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EFFECT OF PROCESSING ON THE PROXIMATE COMPOSITION OF SUNFLOWER (*Helianthus annuus*) SEEDS

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ABSTRACT

Over-exploitation of conventional protein-rich plant resources such as soybean and groundnut for human and livestock consumption has necessitated a search for other suitable and under-utilized alternatives such as sunflower (Helianthus annuus) seeds. This study was undertaken to investigate the effect of processing on the proximate composition of sunflower seeds. The processing methods employed were boiling, roasting, solvent extraction and mechanical extraction. There was a substantial recovery of crude protein after processing from 27.02% (in the raw undehulled sunflower seed sample) to values ranging from 32.21% to 45.31% in the dehulled and differently processed samples. Crude lipid ranged from 6.45 to 21.60%, nitrogen-free extract from 11.32 to 19.52%, moisture content from 6.44to 10.29%, crude fibre from 14.19 to 26.35% and ash content from 4.61 to 5.46%. Values of the above proximate parameters were observed to be statistically different ($p < 0.05$) between the raw and differently processed sunflower seed samples. The results showed that the processing methods employed had improved the nutritional value of sunflower seed. Therefore, in view of its considerably high crude protein content, the study recommends sunflower seed meal as a viable alternative to expensive and over-utilized soybean meal and groundnut cake in feed formulation for fish and livestock.

Key words: sunflower seeds, processing methods, chemical composition, nutritional potential

INTRODUCTION

Increasing demand for feedstuffs between humans and animals has often subjected fish and livestock farmers in most developing countries to grapple with the challenges of inadequate and expensive feedstuffs (Duruma *et al*., 2006; Obun *et al*., 2016). Thus, farmers cannot sufficiently supply the dietary requirements of their livestock and so reduce their operating capacity (Duwa *et al*., 2012). This trend has resulted in a shortage of animal protein production and high cost of animal products. It therefore becomes vitally important to search for and exploit alternative under-utilized feed ingredients that are locally available, cheap and less competed for by humans and animals. Sunflower (*Helianthus annuus* Linnaeus) is a member of the family Compositae, a large and successful family of flowering plants occurring throughout the world. It is one of the major annual crops of the world cultivated for edible oil. It has a nutritional quality comparable to most other oilseed proteins including soybean and other conventional legumes (Sintayehu *et al*., 1996) and its potential as a dietary protein source in animal feeds is well recognized (Olvera-Novoa *et al*., 2002). Studies into the use of sunflower seed meal in the feeds of livestock, poultry birds and some other monogastric animals (including fish) are not as extensive as for soybean meal and groundnut. Sunflower is an important oil-seed crop which can be successfully grown in arid and semi-arid regions of the world (Iqbal *et al*., 2001). The protein-rich cake remaining after oil extraction is used as a livestock feed ingredient. Sunflower seed cake has proved to be a good quality feed for dairy animals and particularly for poultry (Khan *et al*., 1999).Therefore, this study was undertaken to determine the effect of processing on the proximate composition of sunflower (*Helianthus annuus*) seeds.

MATERIALS AND METHODS

Collection of Sunflower Seeds

Five (5) kilograms of raw sunflower seeds used in the study were collected from the sunflower plots of the Teaching and Research Farm of the University of Ibadan and transported in polyethylene sacks to the research laboratory of the Department of Aquaculture and Fisheries Management, University of Ibadan, Ibadan, Nigeria. A sample of the seeds was identified and authenticated at the Herbarium of Botany

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Department. The seeds were immediately spread on wide polyethylene sheets to ensure uniform solar drying and moisture content for two weeks. During drying, remnants such as flower stalks, receptacles and fragments of stems and leaves were completely manually removed. The seeds were then packaged and stored in air-tight plastic containers prior to processing.

Processing of Raw Sunflower Seeds into Different Meal Samples

Raw sunflower seeds were divided into six (6) portions of which four (4) were subjected to boiling, roasting, mechanical and solvent extraction to determine their proximate composition.

Preparation of Raw Undehulled Sunflower Seed Meal (RUSSM)

One hundred (100) grams of undehulled sunflower seeds was ground in a Thomas Wiley grinder. The resultant ground mash was then oven-dried at 60^0C for 6 hours in a Gallenkampoven (Gallenkamp, UK) prior to proximate analysis. The milled sample was packaged in an air-tight plastic container pending proximate analysis.

Preparation of Raw Dehulled Sunflower Seed Meal (RDSSM)

One hundred (100) grams of dehulled sunflower seeds was put in a strong polythene sack tied with a rope and threshed manually with a wooden rod to remove the kernels from the seed coat. The kernels obtained were milled, oven-dried at 60^0C for 6 hours and packaged in an air-tight plastic container pending proximate analysis.

Preparation of boiled sunflower seed meal (BSSM)

One hundred (100) grams of dehulled sunflower seeds was put inside a metal cooking pot containing three liters of water, covered and placed over the Bunsen burner flame at 100^0C for 15 minutes (Olukunle, 1996). The sample was collected, sieved to remove water and transferred into an aluminum tray to cool down. The boiled sample was ground, oven-dried at 60^0C for 6 hours and packaged in an air-tight plastic container pending proximate analysis.

Preparation of roasted sunflower seed meal (RSSM)

One hundred (100) grams of dehulled sunflower seeds was put in a porcelain dish placed over a Gallenkamp electric cooker and roasted at 80^0C for 15 minutes (Akajiaku *et al*., 2014) until the seed coat turned dark brown and emitted a characteristic cooking aroma similar to that of roasted groundnuts. The roasted seeds were transferred into an aluminum tray, allowed to cool, milled and oven-dried at 60^0C for 6 hours. The milled sample was packaged in an air-tight plastic container pending proximate analysis.

Preparation of Mechanically Extracted Sunflower Seed Meal (MESSM)

One hundred (100) grams of dehulled sunflower seeds was oven-dried at 80^0C for 15 minutes and ground (Alegbeleye, 2005). The resultant ground paste was loaded into the receptacle of an improvised mechanical screw press and pressed for 24 hours. The extracted oil was collected in a compartment at the bottom of the screw press and stored away. The resultant cake was hand-crumbled, oven-dried at 60^0C for 6 hours and packaged in an air-tight plastic container pending proximate analysis.

Preparation of Solvent-Extracted Sunflower Seed Meal (SESSM)

One hundred (100) grams of dehulled sunflower seeds was dried in an electric oven at 80^0C for 15 minutes (Alegbeleye, 2005) and milled. The milled paste was de-oiled in a soxhlet apparatus containing petroleum spirit (boiling point range: 60-80^0C) for 12 hours. The resultant meal was then oven-dried at 60^0C for 6 hours and packaged in an air-tight plastic container pending proximate analysis.

Proximate Analysis of Raw and Differently Processed Sunflower Seed Meals

Crude protein, crude fibre, crude lipid (ether extract), ash, moisture and nitrogen-free extract (NFE) contents of the raw and differently processed sunflower seed meals were determined according to the recommended procedures of the Association of Official Analytical Chemists (AOAC, 2010).

Determination of crude protein (total nitrogen)

Crude protein content of the samples was determined by the micro-kjeldhal method. About 100 mg of each meal sample was weighed and transferred into a 30 mL digestion flask. This sample was mixed with 0.5 mL of 14% of $HgSO_4$ solution in 4N H_2SO_4 and a pinch of K_2SO_4 was added along with 2.5 mL of concentrated H_2SO_4. The sample was digested inside a fume cupboard for 45 minutes until the mixture turned colourless. After cooling the digested sample, it was diluted with a small quantity of ammonia-free distilled water and transferred to the distillation apparatus into which 10mL of NaOH-Na_2SO_3 solution was added. The digested sample was steam-distilled for five minutes and the liberated ammonia was collected into 25 ml of 4% boric acid solution. The liberated ammonia (which represented total nitrogen) was then titrated immediately against standard H_2SO_4 (1 mL of 0.1N H_2SO_4 acid, which was equivalent to 1.401 mg N). The total nitrogen

content was multiplied immediately with 6.25 to obtain total protein content.

Determination of Moisture Content
Moisture content of each processed sunflower seed meal sample was determined by weighing 5 g of the sample into a clean previously weighed porcelain crucible. The sample was dried to a constant weight at 100^0C for 24 hours in a Gallenkamp oven (Gallenkamp, UK). The moisture content was calculated by subtracting the final weight of the sample from the initial weight after cooling.

$$Moisture\ content\ (\%) = \frac{weight\ of\ fresh\ sample - weight\ of\ dried\ sample\ X\ 100}{weight\ of\ fresh\ sample}$$

Determination of Dry Matter Content
Dry matter content is a measure of the total solids present in the samples and was determined by oven-drying gravimetric method as described by AOAC (2010). It was calculated as follows: Dry matter content (%) - 100 - % moisture content.

Determination of Crude Lipid (Ether Extract)
Petroleum ether (extraction solvent medium) was continuously volatilized, condensed and passed through the sample to extract ether-soluble materials. At the completion of this process, ether was distilled and collected in another container while the remaining crude fat was dried, weighed and percentage oil was calculated. Crude lipid was determined by the continuous solvent extraction method in a soxlet extraction apparatus as described by AOAC (2010). Two (2) grams of each sample was taken in the thimble and extracted with petroleum ether for 16 hours. The miscella obtained was evaporated on hot water bath, dried at 105 ^{0}C for 30 min, cooled in a desiccator and weighed. Crude lipid content was then calculated as follows:

$$Crude\ lipid\ (\%) = \frac{Wc - Wb\ x\ 100}{Wa}$$

where W_a is weight of processed sunflower seed meal sample (in grams), W_b is weight of the empty cup (in grams), and W_c is weight of the cup and extracted oil (in grams).

Determination of Crude Fibre Content
Crude fibre was determined according to the procedure of AOAC (2010). Two (2) grams of each sample was extracted with 200 mL of 0.255N H_2SO_4 for 30 minutes, filtered through muslin cloth and washed with boiling water until it became acid-free. The residue was further extracted with 200 mL of 0.313N NaOH for 30minutes, filtered through muslin cloth and washed successively with 25 mL of hot 1.25% H_2SO_4, 50 mL of distilled water (thrice) and 25 mL of alcohol. The residue obtained was dried for 2 hours at 130^0C resulting in the formation of a white or grey ash, cooled in a dessicator and weighed. The percentage crude fibre content of the sample was calculated as follows:

$$Crude\ fibre\ content\ (\%) = \frac{W1 - W2\ x\ 100}{W1}$$

where: W_1 is initial weight of residue sample (in grams), and W_2 is final weight of residue sample (in grams).

Determination of Ash Content
Two (2) g of each dried sample of processed sun flower seed meal was ignited at 600^0C for 6 h to burn off all organic material. The resultant inorganic residue which did not burn or volatilize at that temperature constituted the ash content in the sample and was calculated as follows:

$$Ash\ content\ (\%) = \frac{(weight\ of\ crucible + ash) - (weight\ of\ empty\ crucible)x\ 100}{weight\ of\ sample}$$

Determination of Nitrogen-Free Extract (NFE)
The proportion of nitrogen-free extract (carbohydrate content) was determined by subtracting the sum of moisture, crude protein, crude fibre, crude lipid and ash (all expressed in percentages) from 100. NFE - 100 – (% moisture + % crude protein + % crude fibre + % crude lipid + % ash).

Statistical Analysis
The experimental design used in this study was completely randomized design (CRD) involving three replications in each treatment. All data obtained in this study were presented as mean ± standard deviation. Statistical comparisons were made among the values ofraw and differently processed seed samples. One-way ANOVA and Duncan's multiple range tests (Duncan, 1955) were used on SPSS statistical software (Version 17.0 for Windows; SPSS Inc., Chicago, USA) to detect the significant differences in the values of raw and differently processed seed samples. Differences were statistically significant at probability levels below 0.05 (that is, $p < 0.05$).

RESULTS AND DISCUSSION

Proximate Composition of Raw and Differently Processed Sunflower Seed Meals
The results of this study showed that different processing methods (boiling, roasting, mechanical and solvent extraction) affected the proximate composition of the variously processed sunflower seed meals as shown in Table 1.All the parameters measured were statistically ($p < 0.05$)different among the raw and differently processed meal samples.

Table 1: Proximate composition of raw and differently processed sunflower seed meals

Proximate components	RUSSM (%)	RDSSM (%)	SESSM (%)	RSSM (%)	MESSM (%)	BSSM (%)
Dry matter	89.71±0.51^{d}	90.56±0.15^{c}	91.56±0.08^{b}	93.55±0.08^{a}	91.22±0.09^{b}	91.54±0.47^{b}
Crude protein	27.02±0.20^{e}	33.82±0.23^{cd}	45.31±0.06^{a}	37.02±0.17^{bc}	40.80±1.00^{b}	32.21±0.13^{d}
Crude fibre	26.35±0.17^{a}	17.93±0.03^{d}	18.40±0.42^{d}	23.94±0.48^{b}	21.04±1.02^{c}	14.19±0.19^{e}
Crude lipid	12.40±0.53^{c}	20.84±0.02^{b}	6.45±0.06^{e}	12.41±0.01^{c}	10.50±0.03^{d}	21.60±0.01^{a}
Nitrogen-free extract	19.52±0.04^{a}	13.06±1.00^{d}	17.77±0.04^{b}	11.32±0.05^{e}	12.91±0.07^{d}	14.27±0.27^{c}
Moisture	10.29±0.23^{a}	9.44±0.02^{b}	8.44±0.02^{c}	6.45±0.23^{d}	8.78±0.07^{c}	8.46±0.23^{c}
Ash	5.46±0.03^{a}	5.20±0.04^{a}	4.96±0.38^{abc}	4.54±0.09^{c}	4.61±0.03^{bc}	5.10±0.03^{ab}

a,b,c,d,e: indicate that mean values with different superscripts along the same row are significantly ($p < 0.05$) different. RUSSM – Raw undehulled sunflower seed meal; RDSSM – Raw dehulled sunflower seed meal; SESSM – Solvent-extracted sunflower seed meal; RSSM – Roasted sunflower seed meal; MESSM – Mechanically extracted sunflower seed meal; BSSM – Boiled sunflower seed meal

Saulawa *et al*. (2014) reported similar results on baobab seeds. Dry matter content was highest (93.55%) in the roasted meal and least (89.71%) in the raw undehulled meal. The highest value in the roasted meal could be due to heat treatment from roasting which reduced the seeds' moisture content and this indicates that they can be stored for a long time and will be less prone to microbial attack during storage (Udo *et al*., 2016). Crude protein content was highest (45.31%) in the solvent-extracted meal and least (27.02%) in the raw undehulledmeal. These values are similar to 32.10-34.60% in kapok seed meal (Narahari and Asha, 2003), 30.60% in mucuna seed meal and 34.88% in groundnut meal (Olomu, 1995). Besides, the values are higher than those of *Tamarindus indica* seed nut (15.4%) reported by Heuze and Tran (2015), lima bean (21.50%), pigeon pea (23.15-25.31%) and *Canavalia plagiosperma* (24.21%) (Odoemelan and Ahamefule, 2006; Ukpabi, 2007). A criterion for a feedstuff to be regarded as a potential protein source is that its crude protein level must exceed 20% (Auta and Anwa, 2007).This implies that sunflower seed meal has potentials as a good source of protein for fish, livestock and poultry.

The high crude protein content of solvent-extracted meal could be linked with the concentration of all inorganic solvent-soluble components which probably occurred after the separation of the organic solvent-soluble portion of the sunflower seed meal (Hernandez *et al.,* 1995). The relatively lower value of crude protein content of the boiled sunflower seed meal sample agrees with the report of Giami and Ikpimi (1992) and could be associated with losses of soluble solids such as hydrolyzed carbohydrates and soluble lipids because of leaching during boiling. Thermal processing has been reported to adversely affect protein digestibility as observed in mustard oilseed (*Brassica campestris*) cake (Harborne,1989) and sunflower (*Helianthus annuus*) seed meal (Venktash and Prakash, 1993) that were subjected to toasting or dry-heating when fed to fish. Roasting (thermal treatment) has been reported to distort the chemical structure of protein in feed ingredients (Sethi and Kulkarni, 1993). These authors stressed that heating solubilizes and reduces nitrogenous compounds in legume seeds. Olukunle (1996) also observed a reduction in crude protein value from 10.96 g/100g inundehulled sesame (*Sesamum indicum*) seeds to 3.17 g/100g in boiled seeds and then concluded that prolonged cooking beyond 30 minutes at 121^{o}C did not improve protein quality of the meal but caused a decrease in the available lysine and cystine due to the interaction of these amino acids with carbohydrates. The period of boiling might have accounted for the low crude protein content recorded for the boiled meal sample in this study. Besides, Adejumo (2005) noted that boiling caused most significant losses in the protein content of the dietary maize varieties used in a related study while Kumar *et al*. (2012) reported that heating feed ingredients for prolonged periods at high temperatures reduces the availability of amino acids.

Crude fibre was highest (26.35%) in the raw undehulled sunflower seed meal, followed by 23.94% in the roasted meal and least (14.19%) in the boiled meal. Crude fibre refers to the residual indigestible matter or roughage remaining after acid and alkaline digestion (McDonald *et al*., 1998). The reduction in crude fibre might be due to dehulling and removal of some water–soluble oligosaccharides (raffinose families) and the indigestible carbohydrate during thermal processes (Gashaw, 2010). The present values are lower compared to 35.03% found in the raw seeds of *Piliostigma thonningii* (a legume shrub) reported by Jimoh and Oladiji (2005) but are higher than 6.41 - 9.07% in *Bauhinia monandra* seed meal (Balogun, 2011), 2.60% - 6.05% in *Piliostigma reticulatum* seed meal (Musa and Bichi, 2015) and 6.15-6.30% in *Tamarindus indica* seed nut (Akajiaku *et al*., 2014). These variations in crude fibre could be due to the influence of environmental factors on the seeds (Akajiaku *et al*., 2014), morphological differences in plant species, processing techniques or geographical locations. However, the observed values in this study were above the recommended maximum level of 8% crude fibre for fish diet (Dupree and Huner, 1984).

Crude lipid was highest (21.60%) in the boiled meal and least (6.45%) in the solvent-extractedmeal. These values are lower than 27.9% in *Piliostigma reticulum* seed meal reported by Akin-Osanaiye *et al*. (2009) but are higher when compared with 0.35% for raw *Tamarindus indica* seed meal (Nwanna *et al*., 2004) as well as other in species, processing techniques or geographical locations. The value recorded for the mechanically extracted meal could be traced to insufficient removal of oil by mechanical extraction, hence the cake contained an excess of 4.05% above that of the solvent-extracted meal. Alegbeleye (2005) also noted a similar trend when cottonseed meal was processed by solvent-extraction and mechanical extraction methods. The relatively lower value of lipid recorded for the roasted meal could be due to loss of lipid during roasting as reported by Alegbeleye (2005).

High level of crude lipid has been reported to provide enough calories when incorporated into livestock feed (Samuel *et al*., 1997).Feedstuffs containing high lipid content are prone to oxidative rancidity because of long time storage (Effiong and Eyo, 1997). Rancid fats reduce palatability and therefore reduce availability of nutrients to fish (Rumseey, 1980) and can contain harmful and growth-retarding compounds. Haruna (1997) observed that 8-10% lipid content in formulated diets produced highest growth in *Clarias gariepinus*. Nitrogen-free extract (NFE) was highest (19.52%) in the raw undehulledmeal and least (11.32 %) in the roasted meal. The high NFE values suggest that sunflower seeds could also serve as an alternative energy source in fish feeds. However, these values are lower than values obtained for conventional protein sources such as soybean meal (28.60%) and groundnut cake (23.84%) (Olomu, 1995) as well as 65.26% in raw grass pea (Gashaw, 2010), 58.08% in roasted *Tamarindus indica* seed nut (Akajiaku *et al*., 2014), 25.0% in *Piliostigma reticulatum* (Akin-Osanaiye *et al*., 2009) and 23.0% in *Piliostigma thonningii* (Jimoh and Oladiji, 2005). The reduction of NFE in the boiled meal might be due to leaching of soluble carbohydrates like sugars into the boiling water (Esenwah and Ikenebomeh, 2008; Gashaw, 2010). Moisture content was highest (10.29%) in the raw undehulled meal and least (6.45%) in the roasted meal. These values are higher compared to 2.70% in *Piliostigma reticulatum* (Akin-Osanaiye *et al*., 2009). Variations in moisture could be due to processing techniques used. Heat treatments (roasting and boiling) were observed to reduce the moisture content of the meal samples in this study and this corroborates that of Anwa *et al*. (2007) using *Albizzia lebbeck* seeds. The recorded values of moisture content in the raw and processed samples were generally low and fell below 15% moisture content recommended as safe storage alternative protein sources such as 4.52% in *Mucuna cochinchinensis* seed meal (Ukachukwu and Obioha, 2000), 2.94% in sword bean meal (Akinmutimi, 2005), 2.33% in pigeon pea meal (Ahamefule, 2005) and 1.42% in the raw seeds of *Piliostigma thonningii* (Jimoh and Oladiji, 2005). These variations might be due to differences limit for plant feedstuffs (Sena *et al*., 1998). The low moisture content of sunflower seeds offers an advantage in terms of their keeping quality which indicates that they can be stored for a long period of time without becoming moldy or deteriorating in their quality (Abubakar, 2007).

Ash content was highest (5.46%) in the raw undehulled meal, followed by 5.20%in the raw dehulledmeal, 5.10% in the boiled meal and lowest (4.54%) in the roasted seed meal. These values closely agree with 4.0% in *Piliostigma reticulatum* (Akin-Osanaiye *et al*., 2009) but arehigher comparedto 1.17 to 1.73% in *Tamarindus indica* seed nut (Bashir *et al*., 2016). The variations might be due to differences in the processing techniques and geographical locations. Low ash content observed in the roasted meal was probably due to losses of some nutrients during roasting (thermal treatment) as reported by Giami and Ikpimi (1992).

CONCLUSION

The results of this study showed that sunflower seeds have a good nutritional profile with appreciable quantities of protein, lipid and nitrogen-free extract/carbohydrate and can serve as an alternative protein supplement for conventional legumes in feed formulations intended for fish and livestock. The different processing methods used (boiling, roasting, mechanical and solvent extraction) significantly increased the crude protein contents of the variously processed sunflower seed samples. Thus, the study emphasizes the need for processing feed ingredients intended for animal feed formulations to maximize their utilization and thereby increase profitability.

RECOMMENDATION

In view of the results of this study, it is therefore recommended that further non-conventional processing methods be explored to broaden the scope of utilization of sunflower seeds as a feed ingredient in the diets of cultured animals.

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REFERENCES

Abubakar A.S. (2007). Biochemical analysis of four legumes in Zaria. MSc. Thesis, Post Graduate School, AhmaduBello University, Zaria,p. 69

Adejumo C.O. (2005). Utilisation of Millet, *Pennisetum americanum* (L.), in the Nutrition of *Clarias gariepinus* (Burchell, 1822). Ph.D Thesis. University of Ibadan, Ibadan, Nigeria. 131 pp.

Ahamefule F.O. (2005). Evaluation of Pigeon Pea-Cassava Peel Based Diets for Goat Production in South-eastern Nigeria. PhD Thesis, College of Animal Science and Animal Production, MOUAU, Umudike, Nigeria, pp. 45-78

Akajiaku L.O., Nwosu J.N., Onuegbu N.C., Njoku N.E. and Egbeneke C.O. (2014). Proximate, mineral and anti-nutrient composition of processed (soaked and roasted) Tamarind (*Tamarindus indica*) seed nut.*Current Research in Nutritionand Food Science Journal*, **2 (3),** 136-145

Akinmutimi A.H. (2005). Evaluation of Sword Bean (*Canavalia gladiata*) as an Alternative Feed Resource for Broiler Chickens. PhD Dissertation, Michael Okpara University of Agriculture, Umudike, Nigeria. 137 pp.

Akin-Osanaiye B.C., Agbaji A.S. and Abdulkadir O.M. (2009). Proximate composition and the functional properties of defatted seeds and protein isolates of kargo (*Piliostigma reticulatum*) seeds. *African Journal of Food, Agriculture, Nutrition and Development*, **9 (6)**, 1365-1377

Alegbeleye W.A.O. (2005). Growth Performance and Hematological Profiles of *Oreochromisniloticus* (Trewavas, 1983) Fingerlings Fed Differently Processed Cottonseed (*Gossypium hirsutum* Linn., 1735) Meal. Ph.D Thesis. Department of Zoology.University of Ibadan, Ibadan. pp. 213.

Anwa E.P., Auta J., Abdullahi S.A. and Bolorunduro P.I.(2007). Effects of processing on the seeds of *Albezia lebbeck*: proximate analysis and phytochemicalscreening. *Research Journal of Biological Sciences*, **2(1)**, 41-44.

AOAC. (2010). Official Methods of Analysis (19th ed.). Association of Official Analytical Chemists. Washington DC.

Auta J. and Anwa E.P. (2007). Preliminary studies on *Albizzia lebbeck* seeds: proximate analysis and phytochemical screening. *Research Journal of Biological Sciences*, **2 (1)**, 33-35.

Balogun B.I. (2011). Growth Performance and Feed Utilization of *Clarias gariepinus* (Teugels) fed different dietary levels of soaked *Bauhinia monandra* (Linn.) Seed Meal and Sun-Dried Locust Bean (*Schistocerca gregaria*) Meal. PhD Thesis, Postgraduate School, Ahmadu Bello University, Zaria. 184 pp.

Bashir A.Y., Abdullahi S.A. and Suleiman B. (2016). Effect of roasting on the proximate, mineral and anti-nutrient composition of *Tamarindus indica* seed nuts. *FUW Trends in Science and Technology Journal*, **1 (2)**, 493-496

Duncan D.E. (1955). Multiple Range and Multiple F-tests. *Biometrics*, **11**, 1-42

Dupree H.K. and Hunner J.V. (1984). Nutrition and feeding practice. *The Third Report to the Fish Farmers.* U.S. Dept. of Interior. Fish and Wildlife Services, Washington D.C. pp.141-157

Duruma C.A., Udedibie A.B.I., Etuk E.B. (2006). Performance and organ characteristics of broiler finisher chickens fed graded levels of *Anthonotha macrophylla* seed meal as replacement for *Arachis hypogea* meal. In: Proceedings of the 11th Annual Conference of Animal Science Association of Nigeria (ASAN), 18–21 September, held at the Institute of Agricultural Research & Training, Ibadan, pp. 346-356

Duwa H., Oyawoye E.O. and Njidda A.A. (2012). Effect of processing methods on the utilization of sorrel seed meal by broilers. *Pakistan Journal of Nutrition*, **11 (1),** 38-46

Effiong B.N. and Eyo A.A. (1997). Control of mold infestation in stored pelleted feeds. NIFFR Annual Report, pp. 128-134

Esenwah C.N. and Ikenebomeh M.J. (2008). Processing effects on the nutritional and anti-nutritional contents of African locust bean (*Parkia biglobosa* Benth) seeds. *Pakistan Journal of Nutrition*, **7 (2)**, 214-217

Gashaw G. (2010). Effects of Traditional Food Processing Methods On Nutrient Compositions and Anti-Nutritional Factors of Grass Pea (*Lathyrus sativus* L) Foods Consumed in Ethiopia. Published M.Sc. Thesis, Graduate Studies Program, Addis Ababa University, Ethiopia. 69 pp.

Giami S.Y. and Ikpimi I. (1992).The effects of soaking and cooking of winged bean (*Psophocarpus tetragonolobus* LDC). *Nigerian Journal of Nutrition Science*, **13**, 45-49.

Harborne J.B. (1989). Biosynthesis and function of anti-nutritional factors in plants.*Aspects of Applied Biology*, **19**, 21-28

Haruna A.B. (1997). Studies on the Utilization of Agro- and Agro-allied Wastes in the Nutrition of the African Catfish, *Clarias gariepinus* (Burchell, 1822). Ph.D Thesis, Bayero University, Kano.187 pp.

Hernandez T., Centeno C., Martinez C. and Hernandez A. (1995). Effect of solvent extraction on the nitrogen compounds in *Alfalfa* protein concentrates. *Journal of Agriculture and Food Chemistry*, **43**, 3065-3069

Heuzé V. and Tran G. (2015). Tamarind *(Tamarindus indica)*. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/249. Last updated on October 12, 2015, 11:48. Visited on 05/06/2016.

Iqbal J., Qasim M. and Himayatullah A. (2001). Physiological development of sunflower as affected by increasing levels of nitrogen. *On-line Journal of Biological Sciences*, **1 (4),** 238-239

Jimoh F.O. and Oladiji A.T. (2005). Preliminary studies on *Piliostigmathonningii*seeds: proximate analysis, mineral composition and phytochemical screening. *African Journal of Biotechnology*, **4 (12),** 1439-1442.

Khan M.A., Ahmad K. and Ahmad J. (1999). Effect of potassium levels on the yield of sunflower (*Helianthus annuus* L.). *Pakistan Journal of Biological Science*, **2 (2),** 402-403.

Kumar V., Barman D., Kumar K., Kumar V., Mandal S.C. and Clercq E.D. (2012). Anti-nutritional factors in plant feedstuffs used in aqua feeds. *World Aquaculture*, 64-68.

McDonald P., Edwards R.A. and Greenhalgh J.F. D. (1998). *Animal Nutrition*. 5th Ed., Longman, Singapore, pp. 423-441

Musa H. and Bichi A.H. (2015). Effect of different heat processing methods on the proximate composition of *Piliostegma reticulatum* seed meal. *Bayero Journal of Pure and Applied Sciences*, **8 (1),** 115 – 122.

Narahari D. and Asha R.R. (2003). Chemical composition and nutritive value of kapok seed meal for broiler chickens. *British Poultry Science*, **44**, 505-509

Nwanna L., Fagbenro O. and Olanipekun S. (2004). Evaluation of tamarind (*Tamarindus indica*) seed meal as a dietary carbohydrate for the production of Nile tilapia, *Oreoochromis niloticus* L. *Animal Research International*, **1 (3),** 164-168

Obun C.O. Lalabe B.C., Wafar R.J. Olusiyi J.A., and Ojinnaka E.P. (2016). Effects of feeding broiler chicks differently processed tallow (*Detarium microcarpum*, Guill and Sperr) seed meal on performance and blood constituents. In: F.O. Ajayi, L.A.F. Akinola, B.O. Agaviezor and O.S George (eds.), In Proceedings of 21st Annual Conference of Animal Science Association of Nigeria (ASAN), 18–22 October, 2016, Port Harcourt, pp. 845-849

Odoemelam V.U. and Ahamefule F.O. (2006). Effect of de-hulling on proximate composition, anti-nutritional properties and mineral content of *Canavalia plagiosperma*. *Tropical Journal of Animal Production,* **31 (2),** 167-175

Olomu J.M. (1995). Monogastricanimal Nutrition: Principles and Practice. 1st edn.AJachem publication, Benin City, Nigeria, 157 pp.

Olukunle O.A. (1996). Nutritional Potentials of Processed *Sesame indicum* in the Diets of *Clarias gariepinus* (Burchell, 1822) PhD. Thesis. University of Ibadan, Nigeria.172 pp.

Olvera-Novoa M.A., Olivera-Castillo L. and Martinez-Palacios C.A. (2002). Sunflower seed meal as protein source in diets for *Tilapia rendalli* fingerlings. *Aquaculture Research*, **33 (3),** 223-230

Rumseey G.L. (1980). Stability of micro-nutrients infish feed. In: *Fish Feed Technology* (Washington), Chapter 14, pp. 225-229

Samuel A.L., Temple V.J. and Ladeji O. (1997). Chemical and nutritional evaluation of the seed kernel of *Balanitesaegyptiaca*.*Nigerian Journal of Biotechnology*, **18 (1),** 57-63

Saulawa L.A., Yaraduwa A.I. and Shuaibu L. (2014). Effect of different processing methods on proximate, mineral and anti-nutritional factor contents of baobab (*Adansonia digitata*) seeds. *Pakistan Journal of Nutrition*, **13 (6),** 314-318

Sena L.P., Vanderjagt D.J., Rivera C., Tsin A.T., Mahammadu O., Millson M., Pastuszyn A. and Glew R.H. (1998). *Plant Food for Human Nutrition*, **52 (1),** 17-30

Sethi P. and Kulkarni P.R. (1993). In vitroprotein digestibility of *Leucaena leucocephala* seed kernels and protein isolates. *Food Chemistry*, **46**, 159-162

Sintayehu A. Matheis E., Meyer-Burgdorff K.H., Rosenad H. and Gunther K.D. (1996). Apparent digestibilities and growth experiments with tilapia (*Oreochromis niloticus*) fed soybean seed, cotton seed and sunflower seed meals. *Journal of Applied Ichthyology*, **12**, 125-130

Udo M.D., Ekpo U. and Ahamefule F.O. (2016). Effects of processing on the nutrient composition of rubber seed meal. *Journal of the Saudi Society of Agricultural Sciences*, **17 (3),** 234-267

Ukachukwu S.N. and Obioha F.C. (2000). Effect of time duration ofthermal treatments on the nutritive value of *Mucuna cochinchinensis*. *Global Journal of Pure and Applied Sciences*, **6 (1),** 11-15

Ukpabi U.H. (2007). Evaluation of Mucunaseed Meal-Based Diets for Goat Production in South Nigeria. Ph.D. Thesis, Michael Okpara University of Agriculture, Umudike, Abia State. 210 pp.

Venktash A. and Prakash V. (1993). Sunflower seed total protein: effects of dry and wet heating. *Journal of Agriculture and Food Chemistry*, **41,** 1577-1582