Nig J. Biotech. Vol. 23 (2011) 5- 12
ISSN: 0189 17131
Available online at www.biotechsocietynigeria.org.

NIGERIAN JOURNAL OF BIOTECHNOLOGY

Determination of Proximate Composition and Amino Acid Profile of Nigerian Sesame (*Sesamum indicum* L.) Cultivars

Nweke, F.N.[1], Ubi, B.E.[1] and Kunert, K.J.[2]
[1]Department of Biotechnology, Ebonyi State University, P.M.B. 053 Abakaliki, Nigeria.
[2]Forestry and Agricultural Biotechnology Institute, University of Pretoria, South Africa.

(Received 10.08.11, Accepted 13.12.11)

Abstract
The proximate composition and amino acid profile of the seed of 30 Nigerian sesame genotypes were determined based on the standard methods of the Association of Official Analytical Chemists (AOAC) and the Sequential Multi-sample amino acid Analyzer (TSM). Proximate analysis showed that sesame seed contained ash content of between 1.44 and 5.93 %; moisture (0.22 - 3.5 %). Similarly, fibre content ranged between 4.20 and 11.41 %; lipid had the highest value (58.36 ± 1.54 %, with a range of 52-63 %). The carbohydrate content varied from 15.68 - 28.05 %, while the protein content ranged between 3.25-11.27 %. The high protein content in sesame seed was also shown to be rich in essential amino acids needed for enhanced nutrition. This study suggests that the significant variation in the proximate composition and the high biological value of the amino acids in sesame seed could be useful in enhancing human, as well as, livestock nutrition.

Keywords: *Sesamum indicum*; Proximate composition; Amino acid profile; Nutrient value

Correspondence: ubi.benjamin@yahoo.com

Introduction

Sesame (*Sesamum indicum L.*) is an edible oil seed crop of world-wide importance. The world largest producers of sesame are India and China, followed by Sudan, Mexico, Nigeria, Turkey, Uganda and Ethiopia (Bedigian, 2003). In Nigeria, the crop (commonly called benniseed) is widely used for various purposes and is very popular in the Central, North West and North Eastern zones of Nigeria where it is usually grown (Bedigian, 2003) for local consumption and export. In Nigeria, the seeds are used as a soup ingredient, and constitute a useful source of vegetable oil for cooking (Bedigian, 2006).

Edible seeds are important sources of nutrients and energy especially among the resource-poor populations where protein- energy malnutrition (PEM) has continued to hamper optimal growth and development (Perumal *et al*., 2001; Escudero *et al*., 2006). Likewise, edible seeds can sustain livestock production by ensuring the availability of various sources of nutrients that are required for the formulation of animal feed (Singh *et al*., 1993). Although the seed of sesame is primarily used as a source of edible oil for cooking, it is also used in other alternative ways important to human and livestock nutrition. It is sometimes added to breads, including bagels and on top of hamburger buns. The seeds may also be baked into crackers, often in the form of sticks. Whole seeds are found in many salads and baked snacks. In Greece, sesame seeds are used in cakes, while in Togo and Nigeria, the seeds are used as an important soup ingredient and eaten in stews (Bedigian, 2006). Sesame cookies and wafers, both sweet and savory, are still consumed today in places like Charleston and South Carolina in the United States of America. In Cuban cuisine, sugar and white sesame seeds are combined into a bar resembling peanut brittle and sold in stores and street corners. Sesame seeds can also be made into a paste called tahini, which is rich in protein and a very good energy source (used in various ways including hummus) and a Middle Eastern confection called halvah (Bedigian, 1988).

In spite of the importance of sesame seed as an important source of edible oil and as an ingredient in a wide range of food products especially in the bakery and animal feed, little attention has been paid to the study of the proximate composition and amino acid profile of sesame (Eromosele and Eromosele, 1994; Kyari, 2008). It has been reported in the literature that sesame seed contain 50 - 60 % oil and 25 % protein with antioxidant (lignans) (Baydar *et al*., 1999). For instance, sesame flour which is an edible, creamy and light brown powder from sesame seeds has high protein content with high levels of methionine and tryptophan (Dipasa, 2006). Thus, availability of information on the chemical composition of sesame seed particularly among the Nigerian accessions is important to boost its potential utilization as an excellent source of high quality nutrients for humans, as well as in animal feed (Oplinger *et al*., 1997). The present study reports the variation in seed proximate composition and the amino acid profile of Nigerian sesame accessions.

Materials and methods

Samples: Sesame seeds were collected from 30 field-grown Nigerian cultivars during the 2008 growing season (July – October) at the experimental farm of the Biotechnology Research and Development Center, Ebonyi State University, Abakaliki, Nigeria. Approximately, 100 g of sesame seeds harvested at maturity from 10 randomly selected plants for each cultivar grown on a seed-bed measuring 1.5 m^2 (1.5 m x 1.0 m) were sampled, properly labeled and sun-dried. Each of the sampled seeds was used to prepare varietal composites used for the analysis.

Determination of proximate Composition: Proximate composition of sesame seeds was determined as follows: Moisture was determined by Standard Official Methods of Analysis of the AOAC (1990) (method 14:004). This involved drying to a constant weight at 100 ^{0}C and calculating moisture as the loss in weight of the dried samples. The percentage moisture content was calculated from the equation:

$$\% \text{ moisture} = \frac{W2 - W3}{W2 - W1} \times 100$$

where, W_1 = Initial weight of empty crucible , W_2 = Weight of crucible + sample before drying and W_3 = Final weight of crucible + sample after drying

Total ash was determined by Furnace Incineration described by AOAC (1990) (method 14:006) using about 1.0 g of finely ground dried sample. This analytical method is based on the vaporization of water and volatiles with burning organic substances in the presence of oxygen in the air to CO_2 at a temperature of 600 ^{0}C (dry ashing). The % ash content was calculated as:

$$\% \text{ Ash} = \frac{\text{Weight of Ash}}{\text{Weight of original sample}} \times 100$$

Crude fibre was determined using the method of (AOAC, 1990) (method14:020). The percentage crude fiber was calculated as per the formula:

$$\% \text{ crude fiber} = \frac{\text{Weight after drying}}{\text{Weight of sample}} \times 100$$

Total fat was determined using Soxhlet extraction for 4 hr starting with methanol and ethanol, respectively (Eromosele and Eromsele, 1994). The % fat was computed using the formula below:

$$\% \text{ fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100$$

The crude protein content of the samples was determined using the Microkjeldahl method of AOAC (1984), which involved protein digestion and distillation. The, percentage crude protein was calculated from the % Nitrogen as:

% crude protein = % N x F, where, F (conversion factor), is equivalent to 6.25.

The total percentage carbohydrate content was determined by the difference method as reported by Onyeike *et al.* (1995). This method involved adding the total values of crude protein, lipid, crude fibre, moisture and ash constituents of the sample and subtracting it from 100. The value obtained is the percentage carbohydrate constituent of the sample. Thus, % carbohydrate = 100 – (% moisture + % crude fibre + % protein + % lipid + % ash). *Determination of Amino acid Profile of Samples*: Amino acid profile was determined based on the method described by Spackman *et al.,* (1980) using the Technicon Sequential Multi- sample amino acid Analyzer (TSM-1 Technicon Instrument Basingstoke, UK) using Norleucine as an internal standard. TSM is an automated instrument designed to separate, detect and quantitate amino acids. It works maximally within a temperature range of 18.3-35^{0}C (65 – 95 ^{0}F) and humidity of 10 - 80 %. The hydrolysate was vacuum-dried to remove the buffer solution before loading into the TSM. Compressed nitrogen was passed into the TSM to serve as a segmented stream flow of the amino acid which helps the analyzer detect any amino acid found and stop mix-up of amino acids. About 5-10 ml of sample was dispensed into the cartridge of the analyzer. The TSM analyzer is designed in such a way as to separate and analyze free acidic, neutral and basic amino acids of the hydrolysate. The analysis lasted for 76 min.

All solvents / reagents that used were of analytical grade and obtained from Labio Scientific (Lagos, Nigeria), Aquaba Chemical Industry (South Africa) and LI-COR Inc. Biotech Division (USA).

Statistical analysis: All data for the proximate composition and amino acid profile were subjected to analysis of Variance (ANOVA) using SAS 9.0 software Institute Inc. (2008). Where significant differences were obtained, mean comparisons among the trait values were determined based on the least significant difference (LSD) at 5 % level of probability. Correlation analysis was also performed to determine the relationship among the mean proximate values. T-test analysis was also performed to compare the mean differences in amino acid content between shattering and non-shattering varieties using the GraphPad Prism (Ver. 5.04).

Results

Variation in seed proximate composition among the sesame cultivars: The sesame cultivars varied significantly in percentage ash, moisture, fibre, fat/lipid, protein and carbohydrate ($p < 0.0001$) as shown in Table 1. The ash content ranged from 1.44 % in cv. "Eva" to 5.93 % in cv. "Yobe machina" with a mean value of 4.53 $\pm$ 0.62. The $LSD_{0.5}$ for mean comparisons is 0.46 indicating the existence of real differences in the variation for ash content among the cultivars investigated (Table 1). When the cultivars were categorized into types with low (L, 1.44-3.69 %) and high (H, 3.69 – 5.93 %), nearly all the cultivars had high ash content except cv. "Eva" (1.44 %) and "NCRI (Iwo)" (3.01 %) which are grouped as being low in ash content. The moisture content obtained in the cultivars ranged from 0.22 % in cv. "Chimkwale Yellow" to 3.5 % in cv. "Yorri" with a mean value of 1.10 $\pm$ 0.58. Similarly, fibre content ranged between 4.20 % in cv. "INCRIBEN 0.3 L" and11.41% in cv. "Yobe gadaka brown" with a mean value of 7.59 $\pm$ 1.94. The Fat/lipid content varied from 52 % in cv. "Yorri" to 63 % in cv. "Kachia" with a mean value of 58.36 $\pm$ 1.54 (Table 1).

The mean percentage protein content among the sesame cultivars was 6.37 $\pm$ 1.34, with a range of 3.25 – 11.27 % in "Yobe machina" and "Cameronu white", respectively. Of the 30 cultivars investigated, 19 (63 %) can be classified as low in protein content (L, 3.25-7.26 %), while 37 % (representing 11 cultivars) with protein content ranging from 7.26 - 11.27 %), can be classified as being in the high protein group. Sesame being essentially an oil crop, the high protein values obtained in some of these cultivars is appreciable. The mean carbohydrate content was 22.05 ±2.40 % and ranged from 15.68 – 28.05 % in "Kachia" and "Zuru", respectively (Table 1). Generally, the mean trends observed in the proximate levels are in the order of lipid > carbohydrate > fibre > protein > ash > moisture. Only few significant associations ($P < 0.05$) were observed among the proximate values, with most of the significantly correlated traits being negative (Table 2). Percentage ash was positively correlated with moisture, while moderate negative correlations were obtained between moisture and fat/lipid content, carbohydrate and fat content, carbohydrate and fat content, as well as carbohydrate and protein content (Table 2).

Amino Acid Profile of Sesame Seeds: Results of the amino acid content of the sesame seeds grouped into the two major sesame classes (shattering and non-shattering varieties) are shown in (Table 3). The 17 essential amino acids obtained from sesame seed in this study are: Alanine, Arginine, Aspartic acid, Cysteine, Glutamic acid, Glycine, Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Proline, Serine, Threonine, Tyrosine and Valine. The shattering genotypes gave amino acid content ranging between 0.17g/100g for Cysteine and 7.44 g/100g for Glutamic acid and an average value of 2.0±1.18 g/100g. The amino acid levels among the non-shattering genotypes ranged between 0.14g/100g for Cysteine and 6.80g/100g for Glutamic acid respectively, with an average value of 1.8±1.08g/100g. Appreciable percentages of Arginine, Glutamic acid, Isoleucine, Leucine, Methionine, Phenylalanine, Threonine, Tyrosine and Valine was recorded with sesame seeds showing a

Table 1. Diversity in Seed Proximate Composition among Sesame Cultivars

SN	Genotypes	%Ash	%Moisture	%Fibre	% lipid	%Protein	%CHO
1	ABBS	3.79 H	1.50 L	8.71 H	61.25 H	7.63 H	17.12 L
2	Incriben0.3L	4.62 H	0.50 L	4.20 L	54.25 L	9.17 H	27.26 H
3	Cross 95	5.52 H	1.00 L	6.31 L	60.5 H	7.90 H	18.77 L
4	Adaukiari	5.23 H	0.50 L	11.21 H	57.25 L	5.33 L	20.48 L
5	Chimkwale	3.83 H	1.00 L	8.10 H	60.4 H	5.47 L	21.20 L
6	Chimkwale yellow	4.54 H	0.22 L	7.20 L	57 L	5.25 L	25.79 H
7	E.8	4.57 H	0.75 L	5.80 L	59.25 H	7.28 H	22.35 H
8	Eva	1.44 L	1.00 L	7.60 L	57.25 L	9.09 H	23.62 H
9	Zuru	5.91 H	2.75 H	4.21 L	55.5 L	3.58 L	28.05 H
10	34-4-1	4.74 H	3.00 H	8.20 H	57.5 H	4.14 L	22.42 H
11	Alaide	3.86 H	0.50 L	8.60 H	59.5 H	3.30 L	24.24 H
12	Cameronu white	4.89 H	1.50 L	10.20 H	56.25 L	11.27 H	15.89 L
13	Domu	4.35 H	1.50 L	6.41 L	60 H	7.90 H	19.85 L
14	Otobi	4.94 H	0.75 L	7.12 L	58.75 H	7.36 H	21.08 L
15	Yorri	5.41 H	3.5 H	7.31 L	52 L	7.13 L	24.65 H
16	Kwander	4.72 H	0.25 L	6.31 L	58.5 H	5.28 L	24.94 H
17	Incriben0.2m	4.30 H	0.25 L	5.50 L	60.5 H	5.50 L	23.95 H
18	Pachequeno	4.11 H	0.25 L	4.81 L	58.25 H	7.67 H	24.91 H
19	43-9-1	4.19 H	0.63 L	7.11 L	58.7 H	5.36 L	24.01 H
20	Yobe gadaka white	4.73 H	0.25 L	6.42 L	58.75 H	6.71 L	23.14 H
21	Ciano 16	5.38 H	1.50 L	8.81 H	58.25 H	5.88 L	20.18 L
22	69-1-1	5.17 H	1.38 L	10.90 H	57.75 H	6.29 L	18.51 L
23	Jigaw	3.87 H	0.50 L	6.72 L	57.21 L	4.06 L	27.64 H
24	Kachia	4.27 H	1.00 L	9.20 H	63 H	6.85 L	15.68 L
25	Incriben 0.1m	4.55 H	0.50 L	8.31 H	58.38 H	4.32 L	23.94 H
26	Yobe gadaka brown	4.10 H	2.00 H	11.41 H	61 H	5.19 L	16.30 L
27	69-882	4.94 H	1.25 L	6.20 L	60.25 H	7.90 H	19.46 L
28	Yobe machina	5.93 H	1.25 L	10.50 H	58.25 H	3.25 L	20.82 L
29	Ciano 27	4.95 H	1.25 L	7.20 L	57.25 L	6.70 L	22.65 H
30	NCRI (Iwo)	3.01 L	0.88 L	7.20 L	58.25 H	8.19 H	22.47 H
	Mean ±SE	4.55 ± 0.62	1.10 ± 0.58	7.59 ± 1.94	58.36 ± 1.54	6.37 ± 1.34	22.05 ± 2.40
	P- Values	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	LSD	0.46	0.10	0.05	1.60	0.25	1.57

Notes: ash: low (L) =1.44-3.69 %, high (H) = 3.70-5.93%; moisture: L = 0.22-1.88 %; H = 1.89-3.50 %; fibre: L = 4.21-7.81%; H = 7.82- 11.41%; fat/lipid: L= 52.0-57.38 %; H = 57.39-63.0 %; protein: L = 3.25-7.26 %; H = 7.27-11.27 %; carbohydrate: L = 15.68-21.87 %; H = 21.88-28.05 %.

relative chemical score of 50 % or higher in Arginine, Glutamic acid, Leucine, Methionine, Phenylalanine, Threonine and Tyrosine. Very strong positively significant correlation (r = 99.92 %, p < 0.0001) exists between the amino content of the shattering and the non-shattering accessions, indicating that the differences in amino acid content between these two broad groups may not be really significant (Table 3). In fact, unpaired t-test analysis indicated that the shattering cultivars did not differ significantly in amino acid content from the non-shattering cultivars ($t_{0.05}$ = 0.4004 @ 32 df, p value = 0.6915).

Discussion

This study estimated the diversity in proximate composition of 30 Nigerian sesame accessions and analysis of the profile of amino acids. The proximate composition values were determined for ash, moisture, fibre, fats (lipids), protein and carbohydrate among the 30 sesame cultivars. These occurred in sesame seed in this order: lipid > carbohydrate > Fibre > Protein > Ash > moisture. High variability was observed in proximate composition of sesame seeds among the 30 cultivars. The chemical composition of sesame seed was comparatively high in crude fat (58.36±1.54%), followed by carbohydrate (22.05±2.40%), crude fibre 7.59±1.94 and protein (6.37±1.34%) content, respectively. Similarly, moisture (1.10±0.58%), and ash (4.53±0.62%) were very low in composition. The ash content of

Table 2. Correlation Values among Proximate Composition in Sesame Seeds

Trait	%Ash	% Moisture	% Fibre	% Fat/Lipid	% Protein	% CHO
%Ash	1.00000					
% Moisture	0.26600 (0.0366)	1.00000				
% Fibre	0.03218 (0.8039)	0.17471 (0.1744)	1.00000			
% Lipid	-0.27067 (-0.27067)	-0.29577 (0.0196)	0.19979 (0.1195)	1.00000		
% Protein	-0.22766 (0.0752)	-0.03835 (0.7673)	-0.13278 (0.3036)	-0.15201 (0.2382)	1.00000	
% CHO	0.08637 (0.5045)	-0.16880 (0.1897)	-0.45606 (0.0002)	-0.42178 (0.0006)	-0.57220 (< 0.0001)	1.00000

Table 3. Amino Acid Profile of Sesame Seeds and % chemical score relative to the FAO /WHO / UNU Reference Value (g/100g)

Amino acid	Shattering varieties	Non-shattering varieties	FAO/WHO/UNU reference value	% Chemical Score (Shattering)
Alanine	1.63	1.48	20.3	8.02
Arginine	4.61	4.01	4.0	115.25*
Aspartic acid	2.77	2.53	-	-
Cysteine	0.17	0.14	2.0	8.5
Glutamic acid	7.44	6.80	6.3	118.10*
Glycine	1.81	1.58	18.3	9.89
Histidine	0.93	0.80	3.4	27.35
Isoleucine	1.38	1.21	4.2	32.86
Leucine	2.39	2.11	4.2	56.90*
Lysine	0.95	0.87	4.2	22.62
Methionine	1.00	0.86	2.2	45.45*
Phenylalanine	1.66	1.44	2.8	59.29*
Proline	1.28	1.12	-	-
Serine	1.61	1.42	-	-
Threonine	1.26	1.11	2.8	48.57*
Tyrosine	1.36	1.18	2.8	48.57*
Valine	1.70	1.50	4.2	40.48
Mean ±SE	2.0±1.18	1.8±1.08	-	-
P-values	<.0001	<.0001	-	-
LSD	0.0934	0.0401	-	-

* Amino acids with about 50 % chemical score; Significant variation in amino acids was obtained at P value < 0.0001; - = no reference value.

4.53±0.62% for this seed is comparable with that of other legume seeds which have been reported to range between 3.0 and 4.8 % (Elegbede, 1998), while carbohydrate content (22.05±2.40%) is at a relatively lower value when compared with that of other legume seeds ranging from 23 % in groundnut to 66 % in bambara groundnut (Ologhobo, 1994). The low moisture (1.10±0.58%) and ash (4.53±0.62%) content found in sesame seeds falls within the range reported for most seeds and nuts (FAO, 1968; Oyenuga, 1968). The low moisture content is an index of stability, quality, shelf life and also high yields (Levander, 1990). The presence of ash is a reflection of inorganic matter in a food sample.

Our results suggest that sesame seeds are a rich source of fat a lipid value of 58.36±1.54%. The oil obtained from the seed was a mixture of a semi-solid cream colored fat and a colorless liquid at room temperature. The physical characteristic of the oil is indicative of a mixture of saturated and unsaturated fatty acids (Morrison and Smith, 2004). With percentage lipid content of 58.36±1.54%, sesame seed oil compares favorably with the richest oil seed legumes such as soy beans and peanuts. These results suggest that the seeds are a potential source of edible vegetable oil and the extracted meal as a potentially vital source of carbohydrate, fibre and protein for livestock feed. Its exploitation is, therefore, worth considering in this regard. The presence of dietary fibre suggests that the consumption of sesame seed would greatly enhance digestibility and aid in the prevention of non-communicable diseases.

The amino acid profile of sesame seed investigated in this study suggests that sesame seeds are an excellent source of essential amino acids, notably glutamic acid, arginine, phenylalanine and leucine. The other amino acids are present in moderate amounts while tryptophan, asparagine, and glutamine were absent. Significant variation ($P < 0.05$) exists among the individual amino acids in either shattering or non-shattering genotypes especially in glutamic acid and arginine. These differences in amount of amino acids could be attributed to genetic differences among the sesame cultivars (Tashiro *et al.* 2007). No differences were found in the profile of amino acids between the shattering and non-shattering cultivars.

The nutritive value of plant protein quality is usually assessed by comparing its essential amino acids content with reference standards for ideal protein quality set by the World Health Organisation (FAO/WHO/UNU, 1991), which is based on the amino acids requirement for children aged 2- 5 years. Therefore, our results showed that sesame seed contain enough protein (6.37±1.34%) and almost all the essential amino acids needed, with some above the 100 % relative chemical score. This implies that the amino acids in the seed of sesame have a high biological value and could contribute meaningfully in meeting the human requirements for these essential amino acids.

In conclusion, the seeds of the 30 Nigerian sesame cultivars showed significant variation in their proximate constituents. This inherent variability could be usefully exploited in a plant breeding program to achieve genetic gain for nutrient composition in these highly diverse cultivars through selection and hybridization of desirable genotypes. The rich content of nutrients coupled with the high amino acid profile suggest that sesame seeds could meaningfully contribute to human and livestock nutrition.

Acknowledgements

This work was supported by a grant from Education Trust Fund (ETF) Research Fellowship Program of the Federal Republic of Nigeria and Ebonyi State University, Abakaliki, Nigeria. The authors gratefully acknowledge the Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, South Africa for partly providing the research facilities for this study. We are also thankful to the National Cereals Research Institute (NCRI) Badeggi, Niger State, Nigeria for providing the genetic resources.

References

AOAC (1990). Official Methods of Analysis. Association of Official Analytical Chemists, Washington DC. 1-50.

AOAC (1984). Standard Official Methods of Analysis of the Association of Analytical Chemists. 15th edition, S.W. Williams (Ed), Washington DC.5-9

Baydar, H., Targut, I., Turgut, K. (1999). Variation of certain characters and line selection for yield, oil, oleic and linoleic acids in the Turkish sesame (*sesamum indicum* L.) populations. *Tropical Journal of Agriculture* **23**:431-441.

Bedigian, D. (2006). Assessment of sesame and its wild relatives in Africa: In Ghazanfar, S.A. and Beentje, H.J (Eds). Taxonomy and ecology of African plants, their conservation and sustainable use. *Royal Botanic Gardens* **3**:481-491.

Bedigian, D. (2003). Evolution of sesame, domestication, diversity and prospects. *Genetic Resources and Crop Evolution* **50**:773-778.

Bedigian, D. (1988). *Sesamum indicum* L. (Pedaliaceae): Ethnobotany in Sudan, crop diversity, lignans, origin, and related taxa: In Goldblatt, P and Lowry, P.P. (eds). Modern systematic studies in African botany. *Systematic Botany and Garden* **25**:315-321.

Dipasa, B.M. (2006). Sesame honey bits. www.dipasa.nl/seshobit.htm.3-9.

Elegbede, J.A . (1998). Legumes. In: Nutritional quality of plant foods. Pp. 43-56.

Eromosele, I.C., Eromsele, C.O. (1994). Studies on the chemical composition and physicochemical properties of seeds of some wild plants. *Plant Foods for Human Nutrition* **46**: 361-365.

Escudero, N.L., Zirulnik, F., Gomez, N.N., Mucciarelli, S.I., Gimenez, M.S. (2006). Influence of a protein concentrate from *Amaranthus cruentus* seeds on lipid metabolism. *Experimental Biology and Medicine* **231**: 50-59.

FAO United Nations Food and Agriculture Organization (1968). Food Composition Table for use in Africa. Rome: Italy, pp 8-12.

FAO/WHO/UNU (1991). Protein quality evaluation. Food and Agricultural organization of the United Nation Rome; Italy pp. 3-8.

GraphPad Prism 5 for Windows (1992-2010): Version 5.04 (Trial) 1992-2010 GraphPad Software, Inc.

Kyari, M.Z. (2008). Extraction and characterization of seed oils. *International Agro- physics* **22**:139-142.

Levander, O.A. (1990). Fruit and vegetable contribution to dietary mineral intake in human health and disease. *Hort Science* **25**: 1486–1488.

Morrison, E.R., Smith, L.M. (2004). Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol. *Journal of Lipid Research* **5**: 600–608.

Ologhobo, A.D. (1994). Identification, nutritional value and strategies for the promotion of edible wild and semi-wild legumes in Nigeria. *Proceedings of International Workshop on Traditional Food Plants for Food and Nutrition Security in Nigeria*. University of Ibadan, Nigeria, 25-29.

Oplinger, E.S., Putnam, D.H., Kaminski, A.R., Hanson, C.V., Oelke, E.A., Schulte, E.E., Doll, J.D. (1997). Sesame: New approaches for crop improvement. In: Janick, J. and Simon, J.E. (Eds.), Advances in new crops. Timber Press, Portland 1971–1980.

Oyenuga, V.A. (1968). Nigerian Feeds and Feeding stuff 3rd Eds. Ibadan University Press, 23-27.

Onyeike, E.N.; Olungwe, T., Uwakwe, A. A. (1995). Effect of Heat Treatment and Defatting on the Proximate Composition of Some Nigerian Local Soup Thickeners. Food Chemistry 53: 173-175.

Pearson, O. (1976). Chemical analysis of foods. New York: Chemical Publishing Co. 15-24.

Perumal, S., Klaus, B., Harinder, P.S.M. (2001). Chemical composition, protein fractionation, essential amino acid potential and antimetabolic constituents of an unconventional legume, Gila bean (Entada phaseoloides Merrill) seed kernel. *Journal of Science of Food and Agriculture* **82**: 192-202.

SAS Software Institute Inc., (2008). Release *9.0* editions, Cary, NC, USA.

Spackman, D.H., Stein, E.H., Moore, S. (1980). Automatic recording Apparatus for use in the chromatography of amino acids. *Anayltical chemistry*. **30:** 1191-1198.

Tashiro, T., Flukuda, Y., Osawa, T. and Namiki, M. (2007). Oil and minor components of sesame (*Sesamum indicum* L.) strains. *Journal of the American Oil Chemist's Society* **67** (8): 508-511.