International Food Research Journal 25(2): 848-853 (April 2018)

Journal homepage: *http://www.ifrj.upm.edu.my*

Nutrients assessment of some lima bean varieties grown in southwest Nigeria

[1*]Seidu, K.T., [2]Osundahunsi, O.F. and [3]Osamudiamen, P.M.

[1]*Department of Food Technology, Federal Polytechnic, P.M.B. 5351, Ado Ekiti, Nigeria*
[2]*Department of Food Science and Technology, Federal University of Technology, P.M.B. 704, Akure, Nigeria*
[3]*Department of Chemical Sciences, Bells University of Technology, P. M. B. 1015, Ota, Nigeria*

Article history

Received: 29 November 2016
Received in revised form: 7 January 2017
Accepted: 8 January 2017

Keywords

Lima bean
Mineral composition
Amino acid

Abstract

Four varieties of lima bean seeds with accession number NSWP100, NSWP98, NSWP47 and NSWP96 were subjected to standard analytical techniques to evaluate the physical, proximate, mineral and amino acids composition. Significant ($p\leq 0.05$) variations existed among the varieties with respect to their proximate composition, mineral constituent and amino acid profile. NSWP98 showed higher hydration indices (0.70) and percentage cotyledon (87.27 g/100 g). Proximate result revealed low moisture and high protein contents (3.71 to 7.45 g/100 g and 25.91 to 30.29 g/100 g) respectively. The most abundant mineral elements were potassium and sodium (7.53 to 360.80 mg/100 g) and (7.53 to 80.73 mg/100 g) respectively; calcium was in the range of 11.13 to 2014 mg/100 g and iron 11.30 to 18.17 mg/100 g. However, high content of amino acids were also detected, lysine (6.85 to 7.25 g/100 g protein), leucine (8.2 to 8.64 g/100 g protein) and phenylalanine (5.63 to 6.24 g/100 g protein). Highest concentration of total essential amino acids (52.65 g/100 g protein) was observed in NSWP98. Increase in utilisation of lima bean will improve livelihoods and value-added food products that can serve as important driver for economic development.

Introduction

The possible avenue of achieving nutrition security in third world countries is through exploitation of underutilised plant foods sources (Champ *et al*., 2003). In such countries, plant foods are the most important dietary sources to satisfy individuals' nutrient requirements due to the availability and low cost. Legumes also known as pulses are important food source and play a significant role in traditional diets all over the world (Chung *et al*., 2008). In Africa especially and other developing countries, animal proteins are grossly inadequate and relatively expensive. Research effort has been intensified towards finding alternative sources of protein from underutilised grain legume seeds in the last decades (Adebowale *et al*., 2005). Plant proteins have been used extensively for many years in the food industry as food product ingredient due to the amino acid content (Horax *et al*., 2004). Grain legumes are an excellent source of protein, carbohydrates, dietary fiber, vitamins, minerals and phytochemicals (Tharanathan and Mahadevamma, 2003) which has led to the increase in consump¬tion worldwide.

Researchers have dem¬onstrated that legumes could prevent or manage chronic health challenges such as diabetes, cardiovascular disease, cancer, obesity and contribute to overall health and wellness of human body (Basset *et al*., 2010). Frequent consumption of legume (four or more times com¬pared with less than once a week) has been associated with 22% and 11% lower risk of coronary heart disease (CHD) and cardiovascular disease (CVD) respectively (Flight and Clifton 2006). Considerable genetic variation has been reported in the chemical composition of legumes both between and within species. In addition, chemical composition is modified by environmental factors during plant development (Rochfort and Panozzo 2007).

Lima bean *(Phaseolus lunatus)* is a cheap source of protein to the Nigerians rural dwellers (Ezeagu and Ibegbu 2010). Despite the great potential of the crop, it is highly underutilised in Nigeria and is known as "kapala" (Yoruba), "ukpa" (Igbo) in South-western and South-eastern Nigeria respectively; where the seeds are commonly consumed (Ezeagu and Ibegbu 2010; Seidu *et al*., 2014). It has good potential as a cheap and alternate source of protein. The seeds contain 24% proteins, 61% carbohydrate and minerals elements. One of the constraints to the consumption of lima beans, like other beans, is that certain varieties require a longer time to cook or soak than others (Giami, 2001). There is dearth

*Corresponding author.
Email: *seidukt5@gmail.com*

of information on the varietal differences on the physical and nutritional aspects of lima bean species. Hence this study aimed at the evaluation of physical, mineral and amino acids composition of four varieties of lima species (NSWP100, NSWP98, NSWP47 and NSWP96) grown in Southwest states of Nigeria.

Materials and Methods

Materials

Four varieties of lima bean seeds with accession number NSWP100, NSWP98, NSWP47 and NSWP96 were obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria. Chemicals used were of analytical grade. The cleaned lima beans were cracked with hammer mill, soaked in water for 3 h, dehulled, washed and dried at (60±2°C) for 24 h before milling and sieving to give 40 mm mesh size flour which was kept in an airtight plastic container at 4°C prior to use.

Physical analysis

The physical analysis was carried out as described below (Adebowale *et al*., 2005). Lima bean seeds (100 g) was weighed accurately and transferred into 100 ml measuring cylinder, where 100 ml deionised water was added. The seeds were poured into the water and the volume of the displaced water was measured.

Seeds weighing 100 g was counted and transferred into a measuring cylinder with water and left for 24 h at room temperature (30±2°C), after which the seeds were drained with filter paper. The hydration capacity was determined using the relation:

$$\text{Hydration capacity} = \frac{\text{Weight of soaked seeds} - \text{Weight of seed before soaking}}{\text{Number of seeds}}$$

The hydration index was calculated as follows:

$$\text{Hydration index} = \frac{\text{Hydration capacity per seed}}{\text{Weight of one seed}}$$

Seeds weighing 100 g was counted; the volume was noted and soaked overnight in water. Swelling capacity and swelling index per seed was calculated as follows:

$$\text{Swelling capacity} = \frac{\text{Volume after soaking-Volume before soaking}}{\text{Number of seeds}}$$

$$\text{Swelling index} = \frac{\text{Swelling capacity of seed}}{\text{Volume of one seed}}$$

The seeds color was determined subjectively. The proportion of seed coat and cotyledon in the seeds was determined by taking the average measure of 100 g weight.

The proximate composition of lima bean flour was determined by the standard method of AOAC (2005). The carbohydrate content was determined by difference. The phosphorus content of lima bean flour was determined by the phosphovanado-molybdate (yellow) method. The other elemental concentrations were determined, after wet digestion of sample ash with a mixture of nitric and hydrochloric acids (1:1 v/v), using Atomic Absorption Spectrophotometer (AAS, Buck Model 20A, Buck Scientific, East Norwalk, CT06855, USA) (AOAC, 2005).

Amino acid profile was determined using a High Performance Liquid Chromatography (HPLC) system after sample was hydrolyzed for 24 h with 6 M hydrochloric acid according to the procedure described by Bidlingmeyer et al. (1984). The cysteine and methionine contents were determined after performic acid oxidation while tryptophan content was determined after alkaline hydrolysis.

Determinations were made in triplicates and subjected to analysis of variance (ANOVA) using Statistical Package for Social Scientist (SPSS) 16 computer programme for data analysis. Means were separated using Duncan multiple range test. Significance was accepted at $p \leq 0.05$ level of probability.

Results and Discussion

Physical properties of lima bean seeds

The physical properties of lima bean seeds are presented in Table 1. The seed weight was in the range of 0.31 to 0.49 g which is higher than 0.09 g reported for Asparagus bean (Olawuni *et al*., 2013); but lower than 0.59 to 0.98 g/ml reported for mucuna species (Adebowale *et al*., 2005); 100-seed weight was 31.81 to 39.41 g; the percentage seed coat was in the range of 12.41 to 13.81% lower than 36.9% reported for new line lima bean (Giami, 2001) and percentage cotyledon 86.25 to 87.27%. The density of the different seeds ranges from 0.77 to 0.79 g/ml; hydration capacity 0.23 to 0.32 g/seed, hydration index 0.67 to 0.73; swelling capacity 0.19 to 0.25 ml/seed and swelling index 0.27 to 0.34.

Proximate composition

The proximate composition of lima bean species is presented in Table 2. The result revealed low moisture content which are in agreement with 6.45 g/100 g reported for bambara groundnut (Martin *et*

Table 1. Physical properties of lima bean seeds

Parameters	Lima bean species			
	NSWP100	NSWP98	NSWP47	NSWP96
Colour	Light brown	Dark brown	Light brown with dark strips	Purpish-brown
Coat-appearance	glossy	Glossy	smooth	smooth
Grain's weight (g)	0.38±0.04^{b}	0.39±0.03^{b}	0.46±0.01^{a}	0.31±0.01^{c}
100-seed weight (g)	34.48±0.15^{c}	36.53±0.12^{b}	39.41±0.24^{a}	31.81±0.13^{d}
Coat (g/100 g)	13.46±0.31^{b}	12.41±0.41^{d}	13.01±0.13^{c}	13.81±0.11^{a}
Cotyledon (g/100 g)	86.57±0.21^{bc}	87.27±0.58^{a}	87.01±0.38^{ab}	86.25±0.19^{c}
Density (gml^{-1})	0.77±0.02	0.78±0.10	0.77±0.20	0.79±0.12
Hydration capacity (g/g)	0.26±0.01^{b}	0.27±0.01^{a}	0.32±0.01^{a}	0.23±0.01^{c}
Hydration index	0.67±0.06^{d}	0.70±0.05^{b}	0.69±0.03^{c}	0.73±0.02^{a}
Swelling capacity (ml/g)	0.25±0.01^{a}	0.20±0.00^{b}	0.22±0.00^{ab}	0.19±0.00^{b}
Swelling index	0.34±0.01^{a}	0.29 ±0.02^{b}	0.27 ±0.01^{c}	0.33 ±0.01^{a}

Values are means of triplicate determinations ± Standard deviation. Means with different superscript in the same row are significantly different ($p \leq 0.05$).

Table 2. Proximate composition of lima bean varieties (g/100 g dry weight)

Parameters	NSWP100	NSWP98	NSWP47	NSWP96
Moisture	6.11 ± 0.09^{c}	6.35 ±0.05^{b}	6.38 ±0.03^{b}	7.45 ±0.05^{a}
Protein	28.02 ± 0.07^{c}	28.76 ±0.26^{b}	25.91 ±0.15^{d}	30.29 ±0.15^{a}
Fat	2.45 ± 0.14^{b}	2.04 ±0.02^{c}	2.65 ±0.01^{a}	2.10 ±0.02^{c}
Crude fibre	2.64 ± 0.03^{b}	2.80 ±0.02^{a}	2.74 ±0.01^{a}	2.57 ±0.02^{b}
Ash	3.41 ± 0.03^{a}	3.38 ±0.01^{a}	3.08 ±0.02^{b}	3.36 ±0.10^{a}
Carbohydrate	63.50 ± 0.16^{b}	63.03 ±0.14^{b}	65.61 ±0.17^{a}	61.68 ±0.37^{c}

Values are means of triplicate determinations ± Standard deviation. Means with different superscript in the same row are significantly different ($p \leq 0.05$).

al., 2011), lower than the moisture content of cowpea 10.39 g/100 g; mungbean 8.30 g/100 g and peas 9.05 g/100 g (Mosood and Rizwana 2010). This could be an indication of good keeping quality of the seeds. The highest protein (30.29 g/100 g) content was recorded in NSWP96 with the least value (25.91 g/100 g) in NSWP47; all are higher than those recorded for similar seeds: Pigeon pea 24.03 g/100 g, cowpea 24.46 g/100 g (Arawande and Borokini 2010); peas 22.95 g/100 g (Mosood and Rizwana 2010); Castellano chickpea 23.70 g/100 g (Aguilera *et al.*, 2011). Ezeagu and Ibegbu (2010) reported a lower value of 23.17 g/100 g for lima bean; indicating that protein content may be dependent on varieties. The crude fibre content was significantly ($p \leq 0.05$) higher in NSWP98 (2.80 g/100 g) and NSWP47 (2.74 g/100 g) compare to other varieties; but lower than 7.86 g/100 g reported for red kidney beans (Sai-Ut *et al.*, 2009). Fibre, especially in grain legumes, has been reported to be of health benefit.

Mineral composition

Mineral composition in mg/100 g of the lima bean flours is shown in Table 3. The abundant minerals in the studied varieties were potassium and sodium which agrees with the observation of (Olaofe and Sanni, 1988) on the potassium predominance in Nigerian agricultural products. Similar observations have been reported for gingerbread plum (Amza *et al.*, 2011) and lima bean seed coat (Seidu *et al.*, 2014) but contrary to the report on mucuna beans (Adebowale *et al.*, 2005). The samples are high in phosphorus, calcium and magnesium, the minerals which are necessary for teeth and bone development in children (David, 2006). Manganese, zinc and copper content were relatively low. Variation was observed in the quantitative composition of mineral elements in agreement to the report of Seidu *et al.* (2015) as a result of genetic variation and soil conditions. Sodium/potassium (Na/K) ratio observed in this study is within the recommended level (≤1.0) (Aremu *et al.*, 2006) and very vital in the prevention and management of high blood pressure. The calcium/phosphorus ratio (Ca/P) ratio is high (high calcium, low phosphorus intake) only little amount of calcium will be loss through the urine, increasing the calcium level in bones. The Ca/P (0.64 to 1.31) ratio in the present study which is above 0.5 is an indication that the varieties evaluated are potential minerals sources

Table 3. Mineral composition of lima bean varieties (mg/100 g)

Elements	NSWP100	NSWP98	NSWP47	NSWP96
Copper	0.82 ±0.02[a]	0.49±0.01[b]	0.29± 0.01[c]	0.26±0.01[c]
Zinc	2.27 ±0.15[b]	2.33± 0.03[b]	3.13± 0.10[a]	2.24 ±0.01[b]
Manganese	0.16 ±0.01	0.16± 0.02	0.18± 0.03	0.13 ±0.03
Calcium	20.14±0.15[a]	16.42±0.17[b]	12.36±0.15[c]	11.13±0.20[d]
Potassium	7.53 ±0.11[d]	319.91±0.23[b]	360.80±0.27[a]	317.81±0.10[c]
Sodium	7.53 ±0.13[d]	73.17±0.15[b]	80.73±0.18[a]	64.17±0.15[c]
Magnesium	30.15±0.53[d]	54.18± 0.16[b]	67.13± 0.51[a]	53.16 ±0.13[c]
Iron	18.17±0.13[a]	17.22± 0.11[b]	11.30± 0.28[d]	15.22 ±0.15[c]
Phosphorus	15.31±0.12[b]	13.12±0.08[c]	11.50±0.15[d]	17.20±0.13[a]
Na/K	1.00±0.04[a]	0.23±0.01[b]	0.22±0.01[b]	0.20±0.01[b]
Ca/P	1.31±0.01[a]	1.25±0.01[a]	1.07±0.01[a]	0.64±0.00[b]

Values are means of triplicate determinations ± Standard deviation. Means with different superscript in the same row are significantly different ($p \leq 0.05$).

Table 4. Amino acid composition of lima bean varieties (g/100 g of protein)

Amino acid	NSWP100	NSWP98	NSWP47	NSWP96	WHO 2007	
					Child	Adult
ASX	13.15±0.10[a]	12.69±0.10[b]	13.20±0.21[a]	13.07±0.20[a]	-	-
THR*	4.36±0.05[b]	4.82±0.02[a]	4.38±0.01[b]	4.36±0.01[b]	3.40	0.90
SER	7.67±0.10[b]	7.20±0.10[c]	7.78±0.01[a]	7.60±0.01[b]	-	-
GLX	14.18±0.12	14.26±0.11	14.19±0.05	14.10±0.30	-	-
PRO	4.42±0.05[c]	4.30±0.10[c]	4.58±0.02[b]	5.13±0.01[a]	-	-
GLY	4.27±0.05[c]	4.50±0.10[a]	4.42±0.10[b]	4.22±0.01[c]	-	-
ALA	4.15±0.03[c]	4.40±0.10[b]	4.71±0.01[a]	4.47±0.12[b]	-	-
CYS*	0.24±0.00[b]	0.24±0.00[b]	0.54±0.01[a]	0.54±0.01[a]		
VAL*	4.84±0.15[b]	5.11±0.10[a]	4.54±0.01[c]	4.16±0.13[d]	3.50	1.50
MET*	1.15±0.01	1.17±0.01	1.22±0.02	1.12±0.01	2.70	1.70
ILE*	4.40±0.02[b]	4.55±0.10[a]	4.12±0.01[c]	4.38±0.10[b]	2.80	1.30
LEU*	8.64±0.10[a]	8.20±0.10[b]	8.34±0.28[b]	8.26±0.17[b]	6.60	1.90
TYR*	3.31±0.10[b]	3.54±0.10[a]	3.21±0.01[b]	3.41±0.01[a]	-	-
PHE*	6.24±0.15[a]	6.02±0.13[b]	5.63±0.01[c]	6.18±0.10[a]	6.30	1.90
HIS*	4.67±0.12[b]	4.24±0.10[c]	5.14±0.01[a]	5.05±0.03[a]	1.90	1.60
LYS*	7.25±0.11[a]	7.23±0.02[a]	6.85±0.01[b]	7.23±0.41[a]	5.80	1.60
ARG*	5.87±0.10[c]	6.36±0.13[a]	6.08±0.08[b]	6.02±0.21[b]	-	-
TRP*	1.34±0.01[a]	1.35±0.01[a]	1.34±0.02[a]	1.03±0.01[b]	1.10	0.50
TEAA	52.51±0.23[a]	52.65±0.56[a]	51.39±0.44[b]	51.54±0.36[b]	-	-

Values are means of triplicate determinations ± Standard deviation. Means with different superscript in the same row are significantly different ($p \leq 0.05$).
ASX- aspartic acid+asparagine.
GLX- glutamic acid+glutamine
* = Essential amino acid

for bone formation (Nieman *et al*., 1992).

Amino acid composition

The result of amino acid profile is depicted in Table 4, for reference purpose the recommended mode of essential amino acid for children and adult is included in the table (WHO, 2007). The result shows acceptable amino acids composition in the four varieties of lima bean flours evaluated due to the high level of essential amino acids except methionine and cysteine. The low level of methionine/cysteine recorded in this study is a common phenomenon in legumes. However, this challenge can be overcome by complementing the diet with cereal proteins in which sulphur-amino acids are relatively high (Mortuza *et al.*, 2009). Aspartic acid/asparagine and glutamic acid/glutamine were the most abundant amino acids found in all the varieties ranging from 12.69 to13.20 g/100 g and 14.10 to 14 26 g/100 g protein respectively and have been reported as seed storage proteins (Tang and Ma, 2009); as well as important amino acids reservoirs for human body (Vasconcelos *et al.*, 2010).

In terms of essential amino acids, all the varieties exhibited relatively higher amounts of valine, isoleucine, leucine, lysine, threonine and histidine compared to the standard. The contents of tryptophan and sulphur containing amino acids were slightly lower than the recommended mode for children (2-5 years). However, all the essential amino acids contained in samples were adequate for adults (WHO, 2007). Arginine (5.87 to 6.36 g/100 g protein) is an essential amino acid which has direct antioxidant activity (Boger *et al.*, 1996) also necessary for growth in children (Robinson, 1987). Though not essential for adult, but infants may not be able to synthesis the amount required for growth as such some may be needed in infant diets (David, 2006).

Lysine is a major limiting amino acid in most cereals and was presented at 6.85 to 7.25 g/100 g protein in this study, is higher than value reported for *L. cylindrica* seed kernel (2.9 g/100 g protein) (Aremu *et al.,* 2008). This value is higher than what is obtainable in most cereals and can serve as a good complement in diet formulation. NSWP98 had the highest amount of total essential amino acid (52.65 g/100 g protein) while lower value (51.39 g/100 g protein) was observed in NSWP47. The percentage of total essential amino acids is above 39% considered adequate for ideal protein food for infants, 26% for children and 11% for adults (WHO, 1985).

Conclusion

Lima bean varieties studied are good source of proteins, fibre and mineral elements. Besides, they contained high level of essential amino acids which suggest the potential application in infant's food formulation. Therefore, it becomes important to focus on promoting maximal use of locally available inexpensive legume such as lima bean which is highly rich in essential nutrients required for body development.

Acknowledgements

The authors are grateful to the Department of Food Science and Technology, Federal University of Technology Akure, Nigeria, for the provision of facilities. KTS acknowledge with thanks the Post-Graduate Scholarship Award of the Federal Government of Nigeria and OFO is grateful for award of equipment from Alexander von Humboldt Stiftung/Fellowship.

References

Adebowale, Y.A., Adeyemi, I.A. and Oshodi, A.A. 2005. Variability in the physicochemical, nutritional and antinutritional attributes of six mucuna species. Food Chemistry 89: 37-48.

Aguilera, Y., Benítez, V., Mollá, E., Esteban, R.M. and Martín-Cabrejas, M.A. 2011. Influence of dehydration process in castellano chickpea: changes in bioactive carbohydrates and functional properties. Plant Food for Human Nutrition DOI 10.1007/s11130-011-0259-8.

Amza, T., Amadou, I., Zhu, K. and Zhou, H. 2011. Effect of extraction and isolation on physicochemical and functional properties of an underutilised seed protein: Gingerbread plum *(Neocarya macrophylla).* Food Research International 44: 2843–2850.

AOAC 2005. Official Methods of Analysis. Association of Official Analytical Chemists methods, AOAC 18th ed. Washington: AOAC International.

Arawande, J.O. and Borokini, F.B. 2010. Comparative study on the chemical composition and functional properties of three Nigerian legumes. Journal of Emerging Trends in Engineering and Applied Sciences 1: 89-95.

Aremu, M.O., Olaofe, O. and Okiribiti, B.Y. 2008. Chemical evaluation of the nutritive value of smooth luffa *(Luffa cylindrica)* seed's kernel. Electronic Journal of Environment Agriculture and Food Chemistry 7(10): 3444 – 3452.

Aremu, M.O., Olaofe, O.and Akintayo, E.T. 2006. Compositional evaluation of cowpea *(Vigna unquiculata)* and scarlet runner bean *(Phaseolus coccineus)* varieties grown in Nigeria. Journal of Food Agriculture and Environment 4(2): 39–43.

Bassett, C., Boye, J., Tyler, R. and Oomah, B.D. 2010. Molecular, func¬tional and processing characteristics of whole pulses and pulse fractions and their emerging food and nutraceutical applications. Food Research International 43: 397–399.

Bidlingmeyer, B. A., Cohen, S.A. and Tarvin, T. L. 1984. Rapid analysis of amino acids using pre-column derivatisation. Journal of Chromatography 336(1): 93–104.

Boger, R.H., Bode-Boger, S.M., Mugge, A., Klenke, S., Brandes, R., Dwenger, A.and Frollich, J.C. 1996. Supplementation of hypercholesterolemic rabbits with L-Arg reduces the vascular release of superoxide anions and restores no production. Atherosclerosis 117: 273 – 284.

Champ, M., Langkilde, A.M., Bronns, F., Kettlitz, B. and Collet, Y.L.B. 2003. Advances in dietary fibre characterisation, definition of dietary fibre, physiological relevance health benefits and analytical aspects. Nutrition Research Review 16: 71-82.

Chung, H., Liu, Q., Peter, P., Ming, Z. and Rickey, Y. 2008. In vitro starch digestibility, expected glycemic index and some physicochemical properties of starch and flour from common bean (*Phaseolus vulgaris* L.) varieties grown in Canada. Food Research International 111(2): 316-321.

David, A.B. 2006. Benders' dictionary of nutrition and food technology. 8th ed. England: Woodhead.

Ezeagu, I.E. and Ibegbu, M.D. 2010. Biochemical composition and nutritional potential of ukpa: a variety of tropical lima beans *(Phaseolus lunatus)* from Nigeria – a short report. Polish Journal of Food Nutrition and Science 60(3): 231-235.

Flight, I. and Clifton, P. 2006. Cereal grains and legumes in the prevention of coronary heart disease and stroke: a review of the literature. European J ournal of Clinical Nutrition 60: 1145–1159.

Giami, S.Y. 2001. Quality attributes of three new improved lines of Nigerian lima beans *(Phaseolus lunatus* L.Walp.). Plant Foods for Human Nutrition 56: 325–333.

Horax, R., Hettiarachchy, C.P. and Jalaluddin, M. 2004. Preparation and characterisation of protein isolate from cowpea (*Vigna unguiculata* L. Walp). Journal of Food Science 69: 114-121.

Masood, S.B. and Rizwana, B. 2010. Nutritional and functional properties of some promising legumes protein isolates. Pakistan Journal of Nutrition 4: 373-379.

Martin, A.M.M., Samuel, R.M., Israël, L.M. and F.-X Etoa1. 2011. Nutritional potential of bambara bean protein concentrate. Pakistan Journal of Nutrition 10(2): 112-119.

Mortuza, G., Hannan, A. and Tzen, J.T.C. 2009. Chemical composition and functional properties of *Vicia faba* L. from Bangladesh. Bangladesh Journal of Botany 38(1): 93-97.

Nieman, D.C., Butterworth, D.E. and Nieman, C.N. 1992. Nutrition, p. 237-312 Dubuque USA:WmC Brown.

Olaofe, O. and Sanni, C.O. 1988. Mineral content of agricultural products. Food Chemistry 30: 73–77.

Olawuni, I., Ojukwu, M., Iwouno, J.O., Amandikwa, C., Ibeabuchi, C. and Kpaduwa, S. 2013. Effect of pH and temperature on functional physico-chemical properties of asparagus bean *(Vigna sesquipedalis)* flours. International Journal of Basic and Applied Sciences 2 (1):1-16.

Robinson, D.E. 1987. Food biochemistry and nutritional value, p. 327 – 328
England: Longman.

Rochfort, S. and Panozzo, J. 2007. Phytochemicals for health, the role of pulses. Journal of Agriculture Food Chemistry 55:7981–7994.

Sai-Ut, S., Ketnawa, S., Chaiwut, P. and Rawdkuen, S. 2009. Biochemical and functional properties of proteins from red kidney, navy and adzuki beans. Asian Journal of Food Agric-Industry 2(4): 493-404.

Seidu, K.T., Osundahunsi, O.F., Olaleye, M.T.and Oluwalana, I.B. 2014. Chemialcomposition, phytochemical constituents and antioxidant potentials oflimabean seeds coat. Annals Food Science and Technology 15(2): 288 298.

Seidu, K.T., Osundahunsi, O.F., Olaleye, M.T. and Oluwalana, I.B. 2015. Amino acid composition, mineral contents and protein solubility of some lima bean (*Phaseolus lunatus* L. Walp) Seeds Coat. Food Research International 73: 130-134.

Tang, C. H. and Ma, C. Y. 2009. Heat-inducedmodifications in the functional and structural properties of vicilin-rich protein isolate from kidney (*Phaseolus vulgaris* L.) bean. Food Chemistry 115: 859–866.

Tharanathan, R.N. and Mahadevamma, S. 2003. Legumes – a boon to hu¬man nutrition. Trends in Food Science Technology 14: 507–518.

Vasconcelos, I.M., Maia, F.M.M., Farias,D. F., Campello, C. C., Carvalho, A. F. U.,Moreira, R. A. and Oliveira, J. T. A. 2010. Protein fractions, amino acid composition and antinutritional constituents of high-yielding cowpea cultivars. Journal of Food Composition and Analysis 23: 54–60.

WHO 2007. Protein and amino acid requirements in human nutrition; Report of a joint WHO/FAO/UNU Expert Consultation, WHO Technical Report Series no. 935. Geneva: WHO.

WHO 1985. Energy and protein requirements: Report of a joint FAO/WHO/UNU Expert Consultation. WHO Technical Report Series No. 724. Geneva: WHO.