02 ^b	6.60 ± 0.02 ^b
B	22.7 ^a	2.20 ± 0.05 ^e	1.87 ± 0.02 ^e
C	12.0 ^b	3.13 ± 0.05 ^d	1.96 ± 0.05 ^e
D	25.0 ^a	3.13 ± 0.05 ^d	2.17 ± 0.01 ^d
E	8.3 ^c	4.13 ± 0.05 ^c	2.75 ± 0.01 ^c
F	5.0 ^d	8.09 ± 0.02 ^a	8.09 ± 0.02 ^a

Values are means ± standard deviations of triplicate determination. Means with the same superscript within the same column are not significantly different ($P > 0.05$) from each other. *A = Dehulled fermented flour; B = Non-dehulled fermented flour, C = Dehulled-non fermented flour; D= Non-dehulled-non-fermented flour; E = Non dehulled non-fermented non boiled flour; F = Commercial purchased flour condiment (control).

followed the same trend with sample D containing 6.33 ml/100 g followed by sample C (3.07 ml/100 g); sample B had 2.84 ml/100 g had followed by Sample F, 2.61 ml/100 g. Sample A had 2.50 ml/100 g while sample E had the least 2.36 ml/100 g. The results also showed significant differences between ($P \leq 0.05$) the concentrations. The presence of magnesium in the samples showed that samples C and A (78.51 ml/100 g and 76.66 ml/100 g, respectively) were not significantly different ($P \geq 0.05$) from each other but were found to be significantly different ($P \leq 0.05$) from samples D and B (72.31 ml/100 g and 68.67 ml/100 g, respectively) and these were found to be significantly different from samples E (67.16 ml/100 g) and F (58.90 ml/100 g) but samples E and F were not significantly different ($P \geq 0.05$) from each other. Sample F contained the highest amount of phosphorus with value of 298.07 ml/100 g followed by sample A having value of 272.06 ml/100 g and these values were not significantly ($P \leq 0.05$) from each other but were significantly different from samples C and E with values of 178.39 ml/100 g and 174.08 ml/100 g. Samples D and B with values of 167.41 ml/100 mg and 141.29 ml/100 g, respectively were significantly different from each other. The presence of sodium in the samples showed that sample B had the highest sodium concentration of 17.57 ml/100 g followed by sample F with 17.42 ml/100 g. Concentration of sodium in the remaining samples showed that samples A, C, D and E, had 14.53, 13.58 12.43 and 10.22 ml/100 g, respectively and these values were significantly different ($P \leq 0.05$) from each other.

Table 3 showed that sample B had the highest concentration of potassium (138.6 ml/100 g) followed by sample C with 128.4 ml/100 g which were significantly different ($P \leq 0.05$) from each other. Samples A and D had value of 111.9 ml/100 g, respectively and were significantly different ($P \leq 0.05$) from samples F and E with values of 122.10 and 112.60 ml/100 g, respectively which were also significantly different from each other.

The effect of dehulling and fermentation on functional properties of mesquite seed flours is as shown in Table 3. The results on wettability showed that samples D and B

were not statistically different ($P=0.05$) from each other with values of 25.0 and 22.7 min, respectively; but were found to be significantly different from values obtained samples C (12.0 min.), E (8.3 min.), A (6.35 min.) and F (5.0 min.) with all the values showing significant differences ($P \leq 0.05$) among themselves. In terms of water absorption capacity, sample F showed the greatest affinity with values of 8.09 g/ml followed by sample A (6.23 g/ml), samples E (4.13 g/ml), C and D had 3.13 g/ml, respectively; while sample B had 2.20 g/ml. All the values were significantly different ($P \leq 0.05$) from each other except for values obtained in samples C and D which were not statistically different ($P=0.05$) from each other.

In addition, Table 3 indicated that the highest oil absorption capacity was recorded in sample F with value of 8.09 g/ml and samples A, E, D, C and B with values of 6.60, 2.75, 2.17, 1.96 and 1.87 g/ml, respectively. All the values were significantly different ($P \leq 0.05$) from each other.

DISCUSSION

Dehulling and fermentation of mesquite seeds into flours resulted into reduction in the level of percentage of moisture, crude fibre, crude ash and carbohydrate content but increased the percentage composition of crude protein and crude fat contents. The decrease in the percentage moisture content of the mesquite seed flours can be attributed to heat treatment which the products were subjected to. These low values are in conformity with the report of Wachukwu et al. (2003) who recommended that proper drying of product to a very low moisture contents is required to ensure adequate preservation to prevent growth of micro-organisms (bacteria, yeast and mould). The low values of percentage crude fibre content obtained agrees with Alabi et al. (2005) who reported that cellulose and fibre account for approximately 70% of testa and thus, fermentation and dehulling of seeds results in the reduction in carbohydrate and crude fibre.

In addition, the low values obtained may be as a result of milling and sieving involved during processing as most of

the fibre are deposited in the hull. These results were similar with the results of Fetuga et al. (1973) and Oke and Umoh (1987) who reported 4.0% crude fibre in their studies. However, the result obtained in this study is in contrast with the results of Annongu and Termeulen (2004) who got 6.90% crude fibre and Elemo et al. (2011) (11.23%). Crude fibre though, does not contribute nutrients to the body, it adds bulk to food, thus, facilitating bowel movement (paristalsis) and preventing many gastro-intestinal diseases in man (Gernah and Sengev, 2011).

The results of crude ash for samples B and F were higher as compared to the results of Fetuga et al. (1973); Oke and Umoh, (1987) that reported value of 2.0%, but falls within the values obtained by Elemo et al. (2011) (4.24%) and Annongu and Termeulen, (2004) (4.04%). The results of crude ash for other samples were lower when compared to results of the aforementioned workers; the low crude ash obtained may imply loss of some minerals which may have been leached in the water during boiling, dehulling and sieving processes. The increase in the percentage of crude protein for the dehulled and fermented flour agreed with earlier works reported by Esenwah and Ikenebomeh (2008) and Pelig-Ba (2009) who explained that the increase in percentage may be due to the decrease in the concentration of carbohydrates which was used up during fermentation.

Furthermore, the values were within those reported by Alabi et al. (2005) within the range of 34.02%. It was further reported by Alabi et al. (2005) that during fermentation of flour proteolytic enzymes within the flour used up most of the carbohydrate increased the protein and fat content with little amount of carbohydrate resulting in the process. This in addition contributes to flavor and texture of the product. For the non-dehulled and non-fermented samples, the low values for protein may be due to the fact that the seeds were not dehulled and no fermentation took place. Therefore, the carbohydrates were not used up by the fermenting enzymes, hence, the low protein and fat and higher carbohydrate values obtained. It was earlier confirmed that fermentation resulted in protein enrichment of fermented locust beans (Omafuvbe et al., 2000) in which African mesquite seeds fall into the category of high protein plants.

Proteins are essential constituents for all body tissues, which help the body to produce new tissues. The increase in the value for the percentage of crude fat may be attributed to the effect of fermentation on the flours. This type of increase was reported by Adebawale and Maliki (2011) who also observed increase in crude protein and fat and decrease in carbohydrate when *Cajanus cajan* seeds were fermented. The low values obtained for samples C and D may be attributed to the fact that they do not undergo processing operations such as dehulling and fermentation.

Eka (1980) studied the effect of fermentation on nutrient content of locust beans and reported that protein and fat increased when fermented while the quantity of

carbohydrate decreased. However, the low value of fat obtained in this study was desirable to avoid lypolysis as high fat content could lead to problem of objectionable flavor and odour. Fat help the body maintain its core temperature, absorb nutrient and provide energy to the body.

The results of carbohydrate of samples C and E were higher than the results obtained by Fetuga et al. (1973) and Oke and Umoh (1987) for carbohydrate (49.0%) but compares favourably with results of samples D and B. The values for samples F and A, although, lower, were within the values obtained by Eka (1980) (28.49%). Carbohydrate provides heat and energy for all forms of body activity. Its deficiency can cause the body to divert proteins and body fat to produce the needed energy, thus, leading to depletion of body tissues (Gernah and Sengev, 2011). The low values obtained for the carbohydrate content agrees with the observation of Adebawale and Maliki (2011) who also observed reduction in carbohydrate percentage when *C. cajan* seeds were fermented. There was no significant effect in pH of both dehulling and fermented flour samples. This could be due to protein hydrolysis in lowering molecular peptides and amino acids as reported by Sarkar et al. (1997) indicating that during fermentation, protein are hydrolyzed (breaking down) into low molecular peptides and amino acids. However, pH increase could lead to the formation of ammonia from amino acids which may consequently encourage growth of spoilage organisms such as lactobacilli and pediococci (Achi, 1992; Barimalaa et al., 1989; Barber et al., 1989; Omafuvbe et al., 2002). Implication of low pH value is that, under favourable conditions of moisture and warmth, the products could be susceptible to the growth of micro-organism such as yeasts and moulds (Omafuvbe et al., 2002). Wachukwu et al. (2003) reported that proper drying is required before preservation in order to prevent spoilage.

The mineral content of dehulled and fermented mesquite seed flours resulted in reduction in the level of calcium, magnesium, potassium, phosphorus and sodium. Ajeigbe et al. (2012) reported decrease in the level of potassium, phosphorus, calcium and magnesium but indicated that soaking, dehulling and fermentation did not influence the concentration of sodium in *Canavalia ensiformis* seeds. The authors further explained that the diminution in the levels of most of the minerals may be due to leaching, resulting from boiling and dehulling of the seeds during processing and therefore, justifies the reduction in the crude ash content. Adane et al. (2013) also reported significant reduction in the minerals content of the flour product and attributed these losses to the fact that the supernatant solutions from the processed flour were normally discarded. The values obtained for calcium were within the values obtained by Elemo et al. (2011) (222.2 ml/100 g) although, the result of sample B was higher (275.2 ml/100 g). However, the result of samples A, C, D and E were lower than the values obtained by Elemo et al. (2011), but all the

results were within the values of some legumes such as soya, *G. max* with calcium (201 ml/100 g) (Pirman et al., 2001). Calcium builds healthy strong bones and teeth and also assists in blood clotting (Gernah and Sengev, 2011). The results obtained for copper were within permitted levels of trace element (5.0 mg/100 g) in food stuffs (Egan et al., 1981).

In humans, copper is essential for the proper functioning of organs and metabolic processes when in traces but have emetic action when ingested in higher amount (Egan et al., 1981). All the values obtained for iron were permitted levels within and this agreed with the value obtained by Elemo et al. (2011) for iron (9.2 mg/g) while the results of other samples were lower. Iron is a vital component of red blood cells which carry oxygen and make the body more resistant to infections. Iron deficiency causes anaemia, tiredness, headache, insomnia and heart palpitations. Deficiency in children can cause stunted growth and impaired mental capability. All the values of zinc observed were within the permitted levels in humans. These results are in line with the results of Elemo et al. (2011) obtained for zinc (3.8 mg/100 g), except for sample D which had higher zinc value. Zinc is an essential mineral that stimulates the activity of enzymes in the body and supports healthy immune system when in traces but have emetic reaction when ingested in higher amounts (Egan et al., 1981). The results of magnesium showed that all the values fall below results reported by Elemo et al. (2011) magnesium (280.2 mg/100 g).

Magnesium helps the body to maintain and repair cells and also provide energy. Deficiency can result in weakness, tiredness, nervousness, cramps and heart palpitation. The result of phosphorus showed that the values for samples F and A were higher than those reported by Elemo et al. (2011) (170.0 mg/100 g) while the results of other samples were similar with the results of Elemo et al. (2011) except for sample B which falls below with value of 141.29 mg/100 g).

Phosphorus provides energy and help build the structure of bone and teeth. Deficiency can lead to loss of appetite, weakness, bone pain and mental confusion. However, phosphorus deficiency is rare since it is present in many foods (Gernah and Sengev, 2011). The results of sodium showed that all the values for sodium were low compared to the results of Elemo et al. (2011) (29.0 mg/100 g). This is desirable as diet with high sodium increases the blood pressure. The results of potassium were lower compared to that obtained by Gernah and Sengev (2011) values (160.80 ml/100 g) as boiling decreases potassium content. Potassium helps the body to maintain normal water balance in cells, transmit nerve impulses, keep acids and alkalis in balance and stimulate normal movement of the intestinal tract (Gernah and Sengev, 2011). Deficiency can cause vomiting, acute muscle weakness and loss of appetite.

The results of effect of dehulling and fermentation on wettability showed that mesquite seed flour samples took varying time to be absorbed by the samples. This could be

as a result of water being absorbed by the different flour samples due to their varying particle sizes. The smallest particle sizes with larger surface areas have more affinity to absorb moisture readily and couple with the crude fibre inherent in the samples which exert more influence on the ability of the non-dehulled flour to absorb more water at the shortest possible times. This is in line with the result of Ihekonronye and Ngoddy (1985) who reported that wettability (time-taken) for flour depends largely on particle sizes. The results of effect of dehulling and fermentation of mesquite seed flours on water absorption capacity showed that dehulled sample flours had the highest water absorption capacity while non-dehulled sample flours had the least. These different amounts of water absorbed by each sample is evidence to the fact that water absorption capacity varies with level of protein and carbohydrate and this suggest that dehulled flours are more hydrophilic (absorb more) water than non dehulled flours due to high protein and carbohydrate content (Ikegwu et al., 2011).

The results of effect of dehulling and fermentation on oil absorption capacity of mesquite seeds flour showed that, there is an indication that sample F had higher emulsifying potential of absorbing oil during processing which is followed by the other samples. The difference in the values obtained from each sample may also be as a result of differences in the levels of protein and fat contents which can entrap more oil. Basically, the mechanism of oil absorption capacity is mainly due to the physical entrapment of oil by capillary attrition. However, the hydrophobicity of proteins also plays a major role in oil absorption (Abdoulaye et al., 2014).

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