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Nutritional quality assessment of commonly sold steamed bambara groundnut (*Vigna subterranea* L. Verdc) pastes in Lafia motor parks, Nasarawa state, Nigeria

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Abstract

The proximate, amino acid, and mineral compositions of commonly sold steamed bambara groundnut pastes in two different motor parks (SBGM and SBGJ) were investigated using standard procedures and methods. The respective proximate composition values (g/100g sample) of SBGM and SBGJ were: moisture (3.02 and 3.57), ash (7.13 and 7.69), crude fat (14.98 and 18.94), crude protein (21.46 and 19.34), crude fibre (5.90 and 7.34), and carbohydrate by difference (47.53 and 43.14). The most abundant minerals in the samples were potassium (219.63 and 232.86 mg/100g), followed by sodium (164.25 and 158.41 mg/100g). The amino acid profile of the proteins revealed that both samples contained nutritionally beneficialquantities of most essential amino acids. The total essential amino acid (TEAA) (with His) was 42.89 and 45.08g/100g for SBGM and SBGJ samples, respectively. The calculated isoelectric point (pI) and predicted protein efficiency ratio (P-PER) for the samples were (4.22 and 5.18) and (2.08 and 2.45). Valine was the first limiting amino acid in both samples.

Keywords: Steam Bambara groundnut paste; Proximate; Minerals; Amino acids; Amino acid analyzer

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Introduction

Bambara groundnut (*Vigna subterranea*) is a novel African legume grown primarily by subsistence farmers in the intercropping system as it increases the crop yield (Aremu *et al.,* 2016; Tan *et al.,* 2020). It is regarded as a poor man's crop and cultivated well in Africa, particularly Nigeria, which produces about one-third of its annual production (Mayes *et al.,* 2019; Khan *et al.,* 2021). Bambara groundnut is the third most important crop in Africa after groundnut and cowpea (Bamshaiye *et al.,* 2011). Although presently underutilized, Bambara groundnut can be consideredan essential crop due to its high adaptability in different growing conditions and ability to produce a reasonable yield under stressful environmental conditions (Feldman *et al.,* 2019; Mayes *et al.,* 2019). The nut effectively promotes nutrition, increases food security, fosters pastoral improvement, and bolsters sustainable land uses.

Due to its good nutritional contents of proteins, fats, carbohydrates, and minerals, Bambara groundnut is regarded as a completely balanced diet (Tan *et al.,* 2020; Khan *et al.,* 2021). The seed contains 53-70% carbohydrates, 18-25 % proteins, 3-9.7% lipids, 3-12 % fiber and 3-5% ash (Bamshaiye *et al.,* 2011; Hillocks *et al.,* 2012; Halimi *et al.,* 2019).

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Potassium, magnesium, calcium, phosphorus, zinc, and iron were reported as the most abundant minerals in the Bambara nut (Aremu*et al.,* 2006a; Yao *et al.,* 2015; Oyeyinka *et al.,* 2019; Hussin *et al.,* 2020; Qaku *et al.,* 2020).

Based on its composition, Bambara nut can be an important source of affordable protein in diets, particularly in areas where animal protein is expensive. The nut is richer in essential amino acids than other legumes, with a higher protein score (80%) than soya bean (74%) and cowpea (64%) (Plahar and Yawson, 2004; Mubaiwa*et al.,* 2018). Leucine and lysine were reported as the most abundant essential amino acids, while tryptophan has been found the limiting amino acid. However, Bambara nut is poor in sulfur-containing amino acids (methionine and cysteine). Therefore, it is nutritionally recommended to complement cereal-based staple foods that lack lysine but is rich in methionine and cysteine with Bambara nut as a protein source (Boye *et al.,* 2010; Yao *et al.,* 2015; Adebiyi *et al.,* 2019; Hussin *et al.,* 2020).

After roasting or boiling, Bambara groundnut is commonly consumed as a snack food (Murevanhema and Jideani, 2013; Mubaiwa *et al.,* 2018). The seeds and flour have also been used to make various traditional foods in different parts of Africa (Ndidi *et al.,* 2014; Mubaiwa *et al.,* 2018; Bultosa *et al.,* 2020; Mbosso *et al.,* 2020). Bambara groundnut is frequently combined with cereals such as maize and millet to prepare local delicacies (Murevanhema and Jdeani, 2013; Mbosso *et al.,* 2020), which helps to improve protein quality. In Nigeria, especially in the East, Bambara groundnut is used in various recipes. The seeds are roasted, ground, and used to make soup, or they are roasted and chewed with palm kernels (Mayes *et al.,* 2019). Fresh immature green seed is produced and consumed raw or cooked as a vegetable, whereas Bambara groundnut flour is processed with red palm oil to make the famous 'okpa' (steamed Bambara groundnut pudding).

Steam Bambara groundnut paste (okpa) is a well-cherish recipe in Nigeria traditionally eaten alone or with cereal gruel/porridge for breakfast. However, some processing techniques can affect the nutritional values of food products. In addition, there are reported incidences of contamination and adulteration of Bambara groundnut flour used for making okpa. Therefore, based on nutritional security, we aimed to assess the qualities of steam Bambara groundnut pastes sold in Lafia motor parks, Nasarawa state, Nigeria. To the best of our knowledge, this study will be the first of its kind that evaluates the nutritional qualities of 'okpa' sold in the middle belt region of Nigeria.

Materials and methods

Collection of samples

Steamed Bambara groundnut pastes (Okpa) (Fig 1) were purchased from Vendors at Lafia motor parks in MakurdiRoad (SBGM) and Jos Road (SBGJ). The samples were stored in a plastic container and immediately taken to the laboratory for preparation and analysis.

Preparation of samples

The steamed Bambara groundnut pastes purchased from the motor parks were oven-dried in a hot air oven for 48 h at 65^{0}C and ground into powdery form with clean, dried mortar and pestle. The powdered samples were then collected, stored in a dry sealed plastic container,and kept inside the refrigerator at -4^{0}C for further analysis.

Fig. 1. Steamed Bambara groundnut paste (Okpa)

Proximate analysis

The ash, moisture, crude fat, crude protein (N x 6.25), crude fiber, and carbohydrate (by difference) were determined following the standard methods of AOAC (2007). All proximate analyses of the sample flours were carried out in triplicate and reported in percentage. All chemicals were of analytical grade.

Mineral analysis

A flame photometer (Model 405, Corning UK) was used to determine the concentration of potassium and sodium, while phosphorus was determined by the Vanadomolybdate colorimetric method (James, 1996). All other metals were determined by atomic absorption spectrophotometer (Perkin–Elmer Model 403, Norwalk CT). All the minerals determined were reported in mg/100 g sample.

Amino acid analysis

The amino acid analysis was done by Ion Exchange Chromatography (IEC) (FAO/WHO, 1991) using the Technico Sequential Multisample (TSM) Amino Acid Analyzer (Technicon Instruments Corporation, New York). The period of analysis was 76 min for each sample. The gas flow rate was 0.50 mL min^{-1} at 60^{o}C with reproducibility consistent within ± 3%. The net height of each peak produced by the chart recorder of the TSM (each representing an amino acid) was measured and calculated. Amino acid values reported were the averages of two determinations. Nor–leucine was the internal standard. Tryptophan was determined after alkali (NaOH) hydrolysis by the colorimetric method (Freidman and Finely, 1971).

Determination 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):

$$pIm = \sum_{i=1}^{n=1} pIiXi \text{ ------------------ } (1)$$

Where:

pIm = the isoelectric point of the mixture of amino acids;

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 sample protein compared with the needs expressed as a ratio. Amino acid score (AAS) was then estimated by applying the FAO/WHO (1991) formula:

$$AAS = \frac{mg\ of\ amino\ acid\ in\ 1g\ of\ test\ protein}{mg\ of\ amino\ acid\ in\ reference\ protein} \times 100/1 \text{ ---(2)}$$

The predicted protein efficiency ratio (P–PER) of the seed sample was calculated from their amino acid composition based on the equation developed by Alsmeyer *et al.* (1974) as stated thus;

P–PER = –0.468 + 0.454(Leu) – 0.105(Tyr) ----- (3)

Statistical analysis of the samples

The fatty acid values were obtained by multiplying crude fat value of each sample with a factor of 0.8 (i.e. crude fat x 0.8 = corresponding to fatty acids value (Paul and Southgate, 1978). The energy values were calculated by adding up the carbohydrate x 17kJ, crude protein x 17kJ, and crude fat x 37kJ for each sample (Kilgore, 1987). Errors of three determinations were computed as standard deviation (SD) for the proximate composition. Mean, SD, and CV% were determined for the variability test between the two samples.

Results and discussion

The proximate composition of the two steamed Bambara groundnut pastes collected from vendors at Lafia motor parks in Markudi road (SBGM) and Jos Road (SBGJ) is shown in Table I. Significant differences were observed ($p < 0.05$) in all the proximate parameters measured. The samples were characterized by low moisture contents of 3.02±0.73 and 3.57±0.16 g/100g for SBGM and SBGJ, respectively. Although the values were low, but were within the recommended dietary allowance (RDA) (3 – 10) (NRC, 1989). The observed moisture content in the samples suggests that the activity of the microorganisms will be reduced, potentially increasing the shelf-life of the steamed Bambara groundnut. SBGJ exhibited the highest ash content (7.69±0.18 g/100g) compared to SBGM (7.13±0.09 g/100g). The results are favorably compared with the reported ash content of some leguminous crops, such as red kidney bean (3.0-5.8%) (Audu and Aremu, 2011), mung bean (3.78%) (Mubarak, 2005), mucuna bean (3.5%) (Mugendi *et al.,* 2010), and soybean seed (4.61%) (Bayero *et al.,* 2019). The moderately high ash content of the samples may indicate that the Bambara groundnut recipe could provide essential minerals needed for good body development since ash content is directly proportional to inorganic elements.

The samples moderately high protein contents (19.34±021-21.46±0.13) emphasize its importance as a source of essential nutrients in overcoming protein-calorie deficiency, a major nutritional problem among children in Nigeria. Besides, plant foods that provide more than 12% of their calorific value from protein are good protein sources (Ali, 2009). The protein contents obtained in this study are higher compared with 17.03% for Africa yam beans and 16.85% for cowpea (James *et al.,* 2020), 12.90% for Kersting's groundnut (Aremu *et al.,* 2006b), 15.30 g/100g for red kidney bean (Audu and Aremu, 2011) and 9.7 g/100g for cooked kidney bean (Margier *et al.,* 2018). The crude fiber content of SBGM (5.90±0.17 g/100g) and SBGJ (7.34±0.19 g/100g) washigher than the expected values of most leguminous crops (3-5 g/100g) (Borget, 1992). Dietary fiber consumption has been linked to various health benefits, including preventing (colorectal) cancer, cardiovascular disease, obesity and improved gastrointestinal function (Stevenson *et al.,* 2012; De wit *et al.,* 2019). Due to the appreciable amount of crude fiber in all the samples, their consumption will help in improving bowel function and provide fecal bulk.

The total fat content of SBGM and SBGJ were found to be 14.98±0.03 and 18.94±0.18 g/100g, respectively, with the highest (although low) disparity between the samples (CV % =11.67). It has been previously reported that legumes, except for oilseeds (soybean, groundnut), are poor fat sources (Iqbal *et al.,* 2006). With the moderate-fat contents, steamed Bambara groundnut can act as a source of essential fatty acids when included in a diet, especially in a rural community where quality vegetable oil is not affordable. Carbohydrate as Nitrogen Free Extract (NFE) obtained by difference for both the steam Bambara groundnut samples (43.14±0.14 – 47.53±0.18%) was well comparable with 48.8% for black turtle bean (Audu *et al.,* 2013), 44.6-47.4% for Sesbania seeds varieties (Hossain and Becker, 2001), 40.5% for mung bean and 40.4 for pigeon pea (Ene-Obong and Carnovale, 1992). The carbohydrate content suggests that the samples can be used as good energy sources. The metabolizable energy value was 1726.92 kJ/100g in SBGM and 1762.67 KJ/100g in SBGJ, with the least CV of 1.02%. The high energy values were due to the high-fat content in samples. Both samples investigated have higher energy levels than the reported value for Kersting's groundnut (1692.9 KJ/100g) and cranberry beans (1651.7 KJ/100g) (Aremu *et al.,* 2006a), red kidney bean (1678.4 KJ/100g) (Audu and Aremu, 2011), liman bean accessions (1309.59-1372.35 KJ/100g) (Yellavila *et al.,* 2015), and lablab bean (1547.99 KJ/100g) (Mosisa and Tura, 2017).

The mineral compositions in mg/100g of steam Bambara groundnut samples (SBGM and SBGJ) are presented in Table II. The result showed that potassium (219.63 and 232.86 mg/100g), sodium (164.25 and 158.41 mg/100g), and phosphorus (126.93 and 144.84 mg/100g) were the most abundant mineral in both samples SBGM and SBGJ, respectively, with a lower CV range of 1.81 to 6.59 %. The trace elements (Fe, Mn, and Cu) in the samples have higher variation (CV) in their values ranging from 4.00 to 16.67% compared to other minerals in the samples. Sodium and potassium are required to maintain the osmotic balance of body fluids and pH, regulate muscle and nerve irritability and control glucose absorption (Aremu *et al.,* 2012). The results indicate that sodium content of the analyzed samples are below the recommended values of 500 and 400 mg for adult and children, respectively (WHO, 1973). Phosphorus functions as a constituent of bones, teeth, adenosine triphosphate (ATP), phosphorylated metabolic intermediates and nucleic acids (Aremu and Ibrahim, 2014). The magnesium contents of SBGM and SBGJ were 35.83 mg/100g and 32.46 mg/100g, respectively. Magnesium is essential for glucose control and insulin metabolism. It is also required for the structural function of proteins and nucleic acids (Grober *et al.,* 2015). Magnesium is equally vital for all reactions involving ATP (Adenosine Triphosphate). Report has shown that magnesium may help support mineral bone density in older adults (Aremu *et al.,* 2019). The calcium compositions were 21.91 mg/100g for SBGM and 19.61 mg/100g for SBGJ. Calcium in conjunction with phosphorus, magnesium, manganese, vitamin A, C and D, chlorine and protein are all involved in bone formation (Fleck, 1976). In blood coagulation, calcium activates prothrombin to thrombin and takes part in milk clotting (Aremu and Ibrahim, 2014).

Table I. Proximate composition (g/ 100g) of steam Bambara groundnut paste

Parameter /Sample	SBGM	SBGJ	Mean	SD	CV (%)
Moisture	3.02	3.57	3.30	0.28	8.48
Ash	7.13	7.69	7.41	0.28	3.78
Fat	14.98	18.94	16.96	1.98	11.67
Crude protein	21.46	19.34	20.40	1.06	5.20
Crude fibre	5.90	7.34	6.62	0.72	10.88
NFE	47.53	43.14	45.34	2.20	4.85
Fatty acid	11.99	15.15	13.57	1.58	11.64
Energy (KJ/100g)	1726.92	1762.67	1744.80	17.88	1.02

NFE = Nitrogen Free Extract; SBGM = Steam Bambara groundnut paste sold at Makurdi Road Motor Park; SBGJ = Steam Bambara groundnut paste sold at Jos Road Motor Park; SD = Standard Deviation; CV = Coefficient of Variation.

Table II. Mineral Composition (mg / 100g) of steam Bambara groundnut paste

Minerals/Sample	SBGM	SBGJ	Mean	SD	CV (%)
Mg	35.83	32.46	34.15	1.69	4.95
Mn	0.24	0.26	0.25	0.01	4.00
Na	164.25	158.41	161.33	2.92	1.81
Ca	21.91	19.61	20.76	1.15	5.54
K	219.63	232.86	226.25	6.62	2.93
Cu	0.06	0.05	0.06	0.01	16.67
Fe	1.24	1.41	1.33	0.09	6.77
P	126.93	144.84	135.89	8.96	6.59
Na/K	0.75	0.68	0.72	0.04	5.56
Ca/P	0.17	0.14	0.16	0.02	12.50

Na/K = Sodium to potassium ratio; Ca/P = Calcium to phosphorus ratio; SBGM = Steam Bambara groundnut paste sold at Makurdi Road Motor Park; SBGJ = Steam Bambara groundnut paste sold at Jos Road Motor Park; SD = Standard Deviation; CV = Coefficient of Variation.

Table III. Amino acid composition (g/100g crude protein) of steam Bambara groundnut paste

Amino acid	SBGM	SBGJ	Mean	SD	CV (%)
Lysine (Lys)[e]	5.04	6.97	6.01	0.97	16.14
Histidine (His)[e]	2.17	2.71	2.44	0.27	11.07
Arginine (Arg)	5.17	6.02	5.60	0.43	7.68
Aspartic acid (Asp)	7.42	8.96	8.19	0.77	9.40
Threonine (Thr)[e]	3.30	3.89	3.60	0.30	8.33
Serine (Ser)	2.81	3.76	3.29	0.48	14.59
Glutamic acid (Glu)	12.73	13.78	13.26	0.53	4.00
Proline (Pro)[e]	3.05	3.96	3.51	0.46	13.11
Glycine (Gly)	5.37	6.03	5.70	0.33	5.79
Alanine (Ala)	4.86	5.58	5.22	0.36	6.90
Cystine (Cys)	0.72	0.85	0.79	0.07	8.86
Valine (Val)[e]	2.89	4.15	3.52	0.63	17.90
Methionine (Met)[e]	1.87	2.25	2.06	0.19	9.22
Isoleucine (Ile)[e]	2.82	3.54	3.18	0.36	11.32
Leucine (Leu)[e]	6.16	7.15	6.66	0.50	7.51
Tyrosine (Tyr)	2.41	3.02	2.72	0.31	11.40
Tryptophan (Trp)[e]	0.71	0.89	0.80	0.09	11.25
Phenylalanine (Phe)[e]	3.02	3.99	3.51	0.49	13.96
Isoelectric point (pI)	4.22	5.18	4.70	0.48	10.21
P–PER	2.08	2.45	2.27	0.19	8.37
Leu/Ile	2.18	2.02	2.10	0.08	3.81

[e]Essential amino acid; P–PER = Predicted protein efficiency ratio; SBGM = Steam Bambara groundnut paste sold at Makurdi Road Motor Park; SBGJ = Steam Bambara groundnut paste sold at Jos Road Motor Park; SD = Standard Deviation; CV = Coefficient of Variation.

Modern diets rich in animal proteins and phosphorus may promote calcium loss in the urine (Arrinola, 2008). This has led to the concept of the Ca/P ratio. The Ca/P ratio of SBGM and SBGJ were found to be 0.17 and 0.14. Food is considered good if the Ca/P ratio is above 1.0 and 'poor' if the ratio is less than 0.5, while the Ca/P ratio above 2.0 helps to increase the absorption of calcium in the small intestine (Nieman *et al.,* 1992; Aremu *et al.,* 2013). The Na/K ratio were found to be 0.75 for SBGM, and 0.68 for SBGJ. Na/K ratio of less than 1.0 is recommended to prevent high blood pressure (Nieman *et al.,* 1992). Hence, the analyzed samples would probably reduce high blood pressure disease because they had Na/K ratio of less than one.

The amino acid (AA) profile of the steam Bambara groundnut samples is presented in Table III. Variation (CV) in the samples AA contents was generally low (3.80 -17.90 %). Leucine (Leu) and lysine (Lys) were the most abundant essential amino acids in both samples, with 7.15 and 6.97 g/100g cp for SBGJ and 6.16 and 5.04 g/100g cp for SBGM, respectively. Leucine is reported to be instrumental in the repairing and building of muscles, as well as in managing blood sugar levels through the facilitation of glucose uptake in the body cell and improvement of insulin response (Liu *et al.,* 2014; Ispoglou *et al.,* 2016; Osmond *et al.,* 2019). Leucine equally plays a crucial role inthe protein-sparing effects of amino acids (Layman and Walker, 2006). Lysine, despite being susceptible to processing damage, was found in suitable concentrations in both samples, which are comparable to that of black turtle bean (6.50 g/100g cp) (Audu *et al.,* 2013) and African yam bean (6.82 g/100g cp) (Amaechi *et al.,* 2017). The Lys contents in the samples are higher than that of Kerstings groundnut (3.0 g/100g cp) and brown coated cowpea (2.8 g/100g cp) (Aremu *et al.,* 2006a). Lysine is essential for bone formation through calcium absorption and retention, hormone production, and lowering serum triglyceride levels (Civitelli *et al.,* 1992; Gersten, 2013).

The analyzed samples were rich in glutamic and aspartic acids (> 25 % in each sample), both of which serve as important amino group reservoirs in the body. Glutamic acid has received attention as a primary fuel source for the gastrointestinal tract, particularly controlling glycogen synthesis and protein degradation (Mahan and Escott-Stump, 1996; Moussou *et al.,* 2019). Glutamic acid had the highest concentration (12.73-13.78 g/100g cp), followed by aspartic acid (7.42-8.96 g/100g cp) in all the recipes. In both samples, sulfur-containing amino acids, cysteine and methionine were lower than the recommendations by FAO/WHO/UNU (1985). These sulfur-containing amino acids can be complemented when taken in the samples andcereals generally rich in cysteine and methionine. Thus, steam Bambara groundnut paste provides the lysine that grains lack. The methionine contents of 1.87 g/100g cp (SBGM) and 2.25 g/100g cp (SBGJ) were higher than the reported 0.68 g/100g cp for lentil seeds (Pastor-Cavada *et al.,* 2014) and 1.34 g/100g cp for Brunensis soybean (Zaworska-Zakrzewska *et al.,* 2020).

The isoelectric point (pI) is essential in protein purification as it represents the pH at which solubility is typically minimal. SBGJ had the highest computed pI of 5.18, which is the point at which the protein should accumulate during purification. Predicted protein efficiency ratio (P-PER) is one quality parameter used for protein evaluation (FAO/UN/WHO, 1991). P-PER values in this report for SBGM (2.08) and SBGJ (2.45) are higher than the P-PER values of the kernel of *Vitellariaparadoxa* (1.17) (Aremu *et al.,* 2018), *Adansonia digitata pulp* (1.10) (Ibrahim *et al.,* 2016), raw *A. heterophyllus* seed (2.0) (Amaechi *et al.,* 2016) andcooked *Sphenostylis sternocarpa* seeds (2.05) (Amaechi *et al.,* 2017), but slightly lower than those reported by Adeyeye (2010) (2.55), Audu and Aremu (2011) (2.5), Aremu *et al.* (2015) (2.77) and Aremu *et al.,* (2019) (2.55), for raw *A. hypogea* seeds, red kidney bean, tiger nut and *M. charantia* fruit respectively. P-PER is influenced by leucine content and leucine content above 5.00 will result in appreciable P-PER (Amaechi *et al.,* 2015). A protein efficiency ratio less than 1.5 describes a protein of low or poor quality (Friedman, 1996). Having P-PER above 2.0 implies that the analyzed samples are good candidates for providing proteins for human nutrition. The Leu/Ile values are 2.18 and 2.02 for SBGM and SBGJ samples, respectively.

Results on the different classes of amino acids are shown in Table IV. A protein's nutritional value is determined primarily by its ability to meet nitrogen and essential amino acid requirements (Oshodi *et al.,* 1998). Total amino acids (TAA) were 72.52 and 87.57 g/100g cpfor both samples (CV% = 9.40). The total amino acid of SBGJ (87.57 g/100g cp) is higher than 83.50 and 78.25 g/100g cp reported for *A. hypogea* seeds (Adeyeye, 2010) and *S. sternocarpa* seeds, respectively. Total essential amino acids (TEAA) with histidine and total sulphur

Table IV. Concentrations of essential, non–essential, acid, neutral, sulfur, aromatic, etc. (g/100g crude protein) of steam bambara groundnut paste

Amino acid description	SBGM	SBGJ	Mean	SD	CV (%)
Total amino acid (TAA)	72.52	87.57	80.05	7.53	9.41
Total non–essential amino acid (TNEAA)	41.41	48.09	44.75	3.34	7.46
% TNEAA	57.10	54.92	56.01	1.09	1.95
Total essential amino acid (TEAA)					
With histidine	31.11	39.48	35.30	4.19	11.87
Without histidine	28.94	36.77	32.86	3.92	11.93
% TEAA					
With histidine	42.89	45.08	43.99	1.10	2.50
Without histidine	39.91	41.99	40.95	1.04	2.54
Essential alphatic amino acid (EAAA)	15.17	18.73	16.95	1.78	10.50
Essential aromatic amino acid (EArAA)	8.31	10.68	9.50	1.19	12.53
Total neutral amino acid (TNAA)	39.99	49.13	44.56	4.57	10.26
% TNAA	55.14	56.10	55.62	0.48	0.86
Total acidic amino acid (TAAA)	20.15	22.74	21.45	1.30	6.06
% TAAA	27.79	25.97	26.88	0.91	3.39
Total basic amino acid (TBAA)	12.38	15.70	14.04	1.66	11.82
% TBAA	17.07	17.93	17.50	0.43	2.46
Total sulphur amino acid (TSAA)	2.59	3.10	2.85	0.26	9.12
% cystine in TSAA	27.79	27.42	27.61	0.19	0.69

SBGM = Steam Bambara groundnut paste sold at Makurdi Road Motor Park; SBGJ = Steam Bambara groundnut paste sold at Jos Road Motor Park; SD = Standard Deviation; CV = Coefficient of Variation.

amino acids (TSAA) were (42.89 and 2.59g/100 g cp) for SBGM and (45.08 and 3.10 g/100g cp) for SBGJ. The proportion of essential amino acids to total amino acids was 42. 89% (SBGM) and 45.08% (SBGJ) and the ratio of the percentage of essential amino acids to non-essential amino acids was 0.75 (SBGM) and 0.82 (SBGJ), both of which met the FAO/WHO reference values (40% and 0.6%) (FAO and WHO, 1973). The TEAA (%) for all the samples are The TEAA content in this report is significantly higher than the 39% considered adequate for ideal protein food for infants, 26% for children, and 11% for adults. Not only that the TSAA observed values are lower than the 5.8 g/100g cp recommended for infants FAO/WHO (1990), the % Cys in TSAA was also found to be low (27.42 – 27.79 %) compared to the reported value for *Parkiabiglobossa* seeds (44.4%) and *O.*

Table V. Amino acid scores of steam Bambara groundnut based on FAO/WHO standards

EAA	PAAESP g/100g protein	SBGM		SBGJ	
		EAAC	AAS	EAAC	AAS
Ile	4.0	2.82	0.71	3.54	0.89
Leu	7.0	6.16	0.88	7.15	1.02
Lys	5.5	5.04	0.92	6.97	1.27
Met + Cys (TSAA)	3.5	2.59	0.74	3.10	0.89
Phe + Tyr	6.0	5.43	0.91	7.08	1.18
Thr	4.0	3.30	0.83	3.89	0.97
Try	1.0	0.71	0.71	0.89	0.89
Val	5.0	2.89	0.58	4.51	0.83
Total	36.0	28.94	6.28	36.77	7.94

EAA =Essential Amino Acid; PAAESP = Provisional Amino Acid (Egg) Scoring Pattern; EAAC = Essential Amino Acid Composition; AAS = Amino Acid Score; SBGM = Steam Bambara groundnut paste sold at Makurdi Road Motor Park; SBGJ = Steam Bambara groundnut paste sold at Jos Road Motor Park

gratissimum (46.67%) (Adeyeye, 2006). Table IV also shows the percent of total acid amino acids (TAAA) in all samples, which was greater than the percentage of total basic amino acids (TBAA), indicating that the protein is most likely acidic (Aremu *et al.,* 2011). The essential aromatic amino acid (EArAA) varied from 8.31 g/100g cp in SBGM to 10.68g/100g cp in SBGJ. These values fall within the recommended range for infant protein (6.8 – 11.8 g/100g cp) (Hickling, 2003). Essential aliphatic amino acids (EAAA) for both SBGM and SBGJ were 15.17 and 18.73 g/100g cp, respectively.

The essential amino acid scores (EAAS) based on the provisional amino acid scoring pattern (FAO/UN/WHO) are shown in Table V. Results indicated that the SBGJ sample is superior to the SBGM sample based on the amino acids acid scores. Except for leucine, lysine, and phenylalanine + tyrosine in SBGJ, the essential amino acid contents in the samples were lower than the FAO/WHO (1991) recommended provisional pattern. Thus, a diet of SBGJ will require supplementation for Met, Cys, Val, Ile, Thr, and Try, while all the essential amino acids must be supplemented for a healthy diet based on SBGM. Val was the first limiting amino acid in both samples in this study, whereas Ile and Try were the second limiting amino acids in SBGM and SBGJ.

Conclusion

The present study revealed the proximate analysis, minerals content, and amino acid composition of steam Bambara groundnut samples commonly sold in Lafia, Nasarawa State, Nigeria. The Bambara groundnut samples contained nutritionally essential minerals (such as sodium, potassium, and phosphorus) and reasonable quantities of essential amino acids. The recipes were also rich in lysine, which makes them good candidates for complementing cereal-based staple foods that lack lysine. However, dietary formula based on the study samples may require some essential amino acids supplementation such as Val, Ile, and TSAA.

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