PJN
ISSN 1680-5194

Pakistan Journal of Nutrition

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 10 (11): 1069-1075, 2011
ISSN 1680-5194

Effect of Processing on Chemical Composition of Red Kidney Bean (*Phaseolus vulgaris* L.) Flour

S.S. Audu and M.O. Aremu
Department of Chemistry, Nasarawa State University, P.M.B. 1022, Keffi, Nigeria

Abstract: Proximate, mineral and amino acid compositions of raw and processed red kidney bean (*Phaseolus vulgaris* L.) flour were investigated on dry weight bases with a view to finding alternative and cheaper sources of protein to solve the problem of malnutrition due to inadequate protein in nutrition which is a prevalent problem in developing world, especially in Nigeria. Processing methods (cooking, boiling, roasting, sprouting and fermenting) were adopted using the standard analytical techniques. The processing methods showed deviations in nutrient content from the raw seeds. Crude fat was reduced by some processing methods particularly cooking and boiling while crude protein was enhanced in this order: Roasting > fermenting > boiling > sprouting > cooking. Processing significantly affected the mineral content of the red kidney bean flour ($p \leq 0.05$). Boiling and roasting reduced the content of magnesium by 4.7 and 10.3%, respectively. All the processing methods reduced calcium content. Processed red kidney bean seed flour was found to be a good source of essential minerals, while harmful heavy metals such as lead and cadmium were not detected. The amino acid profile revealed cooking, roasting, sprouting and fermenting to have enhanced Total Amino Acid (TAA), while Total Essential Amino Acid (TEAA) and Total Sulphur Amino Acid (TSAA) were reduced by all the processing methods. After processing of the red kidney bean seed sufficient amount of essential amino acids were retained to meet FAO dietary requirement, but supplementation may be done for raw in Ile, Met + Cys, Thr and Val; boiled (Ile, Met + Cys and Thr); cooked (Met Cys and Val); roasted (Ile, Met + Cys and Val); sprouted and fermented (Met + Cys, Thr and Val).

Key words: Red kidney bean, *Phaseolus vulgaris* L. seed, chemical composition, processing

INTRODUCTION

Recent problems linked with meat consumption as source of protein have led to renewed interest in vegetation diet (George, 2005). This phenomenon is reinforced by the fact that physicians have pointed out that consumers eat too many animal products (rich saturated fat) and not enough plant foods. The consumption of a high quantity of meat increases the risk of cardiovascular diseases and some types of cancer. It is to this end that intensive efforts are being made to find alternative sources of protein from the underutilized leguminous plants in nutrition and in the formulation of new food products (Barker, 1996; Katharine, 2002).

Red kidney bean (*Phaseolus vulgaris*) is a herbaceous annual plant of the family leguminosae. It is domesticated independently in ancient Mesoamerica and the Andes; although widely cultivated in hot climate throughout the world. White and black varieties of these kidney-shaped beans are also available but less widely used (Katharine, 2002). Red kidney is an excellent source of vegetable protein, starch, soluble and insoluble fiber, vitamins (especially B group) and minerals (particularly potassium, iron, zinc, magnesium and manganese). They are very low in fat (Eknayake *et al*., 1999). It has not gained widespread industrial, economic and nutritional importance because its acceptability and utilization have been limited (Nowacki, 1980). The beans contain a potentially toxic substance that can cause food poisoning and this must be destroyed by rapid boiling and thorough cooking (Giamin and Bakebain, 1992). The cooked beans are widely used in savoury cuisine throughout the world, for example, in casseroles, salads, curries, soups, pasta and meat dishes. The straws are used as fodders (Katharine, 2002).

Legumes are important sources of dietary proteins for both human and animals, but the presence of relatively high concentration of toxins such as phytate, tannins and oxalate referred to anti-nutritive factors affects the nutritional quality by interacting with intestinal tract and also reduce protein digestibility and amino acid absorption (Nowacki, 1980). According to Liener (1994) unless these substances are destroyed by heat or other treatments, they can exert adverse physiological effects when ingested by man and animals. Therefore, the work was aimed to determine proximate, mineral and amino acid compositions of raw and processed (boiling, cooing, roasting, sprouting, fermenting) red kidney bean (*Phaseolus vulgaris* L.) with a few to providing preliminary information towards effective utilization of this legume in various food applications.

MATERIALS AND METHODS

Collection and preparation of sample: The red kidney been seeds were purchased from a local farmer in

Corresponding Author: S.S. Audu, Department of Chemistry, Nasarawa State University, P.M.B. 1022, Keffi, Nigeria

Bokkos Local Government Area of Plateau State, Nigeria. The seeds were cleaned and the extraneous materials carefully removed by hand sorting. The good sample was divided into two parts in the ratio 1:5. One part dehulled, kept raw and used as control. The other was processed using the following processing methods; boiling, cooking, roasting, sprouting and fermenting.

Preparation of differently processed red kidney seed flour

Raw sample: 500 g of the raw seeds were soaked in distilled water for 2 h, removed and dehulled manually then dried in an oven at 50°C.

Boiled seeds: The red kidney bean seeds (500 g) were boiled in distilled water at 100°C at a ratio 1:15 wt/vol. for 1 h, after which they were drained and oven dried at 50°C.

Cooked seeds: Five hundred grams of the red kidney bean seeds to 15 parts of distilled water was taken for cooking. The cooking was done using an aluminium pot on a Gallenkamp thermostat hot plate for 2 h. The seeds were considered cooked when they become soft to touch. At the end of the cooking time, the water was drained and the seeds were oven dried.

Roasted seeds: Five hundred grams of the dehulled and dried seeds were roasted on a hot cast iron pan at a temperature of 75-85°C. The seeds were continuously stirred until a characteristic brownish colour is obtained.

Sprouted seeds: Five hundred grams (500 g) of the raw seeds were allowed to germinate using sawdust in a locally woven red basket. The seeds were arranged in layers of sawdust and watered daily for a period of 3-4 days and allowed to sprout to a length of 1cm. the sprouted seeds were then removed, dehulled, washed and dried in an oven at 50°C.

Fermented seeds: The dehulled seeds were wrapped in a blanched banana leaves and allowed to ferment for 4 days. The sample was dried in an oven at 50°C till well dried. At the end of the processing, all the raw and processed seeds were finely ground differently into powder (flour) with a Kenwood blender. They were then stored in airtight containers and kept in a deep freezer (-16°C).

Proximate analyses: The proximate analyses of sample for moisture, crude fat, crude fibre and total ash were carried out in triplicate according to the methods of Association of Official Analytical Chemists (AOAC, 2000). Nitrogen was determined by the micro-Kjeldahl method described by Pearson (1976) and the percentage nitrogen converted to crude protein by multiplying by 6.25. The total carbohydrate content was determined by difference (AOAC, 2000).

Mineral analysis: All the metals were determined by Atomic Absorption Spectrophotometer (Solar 969 Unicam) with exception of sodium and potassium that were determined using a flame photometer (Model 405, Corning UK).

Amino acid analysis: The amino acids were quantitatively measured by the procedure of Spackma *et al.* (1958) using automated amino acid analyzer (Technicon Sequential Multi-sample Analyzer, TSM). Sample was hydrolyzed for determination of all amino acids except tryptophan in consistent boiling hydrochloric acid for 22 h under a nitrogen flush.

Estimation of isoelectric point (pI), quality of dietary protein and Predicted Protein Efficiency Ratio (P-PER): The predicted isoelectric point was evaluated according to Olaofe and Akintayo (2000).

$$pIm = \sum_{i=1}^{n=1} pIiXi$$

Where

pIm = The isoelectric point of the mixture of amino acid

pIi = The isoelectric point of the ith amino acids in the mixture

Xi = The mass or mole fraction of the amino acids in the mixture

The quality of dietary protein was measured by finding the ratio of available amino acids in the protein concentrate compared with needs expressed as a ratio (Olaofe and Akintayo, 2000; FAO, 1970). Amino acid score (AMSS) was then estimated by applying the FAO/WHO (1991) formula:

$$AMSS = \frac{\text{mg of amino in 1g of test protein}}{\text{mg of amino acid in 1g reference protein}} \times \frac{100}{1}$$

The Predicted Protein Efficiency Ratio (P-PER) of the fresh sample was calculated from their amino acid composition based on the equation developed by Alsmayer *et al.* (1974): P-PER = 0.468+0.454 (Leu)-0.105 (Tyr).

Statistical analysis of the samples: Sodium/potassium (Na/K) and calcium/phosphorus Ca/P ratios were calculated or the samples. The energy values were calculated by adding up the carbohydrate x 17 kJ, crude protein x 17 kJ and crude fat x 37 kJ for each of the samples. Errors of three determinations were computed as standard deviation for the proximate composition.

RESULTS AND DISCUSSION

Table 1 shows the proximate composition of the red kidney bean flour. The moisture, ash, crude protein, crude fat, crude fibre and carbohydrate content were reported in percentage of the dry weight. The 2.4%

moisture content of the red kidney beans obtained for the raw seed was low when compared to those values obtained and reported by Olaofe *et al.* (2010) for kidney bean flour (8.80%) and the one reported by Apata and Ologhobo (1994) for Yara-1 variety of kidney bean (6.50%) but compares favourably to that value reported by Aremu *et al.* (2010) for processed kersting's groundnut flour (2.8%). The low moisture content of the red kidney bean seed (*Phaseolus vulgaris* L.) remains an asset in storage and preservation of the nutrients. Onyeike *et al.* (1995) observed that higher moisture content could lead to food spoilage through increasing microbial action. The different processing methods employed in this study increased the moisture content in this order: Cooking < sprouting < roasting < boiling < fermenting. The ash content ranged from 2.0% in sprouted to 4.4% in raw samples. The raw seed water soluble ash of 4.4% is comparable with some reported studies on legumes; 3.0-5.8% of the wild jack bean (Vadivel and Janardhanan, 2001) and also compares well with melon seeds, 3.3% (Omafuvbe *et al.*, 2004) and castor seeds (*Ricinus communis*), 3.2% Onyeike and Acheru, 2002).

The crude fat value of 15.8% for the raw seeds showed that the kidney bean flour has a high fat content when compared with other legumes like cowpea (3.1%), scarlet runner bean (7.5%) kersting's groundnut (5.9%) and bambara groundnut (6.7%) (Aremu *et al.*, 2006) and slightly lower than the value reported for soybean (19.5%) (Temple *et al.*, 1991). The different processing methods used in this study were found to reduce crude fat which is contrary to report by Kingsley (1995) that cooking and fermentation enhance crude fat in African oil bean. The reduction in crude fat content in the boiled and cooked seeds may be due to leaching, while in sprouted seeds may be due to metabolic activity in the seeds (Kylen and McCready, 1975).

Crude protein value of 15.3% of the raw *P. vulgaris* seed (Table 1) is comparable to some commonly consumed plant proteins in Nigeria (Akobundu *et al.*, 1982; Ihekoronye and Ngoddy 1985) though lower to results of selected legumes such as African locust bean (*Parkia biglibosa*) 31.0% (Omafuvbe *et al.*, 2004); wild jack bean (*Canavalia ensiformis*) (28.9-35.0%) (Vadivel and Janardhanan, 2001); velvet bean (*Mucuna pruriens*) (31.4%, Siddhuraju *et al.*, 1996) and Bauhinia monandar (33.0% Anhwange *et al.*, 2005). The different processing methods (boiling, cooking, roasting, sprouting and fermenting) enhanced crude protein content of the red kidney bean flour in this order (roasting > fermenting > boiling > sprouting > cooking).

Crude fibre value of 3.6% for raw red kidney bean flour is higher than those legumes such as cowpea (2.10%) (Giami, 1993), cream coat bambara groundnut (2.1%) (Aremu *et al.*, 2008) but lowers than those of soyabean (4.28%) (Temple *et al.*, 1991), lima bean (5.4%), pigeon pea (4.8%) and jack bean (9.5%) (Apata and Ologhobo, 1994). Cooking, roasting and fermenting increased fibre content by 30.6, 58.3 and 33.3% while boiling decreased it by 36.1%. The increase is within acceptable limit which helps to maintain the health of the gastrointestinal tract, but in excess may bind trace elements, leading to deficiencies of iron and zinc (Siddhuraju *et al.*, 1996). Carbohydrate as Nitrogen Free Extract (NFE) calculated by difference accounted for 49.0% in the raw seed flour. The carbohydrate content suggests that the seed could be a good supplement to scarce cereal grains as sources of energy and feed formulations. The carbohydrate value compares well with the range values of 44.6-47.4% of different varieties of Sesbania seeds reported by Hossain and Becker (2001) and 43.3-60.3% reported for the jack bean (Ajah and Madubuike, 1997). All the processing methods increased the carbohydrate content (Table 1). The values are higher than those of soybean (26.3%) as reported by Temple *et al.* (1991), cranberry beans (31.5%) (Aremu *et al.*, 2006) but lower than those reported for lima bean (66.9%), pigeon pea (66.8%) and jack bean (57.3%) (Oshodi *et al.*, 1998). The calculated metabolizable energy and fatty acids values for the raw red kidney bean seed flour were 1678.4 kJ/100g and 12.7%, respectively. The metabolizable energy in this study showed that the sample has an energy concentration more favourable than cereals (Adeyeye and Aye, 1998) while the fatty acid suggest that the oil may be edible and suitable for industrial purposes (Aremu *et al.*, 2006). The values for metabolizable energy compare favourable well with those reported for some legumes such as bambara

Table 1: Mean proximate composition (%)[a] of raw and processed red kidney bean

Parameter	Raw	Boiled	Cooked	Roasted	Sprouted	Fermented
Moisture	2.4±0.23	3.2±0.23	2.9±0.50	3.1±0.50	3.0±1.50	3.3±5.20
Ash	4.4±0.52	2.2±5.20	2.7±2.50	3.4±0.30	2.0±0.50	2.2±0.60
Fat	15.8±0.10	10.3±1.20	10.2±0.60	14.1±2.50	11.6±0.60	11.4±0.70
Crude protein	15.3±0.20	23.6±1.50	18.4±0.53	27.3±1.20	20.1±2.30	26.1±2.30
Crude fibre	3.6±0.50	2.3±0.30	4.7±0.35	5.7±1.31	3.6±0.50	4.8±0.50
[b]Carbohydrate	49.0±0.50	58.5±0.20	61.1±1.10	50.3±0.50	59.7±0.50	49.7±4.50
[c]Energy (kJ/100 g^{-1})	1678.4	1775.2	1549.5	1840.90	1599.2	1709.6
[d]Fatty acids	12.7	8.2	5.8	11.3	9.3	9.1

[a]Each value represents the mean±standard deviation of three replicate determinations.

[b]Carbohydrate percent calculated as the (100-total of other components).

[c]Calculated fatty acids (0.8 x crude fat).

[d]Calculated metabolizable energy (kJ 100 g^{-1}) (protein x 17 + fat x 37 + carbohydrate x 17)

groundnut (1691.3 J/100 g), kersting's groundnut (1692.9 kJ/100 g) cranberry beans (1,651.7 kJ/100 g) (Aremu *et al*., 2006). Changes in energy and fatty acid values of both raw and processed seeds of red kidney bean reflect changes in the observed values of other proximate composition as discussed earlier.

Table 2 presents the mineral content of the red kidney bean seed flour. The most abundant mineral in the raw seed flour sample was magnesium (820.9 mg/100 g), calcium (54.9 mg/100 g), while the least concentrated one was copper (0.7 mg/100 g). The seeds of red kidney bean were also rich sources of the following nutritional valuable minerals: K (14.5 mg/100 g) and Fe (11.5 mg/100 g). The concentrated values of phosphorus (3.7 mg/100 g), calcium and magnesium would make red kidney bean suitable for bone formation for children. The value for magnesium in the raw flour sample is higher than values reported by most authors for some legume seeds (Oshodi *et al*., 1998; Aremu *et al*., 2008; 2010). Furthermore contradicts the report by Olaofe and Sanni (1998) that potassium is the most abundant mineral in agricultural products. Processing significantly affected the content of some minerals in the seed flour ($p<0.05$). All the processing methods (boiling, cooking, roasting, sprouting and fermenting) reduced magnesium, phosphorus, calcium and sodium. Magnesium is an activator of many enzyme systems and maintains the electrical potential in nerves (Shills and Young, 1992). Phosphorus is always found with calcium in the body, both contributing to the blood formation and supportive structure of the body (Ogunlade *et al*., 2005). Modern foods rich in animal protein and phosphorus can promote the loss of calcium in urine (Shills and Young, 1992). This led to the concept of calcium phosphorus ratio. If the Ca/P ratio is low, calcium will be low and there will be high phosphorus intake which leads to calcium loss in the urine more than normal. If the Ca/P ratio of any food is above one that food is considered "good" and "poor" if the ratio is less that 0.5, while a Ca/P ratio above two helps to increase the absorption of calcium in the small intestine. The results of Ca/P ratio in the studied samples was very high especially in processed samples (boiled, cooked and fermented).

Sodium and potassium are required for the maintenance of osmotic balance of the body fluids, the pH of the body to regulate muscles and nerves irritability, control glucose absorption and enhance normal retention of protein during growth (NRC, 1989). The sodium to potassium ratio in the body is of great concern for the prevention of high blood pressure. The Na/K ratio of less than one is recommended. The Na/K ratios for the raw and processed seeds were all above the recommended level. Only the roasted sample has the Na/K ratio less than one. This suggests that all the samples may not have capacity to prevent blood pressure.

Leucine was the most concentrated (7.2-8.2 g/100 g crude protein) essential amino acid while glutamic acid was the most concentrated amino acid (10.2 g/100 g) in the raw red kidney flour sample as is expected in legumes (Olaofe *et al*., 1993; Oshodi *et al*., 1998; Aremu *et al*., 2006). Tryptophan concentrations could not be determined (Table 3), the value of leucine obtained in this study agrees and compares favourably with values obtained by some workers on studies of some Nigerian legumes; lima bean (7.59 g/100 g protein), pigeon pea (8.40 g/100 g protein) and African yam bean (7.45 g/100 g protein) reported by Oshodi *et al*. (1998). Glutamic and aspartic amino acids made up (19.7 g/100 g protein) as the most abundant amino acids in the plant food sample even as reported by some workers (Aremu *et al*., 2006; Adeyeye, 2004; Olaofe *et al*., 1994; Oshodi *et al*., 1998). The least concentrated amino acid is cystine (12 g/100 g) protein in the raw sample while methionine (0.9-1.7 g/100 g) is the least in the processed flour samples of the red kidney bean. Boiling method in this study enhanced Leu, Phe + Tyr and Val which showed an increase of 9.7, 5.2 and 2.0% respectively and reduced the contents of Ile, Met, Thr and Arg by 16.22, 41.18, 2.94 and 11.59%. The other essential amino acids (lysine

Table 2: Mean mineral composition (%) of raw and processed red kidney bean

Mineral	Raw	Boiled	Cooked	Roasted	Sprouted	Fermented
Ca	54.9	47.3	56.3	3.78	46.5	54.2
Ni	4.3	4.5	2.4	2.6	2.9	2.8
Zn	2.7	2.9	3.0	2.1	3.2	2.3
Mn	1.7	1.1	1.6	1.3	2.2	1.2
Cu	0.7	0.7	1.2	0.6	0.9	0.2
Fe	11.5	11.8	10.5	11.0	10.9	7.4
Cr	2.9	2.0	2.1	0.9	2.2	2.0
Cd	N.D	N.D	N.D	N.D	N.D	N.D
Pb	0.01	N.D	N.D	N.D	N.D	N.D
Na	33.0	24.2	23.4	16.4	21.0	24.0
K	14.5	13.3	11.0	15.5	3.8	14.1
P	3.7	2.1	2.7	3.1	3.6	3.3
Na/K	2.3	1.8	2.1	1.1	5.5	1.7
Ca/P	15.0	23.1	21.4	12.4	12.9	16.4
Mg	820.9	782.2	762.2	736.3	751.3	740.0

Na/K = Sodium to potassium ratio; Ca/P = Calcium to phosphorus ratio

Table 3: Mean amino composition (g/100 g crude protein) of raw and processed red kidney bean

Amino	Raw	Boiled	Cooked	Roasted	Sprouted	Fermented
Lysine (Lys)[a]	7.0	7.0	6.2	7.3	6.6	6.9
Histidine (His)[a]	3.0	3.0	2.6	3.1	3.1	3.5
Arginine (Arg)[a]	6.9	6.1	6.8	5.4	6.0	5.9
Aspartic acid (Asp)	9.5	8.4	9.9	9.5	8.5	8.9
Threonine (Thr)[a]	3.4	3.3	4.2	3.7	3.1	3.2
Serine (Ser)	3.1	3.1	3.3	3.2	3.1	3.8
Glutamic acid (Glu)	10.2	10.2	12.6	14.1	14.0	14.4
Proline (Pro)	3.3	3.4	3.2	3.0	5.1	3.2
Glycine (Gly)	5.2	3.6	3.7	4.7	3.7	5.2
Alanine (Ala)	4.4	3.7	3.8	3.6	4.3	3.2
Cystine (Cys)	1.2	1.0	1.4	1.3	1.5	1.1
Valine (Val)[a]	4.1	5.1	4.6	4.2	4.2	4.2
Methionine (Met)[a]	1.7	1.0	1.3	0.9	1.2	0.9
Isoleucine (Ile)[a]	3.7	3.1	4.1	3.1	3.9	3.7
Leucine (Leu)[a]	7.2	7.9	7.0	7.8	7.5	8.2
Tyrosine (Tyr)	3.1	2.9	3.2	2.9	3.1	3.1
Phenylalanine (Phe)[a]	4.6	5.2	4.5	4.1	5.2	4.4
pI[b]	4.9	4.7	4.8	4.1	4.9	4.9
P-PER[c]	2.5	2.8	2.4	2.8	2.6	2.9

[a]Essential amino acid; [b]Isoelectric point; [c]P-PER = Calculated predicted protein efficient ratio

and histidine) were not significantly affected by this processing method. Cooking, roasting, sprouting and fermenting reduced the concentration of most of the essential amino acids except Ile, Leu, Val and Thr; roasting (Lys, His, Thr, Val and Leu); sprouting (His, Val, Leu and Phe); fermenting (His and Val) while on Leu, Phe and Ile, there was no significant effect. Transamination and deamination reactions might be responsible for the slight changes in the amino acid profiles of raw and processed red kidney bean seed flours (Aremu *et al.*, 2009).

The calculated isoelectric point (pI) ranged from 4.1 in roasted seed to 4.9 in the raw seed. This is useful in predicting the pI for protein in order to enhance a quick precipitation of protein isolate from biological samples (Olaofe and Akintayo, 2000). The Predicted Protein Efficiency Ratio (P-PER) is one of the quality parameters used for protein evaluation (FAO/WHO, 1991). The P-PER values in this report ranged from 2.4 in cooked seed to 2.9 in fermented seed. These values are higher than the reported P-PER values of some legume flours/concentrates: *Prosopis africans* (Guill. and Pen.) (2.3) (Aremu *et al.*, 2007), *Lathynis sativus* L. (1.03) (Salunkhe and Kadam, 1998) and *Phaseolus coccineus* (1.91) (Aremu *et al.*, 2008). However, P-PER in the processed red kidney bean seed under study satisfied FAO requirements (FAO/WHO/UNU, 1985).

Nutritive value of a protein depends primarily on its capacity to satisfy the needs for nitrogen and essential amino acids (Oshodi *et al.*, 1998); evaluation report on amino acids based on classification of differently processed red kidney bean seed is shown on Table 4. Total Amino Acids (TAA), Total Essential Amino Acids (TEAA) with His and Total Sulphur Amino Acids (TSAA) of raw seeds were 81.6, 41.5 and 2.9 g/100 g crude protein respectively. Cooking, roasting, sprouting and fermenting enhanced TAA while boiling reduced it. All the processing methods reduced TEAA and TSAA with exception of boiling that increased TAA with His. The TSAA for any of the processed seed flours is lower than the 5.8 g/100 g protein recommended for infants (FAO/WHO/UNU, 1985). The Essential Aromatic Amino Acid (EArAA) varied between 4.1 g/100 g protein in the roasted seed to 5.2 g/100 g protein in boiled and sprouted seed. These values are slightly below the range suggested for infant protein (6.8-11.8 g/100 g) (FAO/WHO/UNU, 1985). Table 4 also shows that Total Acid amino Acid (TAAA) in all the samples which have been found to be greater than Total Basic Amino Acid (TBAA), indicates that the protein is probably acidic in nature (Aremu *et al.*, 2006). The percentage Total Essential Amino Acid (%TEAA) ranged from 58.3% in boiled seed to 60.4% in roasted seed. These values are comparable with that of egg (50%) (FAO/WHO, 1991), *Vigna subterranean* (L.) Verdc. concentrate (49.7%) (Aremu *et al.*, 2008) and beach pea protein isolate (44.4%) (Chavan *et al.*, 2011). With the exception of Leu, Lys, Phe + Tyr and Thr in cooked seeds of the red kidney bean seed flour, the content of essential amino acid are lower than FAO/WHO (1991) recommendations (Table 5). The number of essential amino acids that are higher than the FAO/WHO (1991) recommendation increased from three in raw, roasted and fermented seed to four in boiled and sprouted and to five in cooked. The reason for these changes is that early in the cooking/boiling process there is loss of toxic activity, particularly of the proteinaceous toxins, trypsing inhibitors and haemagglutining (Liener, 1980). As heating proceeds, protein quality increases to a maximum before declining again with continued heating; thus reduction is likely to be related to increasing Maillard browning causing lysine to be rendered unavailable (Aremu *et al.*, 2010). Thus for a healthy diet, based on some methods of processing red kidney bean will require

Table 4: Amino acid composition (g/100 g crude protein) of raw and processed red kidney bean

Amino acid	Raw	Boiled	Cooked	Roasted	Sprouted	Fermented
Total Amino Acid (TAA)	81.6	78.0	82.2	81.9	84.4	83.8
Total non-essential amino acids (TNEAA)	40.0	36.3	40.9	42.3	43.3	42.9
% TNEAA	49.0	46.5	49.8	51.6	51.5	51.2
Total essential Amino Acid (TEAA)						
With histidine	41.5	41.7	41.3	39.6	40.8	40.9
Without histidine	38.6	38.7	38.7	36.5	37.7	37.4
% TEAA						
With histidine	51.4	58.3	58.7	60.4	59.2	59.1
Without histidine	47.3	49.6	47.1	45.6	44.8	44.6
Essential Aliphatic Amino Acid (EAAA)	18.4	19.4	19.9	18.8	18.7	19.3
Essential Aromatic Acid (EArAA)	4.6	5.2	4.5	4.1	5.2	4.4
Total Neutral Amino Acid (TNAA)	45.2	43.3	44.3	42.5	45.9	44.2
% TNAA	55.4	55.5	53.9	51.9	52.2	52.7
Total Acidic Amino Acid (TAAA)	19.7	18.6	22.3	23.6	22.5	23.3
% TAAA	24.1	23.8	27.1	28.8	26.8	27.8
Total Basic Aino Acid (TBAA)	16.7	16.1	15.6	15.8	15.7	16.3
% TBAA	20.5	20.6	19.0	19.3	18.7	19.5
Total Sulphur Amino Acid (TSAA)	2.9	2.0	2.7	2.2	2.7	2.0
% Cystine in TSAA	41.4	50.0	51.9	59.1	55.6	55.0

Table 5: Amino acid score of raw and processed red kidney bean

	PAAESP[a] (g/100 g	Raw		Boiled		Cooked		Roasted		Sprouted		Fermented	
EAA	protein)	EAAC	AAS	EAAC	AAS	EAAC	AAS	EAAC	AAS	EAAC	AAS	EAAC	AAS
Ile	4.0	3.7	0.9	3.1	0.8	4.1	1.0	3.1	0.8	3.9	1.0	3.7	0.9
Leu	7.0	7.2	1.0	7.9	1.1	7.0	1.0	7.8	1.1	7.5	1.1	8.2	1.2
Lys	5.5	7.0	1.3	7.0	1.3	6.2	1.2	7.3	1.3	6.6	1.2	6.9	1.3
Met + Cys (TSAA)	3.5	2.9	0.8	2.0	0.6	2.7	0.8	2.2	0.6	2.7	0.8	2.0	0.6
Phe + Tyr	6.0	7.7	1.3	8.1	1.4	7.7	1.3	7.0	1.2	8.3	1.4	7.5	1.3
Thr	4.0	3.4	0.9	3.3	0.8	4.2	1.1	3.7	0.9	3.1	0.9	3.2	0.8
Try	1.0	-	-	-	-	-	-	-	-	-	-	-	-
Val	5.0	4.1	0.8	5.1	1.0	4.6	0.9	4.2	0.8	4.2	0.8	4.2	0.8
Total	36.0	29.0	5.7	24.4	5.7	30.3	6.1	28	5.4	29.7	5.1	28.8	5.6

EAA = Essential Amino Acid; PAAESP = Provisional Amino Acid (Egg) Scoring Pattern; EAAC = Essential Amino Acid Composition (see Table 3); AAS = Amino Acid Scores; - = Not Determined. [a]Source = Belschant *et al.* (1975)

supplementation with essential amino acids such as Ile, Met + Cys, Thr and Val for the raw, roasted and fermented seeds; Ile, Met + Cys and Thr (boiled); TSAA (cooked); TSAA, Thr and Val (sprouted) since Try was not determined. It has been reported that the essential amino acids most often acting in a limiting capacity are Met (and Cys), Lys and Try. However, TSAA and Val were the first Limiting Amino Acids (LAA) for the raw and sprouted, while boiled, cooked, roasted and fermented samples have TSAA as first LAA (Table 5).

REFERENCES

Adeyeye, E.I., 2004. The chemical composition of liquid and solid endosperm of ripe coconut. Oriental J. Chem., 20: 471-478.

Adeyeye, E.I. and P.A. Aye, 1998. The effects of sample preparation on the proximate composition and the functional properties of the African yam bean flours. Note I. La Rivista Italiana Delle Sostanze Grasse, 75: 253-261.

Ajah, P.O. and F.N. Madubiuke, 1997. The proximate composition of some tropical legume seeds grown in two States of Nigeria. Food Chem., 49: 333-338.

Akobundu, E.N.T., J.P. Cherry and J.G. Simmon, 1982. Chemical, functional and nutritional properties of 'Egusi' (*Colocynthis citrullus*) seed protein products. J. Food Sci., 47: 828-835.

Alsmayer, R.H., A.E. Cunningham and M.L. Hapich, 1974. Equation to predict PER from amino acid analysis. Food Tech., 28: 34-38.

Anhwange, B.A., V.O. Ajibola and S.J. Oniye, 2005. Nutritional potential of seeds of Bauhinia monandra (linn)., J. Food Tech., 3: 204-208.

AOAC, 2000. Association of Official Analytical Chemists. 16th edn. Washington, D.C.

Apata, D.F. and A.D. Ologhobo, 1994. Biochemical evaluation of some Nigerian legume seeds. Food Chem., 49: 333-338.

Aremu, M.O. and O. Olaofe, 2008. Protein and amino acid composition of some legumes grown in Nigeria. A review, Int. J. Chem. Sci., 1: 128-139.

Aremu, M.O., O. Olaofe and C.A. Orjioke, 2008. Chemical composition of bambara groundnut (*vigna subterranean*). Kersting, groundnut (*Kerstingiella geocarpa*) and scarlet runner bean (*phaseolus coccineus*) protein concentrates. La Rivista Taliana Delle Sostanze Grasse, 85: 56-62.

Aremu, M.O., O. Olaofe, S.K. Basu, G. Abdulazeez and S.N. Acharya, 2010. Processed cranberry bean (*Phaseolus coccineus* L.) seed flour for African diet. Can. J. Plant Sci., 90: 719-728.

Aremu, M.O., O.Olaofe and E.T.Akintayo, 2006. Chemical composition and physicochemical characteristic of two varieties of bambara groundnut (*vigna subterranean*). Flours. J. Appl. Sci., 6: 1900-1903.

Aremu, M.O., B.O. Atolaiye, G.R.E. Pennap and B.T. Ashika'a, 2007. Proximate and amino acid composition of mesquite bean (*Prosopis africana*) protein concentrate. Ind. J. Bot. Res., 3: 97-102.

Aremu, M.O., Y.E. Olayioye and P.P. Ikokoh, 2009. Effects of processing on nutritional quality of kersting's groundnut (*Kerstingiella geocarpa L.*) seed flours. J. Chem. Society., 34: 140-149.

Barker, B., 1996. Wild plants for human nutrition in the Sahelian zone. J. Sand Environ., 11: 61-63.

Belschant, A.A., C.K. Lyon and G.O. Kohler, 1975. Sunflower, safflower, sesame and castor proteins. In: Food Protein Sources, N. W. Pirie (ed.), University Press Cambridge, UK, pp: 79-104.

Chavan, U.D., D.B. McKenzie and F. Shahidi, 2011. Nutritional evaluation of beach pea protein isolate. Food Chem., 74: 177-181.

Eknayake, S., E.R. Jansz and B.M. Nasir, 1999. Proximate composition, mineral and amino acid content of nature *Canavalla gladiate* seeds. Food Chem., 66: 119.

FAO, 1970. Amino acid content of foods and biological data in protein. FAO nutritional studies, No. 24, FAO, Rome.

FAO/WHO/UNU, 1985. Energy and protein requirement. Report of a joint FAO/WHO/UNU Expert Consultation World Health Organization Technical Report Series 724, WHO Geneva, Switzerland.

FAO/WHO, 1991. Protein quality evaluation report of joint FAO/WHO expert consultative FAO, food and Nutrient.

George, D., 2005. Pamplona-Roger, M.D., 2005. Foods for reproduction. Encyclopedia of foods and their healing power, 2: 264-274.

Giami, S.Y., 1993. Effect of processing on the proximate composition and functional properties of cowpea (*Vigna unguiculata*) flour. Food Chem., 47: 153-158.

Giamin, S.Y. and O.A. Bakebain, 1992. Proximate composition and functional properties of raw and processed full fat fluted pumpkin (*Telfaria occidentalis*) seed flour. J. Sci. Food Agric., 59: 321-325.

Hossain, M.A. and K. Becker, 2001. Nutrititive value and antinutritional factors in different varieties of *Sesbani* seeds and their morphological fractions. Food Chem. 73: 421-431.

Ihekoronye, A.I. and P.O. Ngoddy, 1985. Integrated Food Science and Technology for the Tropics. Macmillan, London, UK.

Katharine, W., 2002. Healing foods Newlanark, MLII9DJ. Scotland.

Kingsley, M.O., 1995. Effect of processing on some anti nutritive and toxic components and on the nutritional composition of the African oil bean seed (*Pentaclethra macrophylla Benth*). J. Sci. Food Aric., 68: 153-158.

Kylen, M. and R.M. McCready, 1975. Nutrient in seeds and sprouts of alfalfa lents/s, mug beans and soybeans. J. Food Sci., 40: 1008-1013.

Liener, I.E. (ed.), 1980. Toxic Constituents of Plantstuffs. 2nd edn. Academic Press, New York, NY.

Liener, I.E., 1994. Implications of antinutritional components in soya bean foods. CRC Critical Reviews in Food Science and Nutrition.

Nowacki, K., 1980. Heat stable anti-nutritional factors in leguminous plants Summefield, R.J., Buntong, A.H., (ed.). Advances in legume science, Kew: Royal Botanical Gardens, pp: 171-177.

National Research Council (NRC), 1989. Recommeded dietary allowances. 10th ed. National Academic Press, Washington DC.

Ogunlade, I., O. Olaofe and I. Fadare, 2005. Chemical composition, amino acids and nutritional properties of selected seafoods. J. Food Agric. Environ., 3: 130-133.

Olaofe, O., O.Y. Umar and G.O. Adediran, 1993. The effect of nematicides on the nutritive value and functional properties of cowpea seeds. Food Chem., 46: 337-342.

Olaofe, O. and C.O. Sanni, 1998. Mineral contents of agricultural products. Fd. Chem., 30: 7377.

Olaofe, O. and E.T. Akintayo, 2000. Prediction of isoelectric points of legumes and oil seed proteins from amino acid composition. J. Techno. Sci., 4: 49-53.

Olaofe, O., F.O. Adayemi and G.O. Adediran, 1994. Amino acid and mineral composition and functional properties of some oil seeds. J. Agric Food Chem., 42: 878-881.

Olaofe, O., J.A. Famurewa and A.O. Ekuagbere, 2010. Chemical and functional properties of kidney bean seed (Phaseolus vulgaris L.) flour. Int. J. Chem. Sci., 3: 51-69.

Omafuvbe, B.O., O.S. Falade and S.R.A. Adewusi, 2004. Chemical and Biochemical changes in African locust bean (Parkia biglibosa) and melon (Citrullus vilgaris) seeds during fermentation to condiments. Pak. J. Nutr., 3: 140-145.

Onyeike, E.N. and G.N. Acheru, 2002. Chemical composition of selected Nigerian oil seeds and physicochemical properties of the oil extracts. Food Chem., 77: 431-437.

Onyeike, E.N., T. Olungwe and A.A. Uwakwe, 1995. Effect of heat treatment and defatting on the proximate composition of some Nigerian local soup thickners. Food Chem., 53: 173-175.

Oshodi, A.A., K.O. Esuoso and E.T. Akintayo, 1998. Proximate and amino acid composition of some under–utilized legume flour and protein concentrates. La Rivista Italiana Delle Sostanze Grasse, Vol. LXXV-Agosto, 409-412.

Pearson, D., 1976. Chemical analysis of foods, 7th edn. J. & A. Churchill, London: 204-239.

Shills, M.Y.G. and V.R. Young, 1992. Modern nutrition in health and disease. D.C. Nieman, D.E. Butterworth and C.N. Nieman. (ed). Nutrition. Wm. C . Brown publishers, Dubugue, U.S.A., PP: 276-282.

Siddhuraju, P., K. Vijayakumari and K. Janardhanan, 1996. Chemical composition and protein quality of little known legume, velvet bean (*Mucuna pruriens* (L) DC). J. Agric. Food chem., 44: 2636-2641.

Salunkhe, D.K. and S.S. Kadam, 1998. Handbook of World Food Legumes: Nutritional, Chemistry, Processing, Technology and Utilization. CRC Press, Boca Raton, FL.

Spackma, D.H., W.H. Stein and S. Mare, 1958. Automatic recording apparatus for use in the chromatography of amino acids. Anal. Chem., 301: 1185-1190.

Temple, V.J., L. Odewumi and K. Joseph, 1991. Soyabeans and soyabeans based diets. Proceedings of the 3rd regional workshop on rural development, Jos, pp: 45-50.

Vadivel, V. and K. Janardhanan, 2001. Nutritional and anti-nutritional attributes of the under-utilized legume Cassiafloribundacar Food Chem., 73: 286-296.