The Nutritional Evaluation and Consumer acceptability of Steamed Paste from Fermented Bambara Groundnut (Voandzeia Subterranea)

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ABSTRACT

Background: *Bambara groundnut (BG) is an important legume consumed in Nigeria. It is used in producing steamed paste an analogy called 'okpa'; but it contains some antinutritional factors which limits its consumption and affects health of some people.*

Objective: *The study was to determine the effect of fermentation on the nutritional quality of steamed paste ('okpa') and on its consumer acceptability.*

Methods: *The seeds were fermented, dried and milled into flours which was used to produce the steamed paste. Proximate analysis for determination of nutrients and antinutrients were done using standard methods. Sensory evaluation of the products was also done. The mean, standard error of the mean (SEM) and analysis of variance (ANOVA) were done using statistical package for social sciences (SPSS) version 17. Means were separated by Duncan's Multiple Range Test and significance judged at* $P<0.05$.

Result: *The moisture content of products ranged from 60.13 to 62.50%. Product SPF had the highest protein value (11.96%). The ash content of SPT and SPF were 3.10% respectively. The fibre value for SPZ (2.86%) was significantly higher (*$P<0.05$*). The control, SPZ had the highest carbohydrate (16.83%) and antinutrient values. There were significant differences in the minerals assessed (*$P<0.05$*). The control SPZ and SPT had comparable sensory attribute values (*$P>0.05$*).*

Conclusion: *The fermented steamed paste products from 24hr and 48hr fermentation period were found to have higher protein, ash, minerals and reduced antinutritional factors which gave them a better quality attribute.*

Keywords: Fermentation, Bambara-groundnut, steamed-paste, nutritional-quality, acceptability.

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INTRODUCTION

Bambara groundnut (*Voandzeia subterranea*) is an important legume consumed in Nigeria, especially in Enugu State and some Northern States. Freshly harvested pods of bambara groundnut are either roasted and eaten as vegetable snack (1) or milled into flour and used in preparation of moin-moin (2), an analogy called '*okpa*' among the Ibo tribe of Nigeria (3). The bases for the acceptability of okpa are the taste, firmness of the gel and the orange-yellow color imparted to the product by the red palm oil used in its preparation (4)

Bambara groundnut has great potential use in addressing the protein energy malnutrition in Nigeria (5). It is a highly nutritious crop that plays an important role in people's diet having about 63% carbohydrate, 19% protein and 6.5% oil (6).

Unfortunately, like other legumes, bambara groundnut contain some antinutritional factors such as hemagglutinin, cyanide, trypsin inhibitor, tannins and phytate, and negative nutritional factors which include protein and carbohydrate indigestibility, and sulphur amino acid deficiency (7), which limits its utilization. These anti nutritional factors predispose people to unhealthy risk factors like flatulence, indigestibility, heartburn, abdominal distension or pain, diarrhea and others, therefore limiting their consumption.

To this effect, although cooking can reduce these antinutrients to a safe level (8), fermentation offers additional advantages having been utilized in other legumes such as baobab (9), soybeans and sorghum and its effect established.

Fermentation plays an important role in human nutrition. It is an important adjunct to getting nutritional value from foods (10). This study was therefore carried out to determine the effect of fermentation on the nutritional quality of '*okpa*' (bambara groundnut steamed paste) and its consumer acceptability.

MATERIALS AND METHODS

Healthy and mature seeds of Sokoto white specie of the bambara groundnut (*Voandzeia subterranea*) were purchased from Umuahia Main Market, Abia state. The seeds of the bambara groundnut and rice grains used for the study were handpicked to remove dirts and stones.

Eight hundred grammes (800g) each of the bambara groundnut seeds were steeped in clean water and fermented for 24hrs, 48hrs and 72 hrs. The seeds were allowed to ferment by the natural microflora of the seeds. One portion of the bambara groundnut seeds was left unfermented and was coded 0hr.

At the end of each fermentation periods, the seeds were dried separately in oven at 55 ^{0}C and milled into a fine flour using a disc attrition mill/ model 2002 F.H Bentall and Co.,UK) and hence milled twice in order to get fine flour. The milled samples were sieved using muslin cloth as practiced traditionally to remove the chaff and ensure uniform particle size. The steamed paste was prepared following the procedure in figure 1.

Flowchart showing the production of steamed paste ('okpa')

Raw material- (Bambara nut flour (200g), pepper (15g),salt, palm oil (30ml),water warm-250ml)

↓

Mix - (mix flour with oil, pepper, salt, and then water)

↓

Package - (tie in nylon, banana leaf or put in moin-moin cups)

↓

Steam - (put the packaged paste in a pot with water and steam for about 35 mins)

↓

Cool and serve

Fig 1: Production of Bambara groundnut steamed paste ('*Okpa*'

Chemical analysis

Chemical analysis of the nutrient and antinutrient composition were determined using standard methods. Each analysis was carried out in triplicates on all samples. The micro-kjeldahl method was used to determine the crude protein while soxlet method was used to determined fat described by (11). Ash was determined using the dry ashing method as described by (11). Carbohydrate values were determined by difference method. Determination of minerals and vitamins were carried out using the method described by (12). For the antinutrient composition, Hydrogen cyanide (HCN) was quantified using the (13), The estimation Phytin –Phosphate (Phytin –P or phytate) was also determined using the colorimetric procedure of described (13). Tannin and oxalate were determined following the process described by (12).

Data analysis

The mean, standard error of the mean (SEM) and analysis of variance (ANOVA) of the data obtained from the study was computed using computer application software package, statistical package for social sciences (SPSS) version 17. Means were separated by Duncan's Multiple Range Test and significance judged at $P < 0.05$.

RESULTS

Table 1 shows the proximate composition of the steamed paste products. The moisture content of the steamed paste products showed that SPF had the highest value (63.1%) but was not significantly different ($P>0.05$) when compared with SPT (61.34%) and SPS (61.50%). The control SPZ, had the least moisture value (56.25%).

There was a significant difference in the protein content of the steamed paste products ($P<0.05$). Sample SPF had the highest protein values (11.96%) while SPS had the lowest value (10.04%).

There was also significant difference in the fat values of the steamed paste products ($P<0.05$). The control SPZ had the highest fat value (7.83%) whereas SPS had the least fat value (5.6%).

Products SPT and SPF had the highest ash value (3.10%) respectively while SPZ the control, had the lowest value (2.15%).

The fibre content of the control SPZ, had the highest value (2.86%) while SPS had the least fibre value (1.87%).

There was no significant difference in the carbohydrate content of the steamed paste ($P>0.05$). Nevertheless, SPS had the highest value (16.82%) in the carbohydrate content while SPZ the control, had the least value (10.83%). The high carbohydrate value of SPS could be due to fermentation effect on the flour which might have increased the digestible sugar. It could also be as a result of the low protein, fat and ash and fibre content that led to increase in the carbohydrate level (Table 1).

SPZ* (control)- Steamed paste products from unfermented bambara groundnut; SPT- Steamed paste products from 24hr fermented Bambara groundnut, SPF- Steamed paste products from 48hr fermented bambara groundnut; SPS- Steamed paste products from 72hr fermented bambara groundnut.

Table 2 shows the mineral composition of the steamed paste products. There was a significant difference in the calcium content of the steamed paste products ($P<0.05$. The calcium value for SPF (7.81mg/100g) was the highest while SPZ the control had the lowest value (3.23mg/100g). The iron values of steamed paste product SPF had the highest iron value (2.45mg/100g) and was significantly different ($P<0.05$) while SPS had the least value (1.15mg/100g). Product SPT had the highest phosphorus value (0.03mg/100g) among the steamed paste products but this was not significantly different from SPZ and SPF ($P>0.05$) whose values were 0.02% respectively. Meanwhile SPS had the least phosphorus value (0.01mg/100g). There was a significant difference in the magnesium content of the steamed paste products ($P<0.05$). Product SPT had the highest magnesium content (3.10mg/100g) whereas SPS had the lowest magnesium content (2.45mg/100g). The manganese value for the steamed paste varied.

The manganese value of SPT was the highest among the steamed paste products (0.28mg/100g) and is significantly different (P<0.05). Meanwhile, SPZ and SPS had the least values (0.23mg/100g) respectively. The high manganese value of SPT could be linked to the higher manganese content of the flour sample which was used in producing it. This is also applicable to the lower manganese value of SPS. There were also significant differences in the copper values of the steamed paste product (P<0.05). The copper value of SPT (0.31mg/100g) was the highest while SPS had the least copper value (0.22mg/100g). There was a significant difference in the zinc values for the steamed paste products. SPT had the highest value (0.45mg/100g) whereas SPS had the least zinc value (0.26mg/100g).

SPZ*(control)- Steamed paste products from unfermented bambara groundnut; SPT- Steamed paste products from 24hr fermented Bambara groundnut, SPF- Steamed paste products from 48hr fermented bambara groundnut; SPS- Steamed paste products from 72hr fermented bambara groundnut.

Table 3 shows the vitamin composition of the steamed paste products. There were significant differences in the vitamin A value (P 0.05) where sample SPF had the highest (9.42iu) in vitamin A and SPZ had the least value (8.54iu). There were no significant differences in the vitamin C values of the steamed paste products (P>0.05) as the results showed (1.12, 1.13, 1.13 and 1.13mg/100) for SPZ, SPT, SPF and SPS respectively. There was also no significant difference (P>0.05) in the thiamine content of the steamed paste products. Meanwhile, SPZ had the highest thiamine value (1.28mg/100g) while SPS (1.06mg/100g) had the least value. Product SPZ had the highest riboflavin content (0.41mg/100g) while SPS had the least value (0.38mg/100g).

SPZ*(control)- Steamed paste products from unfermented bambara groundnut; SPT- Steamed paste products from 24hr fermented Bambara groundnut, SPF- Steamed paste products from 48hr fermented bambara groundnut; SPS- Steamed paste products from 72hr fermented bambara groundnut.

Table 4 shows the antinutrient composition of the steamed paste products There was a high significant difference in the hydrogen cynide (HCN) of the steamed paste products (P<0.05). SPZ had the highest hydrogen cyanide value (0.37mg/100g) while SPT, SPF and SPS had the same values (0.03mg/100g) respectively. This showed a 97.14% reduction. There was also a significant difference in the phytate levels of the steamed paste products (P<0.05). SPZ had the highest value (1.36mg/100g) among the flour samples while SPT had the least value (0.78mg/100g) showing a 42.64% reduction. The tannin level of steamed paste products ranges from 1.84 to 1.43mg/100g. Tannin level of SPZ (1.84mg/100g) was the highest among the flour samples but not significantly different (P>0.05) from SPF and SPS whose values are 1.81mg respectively. Meanwhile SPT had the least value (1.43mg/100g).

Among the steamed paste products, SPZ had the highest HG value (5.36mg/100g) and was significantly higher (P<0.05) while SPF had the least value (4.39mg/100g).

There was also a significant difference (P<0.05) in the oxalate content of the steamed paste samples. SPZ had the highest value (1.20mg/100g) among the steamed paste samples while SPF had the least value (0.63mg/100g).

SPZ* (control)- Steamed paste products from unfermented bambara groundnut; SPT- Steamed paste products from 24hr fermented Bambara groundnut, SPF- Steamed paste products from 48hr fermented bambara groundnut; SPS- Steamed paste products from 72hr fermented bambara groundnut.

Table 1: Proximate composition of bambara groundnut steamed paste products ('okpa') from flours of different fermentation periods (mg/100g).

Samples	Moisture	Protein	Fat	Ash	Fibre	Carbohydrate	Energy (KJ)
SPZ*	$56.25^{b}\pm0.03$	$10.20^{b}\pm0.04$	$7.83^{a}\pm0.01$	$2.15^{b}\pm0.15$	$2.86^{a}\pm0.03$	$10.83^{a}\pm0.50$	646.81
SPT	$61.34^{a}\pm0.09$	$11.38^{a}\pm0.16$	$7.51^{a}\pm0.01$	$3.10^{a}\pm0.10$	$2.00^{b}\pm0.03$	$11.66^{a}\pm7.40$	668.40
SPF	$62.10^{a}\pm0.09$	$11.96^{a}\pm0.03$	$5.83^{b}\pm0.03$	$3.10^{a}\pm0.20$	$2.30^{b}\pm0.03$	$12.12^{a}\pm0.58$	622.53
SPS	$61.50^{a}\pm0.25$	$10.04^{b}\pm0.97$	$5.67^{b}\pm0.02$	$2.70^{b}\pm0.20$	$1.87^{c}\pm0.00$	$16.82^{a}\pm1.20$	663.04

Mean ± SEM of three determinations; a-c values in the same column with different superscript letters are significantly different ($P<0.05$)

Table 2: Mineral composition of steamed paste ('okpa') from bambara groundnut flours at different fermentation periods (mg/100g).

Samples	Calcium	Iron	Phosphorus	Sodium	Potassium	Magnesium	Manganese	Copper	Zinc
SPZ*	$3.23^{d}\pm0.05$	$1.53^{c}\pm0.00$	$0.02^{a}\pm0.00$	$0.02^{a}\pm0.00$	$0.02^{a}\pm0.00$	$4.11^{c}\pm0.01$	$0.23^{b}\pm0.00$	$0.27^{b}\pm0.01$	$0.40^{b}\pm0.00$
SPT	$4.64^{b}\pm0.02$	$1.91^{b}\pm0.00$	$0.03^{a}\pm0.02$	$0.02^{a}\pm0.00$	$0.02^{a}\pm0.00$	$4.73^{a}\pm0.01$	$0.28^{a}\pm0.00$	$0.31^{a}\pm0.01$	$0.45^{a}\pm0.00$
SPF	$7.81^{a}\pm0.00$	$2.45^{a}\pm0.02$	$0.02^{a}\pm0.00$	$0.02^{a}\pm0.01$	$0.01^{b}\pm0.01$	$4.38^{b}\pm0.01$	$0.26^{a}\pm0.00$	$0.27^{b}\pm0.01$	$0.27^{c}\pm0.00$
SPS	$3.44^{c}\pm0.01$	$1.15^{d}\pm0.10$	$0.01^{b}\pm0.00$	$0.02^{a}\pm0.00$	$0.01^{b}\pm0.00$	$3.78^{d}\pm0.01$	$0.23^{b}\pm0.00$	$0.22^{bc}\pm0.00$	$0.26^{c}\pm0.00$

Mean ± SEM of three determinations; a-d values in the same column with different superscript letters are significantly different ($P<0.05$)

Table 5 shows the sensory scores of steamed paste product of bambara groundnut flours. Among the steamed paste products, the colour value of SPZ was the highest but not significantly different (P>0.05) from SPT and SPF which were 7.00 and 6.85 respectively. SPS had the least value (6.40).

There was a significant difference (P<0.05) in the flavor values. SPZ had the highest value (7.45) followed by SPT and SPF (5.75 and 6.00) respectively. SPS had the lowest value (5.10).

The texture value of the control SPZ (7.45), SPT (6.85) and SPF (6.70) were not significantly different from each other (P>0.05) while SPS had the least value (6.25).

The taste score of the control SPZ had the highest value (7.75). Sample SPT (6.00) and SPF (6.00) had no significant differences in their values (P>0.05) whereas, SPS had the least score (4.40).

General acceptability value of the control SPZ was the highest (7.85) and also significantly different from SPT (6.10), SPF (5.90) and SPS (4.70) which had the least score.

Table 3: Vitamin composition of bambara groundnut steamed paste products ('okpa') from flours at different fermentation periods.

Samples	Vit.A (I.U)	Vit.C(mg/100g)	Thiamine (mg/100g)	Riboflavin (mg/100g)
SPZ*	$8.54^{c} \pm 0.01$	$1.12^{a} \pm 0.01$	$1.28^{a} \pm 0.00$	$0.41^{a} \pm 0.01$
SPT	$9.33^{b} \pm 0.03$	$1.13^{a} \pm 0.02$	$1.14^{b} \pm 0.00$	$0.41^{a} \pm 0.00$
SPF	$9.42^{a} \pm 0.01$	$1.13^{a} \pm 0.02$	$1.09^{b} \pm 0.02$	$0.40^{a} \pm 0.01$
SPS	$8.59^{c} \pm 0.01$	$1.13^{a} \pm 0.03$	$1.06^{b} \pm 0.01$	$0.38^{b} \pm 0.00$

Mean ± SEM of three determinations; a-c values in the same column with different superscript letters are significantly different (P<0.

Table 4: Antinutrient composition of steamed paste '(okpa)' from bambara groundnut flours at different fermentation periods (mg/100/g).

Samples	Hydrogen cynide	Phytate	Tannin	Hemaglutinin	Oxalate
SPZ*	$0.37^{a} \pm 0.00$	$1.36^{a} \pm 0.01$	$1.84^{a} \pm 0.21$	$5.36^{a} \pm 0.01$	$1.20^{a} \pm 0.00$
SPT	$0.03^{b} \pm 0.00$	$0.78^{d} \pm 0.00$	$1.43^{b} \pm 0.00$	$5.13^{b} \pm 0.01$	$0.96^{a} \pm 0.10$
SPF	$0.03^{b} \pm 0.00$	$0.97^{c} \pm 0.01$	$1.81^{a} \pm 0.01$	$4.39^{d} \pm 0.01$	$0.63^{b} \pm 0.02$
SPS	$0.03^{b} \pm 0.00$	$1.25^{b} \pm 0.06$	$1.81^{a} \pm 0.01$	$4.86^{c} \pm 0.01$	$1.02^{a} \pm 0.10$

Mean ± SEM of three determinations; a-d values in the same column with different superscript letters are significantly different (P<0.05).

Table 5: Sensory scores of steamed paste products of bambara groundnut flours.

Samples	Colour	Flavor	Texture	Taste	General acceptability
SPZ*	$7.65^{a} \pm 0.26$	$7.45^{a} \pm 0.25$	$7.45^{a} \pm 0.21$	$7.75^{a} \pm 0.19$	$7.85^{a} \pm 0.20$
SPT	$7.00^{a} \pm 0.24$	$6.00^{b} \pm 0.36$	$6.36^{ab} \pm 0.25$	6.00b ± 0.36	$6.19^{b} \pm 0.34$
SPF	$6.85^{a} \pm 0.24$	$5.75^{b} \pm 0.31$	$6.70^{ab} \pm 0.33$	$6.00^{b} \pm 0.31$	$5.90^{b} \pm 0.32$
SPS	$6.40^{b} \pm 0.43$	$5.10^{b} \pm 0.50$	$6.25^{b} \pm 0.42$	$4.40^{c} \pm 2.11$	$4.70^{c} \pm 0.37$

Mean ± SEM of 20 scores; a-c values of means in the same column with different superscript are significantly different ($P<0.05$).

SPZ* (control)- Steamed paste products from unfermented bambara groundnut; SPT- Steamed paste products from 24hr fermented Bambara groundnut, SPF- Steamed paste products from 48hr fermented bambara groundnut; SPS- Steamed paste products from 72hr fermented bambara groundnut.

DISCUSSION

The higher moisture content of the steamed paste products as compared to the control indicated that they have higher moisture absorbability. Meanwhile, because of the high moisture content of all the steamed paste, they will not have longer keeping quality (14).

The higher protein content of SPF could be due to degradation of complex protein by microorganism thereby releasing peptides and amino acids as discovered by (15). The low fat content of SPS could be as a result of enzymatic breakdown of complex molecules as fermentation progressed. There are lipoxygenases whose activities produce more free fatty acids when fat is hydrolyzed; hence, a reduction in fats. This reduction of fats in the flour samples could be due to hydrolysis and utilization of fats as an energy source for biochemical reactions (16).

The high ash value of SPT and SPF could be as a result of the fermentation effect which releases bound minerals. (17) also found an increase in ash value at 48hr fermentation period in African yam bean flour.

The lower fibre levels of SPS could be attributable to their degradation by the microorganisms as observed by (18).

Though there was no significant difference in the carbohydrate value of the steamed paste products, the higher carbohydrate value of SPS could be due to fermentation effect on the flour which might have increased the digestible sugar. It could also be as a result of the lower protein, fat, ash and fibre content that led to increase in the carbohydrate level (Table.1).

The higher calcium and iron value observed in SPF could be could be as a result of the fact that fermentation brings about the breakdown of phytic acid which is one of the antinutritional factors responsible for binding minerals thus making them not readily bioavailable (19). The high phosphorus value of SPT could be due to the breakdown of phytate by phytase to release more phosphorus. (20) in her study observed increases in iron, phosphorus, protein, calcium, and zinc when African yam bean was fermented for 12 and 24 hrs. The higher magnesium, manganese, copper and zinc content for SPT respectively could be a release of the mineral as result of fermentation as reported by (19) while the lower value of SPS respectively could be attributed to usage up of the minerals by the microorganisms during fermentation or their leaching out into the fermentation medium.

The higher vitamin A values of the steamed paste products is as a result of the palm oil added to it. Naturally, bambara groundnut is not a source of vitamin A as found in (21). The vitamin C content had comparable results. This showed that fermentation had no effect on the vitamin C content. The decrease observed in the thiamine and riboflavin content of the samples could be due to the loss of thiamine from the flour used in producing the steamed paste as a result of leaching out into the fermentation medium since they are water soluble vitamins. This is supported by (22) who discovered that fermentation caused decreases in thiamine and riboflavin contents of yellow maize as a result of leaching.

For the antinutient levels, the lower HCN values of SPT, SPF and SPS indicated that the products are safer to consume in terms of the HCN values. This HCN substance releases cyanide into the body, which can be fatal (23). The lower phytate value of SPT indicated the fermentation effect on the sample. This lower level showed that it is safer to consume. Phytates inhibit the absorption and bioavailabilty of mineral nutrients. The lower tannin value of SPT also showed that fermentation had a reduction effect on it. The increased level of tannin found in SPF and SPS could be due to re-absorption of the antinutrient as fermentation period increases. This was observed by (24) in their study that re-absorption of antinutrients occur as a result of prolonged soaking. This could be prevented by changing the fermentation water daily. Tannins prevent protein digestibility and decrease the absorption of divalent ions in the intestine by forming insoluble complexes with such divalent ions as Fe^{2+}, Zn^{2+} (25). The reduction in hemaglutinin value of SPF as observed was also a function of fermentation. Hemaglutinins impart bitter or unacceptable taste in legumes (25). The significant reduction in the oxalate value of SPF could also be due to the combination of the effect of fermentation and cooking. The low oxalate levels might have nutritional and health benefits. The low oxalate levels might have nutritional and health benefits. This is because as stated by (26) oxalates have a negative effect on mineral availability as they interfere with absorption of divalent minerals, particularly calcium by forming insoluble salts with them. According to (27), 80% of kidney stones were composed of calcium oxalate.
The sensory scores for colour of SPZ, SPT, and SPF had comparable values ($P>0.05$) as result showed. This signified that fermentation did not affect the colour of these products when compared to the control SPZ. This contradicted the result findings of (4) on colour of steamed paste products from germinated bamabra groundnuts. Meanwhile, the colour of SPS had the least score among the entire products. This could be due to the longer duration in the fermentation period that led to increased enzymatic reaction (4) which affected its colour. This is not surprising. It is known that appearance of food evokes response according to (28).

The reason why SPZ had the highest score in flavour could be easily understood. This could be due to the maintenance of the original flavour of the food product as it did not pass through the process of fermentation and that led to its flavour being more acceptable than the other products. The low flavour value for SPS could be attributed to loss of natural flavor-enhancing compounds by leaching during fermentation and volatization during drying as reported by (4).
Fermentation did not affect the texture of SPT and SPF when compared with the control SPZ. Meanwhile, fermentation affected the texture of SPS making it to be coarse as observed through mouthfeel. This led to it's being the least acceptable in texture among the products. This coarse effect could be due to the loss of gummy substances (4) or soluble starch granules from the flour as a result of prolonged fermentation period which might have led to presence of more fibrous content during cooking (29).

The high taste score of SPZ was quite understood. The panelists were already familiar with the taste of this product and could easily differentiate it from the other products. Even though SPZ had the highest score (7.75), SPT (6.00) and SPF (6.00) showed no significant difference in their scores when compared with SPZ ($P>0.05$) but SPS score (4.70) was significantly different ($P<0.05$) from the rest of the products. The low taste score of SPS could be due to the increased activity of microflora during fermentation and loss of natural flavor-enhancing compounds through leaching and volatization during drying as reported by (4) causing unacceptable taste to the product.

The general acceptability of the products was a function of colour, flavor, texture and taste. The high acceptability of SPZ could be easily explained. It is a cherished food among the eastern part of this country Nigeria and so the taste, flavor and texture are very familiar to the panelists. Although SPT and SPF showed a significant difference ($P<0.05$) from the control SPZ; SPT was more acceptable by the panelist than SPF and SPS which had the least acceptability. This is supported by (30) which observed in her study that products from 24hr and 48hr fermentation period had more acceptability than those from 72hr period.

CONCLUSION

The protein, ash and mineral that significantly improved and the reduction in antinutritional factors of the steamed paste products suggests possible use of the fermented bambara groundnut flour as a potential source to improve the nutritional quality of the products. These results also suggest the need for further studies about the possibility of using fermented bambara groundnut flour in food industry.

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