Effects of Conventional Food Processing Methods on the Mineral and Anti-Nutrient Composition of Sunflower (*Helianthus annuus*) Seeds

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Abstract

*This study evaluated the effects of processing on the mineral and anti-nutrient components of sunflower (Helianthus annuus) seeds using boiling, roasting, solvent extraction and mechanical extraction. Mineral and anti-nutrient concentrations of differently processed meal samples were determined using standard analytical procedures and parameters were subjected to statistical analysis. Mineral content analysis revealed the following concentrations: Calcium (0.17 – 0.38 mg/g), Iron (0.25 – 0.52 μg/g), Sodium (0.10 – 0.25 mg/g), Potassium (1.87 – 2.12 mg/g), Phosphorus (1.57 – 1.72 mg/g), Magnesium (0.13 - 0.37 mg/g), Manganese (0.13 – 0.15 mg/kg), Copper (0.01 – 0.04 mg/kg) and Zinc (0.09 – 0.14 mg/kg)**.** These values were statistically different (p<0.05) except for sodium and manganese. Phytochemical screening of the meal samples revealed the presence of some bioactive compounds including tannin, oxalate and phytate and their observed values were statistically different (p<0.05) except for oxalate and phytate. Tannin was highest in the raw undehulled meal (0.45 mg/g) and least (0.21 mg/g) in the boiled meal. Oxalate content was least (0.11 mg/g) in the roasted and boiled meals and highest (0.15mg/g) in the raw dehulled meal. Phytate content was highest (0.16 mg/g) in the raw undehulled meal and least (0.10mg/g) in the boiled meal. Boiled sunflower seed meal had statistically (p<0.05) lower values of anti-nutrients, higher percentage reductions in the levels of these anti-nutrients and appreciable amounts of macro- and micro-minerals. Therefore, in view of its considerably lower values of anti-nutrients, higher percentage reductions of anti-nutrients and appreciable amounts of minerals, the study recommends boiled sunflower seed meal as a viable alternative to soybean meal and groundnut cake in feed formulations for fish and livestock.*

Key words: Sunflower seed, processing techniques, phytochemical screening, mineral content, anti-nutrients.

Effets des Méthodes Conventionnelles de Transformation des Aliments sur la Composition en Minéraux et en Éléments Antinutritionnels des Graines de Tournesol (*Helianthus annuus*)

Résumé

Cette étude a évalué les effets de transfomation sur les composants minéraux et antinutritionnels des graines de tournesol (Helianthus annuus) par ébullition, rôtissage, extraction au solvant et extraction mécanique. Les concentrations en minéraux et en anti-nutriments dans des échantillons de tourteaux transformés différemment ont été déterminées à l'aide de procédures analytiques standard et les paramètres ont été soumis à une analyse statistique. L'analyse de la *teneur en minéraux a révélé les concentrations suivantes: calcium (0,17 à 0,38 mg/g), fer (0,25 à 0,52 µg/g), sodium (0,10 à 0,25 mg/g), potassium (1,87 à 2,12 mg/g), phosphore (1,57 - 1,72 mg/g), magnésium (0,13 - 0,37 mg/g), manganèse (0,13 - 0,15 mg/kg), cuivre (0,01 - 0,04 mg/kg) et zinc (0,09 - 0,14 mg/kg). Ces valeurs étaient statistiquement différentes (p <0,05) sauf pour le sodium et le manganèse. Le dépistage phytochimique des échantillons de repas a révélé la présence de certains composés bioactifs, notamment le tanin, l'oxalate et le phytate, et leurs valeurs observées étaient statistiquement différentes (p <0,05), à l'exception de l'oxalate et du phytate. Le tanin était le plus élevé dans la farine crue sans décortiquer (0,45 mg/g) et le plus faible (0,21 mg/g) dans la farine bouillie. La teneur en oxalate était la plus faible (0,11 mg / g) dans les plats torréfiés et bouillis et la plus élevée (0,15 mg / g) dans les repas crus décortiqués. La teneur en phytates était la plus élevée (0,16 mg/g) dans la farine crue sans décortiqué et la plus faible (0,10 mg/g) dans la farine bouillie. La farine de graine de tournesol bouillie présentait des valeurs antinutritionnelles plus faibles statistiquement (p <0,05), des pourcentages de réduction plus élevés des niveaux de ces antinutritionnels et des quantités appréciables de macro et micro-minéraux. Par conséquent, compte tenu de ses valeurs considérablement plus faibles en anti-nutriments, de son pourcentage de réduction des anti-nutriments et de ses quantités appréciables de minéraux, l'étude recommande que la farine de graine de tournesol bouillie soit une alternative viable au tourteau de soja et au tourteau d'arachide dans les formulations des aliments du poisson et du bétail.*

Mots clés: Graine de tournesol, techniques de transformation, dépistage phytochimique, teneur en minéraux, anti-nutriments

Introduction

Rapidly growing competition between humans and livestock (including fish) due to their excessive dependence on conventional plant-based feed resources such as soybean, groundnut and maize has necessitated a research into other suitable and under-utilized alternatives such as sunflower (*Helianthus annuus*) seeds. Most of such non-conventional ingredients possess high potentials as viable and economic sources of feedstuff for fish feed manufacture (Madu *et al*., 2003) as they contain appreciable levels of utilizable nutrients (Okoli *et al*., 2003). They are locally available, cheap and are not competed for with human beings, hence their optimum utilization may seem more economically viable and sustainable. Sunflower (*Helianthus annuus* Linnaeus) is a member of the family Compositae, a large family of flowering plants occurring throughout the world. It is an important oil-seed crop which can be successfully grown in arid and semi-arid regions of the world (Iqbal *et al*., 2001). Its protein quality is comparable to 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). Research on the use of sunflower seed meal in the feeds of livestock, poultry birds and other monogastric animals (including fish) is not as extensive as that of soybean meal and groundnut cake. The protein-rich cake remaining after oil extraction is used as a livestock feed ingredient and has proved to be a high quality feed for dairy animals and particularly for poultry (Khan *et al*., 1999). Sunflower seeds also contain dietary fibre, some amino acids, vitamin E, vitamin B1 or thiamine, vitamin B5 or pantothenic acid and folate, minerals such as phosphorus, calcium, potassium, magnesium, zinc, iron, manganese, selenium and copper and are rich in cholesterol-lowering phytosterols (Science Daily, 2005).

However, sunflower seeds reportedly contain some anti-nutrients such as protease inhibitors, arginase inhibitors and polyphenolic tannin chlorogenic acid (Tacon *et al.*, 1984). Anti-nutrients in most legumes prevent protein digestion (Abu *et al*., 2005). Virtually all plant-based feed ingredients contain growth-inhibiting components which, in most cases, engulf the protein molecules thereby preventing the digestive enzymes from acting on them. This results in the egestion of most of the protein molecules with the faeces undigested, hence rendering them unavailable for growth and other physiological purposes (Eyo, 2003). The anti-nutrients should be eliminated or reduced to an insignificant level by special processing techniques in order to ensure maximum nutritional value from such feed ingredients. This study therefore focused on evaluating the effects of different processing techniques on the elemental mineral composition and anti-nutrient components of sunflower (*Helianthus annuus*) seeds.

Materials and methods

Sourcing and collection of sunflower seeds

Three kilograms (3 kg) 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 polythene sacks to the research laboratory of the Department of Aquaculture and Fisheries Management, University of Ibadan, Ibadan, Nigeria. A sample of the seeds was taken to the Herbarium of Botany Department for identification and authentication. The seeds were immediately spread on wide polythene sheets for two weeks to ensure uniform sun-drying and moisture content. During drying, remnants such as flower stalks, receptacles and fragments of stems and leaves were completely 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 portions of which four were subjected to boiling, roasting, mechanical and solvent extraction before determining some of their mineral nutrients and anti-nutritional components.

Preparation of raw undehulled sunflower seed meal (RUSSM)

One hundred grams (100 g) of undehulled sunflower seeds were ground in a Thomas Wiley grinder (Thomas Wiley Scientific Mill, Model 4 GMI, Greater Minneapolis/St. Paul Area, USA). The resultant ground mash was then oven-dried at 60^{o}C for 6 hours in a Gallenkamp oven (Gallenkamp OVL 570-010J vacuum oven, Akribis Scientific Limited, UK) prior to proximate analysis. The dried sample was packaged in an air-tight plastic container pending chemical analysis.

Preparation of raw dehulled sunflower seed meal (RDSSM)

One hundred grams (100 g) of dehulled sunflower seeds were 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^{o}C for 6 hours and packaged in an air-tight plastic container pending chemical analysis.

Preparation of boiled sunflower seed meal (BSSM)

One hundred grams (100 g) of dehulled sunflower seeds were put inside a metal cooking pot containing three litres (3 L) of water, covered and placed over the Bunsen burner flame at 100^{o}C 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^{o}C for 6 hours and packaged in an air-tight plastic container pending chemical analysis.

Preparation of roasted sunflower seed meal (RSSM)

One hundred grams (100 g) of dehulled sunflower seeds were put in a porcelain dish placed over a Gallenkamp electric cooker (Gallenkamp 300 Plus Electric Cooker Series, Balerno, Edinburgh, UK) and roasted while stirring for about six (6) 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°C for 6 hours. The milled sample was packaged in an air-tight plastic container pending chemical analysis.

Preparation of mechanically extracted sunflower seed meal (MESSM)

One hundred grams (100 g) of dehulled sunflower seeds were oven-dried at 80°C 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°C for 6 hours and packaged in an air-tight plastic container pending chemical analysis.

Preparation of solvent-extracted sunflower seed meal (SESSM)

One hundred grams (100 g) of dehulled sunflower seeds were dried in an electric oven at 80°C 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°C) for 12 hours. The resultant meal was then oven-dried at 60°C for 6 hours and packaged in an air-tight plastic container pending chemical analysis.

Determination of mineral contents of raw and processed sunflower seeds

The dry ash obtained by dry ashing procedure was used to determine the amounts of calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), manganese (Mn), phosphorus (P), iron (Fe), copper (Cu) and zinc (Zn). The ash after cooling was digested with 100 ml 0.5M HCl on a hot plate until the volume reduced to about 10–15 ml. The digested ash was then filtered through filter paper (Whatman No. 1) and the volume of the filtrate was made up to 100 ml mark with distilled water. The filtrate was transferred into a polythene bottle for analysis using multi-parameter Bench Photometer (Multi-Parameter Bench Photometer Model HI-83200, Chelmsford Essex, UK).

Determination of anti-nutritional factors in raw and processed sunflower seeds

Anti-nutrients in raw and processed sunflower seeds

Tannin, oxalate and phytate contents were determined using the recommended methods of Association of Official Analytical Chemists (AOAC, 2005).

Extraction of tannin

About 100 mg of each seed meal sample were mixed with 5 ml of 2.5 N HCl on boiling water bath for 2 hours and cooled to room temperature. The mixture was neutralized with solid sodium carbonate. The volume of each mixture was made up to 100 ml mark with distilled water and then centrifuged.

Determination of tannin

Tannin content of each sample was quantitatively estimated using the modified vanillin-HCl in methanol method. A standard curve was plotted expressing the results as catechin equivalents, that is, amount of catechin (in mg per ml) which gave a colour intensity equivalent to that given by tannin after correcting the blank.

Determination of oxalate

Two grams (2 g) of each sample were mixed with 75 ml of 5 N H_2SO_4. The solution was carefully stirred intermittently with a magnetic stirrer for 1hour and the extract (filtrate) was collected and titrated hot (80 - 90°C) against 0.1 N $KMnO_4$ solution until the point when a faint pink colour appeared which persisted for at least 30 seconds according to Day and Underwood (1986).

Determination of phytate

Phytate content was determined using the method of AOAC (2005). About 0.2 g of each seed meal sample was weighed into a 250 ml conical flask. Each sample was soaked in 100 ml of 2% concentrated HCl for 3 hours and the mixture filtered. About 500 ml of each filtrate were transferred into a 250 ml beaker and 100 ml distilled water added to it. About 10 ml of 0.3% NH_4SCN solution were added as indicator and titrated with standard $FeCl_3$ solution which contained 0.00195 g Fe per ml.

The percentage phytate (phytic acid) was calculated using the formula:

$$\textit{Phyticacid (\%)} = \frac{\textit{titre value} \times 0.00195 \times 1.19 \times 100}{2}$$

Statistical analysis of data

The data generated in this study were presented as mean ± standard deviation. Statistical comparisons were made among the values obtained for raw and 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 among the values of raw and processed seed samples. Differences were considered to be statistically significant at probability levels ($p < 0.05$).

Results and discussion

Mineral composition of raw and processed sunflower seed meal samples

The results of the study indicated elemental composition of sunflower seed as a rich

Table 1: Mineral composition of raw and processed sunflower seed meals

Mineral Components	RUSSM	RDSSM	SESSM	RSSM	MESSM	BSSM
Calcium (mg/g)	$0.33{\pm}0.01^{b}$	$0.27{\pm}0.02^{c}$	$0.22{\pm}0.01^{d}$	$0.22{\pm}0.01^{d}$	$0.17{\pm}0.02^{e}$	$0.38{\pm}0.02^{a}$
Iron (µg/g)	$0.43{\pm}0.02^{b}$	$0.52{\pm}0.02^{a}$	$0.26{\pm}0.02^{de}$	$0.25{\pm}0.03^{e}$	$0.29{\pm}0.02^{d}$	$0.35{\pm}0.01^{c}$
Sodium (mg/g)	$0.23{\pm}0.01^{a}$	$0.17{\pm}0.02^{a}$	$0.15{\pm}0.01^{a}$	$0.10{\pm}0.01^{a}$	$0.25{\pm}0.21^{a}$	$0.19{\pm}0.02^{a}$
Potassium (mg/g)	$2.12{\pm}0.03^{a}$	$2.03{\pm}0.02^{b}$	$1.95{\pm}0.02^{c}$	$1.87{\pm}0.02^{d}$	$2.01{\pm}0.01^{b}$	$1.96{\pm}0.02^{c}$
Phosphorus (mg/g)	$1.68{\pm}0.02^{b}$	$1.72{\pm}0.02^{a}$	$1.63{\pm}0.02^{c}$	$1.66{\pm}0.02^{bc}$	$1.57{\pm}0.02^{d}$	$1.69{\pm}0.03^{ab}$
Magnesium (mg/g)	$0.37{\pm}0.02^{a}$	$0.22{\pm}0.02^{b}$	$0.13{\pm}0.03^{d}$	$0.15{\pm}0.03^{cd}$	$0.17{\pm}0.01^{c}$	$0.24{\pm}0.02^{b}$
Manganese (mg/kg)	$0.15{\pm}0.02^{a}$	$0.13{\pm}0.02^{a}$	$0.13{\pm}0.01^{a}$	$00.13{\pm}0.03^{a}$	$0.15{\pm}0.02^{a}$	$0.14{\pm}0.01^{a}$
Copper (mg/kg)	$0.02{\pm}0.01^{ab}$	$0.04{\pm}0.01^{a}$	$0.01{\pm}0.01^{b}$	$0.03{\pm}0.01^{ab}$	$0.01{\pm}0.01^{b}$	$0.01{\pm}0.01^{b}$
Zinc (mg/kg)	$0.12{\pm}0.02^{abc}$	$0.09{\pm}0.02^{c}$	$0.14{\pm}0.02^{a}$	$0.13{\pm}0.02^{ab}$	$00.11{\pm}0.01^{bc}$	$0.12{\pm}0.01^{ab}$

Data are presented as mean ± standard deviation.

a,b,c,d,e: indicate that mean values with different superscripts along the same row are significantly different at $p < 0.05$.

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.

source of mineral nutrients and that different processing methods affected the mineral composition of the various processed sunflower seed meals as presented in Table 1. Values of mineral nutrients recorded for these meal samples were statistically different ($p<0.05$) except for sodium and manganese. Calcium content was highest in the boiled meal (0.38 mg/g) and least in the mechanically extracted meal (0.17 mg/g). These values are low in relation to 0.48 mg/g found in the seed meal of *Solanum indicum* shrub (Indian night shade) as reported by Maikidi *et al*. (2005), 0.92 to 1.21 mg/g in kapok (*Ceiba pentandra*) seed meal (Wafar *et al*., 2017), 2.82 mg/g reported by Luka *et al*. (2005) for the seed kernel meal of *Canarium schweinfurthii* (African olive tree) and 3.0 mg/g for raw *Tamarindus indica* seed (Heuze and Tran, 2015). Calcium combines with magnesium, chlorine and protein to facilitate bone formation (Abdullude, 2007). Calcium availability in the body depends on calcium-to-phosphorus ratio as well as presence of phytate and oxalate (Bentiff and Koster, 2006). Iron content was highest in the raw dehulled meal (0.52 µg/g) and least in the roasted meal (0.25 µg/g). However, these values are higher than 0.10 to 0.13 µg/g obtained in kapok seed meal (Wafar *et al*., 2017), 0.06µg/g in the seed kernel meal of *Canarium schweinfurthii* (Luka *et al*., 2005) and 0.02 µg/g found in the seeds of *Solanum indicum* shrub as reported by Maikidi *et al*. (2005).

Mechanically extracted meal had the highest sodium content (0.25 mg/g) while the roasted meal had the lowest (0.10 mg/g). These values closely agree with 0.23 mg/g in *Tamarindus indica* seed meal (Nwanna *et al*., 2004), are higher than 0.06 to 0.07 mg/g obtained in kapok seed meal (Wafar *et al*., 2017) but lower when compared with 1.23 mg/g found in the seeds of *Solanum indicum* shrub (Maikidi *et al*., 2005). Potassium content was highest in the raw undehulled meal (2.12 mg/g) and least in the solvent-extracted meal (1.95 mg/g). These values are higher than 0.99 to 1.21 mg/g obtained in kapok seed meal (Wafar *et al*., 2017) but fall below 6.30 mg/g reported by Luka *et al*. (2005) for *Canarium schweinfurthii* seed kernel meal and 13.09 mg/g found in the seeds of *Solanum indicum* shrub (Maikidi *et al*., 2005).

Raw dehulled meal had the highest phosphorus content (1.72 mg/g) while mechanically extracted meal had the least value (1.57 mg/g). These values are slightly

Table 2: Levels of anti-nutrients in raw and processed sunflower seed meals

Anti-Nutritional Components	RUSSM	RDSSM	SESSM	RSSM	MESSM	BSSM	Permissible Levels
Tannin (mg/g)	0.45±0.03[a]	0.34±0.04[b]	0.26±0.05[b]	0.24±0.03[c]	0.30±0.05[b]	0.21±0.05[c]	20.0 mg/g[A]
Oxalate (mg/g)	0.18±0.07[a]	0.15±0.05[a]	0.12±0.02[a]	0.11±0.02[a]	0.13±0.03[a]	0.11±0.01[a]	0.02 mg/g[B]
Phytate (mg/g)	0.16±0.04[a]	0.14±0.03[a]	0.13±0.03[a]	0.11±0.04[a]	0.12±0.02[a]	0.10±0.03[a]	2.50 -5.00 mg/g[C]

Data are presented as mean ± standard deviation.
a,b,c: indicate that mean values with different superscripts along the same row are significantly different at $p < 0.05$.
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.
A: Ndidi *et al.* (2014); B: Mada *et al.* (2012); C: Ndidi *et al.* (2014)

above 0.62 to 1.1 mg/g obtained in kapok seed meal (Wafar *et al*., 2017) but quite higher than 0.05 mg/g obtained by Luka *et al*. (2005) for *Canarium schweinfurthii* seed kernel meal and 0.43 mg/g found in the seeds of *Solanum indicum* shrub (Maikidi *et al*., 2005). Magnesium content was highest (0.37 mg/g) in the raw undehulled meal and least (0.13 mg/g) in the solvent-extracted meal sample. These values are lower than 1.68 mg/g observed in the seeds of *Solanum indicum* shrub (Maikidi *et al*., 2005). Magnesium has been reported to be essential as it maintains and repairs cells, provides energy and its deficiency may result in vertigo, convulsions, nervousness and heat palpitation (Glew*et al*., 1997). It also facilitates muscles' reservoir of oxygen and increases the body's resistance to infection. Its deficiency results in anaemia, tiredness, insomnia and palpitations (Glew *et al*., 1997).

Manganese content had the highest and similar values (0.15 mg/kg) in the raw undehulled and mechanically extracted meal samples while it was least (0.13 mg/kg) in the raw dehulled, solvent-extracted and roasted meal samples (Table 1). These values fall within the range of 0.13 and 0.23 mg/kg obtained in kapok seed meal (Wafar *et al*., 2017). Copper content was highest in the raw dehulled meal (0.04 mg/kg) and least in the solvent-extracted, mechanically extracted and boiled meal samples (0.01 mg/kg) (Table 1). These values closely agree with the range of 0.01 and 0.02 mg/kg observed in kapok seed meal (Wafar *et al*., 2017). Zinc content was highest in the solvent-extracted meal (0.14 mg/kg) and least in the raw dehulled meal (0.09 mg/kg). These values closely agree with the range of 0.14 and 0.17 mg/kg reported for kapok seed meal (Wafar *et al*., 2017) but are lower compared to 50.01 mg/kg reported by Luka *et al*. (2005) for *Canarium schweinfurthii* seed kernel meal. The reduced values of iron, sodium, potassium, magnesium, manganese and copper in the boiled meal sample could have resulted from loss of these minerals into the boiling water as observed in different legume seeds (El-Adawy, 2002). In addition to appreciable quantities of protein (32.21 - 45.31%), lipid (6.43 – 21.60%) and nitrogen-free extract/carbohydrate (11.32 – 17.77%) obtained in processed sunflower seeds in a closely related study (Adesina, 2018), values of mineral nutrients obtained in the present study are indications of high biological value of sunflower seed meal as a rich feedstuff for fish, livestock and poultry.

Effects of different processing methods on the levels of anti-nutrients in the processed sunflower seed meals

The processing methods used in this study reduced the levels of anti-nutrients, namely tannin, oxalate and phytate, in the raw sunflower seeds (Table 2). This supports the

Table 3: Percentage reduction of anti-nutritional components in raw and processed sunflower seed meals

Anti-nutritional Components	RUSSM	RDSSM	SESSM	RSSM	MESSM	BSSM
Tannin (%)	0.00	24.44	42.22	46.67	33.33	53.33
Oxalate (%)	0.00	16.67	33.33	38.89	27.78	38.89
Phytate (%)	0.00	12.50	18.75	31.25	25.00	37.50

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.

findings of Wafar *et al*. (2015) who reported a similar trend on differently processed Velvet beans and *Mucuna sloanei* seeds, Nwosu (2011) on Oze (*Bosqueia angolensis*) seeds and Nwaoguikpe *et al*. (2011) that pre-treatments such as soaking and boiling significantly reduced the concentrations of anti-nutrients present in *Mucuna pruriens* (Velvet bean) seeds. The observed values of anti-nutrients were statistically different ($p<0.05$) except for oxalate and phytate. Tannin was highest in the raw undehulled sunflower seed meal (0.45 mg/g), followed by 0.34 mg/g in the raw dehulled sunflower seed meal and least (0.21 mg/g) in the boiled meal. The values of tannin in the four processed meal samples closely conform to 0.20 mg/g found in the raw seed meal of *Albizzia lebbeck* (Auta and Anwa, 2007) but are much lower than 0.80 mg/g recorded for *Mucuna pruriens* (Akinmutimi, 2007). Tannin values obtained in the present study fell below the permissible level/limit (20 mg/g) for food crops as reported by Ndidi *et al.* (2014) (Table 2). The least value of percentage reduction (24.44%) in tannin was recorded in the raw dehulled sunflower seed meal (RDSSM) (Table 3). The reduction in tannin level due to the processing methods supports the recommended methods for the removal of condensed tannins which include dehulling the seeds to remove the tannin-rich outer layer, autoclaving or treatment with alkali (Griffiths, 1991). Mukhopadhyay and Ray (1999a) observed a reduction in the tannin content of sesame (*Sesamum indicum*) seed meal from 20 g to 10 g/kg after fermentation with lactic acid bacteria. Limited literature on the effects of purified tannins on fish suggests that fish are sensitive to tannins and caution should be exercised in incorporating seeds and agro-industrial by-products containing high levels of tannins (Makkar and Becker, 1996).

Moist heating (boiling) has been observed to reduce the levels of anti-nutrients and thereby improve the nutritional value of legume seeds (Medugu *et al*., 2012; Wafar *et al*., 2015). Cooking *Mucuna sloanei* seeds was reported to have destroyed up to 37.50% tannin content after 30 minutes (Wafar *et al*., 2015). The significantly ($p < 0.05$) lower tannin values of boiled and roasted sunflower seed meals compared to the raw and other processing methods indicate that boiling and roasting are effective methods of detoxifying tannins. This finding supports the earlier reports of Anya (2012) and Obun *et al*. (2016) on African yam bean and tallow (*Detarium microcarpum*) seeds respectively. Tannins have traditionally been regarded as anti-nutrients but presently their health benefits and/or deleterious effects depend upon their chemical structure and dosage and the total acceptable daily tannin intake for man is 560 mg (Stéphane, 2004).

Oxalate content was least (0.11 mg/g) in the roasted and boiled sunflower seed meals and highest (0.15 mg/g) in the raw dehulled sunflower seed meal (RDSSM) compared to 0.18 mg/g in the raw undehulled sunflower seed meal (RUSSM). These values are quite lower than 2.80 mg/g observed in *A. lebbeck* seed meal (Auta and Anwa, 2007) and 0.33 mg/g in *Mucuna urens* seed meal (Effiong and Umoren, 2011) while they are much higher than 0.04 mg/g obtained by Haruna *et al*. (2015). Besides, Balogun (2011) reported 0.12 mg/g on *B. monandra* seed meal which agreed with the range of values (0.11 - 0.18 mg/g) in the present study. Oxalate values found in the present study were slightly above the permissible level (0.02 mg/g) for food crops as reported by Mada *et al.* (2012) (Table 2). The variations in values from other studies could be due to species variation, seed condition (wet or dry), geographical location, climate and processing methods among others. Soaking and boiling of foodstuffs rich in oxalate usually reduce the oxalate content by leaching. Boiling may cause significant skin rupture and facilitate leakage of soluble oxalate into boiling water; this plausibly caused the observed high reduction in oxalate level after boiling as also observed by Bhandari and Kawabata (2004). The least value of percentage reduction (16.67%) in oxalate was recorded in the raw dehulled sunflower seed meal (RDSSM) (Table 3). Oxalate has been demonstrated to reduce the physiological value of calcium in the seed (Narasinga, 1985). However, dehulling reduces the oxalic acid (oxalate) content of the seed (Salunkhe *et al.,* 1991). A maximum dietary intake of 50 – 60 mg oxalate per day has been recommended for patients (Massey *et al*., 2001).

Phytate content was highest (0.16±0.04 mg/g) in the raw undehulled sunflower seed meal (RUSSM) while the other meals had values ranging between 0.10±0.03 mg/g and 0.14±0.04 mg/g. These values are much below 0.26 mg/g observed in raw *A. lebbeck* seed meal (Auta and Anwa 2007), 0.68 - 0.72 mg/g reported for African yam bean seeds (Anya, 2012), 0.61 - 1.27 mg/g found in raw kapok seeds (Wafar *et al*., 2015), 3.45 mg/g in thermally processed soybean seeds (Ari *et al*., 2012) and 3.52 mg/g recorded for grass pea (*Lathyrus sativus*) (Gashaw, 2010). Phytate values observed in the present study fell below the permissible levels of 2.50 - 5.00 mg/g) reported by Ndidi *et al.* (2014) and 30 mg/g reported by Mada *et al.* (2012) for food crops (Table 2). The least value of percentage reduction (12.50%) in phytate was recorded in the raw dehulled sunflower seed meal (RDSSM) (Table 3). The decrease in phytate content by boiling could be due to its leaching out into boiling water (Osman, 2007). Among heat treatments, boiling has been reported as most effective in reducing phytate level as high as 20% of phytate (Bhandari and Kawabata, 2004). The bio-availability of phosphorus for animals depends on the level of phytate-splitting enzyme, phytase, in the intestinal tract. Monogastric animals, including fish, have little or no phytase activity (Liener, 1989).

Phytate in the raw and processed sunflower seed meals can chelate/bind with divalent and trivalent mineral ions such as Ca^{2+}, Mg^{2+}, Zn^{2+}, Cu^{3+} and Al^{3+} and render these ions unavailable for consumers (Duffus and Duffus, 1991). Since phytates cannot be broken down by non-ruminants, their occurrence in feed reduces the bio-availability of phosphorus to these animals (Liener, 1989). Phytates also form sparingly digestible phytate-protein complexes, thus reducing the bio-availability of dietary protein (Richardson *et al.*, 1985). The percentage reduction range values of 12.50 – 37.50% obtained in this study for phytate are lower than 35.71 - 100% obtained by Haruna *et al*. (2015) and 48.12 - 71.71% in soybean seeds (Ari *et al*., 2012). The highest reduction of phytate in the boiled sunflower seeds validates the report of Udensi *et al*. (2007) on vegetable cowpea (*Sesqui pedalis*) seeds, using thermal processing methods (boiling, roasting and autoclaving). Esenwah and Ikenebomeh (2008) stated that phytate as an anti-nutrient in cereals, seeds and beans can be lowered by processing. However, recent research has shown that phytate has many health benefits such as anti-oxidant, anti-cancer, hypocholesterolemic and hypolipidemic effects (Banupriya and Vijayakumar, 2016). Based on the amount of plant-derived food ingredients in the diet and the extent of food processing, the daily intake of phytate can be as high as 4500 mg. The average daily intake of phytate has been estimated to be 150 – 1400 mg for people on mixed diets and 2000 – 2600 mg in the diets of vegetarians and rural dwellers in developing countries (Habtamu and Negussie, 2014).

Conclusion

In view of the appreciable quantities of protein (32.21 - 45.31%), lipid (6.43 –

21.60%) and nitrogen-free extract / carbohydrate (11.32 –17.77%) observed in processed sunflower seeds in a closely related study (Adesina, 2018), values of mineral nutrients obtained in this study are indications of high biological value of sunflower seed meal as a rich feedstuff for fish, livestock and poultry. The results of this study showed that sunflower seeds have appreciable quantities of various macro- and micro-minerals and can serve as a good substitute for conventional plant-based feed ingredients such as soybean meal and groundnut meal used in feed formulations for fish and livestock. Although the seeds have anti-nutrients, various processing methods can be used to reduce their levels to minimal acceptable consumption levels for animals. The study has showed the importance of processing on the seeds, since it reduced their anti-nutrient levels. Among the processing methods adopted in this study, boiling significantly ($p < 0.05$) reduced the levels of tannins, oxalates and phytates in the seeds as boiling produced the highest percentage reduction in the levels of these anti-nutrients, indicating that sunflower seeds could be utilized as a feed ingredient in the diets of cultured animals. Thus, the study emphasizes the need for processing feed ingredients intended for animal feed formulation in order to reduce the levels and effects of anti-nutrients in them, thereby maximizing their utilization for increased profitability.

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