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Development and Nutritional Quality Evaluation of Kersting's Groundnut-Ogi for African Weaning Diet

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ABSTRACT

Ogi is a maize product and a popular starchy porridge in the west coasts of Africa. Although consumed by adults as a breakfast cereal, its main use is as weaning food for infants. In this study, the nutritional quality of ogi from a composite mixture of maize (*Zea mays* L.) and kersting's groundnut (*Kerstingiella geocarpa* L.) flours was evaluated using standard processing techniques. Maize flour was substituted with kersting's groundnut seed flour at ratios of 90:10, 80:20, 70:30 and 60:40 maize: kersting's groundnut; with 100% maize ogi flour as control. The results showed that protein and fat contents increased with increased kersting's groundnut seed flour substitution, reaching 61.14 and 14.63% dry weight, respectively at 60:40 ratios. All the macro-minerals (Ca, P, Mg, K and Na) analyzed for also recorded increased concentrations in the ogi flours with increased kersting's groundnut seed substitutions. Harmful heavy metals such as lead and cadmium were not detected. The Total Essential Amino Acids (TEAA) ranged from 26.4-32.6 g/100 g crude protein or from 47.9-48.4% of The Total Amino Acid (TAA) while the Limiting Amino Acid (LAA) for all the samples was Met+Cys based on the provisional FAO/WHO standards. Generally, the present study indicates that at = 30% *Kerstingiella geocarpa* seed substitution ogi can be maintained, with higher nutrient content.

Key words: Maize ogi, kersting's groundnut, supplementation, nutritional quality

INTRODUCTION

Children in most developing countries particularly those in low-income classes are weaned on cheap, readily available starchy foods. This can be attributed to several factors including poor nutritional education, decline in household incomes and the unavailability of nutritious commercial formulae (Adeyemi *et al.*, 1987). This has led to the continued research foods and their incorporation into traditional staples. Efforts are also made to ferment the local starchy staples in order to raise their nutritional status (Enujiugh, 2003).

Fermented maize product, ogi, is a popular weaning and breakfast cereal in sub-Saharan African (Banigo and Muller, 1972). Ogi is traditionally prepared by natural fermentation (steeping maize grains in water for 2-4 days at room temperature), followed by wet milling, sieving and souring slurry (2-3 days rest at room temperature). The periods of fermentation and souring determine the degree of sourness (measured by titratable acidity) acid, to a large extent, the nutrient status of ogi (Adeyemi and Beckkley, 1986). Although previous investigators produced ogi with acceptable sensory characteristics without a steeping stage (Adeniji and Potter, 1978;

Sokari *et al.*, 1991), it is during the steeping stage that the desirable microorganism for fermenting the ogi slurry comes into prominence by outgrowing other microorganism (Aremu *et al.*, 2011).

Attempts are currently made in the developing world where maize is a major staple, to supplement it with certain unconventional legumes and oilseeds that contain adequate amounts of the limiting amino acids. One such legume source is kersting's groundnut (*Kerstingiella geocarpa* L.) seed. *Kerstingiella geocarpa* seed, like some other legumes and oilseeds, is known to contain essential minerals (Aremu *et al.*, 2008), nutritionally useful quantities of essential amino acids (Aremu *et al.*, 2006a), phytate and tannins (Aremu *et al.*, 2009) but these anti-nutritional factors are usually removed or greatly reduced during hydrothermal treatment, soaking and fermentation which the seeds are subjected to during processing (Audu and Aremu, 2011). However, it remains to be known how much of the treated seed is needed by a weaning-age child without negative nutritional effects. The present study examines the effect of supplementing maize product, ogi, with defatted hydrothermal treated *Kerstingiella geocarpa* seeds on the nutritional status of the product.

MATERIALS AND METHODS

Sample collection and preparation: The white maize grains (*Zea mays* L.) and kersting's groundnut seeds (*Kerstingiella geocarpa* L.) used for the study were purchased from Nasarawa market in Nasarawa State, Nigeria. The ogi and *Kerstingiella geocarpa* seed flours were produced in the laboratory as outlined in Fig. 1. Wet milling was done using laboratory Kenwood blender (Mini-Processor Model A90LD, Thom Emi Kenwood Small Appliance Ltd., Hampshire, UK) while milling of the flours was done using Hammer Mill, to pass through a 0.25 mm screen. The dehulled *Kerstingiella geocarpa* seed flour was added to maize flour at substitution levels of 10, 20, 30 and 40%, respectively; 100% maize flour served as control. The blended flours were then packaged in moisture-proof, air-tight polyethylene containers and kept at 4°C prior to analyses.

Proximate analyses: The moisture, ash, ether extract, crude fibre, crude protein (N x 6.25) and carbohydrate (by difference) were determined in accordance with AOAC (1995) methods. All proximate analyses of the sample flours were carried out in triplicate and reported in percentage. All chemicals were of analar grade.

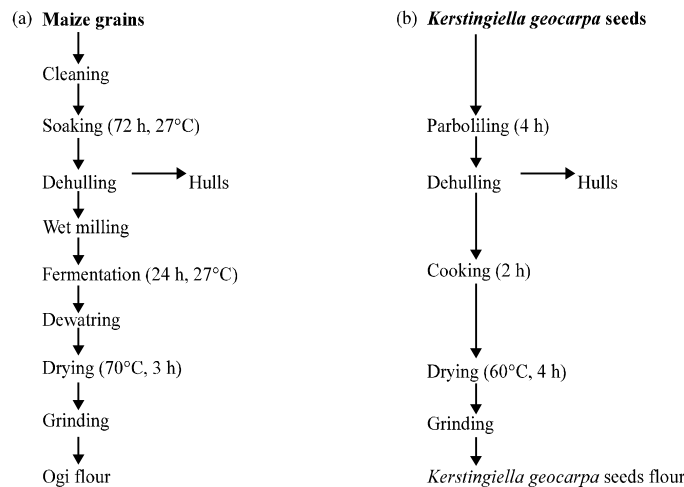


Fig. 1(a-b): Processing methods adapted for the production of (a) ogi and (b) *Kerstingiella geocarpa* seed flours

Mineral analysis: The minerals were analyzed by dry-ashing the samples at 500°C to constant weight and dissolving the ash in volumetric flask using distilled, deionised water with a few drops of concentrated hydrochloric acid. Sodium and potassium were determined by using a flame photometer (Model 405, Corning, UK) using NaCl and KCl to prepare the standards. All other metals were determined by atomic absorption spectrophotometer (Perkin-Elmer Model 403, Norwalk, CT, USA).

Amino acid analysis: Amino acid analysis was by Ion Exchange Chromatography (IEC) (FAO/WHO, 1991) using the Technicon 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°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. The amino acid values reported were the averages of two determinations. Norleucine was the internal standard. Tryptophan was not determined.

Determination of quality parameters

Determination of isoelectric point (pI): The predicted isoelectric point was evaluated (Olaofe and Akintayo, 2000):

$$pI_m = \sum_{i=1}^{n-1} pI_i X_i$$

where, pI_m is the isoelectric point of the mixture of amino acids, pI_ø is the isoelectric point of the øth amino acids in the mixture and X_ø is the mass or mole fraction of the amino acids in the mixture.

Determination of amino acid scores: Determination of the amino acid scores was first based on whole hen's egg (Paul *et al.*, 1976). In this method, both essential and non-essential amino acids were scored. Secondly, amino acid score was calculated using the following formula (FAO/WHO, 1973):

$$\text{Amino acid score} = \frac{\text{Amount of amino acid per test protein (mg}^{-1}\text{)}}{\text{Amount of amino acid per protein in reference pattern (mg g}^{-1}\text{)}}$$

In this method, Met+Cys and Phe+Tyr were each taken as a unit. Also, only essential amino acids determined were scored. Amino acid score was also calculated based on the composition of the amino acids obtained in the samples compared with the suggested pattern of requirements for pre-school children (2-5 years). Here, Met+Cys and Phe+Tyr were each taken as a unit. Also, only essential amino acids with (His) were scored.

Determination of the essential amino acid index: The Essential Amino Acid Index (EAAI) was calculated by using the ratio of test protein to the reference protein for each of the eight essential amino acid plus histidine in the equation that follow (Steinke *et al.*, 1980; Adeyeye, 2010).

$$\text{Essential amino acid index} = 9 \sqrt{\frac{\text{mg lysine in lg test protein}}{\text{mg lysine in lg reference protein}}} \times 8 \text{ essential amino acids His, etc. for all}$$

Methionine and cystine are counted as a single amino acid value in the equation, as are Phe+Tyr.

Determination of the predicted protein efficiency ratio: The predicted protein efficiency ration (P-PER) was determined using the following equation (Nieman *et al.*, 1992):

$$\text{P-PER} = 0.468 + 0.454 (\text{Leu}) - 0.105 (\text{Tyr})$$

Calculations and statistical analyses: Sodium/potassium (Na/K), calcium/phosphorus (Ca/P) and Leu/Ile ratios were calculated for the samples (Nieman *et al.*, 1992; Adeyeye and Aremu, 2010). The fatty acid values were obtained by multiplying crude fat value of each sample with a factor of 0.8 (i.e., crude fat × 0.8 = corresponding to fatty acids value (Paul and Southgate, 1978). The energy values were calculated by adding up the carbohydrate × 17 kJ, crude protein × 17 kJ and crude fat × 37 kJ for each of the samples (Kilgore, 1987). Standard deviations were calculated using MS Excel spread sheet from the three determinations done on each sample for the proximate composition and was used as the measure of dispersion.

RESULTS AND DISCUSSION

Increased *Kerstingiella geocarpa* seed substitution gave progressively higher protein and oil content of the product, with lower carbohydrate content (Table 1). It has been reported (Enujiugha, 2006; Aremu, 1993) that the traditional method of ogi processing is usually accompanied by severe nutrient losses which aggravates the poor nutritional quality of normal dent corn. There was progressive decrease in moisture content of the fortification product; this could mean a reduction in pre-disposition to shelf spoilage (Aremu *et al.*, 2006a). Though, there was progressive decrease in the calculated metabolizable energy values of *Kerstingiella geocarpa* seed-substituted maize-ogi flours but difference in each product not significant (p > 0.05). *Kerstingiella geocarpa* is known to have containing energy concentration favourably compare to

Table 1: Mean proximate composition (%) of maize ogi fortified with *Kerstingiella geocarpa* seed flour

Parameter	Maize:KG					Mean	SD	CV (%)
	100 % maize Ogi	90:10	80:20	70:30	60:40			
	I	II	III	IV	V			
Moisture	4.4 (0.01) ^z	4.2 (1.20)	4.0 (0.50)	3.9 (0.20)	3.8 (1.00)	4.1	0.26	6.42
Ash	0.8 (0.50)	0.9 (1.50)	1.2 (0.00)	1.5 (1.50)	1.8 (1.50)	1.3	0.38	30.40
Crude fat	4.1 (1.00)	4.3 (1.50)	4.4 (0.50)	4.5 (2.50)	4.7 (0.10)	4.0	0.90	22.50
Crude fibre	1.0 (0.00)	1.3 (2.10)	1.6 (0.50)	1.8 (0.50)	2.1 (0.10)	1.5	0.39	25.32
Crude protein	7.0 (1.50)	8.5 (1.15)	9.1 (1.50)	10.2 (2.50)	11.3 (2.00)	9.2	1.46	15.84
Carbohydrate ^y	82.7 (1.00)	81.0 (1.10)	79.7 (2.10)	78.0 (3.00)	76.3 (5.50)	78.5	2.21	2.78
Fatty acid ^x	3.3 (1.00)	3.5 (1.50)	3.5 (2.50)	3.6 (3.00)	3.8 (4.50)	3.6	0.61	4.51
Energy ^w	1676.1 (2.50)	1677.4 (5.50)	1673.1 (4.20)	1668.2 (2.00)	1663.3 (5.60)	1671.6	5.21	0.31

^zNo. in parentheses are standard deviations of triplicate determinations, ^yCarbohydrate percent calculated as the (100-total of other components), ^xCalculated fatty acids (0.8 x crude fat), ^wCalculated metabolizable energy kJ 100 g⁻¹ (protein x 17+fat x 37+carbohydrate x 17), KG: *Kerstingiella geocarpa*

cereal (Aremu *et al.*, 2011). Despite the effect of fortification processes the coefficient of variation (CV%) levels were relatively close with hot spot at 30.40 in ash content whereas others ranged from 0.31 in energy to 25.32 in crude fibre (Table 1). Differences in the mean proximate composition between maize-ogi and different fortification products are presented in Table 2. All the proximate composition parameters were progressively increased with different fortification products except moisture and carbohydrate contents. The most affected by *Kerstingiella geocarpa* seed-substituted maize-ogi flours was crude protein which was increased between 21.0-61.1% with CV% of 38.49. Range of reduction of moisture and carbohydrate were 6.3-14.4 and 2.1-7.7%, respectively. The CV% was variously varied with a range of 27.27-72.23 (Table 2).

All the macro-minerals analyzed for (Ca, P, Mg, K and Na) recorded increased concentrations in the ogi flour with increased *Kerstingiella geocarpa* seed substitutions (Table 3). Calcium in conjunction with phosphorus, magnesium, vitamin A, C and D, chlorine and protein are all involved in bone formation (Fleck, 1976). Calcium is also important in blood clotting, muscle

Table 2: Differences in the mean proximate composition between maize ogi and different fortified products

Parameter	I-II	I-III	I-IV	I-V	Mean	SD	CV (%)
Moisture	0.28 (6.3%)	0.43 (9.7%)	0.56 (12.6%)	0.64 (14.4%)	0.48	0.18	37.50
Ash	-0.11 (-13.8%)	-0.41 (-51.25%)	-0.74 (-92.5%)	-1.0 (-125.0%)	0.57	0.34	59.65
Crude fat	-0.14 (-3.4%)	-0.30 (-7.3%)	-0.44 (-10.7%)	-0.60 (-14.6%)	0.37	0.17	45.95
Crude fibre	-0.26 (-26.0%)	-0.55 (-55.0%)	-0.80 (-80.0%)	-1.1 (-110.0%)	0.68	0.24	35.29
Crude protein	-1.47 (-21.0%)	-2.14 (-30.6%)	-3.21 (-45.9%)	-4.28 (-61.1%)	2.78	1.07	38.49
Carbohydrate	1.70 (2.1%)	2.97 (3.6%)	4.63 (5.6%)	6.34 (7.7%)	3.91	1.74	44.50
Fatty acids	-0.26 (-7.9%)	-0.24 (-7.3%)	-0.35 (-10.7%)	-0.48 (-12.82%)	0.33	0.09	27.27
Energy (kJ/100 g)	-1.27 (-0.07%)	3.01 (0.2%)	7.83 (0.5%)	12.82 (0.8%)	6.23	4.50	72.23

I: 100% maize ogi; II: 90 Maize ogi: 10 KG; III: 80 maize ogi: 20 KG; IV: 70 maize ogi: 30 KG; V: 60 maize ogi: 40 KG, KG: *Kerstingiella geocarpa*

Table 3: Mean mineral composition (mg 100 g⁻¹) of maize ogi fortified with *Kerstingiella geocarpa* seed flour

Mineral	I	II	III	IV	V	Mean	SD	CV (%)
Ca	108.1 (1.50) ^z	110.1 (2.10)	114.4 (1.05)	118.5 (0.50)	120.7 (2.00)	114.4	4.77	4.17
Cr	2.6 (0.10)	2.1 (0.00)	2.6 (0.50)	2.9 (1.20)	3.2 (0.10)	2.7	0.38	14.29
Co	ND ^y	ND	ND	0.6 (0.15)	0.7 (0.50)	-	-	-
Cd	ND	ND	ND	ND	ND	-	-	-
P	37.9 (2.10)	46.5 (1.20)	48.0 (1.00)	48.5 (0.50)	49.6 (0.01)	46.1	4.21	9.14
Zn	4.9 (0.00)	5.9 (1.05)	6.5 (1.50)	6.5 (0.10)	5.0 (0.10)	5.8	0.70	12.13
Cu	ND	ND	ND	0.4 (1.10)	0.5 (0.50)	-	-	-
Mn	0.6 (1.00)	0.6 (0.50)	0.9 (1.50)	1.2 (0.00)	1.4	1.0	0.31	32.63
Ni	ND	ND	ND	0.3 (0.10)	0.5 (0.50)	-	-	-
Fe	18.1 (1.00)	20.1 (2.50)	20.1 (1.50)	21.0 (2.05)	22.0 (1.01)	20.2	1.28	6.32
Mg	77.1 (0.10)	239.1 (5.00)	266.0 (2.50)	371.5 (1.50)	395.6 (0.10)	269.9	113.35	42.00
K	27.0 (0.40)	30.2 (2.50)	35.9 (0.50)	36.5 (1.50)	43.0 (0.50)	34.5	5.53	16.0
Na	53.8 (0.50)	54.4 (0.10)	56.1 (0.50)	58.8 (2.00)	59.0 (0.10)	56.4	2.16	3.83
Pb	ND	ND	ND	ND	ND	-	-	-
^w Ca/P	2.85 (0.50)	2.34 (2.50)	2.39 (0.10)	2.44 (1.20)	2.43 (1.05)	2.49	0.18	7.23
^x Na/K	1.96 (0.10)	1.80 (0.20)	1.84 (0.50)	1.61 (0.50)	1.37 (1.10)	1.72	0.04	2.33

^zNumbers in parentheses are standard deviations of triplicate determinations, ^yND: Not detected; ^xNa: K: Sodium to potassium ratio; ^wCa: P: Calcium to phosphorus ratio, I: 100% maize ogi; II: 90 Maize ogi:10 KG; III: 80 maize ogi:20 KG; IV: 70 maize ogi:30 KG; V: 60 maize ogi :40 KG, KG: *Kerstingiella geocarpa*

contraction and in certain enzymes in metabolic processes (Adeyeye and Fagbohun, 2005). Magnesium is an activator of many enzyme systems and maintains the electrical potential in nerves (Shills, 1973). Phosphorus assists calcium in many body reactions although it also has independent functions. Modern diets which are rich in animal proteins and phosphorus may promote the loss of calcium in the urine (Shills and Young, 1992). Among the micro-minerals, only Cr decreased with increased substitution at 90:10 ratio while others (Zn, Mn, Co, Cu, Ni and Fe) increased in concentration. It is interesting to note that harmful minerals such as lead and cadmium were not detected in the 100% maize ogi or fortification products The CV% levels of all the minerals were also relatively close with the highest found in Mg (42.00) (Table 3). Differences in the mean mineral composition between maize ogi and different *Kerstingiella geocarpa* substitutions showed that CV% ranged from 10.84 in P to 75.00 in Mn (Table 4). Overall, it could be concluded that the substitution of maize with *Kerstingiella geocarpa* seed in the production of ogi yielded products with improved mineral content. This is also substantiated by the increased ash content at all substitution levels (Table 1). Some workers (Adeyemi and Soluade, 1993; Enujiugha, 2006) also observed significant increase in ash and mineral contents in pawpaw-ogi and African oil bean-ogi, respectively. The *Kerstingiella geocarpa* seed is known to contain appreciable amounts of important minerals (Aremu *et al.*, 2006b) and this is expected to reflect in any legume-based or supplemented food product. Food is considered good if Ca/P ratio is above one and poor if the ratio is less than 0.5 while Ca/P ratio above two helps to increase the absorption of calcium in the small intestine. The results of Ca/P ratios in ogi sample and fortified products (Table 3) were not only good but also gave an indication that they would help to increase the absorption of calcium in the small intestine.

Aspartic acid and glutamic acid had the highest concentrations among the group of Amino Acids (AA) in the maize ogi and fortified products (Table 5), as is expected in legumes (Olaofe *et al.*, 1994; Aremu *et al.*, 2010). Leucine constituted the highest single Essential Amino Acid (EAA) in all the samples. The pattern of concentration of Leu was 70:30>80:30>60:40>100%>90:10 of maize ogi to *Kerstingiella geocarpa* substitution ratios. Tryptophan concentrations could not be determined.

Table 4: Differences in the mean mineral composition between maize ogi and different fortified products

Mineral	I-II	I-III	I-IV	I-V	Mean	SD	CV(%)
Ca	-2.04 (-1.9%)	-6.35 (-5.9%)	-10.41 (-9.6%)	-12.55 (-11.6%)	7.84	5.05	64.41
Cr	0.49 (19.1%)	-0.04 (-8.16%)	-0.31 (-12.1%)	-0.66 (-25.8%)	0.38	0.23	26.53
Co	-	-	-	-	-	-	-
Cd	-	-	-	-	-	-	-
P	-8.62 (-22.8%)	-10.02 (-26.4%)	-10.62 (-28.0%)	-11.68 (-30.8%)	10.24	1.11	10.84
Zn	-0.97 (-19.7%)	-1.59 (-32.3%)	-1.59 (-32.3%)	-0.05 (-1.0%)	1.05	0.63	60.00
Cu	-	-	-	-	-	-	-
Mn	0 (0.0%)	-0.27 (-42.9%)	-0.54 (-85.7%)	-0.79 (-125.4%)	0.40	0.30	75.00
Ni	-	-	-	-	-	-	-
Fe	-1.95 (-10.8%)	-1.98 (-10.9%)	-2.9 (-16.0%)	-3.86 (-21.3%)	2.67	0.78	29.21
Mg	-161.97 (-210.0%)	-188.92 (-245.0%)	-294.36 (-381.7%)	-318.47 (-413.0%)	249.93	66.73	27.70
K	-3.2 (-11.9%)	-8.9 (-33.0%)	-9.5 (-35.2%)	-16.00 (-59.0%)	9.40	4.53	48.19
Na	-0.6 (-1.1%)	-2.3 (-4.3%)	-4.7 (-8.7%)	-5.20 (-9.7%)	3.20	1.86	59.06
Pb	-	-	-	-	-	-	-
Ca/P	0.51 (17.9%)	0.46 (16.1%)	0.41 (14.4%)	0.42 (14.7%)	0.45	0.04	8.33
Na/K	0.16 (8.2%)	0.12 (6.1%)	0.35 (17.9%)	0.59 (30.1%)	0.31	0.19	61.29

I: 100% maize ogi; II: 90 Maize ogi:10 KG; III: 80 maize ogi:20 KG; IV: 70 maize ogi:30 KG; V: 60 maize ogi :40 KG, KG: *Kerstingiella geocarpa*

Table 5: Amino acid profiles of maize ogi fortified with *Kerstingiella geocarpa* seed flour (g/100 g⁻¹ crude protein)

Amino acid	I	II	III	IV	V	Mean	SD	CV(%)
Lysine (Lys) ^y	3.2	2.9	3.6	3.5	2.9	3.2	0.33	10.22
Histidine (His) ^y	2.1	1.8	2.3	2.0	2.3	2.2	0.24	10.76
Arginine (Arg) ^y	4.6	5.0	5.1	4.1	4.2	4.6	0.42	9.13
Aspartic acid (Asp)	8.5	7.2	8.7	7.9	9.0	8.3	0.65	7.85
Threonine (Thr) ^y	2.3	2.1	2.4	2.6	2.4	2.4	0.18	7.63
Serine (Ser)	3.0	1.9	3.5	3.8	3.2	3.2	0.63	19.87
Glutamic acid (Glu)	7.3	8.3	8.5	7.7	7.4	7.8	0.54	6.91
Proline (Pro)	3.1	2.0	3.2	3.2	3.1	2.9	0.45	15.46
Glycine (Gly)	3.4	2.6	3.5	3.1	3.5	3.2	0.34	10.56
Alanine (Ala)	4.3	3.6	4.8	4.9	4.3	4.4	0.45	10.34
Cystine (Cys)	0.6	0.5	0.9	0.9	0.7	0.7	0.17	24.29
Valine (Val) ^y	3.6	2.9	3.8	4.2	3.5	3.6	0.40	11.14
Methionine (Met) ^y	0.7	0.5	0.8	0.7	0.8	0.7	0.19	26.76
Isoleucine (Ile) ^y	2.6	2.3	2.8	3.0	3.9	2.9	0.54	18.43
Leucine (Leu) ^y	7.3	5.9	7.7	7.9	7.5	7.3	0.71	9.77
Tyrosine (Tyr)	2.3	2.1	2.4	2.5	2.4	2.3	0.37	15.88
Phenylalanine (Phe) ^y	3.7	3.0	4.0	3.6	3.6	3.6	0.30	8.40

^yEssential amino acids, I: 100% maize ogi; II: 90 Maize ogi :10KG; III: 80 maize ogi :20KG; IV: 70 maize ogi :30KG; V: 60 maize ogi: 40 KG, KG: *Kerstingiella geocarpa*

CV% levels ranged from 6.91 in Glu to 26.76 in Met. Differences in the amino acid profiles between 100% maize ogi and 90:10, between 100% maize ogi and 80:20, between 100% maize ogi and 70:30 and between 100% maize ogi and 60:40 ratio substitution revealed that there was progressive increase of all the AA from 80:20 to 60:40 substitutions except His, Arg and Asp which had decrease of 4.2, 11.3 and 6.9%, respectively at 70:30 substitution ratio (Table 6). At 90:10 *Kerstingiella geocarpa* seed-substituted maize ogi flours all the AA concentration levels were reduced with the exception of Arg and Glu which had increase of 9.1 and 13.9%, respectively. The CV% was variously varied with a range of 10.64 in Arg to 134.38 in Pro. Highlights of the increases recorded in EAA were (in %): Lys (9.3-11.8), His (4.2-8.9), Arg (9.1-11.3), Thr (3.9-19.1), Val (3.1-15.3), Met (4.3-18.6), Ile (6.8-47.3), Leu (3.7-9.1) and Phe (4.0-6.7) (Table 6).

The concentrations of total AA (TAA), total non-essential AA (TNEAA), total essential AA (TEAA) with His, essential aphatic AA (EAAA), essential aromatic AA (EArAA) and total sulphur AA (TSAA) of 100% maize ogi were 62.53, 32.37, 30.16, 16.49, 3.73 and 1.30 g 100 g⁻¹ crude protein (cp), respectively (Table 7). Fortified samples had progressive increase in the concentration levels of TAA, TNEAA, TEAA, EAAA, EArAA and TSAA. The contents of TEAA of 30.16, 26.39, 32.56, 31.60 and 31.37 g 100 g⁻¹ cp without tryptophan were close to the value for egg reference protein (56.6g 100 g⁻¹ cp) (Paul *et al.*, 1976); for soya bean, it is 44.4 g 100⁻¹ cp (Adeyeye, 2010). The TAA here (54.56-68.01 g 100 g⁻¹ cp) were close to the TAA in the bambara groundnut (70.8 g 100 g⁻¹ cp) (Aremu *et al.*, 2006a) and dehulled African yam beans (70.3-91.8 g 100 g⁻¹) (Adeyeye, 1997). The contents of TSAA (0.96-1.66 g 100 g⁻¹ cp) were lower than the 5.8 g 100 g⁻¹ cp recommended for infants (FAO, WHO and UNU, 1985). The EArAA range suggested for ideal infant protein (6.8-11.8 g 100 g⁻¹ cp) (FAO, WHO and UNU, 1985) has current values close to the minimum, i.e., 3.04-3.97 g 100 g⁻¹ cp). The EArAA are precursors of epinephrine and thyroxin (Robinson, 1987). The percentage ratios of TEAA to TAA in the samples ranged from 47.88 to 48.37% which were well above the 39% considered to be adequate for ideal protein food for infants, 26% for children and 11% for adults (FAO, WHO and UNU, 1985). The TEAA/TAA percentage

Table 6: Differences in the mean amino acid composition between maize ogi and different fortified products

Amino acid	I-II	I-III	I-IV	I-V	Mean	SD	CV (%)
Lys ^z	0.32 (9.9%)	-0.38 (-11.8%)	-0.30 (-9.3%)	-0.32 (-9.9%)	0.33	0.17	51.52
His ^z	0.38 (17.8%)	-0.19 (-8.9%)	0.09 (4.2%)	-0.16 (-7.5%)	0.21	0.13	61.90
Arg ^z	-0.42 (-9.1%)	-0.51 (-11.1%)	0.52 (11.3%)	0.43 (9.3%)	0.47	0.05	10.64
Asp	1.31 (15.39%)	-0.22 (-2.6%)	0.59 (6.9%)	-0.53 (-6.2%)	0.66	0.40	60.61
Thr ^z	0.25 (10.9%)	-0.44 (-19.1%)	-0.31 (-13.5%)	-0.09 (3.9%)	0.27	0.13	48.15
Ser	1.08 (35.8%)	-0.49 (-16.2%)	-0.73 (-24.2%)	-0.14 (-4.6%)	0.61	0.55	90.16
Glu	-1.01 (-13.9%)	-1.23 (-16.9%)	-0.39 (-5.37%)	-0.17 (-2.35)	0.70	0.42	60.00
Pro	1.06 (34.4%)	-0.11 (-3.6%)	-0.11 (-3.6%)	0 (0%)	0.32	0.43	134.38
Gly	0.80 (23.5%)	-0.10 (-2.9%)	0.31 (9.1%)	-0.1 (-2.9%)	0.33	0.29	87.88
Ala	0.66 (15.5%)	-0.50 (-11.8%)	-0.61 (-14.4%)	-0.04 (-0.1%)	0.45	0.25	55.56
Cys	0.14 (25.3%)	-0.26 (-43.3%)	-0.33 (-55.0%)	-0.06 (-10.0%)	0.20	0.10	50.00
Val ^z	0.69 (19.2%)	-0.18 (-5.0%)	-0.55 (-15.3%)	0.11 (3.1%)	0.38	0.24	63.16
Met ^z	0.20 (28.6%)	-0.08 (-11.4%)	-0.03 (-4.3%)	-0.13 (-18.6%)	0.11	0.06	54.55
Ile ^z	0.35 (13.3%)	-0.18 (-6.8%)	-0.37 (-14.0%)	-1.25 (-47.3%)	0.53	0.42	79.25
Leu ^z	1.32 (18.2%)	-0.49 (-6.8%)	-0.66 (-9.1%)	-0.27 (-3.7%)	0.69	0.39	56.52
Tyr	0.16 (7.1%)	-0.17 (-7.6%)	-0.22 (-9.8%)	-0.17 (-7.6%)	0.18	0.02	11.11
Phe ^z	0.68 (18.3%)	-0.25 (-6.7%)	0.17 (4.6%)	0.15 (4.0%)	0.31	0.20	64.52

^zEssential amino acid, I: 100% maize ogi; II: 90 Maize ogi :10KG; III: 80 maize ogi :20KG; IV: 70 maize ogi :30 KG; V: 60 maize ogi: 40 KG, KG: *Kerstingiella geocarpa*

Table 7: Concentrations of essential, non-essential, acidic, neutral, sulphur, aromatic, etc. (g 100 g⁻¹ crude protein) of maize ogi fortified with *Kerstingiella geocarpa* seed flour

Parameter	I	II	III	IV	V	Mean	SD	CV (%)
Total amino acid (TAA)	62.53	54.56	68.01	65.46	64.95	63.10	4.61	7.31
Total non-essential amino acid (TNA A)	32.37	28.17	35.45	33.86	33.58	32.69	2.46	7.53
TNEAA (%)	51.77	51.63	52.12	51.73	51.70	51.79	0.17	3.28
Total essential amino acid (TEAA)								
*With histidine	30.16	26.39	32.56	31.60	31.37	30.42	1.88	6.19
*Without histidine	28.03	24.64	30.24	29.56	29.08	28.31	1.97	6.96
TEAA (%)								
*With histidine	48.23	48.37	47.88	48.27	48.30	48.21	0.38	0.79
*Without histidine	44.83	45.16	44.46	45.15	44.77	44.87	0.26	0.58
Essential aliphatic amino acid (EAAA)	16.49	13.18	16.78	20.68	21.18	17.66	2.96	16.76
Essential aromatic amino acid (EArAA)	3.72	3.04	3.97	3.55	3.89	3.63	0.33	9.09
Total neutral amino acid (TNA A)	36.81	29.42	39.76	40.25	39.12	37.07	4.00	10.79
TNA A (%)	58.87	53.92	58.46	61.49	60.23	58.64	2.57	4.38
Total acid amino acid (TAA A)	15.77	15.47	17.22	15.57	16.47	16.10	0.66	4.10
TAA A (%)	25.22	28.35	25.32	23.79	25.36	25.61	0.56	3.36
Total basic amino acid (TBAA)	9.95	9.37	11.03	9.64	9.36	9.87	0.62	6.28
TBAA (%)	15.91	17.17	19.22	14.73	14.14	16.29	1.76	10.80
Total sulphur amino acid (TSAA)	1.30	0.96	1.64	1.66	1.49	1.41	0.24	17.02
Cystine in TSAA (%)	46.15	47.92	52.44	56.02	44.30	49.37	4.40	8.91
(P-PER) ^a	2.59	2.00	2.79	2.86	2.69	2.59	0.31	11.97
(pI) ^b	3.65	3.19	3.95	3.82	3.89	3.70	0.27	7.30
(EAAI) ^c	0.88	0.79	0.98	0.96	0.79	0.88	.31	9.04
Leu/Ile (ratio)	2.75	2.59	2.74	2.63	1.93	2.53	0.31	12.25
Leu-Ile (diff)	4.61	3.64	4.92	4.90	3.63	4.34	0.59	13.59
% Leu-Ile (diff)	63.58	61.38	63.57	61.95	48.27	59.27	59.75	9.72

^a(P-PER): Calculated predicted protein efficiency ratio; ^b(pI): Calculated isoelectric point; ^c(EAAI): Essential amino acid index, I: 100% maize ogi; II: 90 Maize ogi: 10 KG; III: 80 maize ogi:20 KG; IV: 70 maize ogi:30 KG; V: 60 maize ogi:40 KG, KG: *Kerstingiella geocarpa*

contents were strongly comparable to that of egg (50%) (FAO/WHO, 1991) and 43.6% reported for pigeon pea flour (Oshodi *et al.*, 1993), 43.8-44.4% reported for beach pea protein isolate (Chavan *et al.*, 2001) and 40.6% reported for cashew nut (Aremu *et al.*, 2006c). The P-PER values (Table 7) were higher than pigeon pea (1.82) and cowpea (1.21) (Oyarekua and Eleyinmi, 2004); sorghum ogi (0.27) and millet ogi (1.62) (Fennema, 1985). The presence of D-isomers also reduces the digestibility of the protein, because peptide bonds involving D residues are less easily hydrolysed *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 (Fennema, 1985). This elucidates a word of caution on the excessive consumption of maize ogi or its fortified products. A common feature of sorghum and maize is that the proteins of these grains contain a relatively high proportion of leucine. It was therefore suggested that an amino acid imbalance from excess leucine might be a factor in the development of pellagra (FAO, 1995). Clinical, biochemical and pathological observations in experiments conducted in humans and laboratory animals showed that high leucine in the diet impairs the metabolism of tryptophan and niacin and is responsible for niacin deficiency in sorghum eaters (Ghafoorunissa and Narasinga Rao, 1973). High leucine is also a factor contributing to the pellagrigenic properties of maize (Belavady and Gopalan, 1969). These studies suggested that the leucine/isoleucine balance is more important than dietary excess of leucine alone in regulating the metabolism of tryptophan and niacin and hence the disease process. The present Leu/Ile ratios were low in values (1.93-2.75). The pI value range was 3.19-3.95. The pI of any organic matter is important when the protein isolate is to be prepared (Olaofe and Akintayo, 2000; Aremu and Ekunode, 2008). The essential AA index (EAAI) ranged from 0.79-0.98. EAAI is useful as a rapid tool to evaluate food formulations for protein quality, although it does not account for differences in protein quality due to various substitution levels or certain chemical reactions (Adeyeye, 2010). The EAAI for soy flour is 1.26 (Nielson, 2002) which is better than the current result.

The AA scores (AAS) of the samples based on white hen's egg profile (Paul and Southgate, 1978) are shown in Table 8. The scores had values greater than 1.0 in Gly for all the

Table 8: Amino acid scores of maize ogi fortified with *Kerstingiella geocarpa* seed flour based on white hen's egg amino acid

Amino acid	I	II	III	IV	V	Mean	SD	CV (%)
Lys ³	0.52	0.47	0.58	0.57	0.47	0.52	0.05	9.62
His ³	0.89	0.73	0.97	0.85	0.95	0.88	0.09	10.23
Arg ³	0.75	0.82	0.84	0.67	0.68	0.75	0.07	9.33
Asp	0.80	0.67	0.82	0.74	0.84	0.77	0.006	7.79
Thr ³	0.45	0.40	0.48	0.51	0.47	0.46	0.04	8.70
Ser	0.38	0.24	0.45	0.48	0.40	0.39	0.09	23.07
Glu	0.60	0.69	0.71	0.64	0.62	0.65	0.04	6.15
Pro	0.81	0.53	0.84	0.84	0.81	0.77	0.01	1.30
Gly	1.13	0.87	1.17	1.03	1.17	1.07	0.11	10.28
Ala	0.78	0.66	0.87	0.90	0.79	0.80	0.07	8.75
Cy	0.06	0.05	0.08	0.09	0.07	0.07	0.01	14.29
Val ³	1.99	1.61	2.09	2.29	1.93	1.98	0.28	14.14
Met ³	0.09	0.07	0.10	0.10	0.11	0.09	0.01	11.11
Ile ³	0.47	0.41	0.41	0.53	0.69	0.50	0.10	20.00
Leu ³	0.88	0.72	0.94	0.96	0.91	0.88	0.09	10.23
Tyr	0.44	0.41	0.47	0.48	0.47	0.45	0.03	6.67
Phe ³	0.93	0.76	0.99	0.89	0.89	0.89	0.27	30.34

³Essential amino acid, I: 100% maize ogi; II: 90 Maize ogi:10 KG; III: 80 maize ogi:20 KG; IV: 70 maize ogi:30 KG; V: 60 maize ogi: 40 KG, KG: *Kerstingiella geocarpa*

samples except 90:10 substitution ratio and Val for all the samples. The CV% between AA levels for all the samples ranged between 1.30 in Pro to 30.34 in Phe (Table 8.). For the essential AA scores (EAAS) based on the provisional amino acid scoring pattern (FAO/WHO, 1973) the EAAS greater than 1.0 were Leu and Phe+Try for all the samples except 90:10 ratio. The limiting AA (LAA) for all the samples was Met+Cys. The FAO, WHO and UNU (1985) standards for pre-school children (2-5 years) were (g 100 g⁻¹ protein): Leu (6.6), Phe+Tyr (6.3), Thr (3.4), Try (1.1), Val (3.5), Ile (2.8), Lys (5.8), Met+Cys (2.5), His (1.9) and total (33.9 with His) and 32.0 (no His). CV% between AA levels for all the samples ranged between 8.82 in Phe+Tyr to 18.42 in Ile (Table 9).

The EAAS based on these requirements showed that His had the highest score of 1.22 at 80:20 ratio (Table 10). Histidine is a semi-essential AA particularly useful for children growth. It is the precursor of histidine present in small quantities in cells. When allergens enter the tissues it is liberated in larger quantities and is responsible for nettle rash (Bingham, 1977). Ile is an EAA for both old and young. Maple Syrup Urine Disease is an Inborn Error of metabolism in which brain damage and early death can be avoided by a diet low in Ile and two other EAA, Leu and Val. Ile, Leu and Val had high scores in some samples in the current report.

Table 9: Amino acid scores of maize ogi fortified with *Kerstingiella geocarpa* seed flour based on FAO/WHO standards [13]

Amino acid	I	II	III	IV	V	Mean	SD	CV(%)
Ile	0.7	0.6	0.7	0.8	1.0	0.76	0.14	18.42
Leu	1.0	0.8	1.1	1.1	1.1	1.02	0.12	11.76
Lys	0.6	0.5	0.7	0.6	0.5	0.58	0.07	12.07
Met+Cys	0.4	0.3	0.5	0.5	0.4	0.42	0.07	16.67
Phe+Tyr	1.0	0.9	1.1	1.0	1.1	1.02	0.09	8.82
Thr	0.6	0.5	0.6	0.7	0.6	0.60	0.06	10.00
Try	-	-	-	-	-	-	-	-
Val	0.7	0.6	0.8	0.8	0.7	0.72	0.07	9.72
Total	4.4	3.7	4.8	4.9	4.9	4.54	0.45	9.91

I: 100% maize ogi; II: 90 Maize ogi:10 KG; III: 80 maize ogi:20 KG; IV: 70 maize ogi:30 KG; V: 60 maize ogi:40 KG, KG: *Kerstingiella geocarpa*

Table 10: Amino acid scores of maize ogi fortified with *Kerstingiella geocarpa* seed flour based on requirements of pre-school child (2-5 years)

Amino acid	I	II	III	IV	V	Mean	SD	CV(%)
Ile	0.94	0.82	1.01	1.08	1.39	1.05	0.19	18.10
Leu	1.10	0.90	1.17	1.20	1.14	1.10	0.11	10.00
Lys	0.56	0.50	0.62	0.62	0.50	0.56	0.05	8.93
His	1.12	0.92	1.22	1.07	1.21	1.11	0.10	9.01
Met+Cys	0.52	0.38	0.66	0.66	0.60	0.56	0.11	19.64
Phe+Tyr	0.95	0.81	1.01	0.96	0.95	0.94	0.07	7.45
Thr	0.68	0.60	0.72	0.77	0.70	0.69	0.06	86.96
Tyr	-	-	-	-	-	-	-	-
Val	1.03	0.83	1.08	1.19	0.99	1.02	0.12	11.76
Total	5.87	5.76	7.49	7.55	7.48	6.83	0.83	12.15

I: 100% maize ogi; II: 90 Maize ogi:10 KG; III: 80 maize ogi:20 KG; IV: 70 maize ogi:30 KG; V: 60 maize ogi:40 KG, KG: *Kerstingiella geocarpa*

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