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Nutritive and Antinutritive Values of Fermented Guinea Corn (*Sorghum bicolor* L.) Fortified with Bambara Groundnut (*Vigna subterranea* L.) Flour

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Abstract

The fermented guinea corn (*Sorghum bicolor* L) is a processed "ogi baba" and a popular starchy porridge in the west coasts of Africa. Although it is consumed by both young and old as a breakfast cereal, its main use is as weaning food for infants. In this study, the nutritive and antinutritive values of "ogi baba" from a composite mixture of guinea corn (*Sorghum bicolor* L) and bambara groundnut (*Vigna subterranea* L) were evaluated using standard processing techniques. Sorghum flour was substituted with bambara groundnut flour at ratios of 90:10, 80:20, 70:30 and 60:40 guinea corn:bambara groundnut; with 100% sorghum-ogi and 100% bambara groundnut flours as controls. The results showed that the contents of ash, crude fat, crude protein and crude fibre were enhanced with increased bambara groundnut flour substitution. All the nutritive minerals such as Na, K, Ca, Mg and P also recorded increased concentrations in the fortified samples. Harmful metals such as cadmium and lead were not at detectable range of atomic absorption spectrophotometer (AAS). The total essential amino acids (TEAA) ranged from 28.74–37.14 g/100g crude protein or from 43.70–44.26% of the TAA while 60:40 substitution ratio has the best essential amino acid score values amongst the fortified samples based on the provisional FAO/WHO standards. There were decrease in the values of saponins, phytate, oxalate and alkaloids in the fortified samples compared with the controls. The results of sugars showed that there was gradual increase in the total sugar concentration with increased bambara groundnut flour substitution from 1.54 g/100g (90:10 ratio) reaching 2.41 g/100g (60:40 ratio). Generally, the present study reveals that at = 40% *Vigna subterranea* flour substitution "ogi" with higher nutrients can be maintained in the food blend.

Keywords: Sorghum-ogi, bambara groundnut, fortification, nutritional quality

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Introduction

Guinea corn (*Sorghum bicolor* (L.) is a very important staple food crop which belongs to a member of the family Poaceae. It is a drought tolerant crop that provides a good source of energy and antioxidant [1]. To be used for human consumption, guinea corn is processed into a variety of traditional foods such as unleavened bread, porridges, cookies, cakes, cereal extracts, malted alcoholic and non-alcoholic beverages [2]. However, guinea corn-based foods have continued to be nutritionally deficient and organoleptically inferior. This is largely due to the presence of antinutritional factors such as tannin, phytic acid, oxalate, polyphenol and trypsin inhibitors which are the reason for it sour taste [3].

These antinutritional factors bind food ingredients into complexes making them inaccessible for both animals and human nutrition [4]. The nutritional quality of a complementary food depends on a number of factors including the nature of raw materials, methods of processing and fortification practices adopted. Fermentation has been reported as an effective biochemical process in the reduction of antinutritional factors in cereals and improves their starch and protein digestibility, amino acid balance as well as nutritive significances [5]. Most previous research focused on sorghum flour fermentation known as "ogi" which is also referred to as "ogi-baba" consumed in many parts of West Africa [3]. This has limits the flour's application for further uses because most of the nutrient contents such as proteins and minerals are lost during the processing [6, 7]. This has led to many studies on the fortification of the gruel to enhance its nutritive value. One of the strategies to enhance the nutritional requirements of cereal meal is by supplementation with legumes [8].

Bambara nut (*Vigna subterranea* L.) is a leguminous crop that belongs to the family *Fabaceae*. It is the third most important member of the leguminous crops family after cowpea and groundnut [9].Nutritionally, bambara groundnut represents a cheap protein-rich source that can improve the nutrition security status of food supplements [10]. Nutritional studies reveal that bambara groundnut produces an almost balanced diet. The nut was found to be richer in essential amino acids than groundnut with a protein score of 80% [10, 11]. Therefore, this study is to investigate the proximate, mineral, amino acid, phytochemical and sugar compositions of guinea corn(*Sorghum bicolor* L.) blended with bambara groundnut (*Vigna subteranea* L.) with a view to providing preliminary information towards utilization of this legume in various food applications in Africa.

Materials and Methods

Sample collection and preparation

The guinea corn (*Sorghum bicolor* L.) and bambara groundnut (*Vigna subteranea* L.) were purchased in Lafia modern market, Nasarawa State, Nigeria. The samples were thoroughly clean of stones, sticks, chaffs and bad seeds. The cleaned bambara groundnut was soaked in a boiled water for 1 h at 100°C and dehulled. The dehulled seeds were dried at 35^0C for 96 h. The dried bambara groundnut was ground to flour with a Kenwood blender and sieved using the Hammer mill to pass through a 0.25 mm screen. The method described by Aremu *et al.* [12] was used for the preparation of "ogi". The cleaned guinea corn was steeped in 6 L of clean water in a plastic container for three days (72 h). The water was decanted and grains were wet-milled before sieving with muslin cloth. The pomace was discarded and the starch suspension was allowed to sediment during which fermentation occur by natural flora of the grains. The slurry was filtered and oven dried at 50°C for about 12 h. The dried guinea corn (ogi) cake was fine milled to flour by the use of a blender, while flour was sieved using the Hammer mill to pass through a 0.25 mm screen.

Fortification level with Bambara groundnut

The dehulled bambara groundnut flour was added to the guinea corn flour at the following ratios: 10:90, 20:80, 30:70, and 40:60. The two controls were unfortified fermented guinea corn (100%) and unfortified bambara groundnut flours (100%), respectively.

Proximate analysis

The moisture, ash, crude fat, crude fibre, crude protein (N x 6.25) and carbohydrate (by difference) were determined in accordance with the standard methods of AOAC [13]. All proximate analyses of the sample flours were carried out in triplicate and reported in %. All chemicals were of Analar grade. All results were on dry weight (dw) basis.

Mineral analysis

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

Amino acid analysis

The amino acid analysis was by Ion Exchange Chromatography (IEC) [14] 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 $mLmin^{-1}$ at 60°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.
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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 [15]:

$$plm = \sum_{i=1}^{n=1} pliXi --------(1)$$

Where:

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

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

pIi = the isoelectric point of the ith 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 formula [16]:

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

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.* [17] as stated thus;

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

Anti–nutritient content determination

The contents of saponins, tannins, trypsin, cyanide, phytate, oxalate and alkaloids were determined on each of the sample flours by methods described by some workers [18].

Sugar content determination

The various sugar content determinations were carried out as described by Lane and Eynon's method [19]. All chemical used were of analytical grade and were obtained from British Drug Houses (BDH, London, UK). All results were on wet basis.

Statistical analysis of 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. 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. Errors of three determinations were computed as standard deviation (SD) for the proximate composition. Standard deviation and percentage of coefficient of variation for the seed and pulp samples were also determined.

Results and Discussion

Proximate compositions of unfortified fermented guinea corn (A), unfortified bambara flour (B) and fermented guinea corn fortified with bambara groundnut flour (C, 90:10; D, 80:20; E, 70:30; F, 60:40) are presented in Table 1. Sample F has the lowest value of moisture (5.83±0.08) with progressive increase within the blends. The high moisture content of the raw material may affect the storage quality of the formula, because high moisture content in foods has been shown to encourage microbial growth [20]. Carbohydrate content in the unfortified guinea corn flour (B) was seen to be higher than the value of blends but no significant difference has been found between the samples. When compared to Ajanaku (64.1-86.5%) and Dewey (63.95±0.04%) these values are acceptable [3, 21]. The fat content of A was lower than that of the fortified samples. It could be inferred that fortification has significant effects on the fat content. However, any diet that provides 1-2% of its calories as fat is said to be sufficient for human beings [22]. There was a significant increased with fortification level to the values of ash, crude fibre, and protein. Generally, there are no much deviations as indicative of the SD. The high calculated metabolizable energy value of the experimental flours can be explained by the high content of carbohydrates and fats. The FAO and WHO have recommended that foods fed to infants and children should be energy-dense [23]. This is necessary because low-energy foods tend to limit total energy intake and the utilization of other nutrients. Energetic diets are necessary for children to cover their needs considering the size of their stomachs. High nutrient density is also a desirable characteristic in flours that are used as a base for infant food formulation [23]. The differences recorded in calculated energy and fatty acid values of the samples reflect differences in the observed values of other proximate composition as discussed above. From the foregoing, it can be seen that fortification of sample F gave the more favourable results compared to all the samples. The CV% varied with a range of 7.36 in carbohydrate to 1448.06 in metabolizable energy.

Table 1: Proximate composition (%) of the samples

Parameters/samples	A	B	C	D	E	F	Mean	SD	CV%
Moisture	6.47±0.2	8.05±0.47	6.1±0.07	6.52±0.06	5.97±0.07	5.83±0.08	6.49	0.81	12.50
Ash	1.46±0.04	2.83±0.04	1.5±0.12	1.65±0.01	2.14±0.03	1.81±0.2	1.90	0.52	27.34
Fat	2.89±0.2	5.83±0.38	3.94±0.02	4.51±0.26	5.00±0.58	5.37±0.28	4.59	1.06	23.12
Crude protein	8.5±0.08	16.66±0.45	9.4±0.06	9.5±0.2	13.12±0.03	14.36±0.05	11.92	3.28	27.50
Crude fibre	1.55±0.3	2.15±0.2	1.65±0.03	1.85±0.04	1.9±0.02	2.05±0.02	1.86	0.23	12.32
Carbohydrate	79.13	64.48	77.41	75.97	71.87	70.58	73.24	5.39	7.36
Fatty acid[a]	2.31	4.66	3.15	3.61	4.00	4.30	3.67	0.85	18.50
Energy[b]	1596.64	1595.09	1621.55	1613.40	1629.83	1642.67	1617.55	186.61	1448.06

SD = Standard Deviation, %CV = Percentage Coefficient of Variation, A = 100% Guinea corn flour, B = 100% Bambara groundnut flour, C = 90:10; D = 80:20; E = 70:30;F= 60:40 of Guinea corn flour: Bambara groundnut flour, respectively. [a]Calculated fatty acids (0.8 x crude fat). [b]Calculated metabolizable energy (kJ/100g) (Protein x 17+Fat x37+Cabohydrate x 17).

The mineral composition in mg/100g of the fermented and unfortified guinea corn, unfortified bambara groundnut and the blends are presented in Table 2. Sodium (86.6 – 109.12), potassium (223–444) and phosphorus (112.38 – 146.28) were the abundant minerals in the blended samples.

Table 2: Mineral composition (mg/100g) of the samples

Mineral content	A	B	C	D	E	F	Mean	SD	%CV
Na	102.1	141.9	96.4	121.1	86.6	106.6	109.12	19.71	18.06
K	310	489	223	267	356	444	348.17	102.75	29.51
Ca	33	22.48	17.99	20.09	22.23	25.15	23.49	5.25	22.33
Mg	29.97	80.15	36.43	42.5	58.39	62.47	51.65	18.76	36.32
Mn	4.15	5.9	5.33	3.86	4.41	6.29	4.99	1.00	19.94
Fe	5.14	6.46	10.89	6.04	7.36	5.03	6.82	2.17	31.87
Zn	40.04	86.25	61.25	68.00	36.25	66.61	59.73	18.76	31.41
Cu	2.98	2.17	1.36	3.67	2.20	5.41	2.97	1.43	48.33
P	67.68	93.26	112.38	121.62	148	146.28	114.87	31.08	27.06
Cd	ND	ND	ND	ND	ND	ND	na	na	na
Pb	ND	ND	ND	ND	ND	ND	na	na	na
Na/K	0.33	0.29	0.43	0.45	0.24	0.24	0.33	0.09	27.84
Ca/P	0.49	0.24	0.16	0.17	0.15	0.17	0.23	0.13	57.09

ND= Not detected, na = Not applicable, Na/K = Sodium to Potassium ratio. Ca/P = Calcium to Phosphorus ratio

Sample F showed high values of all test parameters among the samples. It has been reported that calcium in conjunction with phosphorus, magnesium, manganese, vitamin A, C and D, chlorine and protein are all involved in bone formation [24]. Calcium is also important for blood clotting, muscle contraction and in certain enzymes in metabolic processes. Magnesium is an activator of many enzyme systems and maintains the electrical potential in nerves. Phosphorus assists calcium in many body reactions; although it also has independent functions [25]. Iron (5.03 – 10.89) and copper (1.36 – 5.41) are the lowest minerals while cadmium and lead were not at the detectable range of AAS in any of the samples. The result of mineral contents of sample B in this study is as expected and in agreement with Olanipekun *et al.* [26] who reported values for mineral for bambara groundnut. Lead can impair the nervous system and affect foetus, infants and children in lowering of intelligent quotient (IQ), even at its lowest dose. Lead and cadmium, even at low concentration, are known to be toxic and have no known function in biochemical process [25]. The Na/K ratio is less than one which is due to high concentration of potassium.

We can therefore deduce that the fortified meals are healthy for human consumption especially in the case of cardiovascular disease prevention. The Ca/P ratio in the present study ranged between 0.14 – 0.49. Modern diets which are rich in animal proteins and phosphorus may promote the loss of calcium in the urine. If the Ca/P ratio is low (low calcium, high phosphorus intake) more than the normal amount of calcium may be loss in the urine, decreasing the calcium level in bones. Food is considered "good" if the ratio is above one and "poor" if the ratio is less than 0.5 [24]. Therefore, the fortified samples may not be able to participate well with respect to the content of Ca/P ratio in this report. The CV% of the results from the mineral determinations ranged from 19.94 to 48.3.

Table 3 presents the results of amino acid composition (g/100g crude protein, cp) of the samples. Glutamic acid and tryptophan represent the most abundant and lowest amino acids in all the samples, respectively. The concentrations of leucine (12.19), tryptophan (1.16), phenylalanine (4.78), valine (5.14), glutamic acid (19.12) and serine (7.39) in sorghum were progressively increased in fortified samples with substitution of bambara groundnut flour. The calculated isoelectric point (pI) values ranged from 3.73 - 5.45. This is useful in predicting the pI for protein in order to enhance a quick precipitation of protein isolate from biological samples [15, 27]. The predicted protein efficiency ratio (P-PER) is one of the quality parameters used for protein evaluation [28]. The P-PER values (2.36-4.66) in this report is an indicative of a good source of protein. Clinical, biochemical and pathological observations in research conducted in humans and laboratory animals revealed that high leucine in food stuff impairs the metabolism of tryptophan and niacin and it is responsible for deficiency of niacin in sorghum eaters [25]. The Leu/Ile ratios in the samples (1.99-3.24) were relatively low which is an indicative of the impact of bambara groundnut fortification. The low Leu/Ile ratio in both samples was desirable because it leads to amino acid balance in cereals that are already high in leucine and low in tryptophan and isoleucine. The CV% was variously varied with a range of 8.96% in His to 39.2 in Pro.

Table 3: Amino acid composition (g/100g crude protein) of the samples

Amino acid	A	B	C	D	E	F	Mean	SD	CV %
Leucine (Leu)[e]	12.19±0.13	7.26±0.09	6.77±0.04	8.55±0.04	8.8±0.01	9.29±0.05	8.81	1.91	21.71
Lysine (Lys)[e]	2.35±0.02	5.73±0.14	3.12±0.06	4.08±005	3.74±0.04	4.36±0.01	3.90	1.15	29.55
Isoleucine(Ileu)[e]	3.76±0.05	3.65±0.02	2.65±0.03	3.06±0.05	3.21±0.01	3.44±0.04	3.30	0.41	12.45
Phenylalanine (Phe)[e]	4.78±0.1	4.37±0.03	3.05±0.04	3.24±0.05	3.44±0.02	3.81±0.09	3.78	0.68	17.89
Tryptophan (Try)[e]	1.16±0.01	1.05±0.00	0.74±0.02	0.89±0.00	0.91±0.01	1.00±0.01	0.96	0.15	15.16
Valine (Val)[e]	5.14±0.04	4.13±0.07	3.72±0.04	4.01±0.05	3.9±0.06	4.28±0.02	4.20	0.50	11.92
Methionine(Mee)[e]	1.95±0.03	1.45±0.05	1.12±0.02	1.24±0.04	1.29±0.01	1.34±0.03	1.40	0.29	20.84
Proline (Pro)[e]	8.06±0.16	3.38±0.08	3.44±0.02	4.03±0.03	3.86±0.00	4.33±0.03	4.52	1.77	39.24
Arginine (Arg)	4.10±0.04	6.55±0.01	4.18±0.05	2.75±0.00	4.93±0.03	5.05±0.06	4.59	1.26	27.47
Tyrosine (Tyr)	3.86±0.1	3.13±0.03	2.37±0.05	4.68±0.05	3.06±0.04	3.19±0.09	3.38	0.79	23.44
Histidine(His)[e]	2.47±0.04	2.64±0.02	2.03±0.02	2.22±0.02	2.31±0.01	2.38±0.02	2.34	0.21	8.96
Cystine (Cys)	1.91±0.03	1.22±0.01	1.04±0.01	1.18±0.03	1.25±0.03	1.42±0.03	1.34	0.31	22.92
Alanine (Ala)	8.82±0.02	4.49±0.03	5.02±0.02	6.06±0.03	5.57±0.08	6.26±0.04	6.04	1.51	25.06
Glutamic acid (Glu)	19.12±0.12	13.58±0.05	12.11±0.09	14.14±0.18	15.15±0.01	15.52±0.08	14.94	2.38	15.94
Glycine (Gly)	3.57±0.04	4.95±0.06	3.19±0.03	3.58±0.06	3.67±0.01	3.77±0.02	3.79	0.60	15.89
Threonine (Thr)[e]	3.36±0.03	3.41±0.02	2.10±0.02	2.45±0.04	3.04±0.04	2.91±0.02	2.88	0.52	17.93
Serine (Ser)	4.44±0.04	3.87±0.04	2.22±0.02	3.13±0.03	3.32±0.02	3.47±0.04	3.41	0.75	21.87
Aspartic acid (Asp)	7.39±0.02	9.75±0.05	6.90±0.11	7.29±0.03	7.53±0.04	8.04±0.03	7.82	1.02	13.01
Isoelectric point (pI)	5.45	5.00	3.73	4.10	4.48	4.48	4.54	0.62	13.57
P-PER	4.66	2.49	2.36	2.92	3.21	3.41	3.18	0.83	26.20
Leu/Ile	3.24	1.99	2.55	2.79	2.74	2.7	2.67	0.41	15.19

P-PER = Predicted Protein Efficiency Ratio,[e]Essential amino acid, Leu/Ile = Leucine to Isoleucine ratio

Table 4: Concentrations of essential, non-essential acids, neutral, sulphur, aromatic etc. (g/100g crude protein) of the samples

Amino acid description	A	B	C	D	E	F	Mean	SD	CV%
Total amino acid (TAA)	98.43	84.61	65.76	76.58	78.98	83.92	81.38	10.77	13.24
Total non-essential amino acid (TNEAA)	53.21	47.54	37.02	42.81	44.48	46.78	45.31	5.39	11.89
%TNEAA	54.06	56.19	56.27	55.90	56.32	55.74	55.75	0.86	1.54
Total essential amino acid (TEAA): With histidine	45.22	37.07	28.74	33.77	34.50	37.14	36.07	5.43	15.05
Without histidine	42.75	34.43	26.71	31.55	32.19	34.78	33.74	5.28	15.65
%TEAA: With histidine	45.94	43.81	43.70	44.10	43.68	44.26	44.25	0.86	1.94
Without histidine	43.43	40.69	40.61	41.20	40.76	41.42	41.35	1.07	2.58
Essential Aliphatic amino acid (EAAA)	24.45	18.45	15.24	18.08	18.95	19.92	19.18	3.02	15.75
Essential aromatic amino acid (EArAA)	8.41	8.06	5.82	6.35	6.66	7.19	7.08	1.00	14.17
Total neutral amino acid (TNAA)	69.57	55.55	43.64	51.67	52.56	56.00	54.83	8.48	15.46
%TNAA	70.68	65.65	66.36	67.47	66.55	66.73	67.24	1.78	2.65
Total acidic amino acid (TAAA)	26.51	23.33	19.00	21.43	22.68	23.56	22.75	2.49	10.93
%TAAA	26.93	27.57	28.89	27.98	28.72	28.07	28.03	0.73	2.59
Total basic amino acid (TBAA)	8.92	14.92	9.33	10.98	10.98	11.8	11.16	2.14	19.22
%TBAA	9.06	17.63	14.19	14.34	13.9	14.06	13.86	2.74	19.79
Total sulphur amino acid (TSAA)	3.86	2.67	2.16	2.42	2.54	2.76	2.74	0.59	21.56
%cystine in TSAA	49.48	45.69	48.15	48.76	49.21	51.45	48.79	1.88	3.86

Table 5: Amino acid scores of the samples based on FAO/WHO standards

EAA	PAAESP g/100g protein	A EAAC	A AAS	B EAAC	B AAS	C EAAC	C AAS	D EAAC	D AAS	E EAAC	E AAS	F EAAC	F AAS
Ile	4.0	3.76	0.94	3.65	0.91	2.65	0.66	3.06	0.77	3.21	0.80	3.44	0.86
Leu	7.0	12.19	1.74	7.26	1.04	6.77	0.97	8.55	1.22	8.80	1.26	9.29	1.33
Lys	5.5	2.35	0.43	5.73	1.04	3.12	0.57	4.08	0.74	3.74	0.68	4.36	0.79
Met + Cys (TSAA)	3.5	3.86	1.10	2.67	0.76	2.16	0.62	2.42	0.69	2.54	0.73	2.76	0.79
Phe +Tyr	6.0	8.64	1.44	7.5	1.25	5.42	0.90	5.99	1.00	6.5	1.08	7.0	1.17
Thr	4.0	3.36	0.84	3.41	0.85	2.10	0.53	2.45	0.61	3.04	0.76	2.91	0.73
Try	1.0	1.16	1.16	1.05	1.05	0.74	0.74	0.89	0.89	0.91	0.91	1.00	1.00
Val	5.0	5.14	1.03	4.13	0.83	3.72	0.74	4.01	0.80	3.90	0.78	4.28	0.86
Total	36.0	40.46	8.68	35.4	7.73	26.68	5.73	31.45	6.72	32.64	7.0	35.04	7.53

The total amino acids (TAA), total essential amino acids (TEAA), total non–essential amino acids (TNEAA), total acidic amino acids (TAAA) , total basic amino acids (TBAA) and total neutral amino acids (TNAA) of the samples are shown in Table 4. The fortified samples had progressive increase in the concentration of TAA, TEAA, EAAA and TSAA. The TEAA of fortified food samples (28.74, 33.77, 34.50 and 37.14 g/100g cp) are close to the value for egg reference protein (56.6 g/100g cp) [29]. The contents of TSAA in fortified samples (2.16–2.76 g/100g cp) are lower than the 5.8 g/100g cp recommended for infants [30]. The EArAA range suggested for ideal infant (6.8–11.8 g/100g cp) [30] has current values close the minimum i.e. 5.82–7.19 g/100g cp. The EArAA are precursors of epinephrine and thyroxin [31]. The percentage ratios of TEAA to TAA in the fortified samples were 43.68 to 44.26% which are well above the 39% considered to be adequate for ideal protein food for infants, 26% for children and 11% for adults [30]. The TEAA/TAA percentage contents are strongly close to that of egg (50%) [28] and above 40.6% reported for cashew nut [32]. The P–PER values (Table 3) are higher than pigeon pea (1.82) and cowpea (1.21) [33]; sorghum–ogi (0.27) and millet-ogi (1.62) [21]. The presence of D–isomers also reduces the digestibility of the protein because peptide bonds involving D residues are less easily hydrolyzed *in* vivo than those containing only L residues. Moreover, certain D amino acids exert a toxic action, in proportion to the amount absorbed through the intestinal wall [34]. This elucidates a word of caution inthe excessive consumption of sorghum-ogi or its fortified products. The highest value of CV% in this study is 21.50 with 2.59 being the lowest (Table 4).

Table 5 displays the essential amino acid scores of the samples based on white hen's egg profile [35]. The EAA score values for samples A and B are mostly greater than 1.0 except for Ile, Lys, and Thr in sample A; Ile, Met + Cys (TSAA) and Thr in sample B which may require supplementation based on the provisional amino acid scoring pattern [28]. The sample F has the best EAA score values amongst the fortified samples.

One of the major drawbacks limiting the nutritional and food qualities of diets is the presence of antinutritional factors [36]. Phytic acid reduces the bioavailability of some essential minerals and tannins inhibit the digestibility of protein [37]. The data related to antinutrients are summarized in Table 6. The result showed a gradual decrease in the values of saponins, phytate, oxalate and alkaloids upon higher ratios of fortification with bambara groundnut flour. The values of tannins (1.06 – 1.38 mg/100g) and trypsin (0.08 – 0.31 mg/g) in the fortified samples are low compared with the work of Mbata *et al.* [38]: tannins (36.40–42.70 mg/100g) and trypsin inhibitors (38.20–49.70 mg/100g) in unfortified maize flour and fortified products with bambara flours. Tripsin inhibitor, when ingested in large quantity disrupts the digestive process and may lead to undesirable physiological reactions. Both samples A and B showed higher values of saponins, phytate and alkaloids than those of the fortified samples (C, D, E & F). The results showed significant differences as CV% (20.68 – 50.00%) are far spread from each others.

Table 6: Antinutritional parameters

Parameters/Samples	A	B	C	D	E	F	Mean	SD	CV%
Saponins mg/100g	2.07±0.4	1.15±0.03	1.06±0.02	1.00±0.04	1.05±0.05	1.05±0.07	1.23	0.41	33.33
Tannins mg/100g, TAE	0.72±0.08	1.23±0.01	1.06±0.03	1.22±0.00	1.34±0.02	1.38±0.04	1.16	0.24	20.68
Trypsin mg/g	0.11±0.05	0.33±0.02	0.08±0.00	0.25±0.02	0.31±0.04	0.27±0,06	0.23	0.11	47.83
Cyanide mg/g	0.16±0.0.03	0.26±0.02	0.17±0.03	0.20±0.03	0.19±0.01	0.30±0.04	0.21	0.06	28.57
Phytate mg/g	2.19±0.35	1.77±0.06	1.32±0.04	0.81±0.20	0.96±0.12	1.02±0.4	1.33	0.54	40.60
Oxalate mg/g	0.74±0.01	0.91±0.03	0.33±0.03	0.66±0.05	0.39±0.04	0.23±0.03	0.54	0.27	50.00
Alkaloids %	1.94±0.05	2.3±0.24	1.8±0.30	1.68±0.08	1.08±0.03	2.17±0.16	1.83	0.43	23.49

TAE= Tannins Equivalent

Table 7: Sugar concentration of the samples in g/ 100g, % w/w

Sugars	A	B	C	D	E	F	Mean	SD	CV%
Ribose	7.13e-05	9.88e-05	9.94e-05	7.91e-05	1.24e-04	8.16e-05	9.237e-05	2.054e-05	22.24
Xylose	3.53e-05	5.51e-03	2.02e-03	2.80e-03	4.46e-03	4.02e-03	0.0031409	0.002134	67.94
Arabinose	6.45e-05	1.03e-04	7.58e-05	8.32e-05	9.70e-05	9.31e-05	8.61e-05	1.562e-05	18.14
Mannose	2.99e-05	3.06e-05	3.00e-05	3.00e-05	3.01e-05	3.03e-05	3.015e-05	2.775e-07	0.92
Fructose	5.87e-01	9.16e-01	6.02e-01	6.30e-01	6.68e-01	7.08e-01	0.6851667	0.1351584	19.73
Glucose	9.57e-02	1.28e-01	1.02e-01	1.04e-01	1.10e-01	1.16e-01	0.1092833	0.0123214	11.27
Galactose	5.86e-05	5.92e-05	5.87e-05	5.87e-05	5.88e-05	5.90e-05	5.883e-05	2.345e-07	0.40
Sucrose	6.17e-01	2.99	8.32e-01	1.09	1.32	1.58	1.40	0.94	67.17
Total	1.3	4.04	1.54	1.84	2.11	2.41	2.21	1.09	49.45

The composition of sugars in fermented sorghum (A), bambara groundnut flour (B) and fermented guinea corn fortified with varying concentrations of bambara groundnut flour (C, D, E and F) are presented in Table 7. The values obtained for glucose and fructose were promising as expected in the food samples. Hence, values increased with change in ratio of fortification level of bambara groundnut four. The present study showed lower values of glucose ($9.57e^{-02}$ – $1.28e^{-01}$), fructose (7.08 – 6.02), D-ribose (9.94 – 1.24) and D-galactose (1.02 – 1.16) in comparison with the result of Rafael *et al*. [39]. However, Aremu *et al.* [40] reported higher values of fructose (0.21 and 3.08), glucose (0.11 and 3.34) and sucrose (2.76 and 1.85) in seed and pulp of desert date (*Balanites aegyptiaca* L.), respectively. The coefficient of variation (CV%) for this study ranged from 0.40 in galactose to 67.17 in xylose.

Conclusion

From the result of this study, it has been revealed that bambara groundnut flour served as a good ingredient for fortification of guinea corn porridge. Both the nutritional and the antinutritional studies showed a progressive increase in most parameters due to the presence of secondary metabolites which has therapeutic properties. Sample F stand out as the best fortification blend from this analysis. It is therefore recommended to be consumed by both young and adult for healthy living.

Conflict of interest: Authors have declared that there is no conflict reported in this study.

References

[1] Ojokoh, A. O., Alade, R. A., Ozabor, P. T. and Fadahunsi, I. F. (2020). Effect of fermentation on sorghum and cowpea flour blends. *J. of Agric Biotech and Sust. Dev.*, 12(2), 39-49. https://doi.org/10.5897/JABSD2019.0365.

[2] Taylor, J. R. N. (2003). Overview: Importance of sorghum in Africa. Workshops on proteins of sorghum and millet: Enhancing Nutritional and Functional Properties for Africa.

[3] Ajanaku, K. O., Ajanaku, C. O., Edoboh-osoh, A. and Nwiyin, O. C. (2012). Nurtitive value of sorghum-'ogi' fortified with groundnut seed (*Arachis hypogaea L*.). *Am. J. Food Technol*., 7, 82-88. https://doi.org/10.3923/ajft.2012.82.88

[4] Feyera, M. (2021). Overview of malting and fermentation role in sorghum flour, primarily for antinutrient reduction. *J. Hum. Nutr. Food Sci.* 9(1), 1138. https://doi.org/10.47739/23336706/1138.

[5] Singh, A., Yadav, N., Sharma, S., Masamba, K. G. and Luo, Y. (2012). Effect of fermentation on physicochemical properties and in-viro starch and protein digestibilities of selected cereals. *Int. Food Res. J.*, 2, 66-70.

[6] Zakari, U., Hassan, A. and Abbo, E. (2010). Physico-chemical and sensory properties of "agidi" from pearl-smillet (*Pennisetum glaucum*) and bambara groundnut (*Vigna subterranea*) flour blends. *African Journal of Food Science*, 4(10), 662-667.

[7] Putri, S. N. A., Utari, D. P., Martati, E. and Putri, W. D. R. (2021). Study of sorghum (*Sorghum bicolor* (L.) Moench) grains fermentation with *Lactobacillus plantarum* ATCC 14977 on tannin content. *IOP Conf. Ser.: Earth Environ. Sci.*, 924, 012037. https://doi.org/10.1088/1755-1315/924/1/012037

[8] Mugendi, J. B., Njagi, E., Kuria, E., Mwasaru, M., Mureithi, J. and Apostolides, Z. (2010). Effects of processing techniques on the nutritional composition and anti-nutrient content of mucuna bean (*Mucuna pruriens L*). *African Journal of Food Science*, 4(4): 156-166.

[9] Ocran, V. K. (1998). Seed Management Manual for Ghana. Accra Ghana: MOFA.

[10] Enwere, N. and Ngoddy, P. (1986). Effect of heat treatment on selected functional properties of cowpea flour. *Tropical Science*.

[11] Schaafsma, G. (2012). Advantages and limitations of the protein digestibility-corrected amino acid score (PDCAAS) as a method for evaluating protein quality in human diets. *British J. of Nutr.*, 108(S2), https://doi.org/10.1017/S0007114512002541

[12] Aremu, M. O., Osinfade, B. G. Basu, S. K. and Ablaku, B. E. (2011). Development and nutritional quality evaluation of kersting's groundnut for African weaning diet. *American J. Food Technology*, 6(12): 1021 – 1033. https://doi.org/10.3923/ajft.2011.1021.1033.

[13] AOAC. Association of Official Analytical Chemists (2005). *Official Method of Analysis 16th Edn.* Washington DC.

[14] Paul, A. and Southgate, D. (1978). *The Composition of Foods*. 4th Edn. Eleservier, North.

[15] Olaofe, O. and Akintayo, E. T. (2000). Prediction of isoelectric points of legume and oil seed proteins from amino acid composition. *J. Technoscience*, 4, 49-53.

[16] FAO/WHO (1991). Protein Quality Evaluation Report of Joint FAO/WHO Expert Consultative FAO Food and Nutrient.FAO, Rome, Italy.

[17] Alsmeyer, R. H., Cunningham, A. E. and Happich, M. L. (1974). Equation to predict (PER) from amino acid analysis. *Food Technology*, 28, 34 – 38.

[18] Olonisakin, A., Aremu, M. O. and Omonigbehin, E. A. (2004). Phytochemical and antimicrobial investigations of extractive from *Phyllantusamarus. Biosci. Biotech. Research, Asia*, 2(1), 33 – 36.

[19] Usoro, E. U., Suyamsothy, E. and Sanni, G. A. (1982). *Manual of Chemical Methods of Food Analysis*. Bencox International Ltd, Lagos.

[20] Temple, V. J., Badamosi, E. J., Ladeji, O. and Solomon, M. (1996). Proximate chemical composition of three locally formulated complementary foods. *West Afr. J. Biol. Sci.*, 5, 134-143.

[21] Dewey, K. G. (2003). Nutrient composition of fortified complementary foods: Should age-specific micronutrient content and ration sizes be recommended. *J. Nutr.*, 133: 2950S-2952S, https://doi.org/10.1093/jn/133.9.2950S.

[22] Anita, B. S., Akpan, E. J., Okon, P. A. and Umoren, I. U. (2006). Nutritive and antinutritive evaluation of sweet potatoes leaves. *Pak. J. Nutr.*, 5, 166-168, https://doi.org/10.3923/pjn.2006.166.168.

[23] FAO/WHO (1998). Preparation and use of Food-Based Dietary Guidelines. Report of a Joint FAO/WHO Consultation. Technical Report series 880. WHO, Geneva, Switzerland.

[24] Aremu, M. O, Olaofe, O. and Akintayo, E. T. (2006). A comparative composition of some Nigerian under-utilized legume flours. *Pak. J. Nutri.*, 5(1): 34-8, https://doi.org/10.3923/pjn.2006.34.38.

[25] Audu, S. S. and Aremu, M. O. (2011). Nutritional composition of raw and processed pinto bean (*Phaseolus vulgaris L.*) grown in Nigeria. *J. of Food Agric. and Environment*. 9(3&4), 72-80. https://www.researchgate.net/publication/287562235

[26] Olanipekun, B. F., Otunola, E. T. and Oyelade, O. J. (2014). Effect of fermentation on the vitamin and mineral contents of bambara nut using selected rhizopus species. LAUTECH. *Journal of Engineering and Technology*, 8(2), 69 – 78. http://www.laujet.com/index.php/laujet/article/view/132

[27] Aremu, M. O., Passali, D. B., Ibrahim, H. and Akinyeye, R. O. (2018). Chemical composition of wonderful kola (*Bucchlozia coriacea*) and breadfruit (*Artocarpus altilis*) seeds grown in south-south, Nigeria. *Bangladesh J. Sci. Ind. Res.* 53(2), 125-132. https://doi.org/10.3329/bjsir.v53i2.36673.

[28] FAO/WHO. (1991). Protein Quality Evaluation Report of Joint FAO/WHO Expert Consultative FAO. *Food and Nutrient FAO. Rome, Italy*.

[29] Paul, A. D., Southgate, A. T. and Russel, J. (1976). First Supplement to McCane and Widdowson's, The Composition of Foods. HMSO, London.

[30] FAO/WHO/UNU (1985). Energy and Protein Requirements. Report of a Joint FAO/WHO/UNU Expert Consultation, WHO Tech. Rep. Ser. No. 724. Geneva: WHO.

[31] Robinson, T. (1985). The organic constituents of higher plants, their chemistry and inter–relationship, 3rd edn. *Corcleus Press North Amlerst Mass*, 6, 430–435.

[32] Aremu, M. O., Olonisakin, A., Bako, D. A. and Madu, P. C. (2006). Compositional studies and physiochemical characteristics of cashew nut (*Anarcadium occidentale*) flour, *Pak. J. Nutrition*, 5(4). 328 – 333. https://doi.org/10.3923/pjn.2006.328.333.

[33] Oyarekua, M. A. and Eleyinmi, A. F. (2004). Comparative evaluation of the nutritional quality of corn, sorghum and millet ogi prepared by modified traditional technique. *Food Agric. Environ*., 2, 94–99.

[34] Fennema, O. R. (1985). Principles of Food Chemistry. 2nd Edn., Marcel Decker, New York, USA, ISBN–13: 9780824774493, p.991.

[35] Paul, A. and Southgate, D. (1978). The Composition of Foods. 4th Edn., Elesevier/North–Hollond Biomedical Press, Amsterdam.

[36] Verma, A. K., Kumar, A. and Baghel, S. S. (2019). Physicochemical properties and nutritional composition of improved varieties of grain cowpea grown in Pantnagar. *J. of Pharmacognosy and Phytochemistry*, 334–338.

[37] Van der Poel, A. F. B. (1990). Effect of processing on antinutritional factors and protein nutritional value of dry beans. *Ani. Feed Sci. and Techn*., 2, 179–208. https://doi.org/10.1016/0377–8401(90)90027–6.

[38] Mbata, T. I., Ikenebomeh, M. J. and Alaneme, J. C. (2009), Studies on the microbiological, nutrient composition and antinutritional contents of fermented maize flour fortified with bambara groundnut (*Vigna subterranean* L). *Afr. J. Food Sci.* 3(6), 165 – 171, https://doi.org/10.5897/AJFS.9000276.

[39] Rafael, D. B., Leandro, L. B., Pedro, I. V. G. G., Newton, D. P., Arlindo, I. T., Cosme, D. C. and Everaldo, G. D. (2018). Quantification of anti-nutritional factors and their correlations with protein and oil in soybeans. *Anais da Academia*, https://doi.org/10.1590/0001-3765201820140465.

[40] Aremu, M. O., Andrew, C., Oko, O. J., Odoh, R., Ambo, I. A. and Hikon, N. B. (2021). Nutrient, antinutrient and sugar contents in desert date (*Balanites aegyptiaca* (L.) Del.) seed and pulp. *Int. J. Sci.*, 10(7), 12–21. https://doi.org/10.18483/ijSci.2484.

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