NUTRITIONAL EVALUATION OF MAIZE-MILLET BASED COMPLEMENTARY FOODS FORTIFIED WITH SOYBEAN

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Abstract

Traditional complementary foods are mainly based on cereal grains which could not satisfy protein and energy needs of infants and young children. This study was carried out to investigate the effect of combined processing method on nutritional quality of maize-millet-soybean complementary food. Maize, millet, and soybean grains were processed using submerged fermentation, germination and roasting methods (120 ± 10^{o}C) singly and combined. Four complementary food samples (including the control) were formulated and mixed in ratio 50:30:20 maize, millet, and soybean respectively, and analyzed for protein quality using rat assay method, fatty acid profile, and micronutrients. Data were analyzed using computer software for analysis of variance, while Duncan multiple range test (DMRT) was used to separate means where there is a significant difference. Results showed that combining fermentation or germination with roasting method significantly ($p<0.05$) increased protein, energy, iron, zinc, magnesium, phosphorus, and β-carotene content of the samples, while vitamin C decreased. Combination of the processing methods also increased linoleic (0.45 – 0.90%TME), linolenic (1.21 – 1.49%TME) and arachidonic acids (0.03 – 0.06%TME). The range of biological value and net protein utilization were 88 – 93% and 77 – 86% respectively. Protein efficiency ratio of the fermented-roasted sample was comparable with casein- diet group. The study showed that combination of fermentation or germination with roasting methods enhanced nutritional value of complementary food produced from maize-millet-soybean for infants and young children.

Keywords*:* combined processing method, complementary food, micronutrients, nutritional quality.

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1. INTRODUCTION

Traditional processing of making *ogi*, a common complementary food used for weaning infants and young children in Nigeria, has a number of slight processing methods/variations described by several authors (Banigo *et al*., 1974; Akingbala *et al*., 1981; Brown *et al*., 1998; Onofiok and Nnanyelugo, 2007). Research has shown that fermentation of cereal grains to produce *ogi* (complementary food) not only removes parts of its kernel such as seed coat and germ, but also involves washing, sieving and decanting, all of which induce changes in the chemical composition and nutritive value of the final fermented. Cereal based traditional complementary foods commonly fed to infants are inadequate to meet daily nutrients, energy and micronutrients requirements, while infant's formula foods are too expensive for mothers of low socio-economic status. Many researchers in Nigeria (food technologists, food scientists, nutritionists and etcetera) have worked extensively on how to improve the nutrient value of existing complementary foods by trying to combine cereals, legumes, and other staples in such a way that will maximize the efficiency of their proteins for weaning, while few have work on combined processing methods.

It could therefore be concluded that the search for local foodstuffs in the formulation of adequate nutritional complementary food has long been in existence and is still in progress. Therefore, it is inevitable to develop and produce traditional complementary foods of high nutrients density that provides enough nutrients intakes per meal in relation to their small stomach through cottage industry

processing. The study employed combination of fermentation, germination, and roasting processing methods on maize-millet-soybean with a view of producing a complementary food that would be easy to formulate and produce at cottage level technology.

2. MATERIAL AND METHODS

Materials

The yellow maize (*Zea mays*), finger millet (*Eleusine coracana*), and soybean (*Glycine max*) used in this study were purchased at Lafenwa market, Abeokuta, Ogun State, Nigeria. The three raw materials of four kilogram each were divided into four portions and each portion (1 kg) of raw material was subjected to processing methods of fermentation-roasting, germination-roasting, and germination-fermentation-roasting, while the last portion served as control.

Flour preparation

The complementary flours were formulated by blending all the already dried fermented and germinated flours of maize, millet, and soybean in 50:30:20 ratios, respectively. Three kilogram of each raw material (yellow maize, millet and soybean) was sorted to remove dirt, stones, damaged and discoloured grains, winnowed and washed in clean plastic bucket at 30 $\pm$ 2 ^{o}C and soaked for 48 h as described by Adeyemi and Beckley (1986). Also, Three kilogram of each raw material (yellow maize, millet and soya bean) was sorted to remove dirt, stones, damaged and discoloured grains, winnowed and washed in clean distilled water. Each of the raw materials was germinated using the method described by Kulkarni *et al*. (1991). The dried fermented and germinated grains were milled and roasted separately at 120±5 ^{o}C for 10 min and packaged in low density polyethene (LDPE) bags. The packed samples were stored at a cool dry room at 30±2^{o}C. The composite flours of the four complementary foods include the control were formulated equally to determine the effect of combined processing methods on them.

Sample 1 (Control): Raw maize, millet, and soybean flour
Sample 2 (SFR): Fermented (maize, millet, soybean) and roasted
Sample 3 (SGR): Germinated (maize, millet, soybean) and roasted
Sample 4 (SGFR): Germinated (maize, millet, soybean), solid fermentation for 36 h and roasted

Methods

The composite flours were analyzed for their protein quality using rat assay, fatty acids and minerals profile, and vitamins.

Nutritional Quality of Maize-Millet-Soybean Complementary Food

Determination of protein (rat assay method)

All the rats were allowed weighed diet and water through an attached feeding bottle *ad libitum*. The food was placed in small bowls firmly attached to the cages to minimize spillage and scattering. Daily records of food consumption were kept by weighing the food given and that which remains after 24hours. The experimental period was 19 days, which include an initial stabilization period of five days. Weight changes in the rats were taken every 48 hours. During the last five days, urine and faeces from each rat were collected separately on daily basis, stored in screw – capped sample bottles containing a preservative (a drop of toluene) and then frozen at - 80^{0}C. At the end of the experiment, the urine and feaces samples were then pooled together according to group and diets. The bulked feacal matter was dried, milled and stored in airtight zip locked bags in the desiccators until required for analysis. The urine samples were also stored frozen at –80^{0}C until required for analysis. The concentration of nitrogen in the urine and feaces were estimated by the AOAC (2005) method for each group, while method of Pellet and Young (1980) was used to calculate Biological Value (BV), Net Protein Utilization (NPU), Protein Efficiency Ratio (PER), True Digestibility (TD) and Nitrogen Balance (NB) of the complementary food samples. All the experimental rats were killed with chloroform

at the end of the rat assay study. Incision was made into the skull, thoracic, body cavities of each rats and examined for any abnormal growth under microscope. All the incisor-rats were later disposed under the ground.

Protein Efficiency Ratio (PER): % PER = Weight gain (g) x 100 / Protein intake
Biological Value (BV): % BV = Retained N x 100 / Digested
Net Protein Utilization (NPU): % NPU = Retained N x 100 / N Intake
True Digestibility (TD): TD = I – (F – Fk) x 100 / I.
Where: I = Nitrogen intake, F = Faecal nitrogen of the diets, Fk = Faecal nitrogen of basal diet.
Nitrogen Balance (NB): NB = I – (F + U)

Where: I = Nitrogen intake, F = Faecal nitrogen of the diets, U = Urinary nitrogen of the diets.

Determination of fatty acid profile
Fatty acids were separated and quantified after extraction with benzene (1:5, v/v). The mixture was transferred into a separating funnel and shaken further to separate the benzene extract and 2 ml of 10% copper acetate solution was added to develop a blue colour. After this, the reaction mixture was cooled to room temperature (28 ± 2 ^{o}C) and 20 ml of 0.17M sodium chloride solution was added. Finally, the methyl esters were extracted from the mixture with 10 ml of n-hexane and the percentage of each fatty acid was determined as described by AOCS (1978).

Determination of micro-nutrients analysis
The standard methods of Association of Analytical Chemists (AOAC, 2005) were used to determine thiamine, riboflavin, cobalamine, and ascorbic acid, while β-carotenoid was determined using AOAC (1980) method. Pyridoxine was determined according to the method described by Guilarte *et al.* (1980).
Statistical Analysis
All data were statistically analyzed using SPSS version 21.0 for analysis of variance, while Duncan multiple range test (DMRT) was used to separate means where there is a significant difference. For each sample, triplicate determinations were carried out.

3. RESULTS AND DISCUSSION

Rat assay results of the complementary food samples are as shown in Table 1. The average food intake of the albino rats ranged from 67.23 in SFR (fermented-roasted) to 81.50 in SC (control) sample, while the mean weight gained of the albino rats ranged from 13.54 to 16.61 for SGFR (germinated-fermented-roasted) and SC (control) samples, respectively. The physical appearance of the weanling rats used in the animal studies showed an ideal growth and development with the test diets. The variation in weight gain may be as a result of the quantity of food consumed and the total nitrogen intake of the experimental rats. The rats fed the SC (control) diet consumed more food (81.50g) than the other diets group (67.23 – 80.98 g), but the rats fed the FR sample gained more weight than rats fed with other diets. The weight gained over time by the albino rats shows that the rats fed with fermented-roasted (SFR) sample had percentage gain of 114.1%, while those group of rats fed with the germinated-fermented-roasted sample showed the least weight gain (101.6 %). The rats fed with the casein diet gained more weight (118.3%) than rats' feds with the formulated complementary foods, while there was decreased in weight of rats fed with nitrogen-free diet throughout the study period. This result agrees with the work of other workers (Dhingra and Jood, 2001; Ikujendola and Fashakin, 2005; Ikegwu, 2010).
The average nitrogen intake ranged from 1.58 in SFR (fermented-roasted) to 2.16 in SGFR (germinated-fermented-roasted) sample. There were significant difference ($p<0.05$) in the food intake, weight gained, and nitrogen intake of the experimental animals. Feacal nitrogen values ranged from 0.14g to 0.21g for SGR (germinated-roasted) and SC (control) samples, while values for digested nitrogen ranged from 1.42 for SFR sample to 2.0 for SGFR sample.

The values for urinary nitrogen values ranged from 0.14g in SFR sample to 0.20g in SC sample. The results showed that there were no significant differences ($p>0.05$) in the faecal nitrogen, digested nitrogen, and urinary nitrogen of the experimental animals.

Table 1: Protein quality of maize-millet-soybean complementary foods

Parameter	BD	CD	SC	SFR	SGR	SGFR
Weight Gained, g	-8.84±0.83^{a}	18.28±0.06^{de}	16.61±1.33^{cd}	15.43±1.84^{cd}	13.92±2.43^{bcd}	13.54±1.70^{bc}
Food Intake, g	79.20±1.63^{bc}	66.45±0.21^{a}	81.50±1.36^{b}	67.23±4.40^{a}	80.98±1.52^{bc}	79.21±1.20^{bc}
Nitrogen Intake, g	-------	2.24±0.276^{c}	1.85±0.41^{ab}	1.58±0.26^{a}	2.07±0.07^{ab}	2.16±0.09^{b}
Digested Nitrogen, g	-------	2.29±0.13^{b}	1.64±0.44^{a}	1.42±0.26^{a}	1.93±0.11^{a}	2.00±0.06^{a}
Feacal Nitrogen, g	0.19±0.32^{b}	0.17±0.01^{c}	0.21±0.04^{a}	0.16±0.06^{a}	0.14±0.04^{a}	0.16±0.03^{a}
Urinary Nitrogen, g	0.18±0.16^{b}	0.18±0.11^{b}	0.20±0.00^{a}	0.14±0.07^{a}	0.14±0.03^{a}	0.14±0.01^{a}
Biological Value (%)	------	100.00±0.22^{g}	88.31±0.13^{a}	90.11±2.02^{a}	93.08±0.17^{a}	93.44±0.10^{a}
NPU (%)	-----	92.14±2.10^{a}	77.84±3.13^{a}	81.01±0.03^{ab}	86.47±5.81^{b}	86.11±2.91^{b}
PER (%)	------	5.58±4.21^{ab}	0.69±0.04^{d}	0.82±0.03^{cd}	0.93±0.10^{ab}	1.08±0.23^{ab}
True Digestibility (%)	-----	85.37±1.78^{a}	98.92±3.00^{a}	98.73±1.53^{a}	100.00±0.00^{a}	99.07±0.70^{a}
Nitrogen Balance, g	-----	2.11±0.04^{d}	1.44±0.17^{a}	1.28±0.11^{a}	1.79±0.21^{bc}	1.86±0.16^{c}

Values are means of trplicate determination. Mean values in the same row with different superscript are significantly different ($p< 0.05$); BD: Nitrogen-free diet; CD: Casein diet; SC: Control sample; SFR: Fermented-Roasted maize-millet-soybean flour

SC: Control sample; SFR: Fermented-Roasted maize-millet-soybean flour; SGR: Germinated-Roasted maize-millet-soybean flour; SGFR: Germinated maize-Germinated millet-Fermented soybean

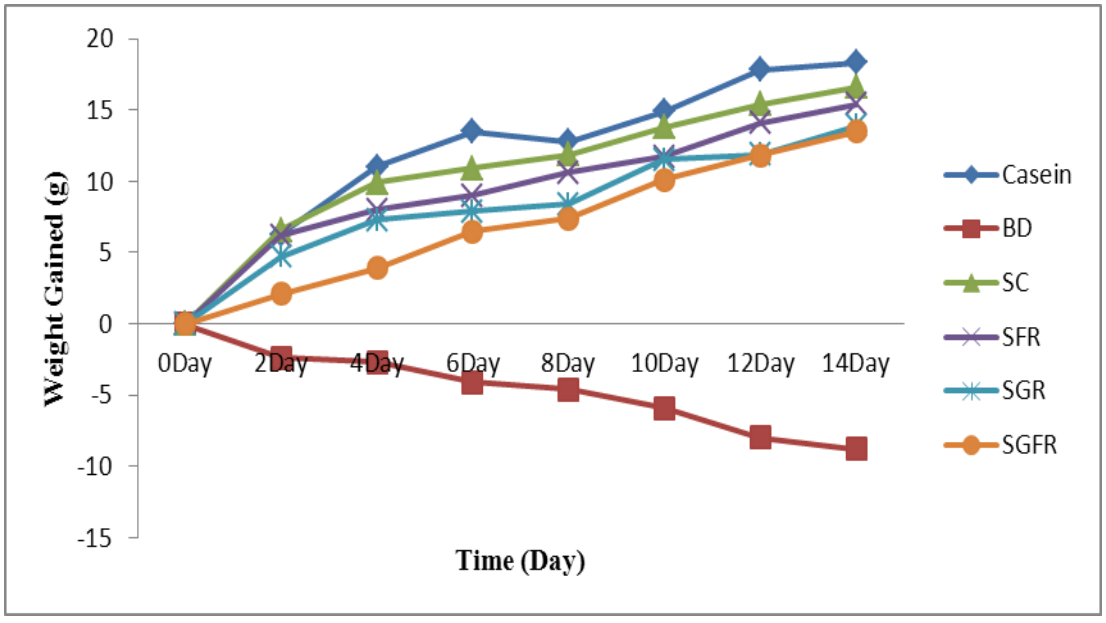

Figure 1: Weight Gained - Time of Albino Rat

BD: Nitrogen-free diet; SC: Control sample; SFR: Fermented-Roasted maize-millet-soybean flour; SGR: Germinated-Roasted maize-millet-soybean flour; SGFR: Germinated maize-Germinated millet-Fermented soybean.

The biological value (BV) ranged from 88.31 in SC to 93.44% in SGFR. The high BV of the complementary diets could have been due to increases in soluble proteins and free amino acids due to partial hydrolysis of stored protein by endogenous proteases produced during the rat assay study of the blended flours. Wondimu and Malleshi (1996) reported a biological value of between 93.1 – 96.65% for a weaning diet combination of malted, popped, and roller-dried barley and chickpea. Similar result was also reported by Omueti *et al*. (2000) with a BV of between 70 – 91% for soy-corn milk in a rat feeding studies. BV obtained in this study reveals the good growth-promoting quality of the complementary foods as a result of the processing treatment and mix ratio given to the raw ingredients. The net protein utilization of the complementary food samples ranged from 77.84 in SC to 86.47% in SGFR. All the complementary foods in this study had net protein utilization (NPU) values higher than 60% recommended by Protein Advisory Group of the United Nations (1971) for complementary foods. The NPU values of (77.84 – 86.47%) were obtained in the study and are similar to reported NPU values of between 79% - 88% for malted and popped barley and chickpea as reported by Wondimu and Malleshi (1996), while Wadud *et al*. (2004) reported a NPU of 83% to 85% for weaning food prepared from soy-based foods after fortification with mineral and vitamins by dry mixing. The protein efficiency ratio values ranged from 0.69% to 1.08% for SGFR and SC samples. The protein efficiency ratio (PER) obtained in the present study are far below those reported (1.38 – 2.37%) by Annan and Planar (1995) in a soy-fortified Ghanaian complementary food and that obtained (1.21 – 3.10) by Omueti *et al*. (2000) for soy-corn milk. There were no significant differences ($p>0.05$) in the true digestibility of the complementary foods. True digestibility values ranged from 98.73 to 100% for SFR and SGR samples. According to Onabanjo (2007), true digestibility rather than apparent digestibility is corrected for endogenous nitrogen losses and gives more accurate estimate of the digested nitrogen than apparent digestibility and to be independent of the level of protein intake in rats fed casein, whole egg and wheat gluten diets. This showed that the complementary foods were well digested and utilized by the experimental animals, hence it promote growing in the experimental animals.

Nitrogen balance values ranged from 1.28 in SFR (fermented-roasted) to 1.86g in SGFR (germinated-fermented-roasted) sample. The study showed that the protein quality indices of the complementary food samples are significantly increases ($p<0.05$) when processed. The graph of weight gained over time of the albino rats showed that SFR (fermented-roasted) sample was best digested and utilized followed by SGFR (germinated-fermented-roasted) sample, while there was a declined in weight of rats fed with BD (nitrogen-free) diet as shown in (Figure 1).

Fatty acid Profile of Maize-Millet-Soybean Complementary Foods

The result of the fatty acid profile of the complementary foods is presented in Table 2. The complementary food samples in this study meet the WHO (1985) recommendations for lipids content in formulation of complementary food.

The WHO values were constructed based on the recommendation that complementary food should have similar fatty acid composition to breast milk. All the four complementary foods contained moderate total unsaturated fat and low total saturated fat, which resulted in high total unsaturated/saturated fatty acid ratio. The lauric acid value ranged from 1.64 to 2.44%TME for SGFR (germinated-fermented-roasted) and SFR (fermented-roasted) samples, respectively, while myristic acid values were very low, varying from 0.02%TME for SFR (fermented-roasted maize-millet-soybean) to 0.09%TME in SGR (germinated-roasted) sample.

The palmitic acid values ranged from 2.91%TME in SGFR (germinated-fermented-roasted) to 3.48%TME in SGR (germinated-roasted) samples.

Table 2: Fatty acids profile of maize-millet-soybean complementary food

Fatty Acid Composition (% Total methyl ester, TME)	SC	SFR	SGR	SGFR
Lauric	2.12±0.16^{abc}	2.44±0.06^{c}	1.87±0.06^{abc}	1.64±0.48^{a}
Myristic	0.06±0.01^{ab}	0.02±0.01^{a}	0.09±0.06^{abc}	0.06±0.01^{ab}
Palmitic	3.42±0.31^{cd}	3.29±0.16^{abc}	3.48±0.28^{d}	2.91±0.16^{ab}
Stearic (18:0)	0.15±0.04^{ab}	0.29±0.01^{ab}	0.18±0.06^{ab}	0.17±0.06^{ab}
Oleic Acid (18:1)	1.21±0.13^{b}	0.88±0.31^{ab}	0.79±0.30^{ab}	0.74±0.27^{ab}
Linoleic (18:2)	0.45±0.03^{a}	0.94±0.07^{b}	0.88±0.17^{b}	0.58±0.31^{ab}
Linolenic (18:3)	1.21±0.17^{a}	1.38±0.04^{a}	1.41±0.04^{a}	1.47±0.28^{a}
Arachidonic (20:4)	0.03±0.00^{a}	0.04±0.03^{a}	0.04±0.01^{a}	0.06±0.03^{a}

Values are means of trplicate determination. Mean values in the same row with different superscript are significantly different ($p< 0.05$)

SC: Control sample; SFR: Fermented-Roasted maize-millet-soybean flour; SGR: Germinated-Roasted maize-millet-soybean flour; SGFR: Germinated maize-Germinated millet-Fermented soybean.

The mono-unsaturated fatty acid (Oleic acid) values were fairly low ranged from 0.74%TME in SGFR (germinated-fermented-roasted) to 1.21%TME in control sample (SC), while the polyunsaturated fatty acid values ranged from 0.45 to 0.94%TME for Linoleic acid (18:2); 1.21 to 1.47%TME for linolenic acid (18:3); and 0.03 to 0.06%TME for arachidonic acid (20:4) respectively. However, linoleic acid to linolenic acid ratio observed in this study is lower than the recommended values (5:1 – 10:1) of FAO/WHO/UNU. According to Onabanjo *et al*. (2008) reported that relatively high levels of linoleic acid might inhibit the synthesis of decosahexaenoic acid from linolenic acid. Fatty acids, especially the essential fatty acids (EFA), linolenic acid and linoleic are precursors to decosahexaenoic acid and arachidonic acid that are critical for growth and development, particularly of the nervous system in the first 6 months of life (Salem *et al*., 1996; Onabanjo *et al*., 2008). According to the report linoleic and linolenic acids are necessary components of myelin, synaptic cell membranes, and photoreceptor cells. Complementary foods low in fat may still be adequate as long as the minimum requirements for essential fatty acids are met (Brown *et al*., 1998; Onabanjo *et al*., 2008). Fernandez *et al*. (2002) reported their findings on the fatty acid composition of Nigerian complementary foods that the foods were devoid of arachidonic and decosahexaenoic, but high in linoleic and linolenic acids. Onabanjo (2007) reported that linoleic acid (18:2) is one of the major fatty acid in soybean, while nutritional deficiency symptoms such as growth retardation, increased skin permeability and malfunctions in many organs, have been associated with the absence of linoleic acid in the diet. This means that all the complementary foods are of good fatty acids quality and will enhance growth in infants and young children.

Mineral Composition of Maize-Millet-Soybean Complementary Food

The values of the micronutrient content of the complementary food samples minerals were presented in Table 3. The mineral content of complementary flours observed in this study were found to be inadequate in some minerals (manganese, calcium, sodium) compared to the Codex Alimentarius standards, but more than adequate in iron, zinc, magnesium, potassium and selenium. Iron content of the complementary food samples ranged from (10.42–12.56 mg/100g) for SGFR (germinated-fermented-roasted) and SGR (germinated-roasted) SGR (germinated-roasted) samples respectively. Iron has been reported to be an important component of the red blood cells, and enhances the oxygen-carrying capacity of the red blood cells (Agbon *et al*., 2009), while its deficiency is believed to affect 20 – 50% of the world population, making it the most common micronutrient deficiency in the world (Onabanjo, 2007).

Table 3: Minerals composition of maize-millet-soybean complementary food

Mineral (mg/100g)	SC	SFR	SGR	SGFR
Iron	10.82±1.09^{ab}	11.46±3.35^{c}	12.56±1.86^{d}	10.42±1.64^{a}
Zinc	6.06±0.78^{a}	7.04±0.35^{de}	7.29±0.38^{e}	6.77±1.46^{c}
Manganese	4.63±0.16^{a}	5.14±0.18^{c}	5.46±0.37^{e}	5.22±1.46^{cd}
Molybdenum	3.47±1.09^{a}	3.88±0.70^{cde}	4.05±0.74^{e}	3.97±1.27^{de}
Copper	1.61±0.93^{ab}	2.68±0.12^{cd}	2.19±0.61^{bc}	1.22±1.79^{a}
Lead	3.35±0.93^{a}	4.48±0.61^{b}	4.00±0.37^{ab}	3.88±6.21^{ab}
Selenium	2.64±3.59^{a}	3.06±0.24^{ab}	3.70±0.91^{bc}	4.07±0.91^{c}
Nickel	4.62±0.84^{a}	5.03±0.25^{abc}	5.40±1.49^{cd}	5.58±1.84^{d}
Calcium	54.59±0.27^{abc}	51.02±0.73^{abc}	64.09±0.59^{c}	41.85±7.30^{a}
Potassium	591.1±0.35^{cd}	495.2±0.73^{ab}	648.8±0.81^{de}	414.8±0.15^{a}
Magnesium	121.5±0.96^{a}	137.9±0.98^{bc}	151.6±0.43^{d}	133.7±0.01^{bc}
Sodium	7.12±0.63^{ab}	8.01±0.47^{ab}	8.56±0.85^{b}	8.25±0.39^{b}
Phosphorus	28.90±0.39^{a}	32.48±0.45^{cd}	35.27±0.32^{e}	31.13±0.80^{bc}
Aluminum	5.83±0.16^{a}	6.13±0.85^{a}	5.36±0.93^{a}	5.62±0.14^{a}

Values are means of trplicate determination. Mean values in the same row with different superscript are significantly different ($p< 0.05$)
SC: Control sample; SFR: Fermented-Roasted maize-millet-soybean flour; SGR: Germinated-Roasted maize-millet-soybean flour; SGFR: Germinated maize-Germinated millet-Fermented soybean.

The values of iron obtained in this study was lower than values reported for complementary foods prepared from malted wheat, malted green gram, jiggery (49.5mg/100g) by Poonam and Salil (1993) and more than those reported by other workers (Asma *et al*., 2006; Onabanjo *et al*., 2008), which contained iron less than or equal to 9.1mg/100g. The values of zinc (6.06 – 7.29 mg/100g) were slightly lower than the recommended complementary food standard level of 10 mg/100g (zinc) prescribed by the FAO/WHO (1991) for infant and young children. According to Onabanjo (2007), zinc is an integral component of almost 100 different enzymes, vital to about 200 different enzymes and appears to play an essential role in all the major metabolic pathways. Zinc content of all the complementary flours were more than the RDA value (4 – 6mg/100g) according to the Protein Advisory Group standard but lower than the value of 10mg/100g recommended by the Codex Alimentarius Guidelines for formulated supplementary foods for older infants and young children (FAO/WHO, 1991).There were significant differences ($p<0.05$) in the values of manganese, molybdenum, copper, lead, selenium, and nickel obtained in the study. The selenium content (2.6 – 4.1mg/100g) of all the complementary flours were more than the RDA value (0.1mg/100g) according Codex Alimentarius Guidelines for formulated supplementary foods for older infants and young children (FAO/WHO, 1991).

Calcium values ranged from 41.85 to 64.09 mg/100g in SGFR and SGR samples, respectively. These values obtained for calcium were far below the RDA of 130 mg/100g (FAO/WHO, 2002).

Potassium and magnesium were the most abundant mineral elements with values ranging from 414.8 – 648.8 mg/100g for SGFR and SGR samples, and 121.5 – 151.6 mg/100g for SC and SGR samples respectively. Sodium ranged from 7.12 – 8.25 mg/100g for SC and SGFR samples, while phosphorus ranged from 28.9 – 35.27 mg/100g for SC and SGR samples respectively. Aluminum ranged from 5.36 mg/100g in SGR to 6.13 mg/100g in SFR sample. All the complementary food samples were found to provide more than adequate intake of iron (10.82 – 12.56 mg/100g); potassium (414.8 – 648.8mg/100g); selenium (2.64 – 4.07 mg/100g); magnesium (121.5–151.6mg/100g), but very low in calcium content (41.85 – 64.09 mg/100g). The result

showed that combined processing methods (especially fermentation, germination and roasting) significantly have effect ($p<0.05$) on complementary food formulation, and this is in agreement with the work of Wadud *et al.* (2004), Onabanjo *et al*. (2008), Martin *et al*. (2010).

Vitamin Content of Maize-Millet-Soybean Complementary Food

The vitamins content of the complementary food samples are reported in Table 4. The values of β-carotene ranged from 2691µg/100g in SC (control) to 3137µg/100g in SGFR (germinated-fermented-roasted) sample. There were significant differences ($p<0.05$) in the β-carotene content of the complementary food samples. The values significantly increased from control to processed samples by 17%. The β-carotene values were higher than the 2500 – 3000µg/100g recommended daily allowance (RDA) for a child of 6 – 11 months. The calculated Vitamin A values ranged from 448 – 523RE (Retinol activity equivalent) for SC (control) and SGFR (germinated-fermented-roasted) samples, respectively. The calculated vitamin A content of the complementary flours shows that soybeans and millet could be a very good source of pro-vitamin A in complementary food formulations. The increase in the level of calculated vitamin A (448 – 523RE) of the formulated flours shows the beneficial effect of processing methods (fermentation, germination and roasting) in infant food formulation. Thiamin (vitamin B_1) value ranged from 0.28 to 0.57 µg/100g for SC (control) and SFR (fermented-roasted) samples, respectively. The Vitamin B_1 values obtained for the complementary food samples were higher than the RDA values of 0.03 – 0.04µg/100g. Riboflavin (vitamin B_2) were very low, varying from 0.02µg/100g for SC (control) to 0.08 µg/100g in SGR (germinated-roasted) sample as against 0.50 – 0.80µg/100g RDA values. Pyridoxine (vitamin B_6) values ranged from 0.21 µg/100g for SC sample to 0.33 µg/100g for SGR sample, while Cobalamine (vitamin B_{12}) values ranged from 0.07 – 0.21µg/100g for SC (control) and SGR (germinated-roasted) samples, respectively. Ascorbic acid (vitamin C) values of the complementary food samples ranged from 2.09mg for SGFR (germinated-fermented-roasted) to 3.92 mg for SC (control) sample. The levels of ascorbic acid found in the blended mixtures were significantly low ($p<0.05$) probably due to the raw ingredients used in formulation of the complementary foods. Ascorbic acid of the complementary flours obtained are lower (2.09 – 3.92 mg/100g) than Codex Alimentarius standard (FAO/WHO, 1991) of 13.34mg/100g. The study showed that multiple processing treatments of the complementary food samples increased value of all the vitamins determined compare to control sample, while vitamin C value decreased as multiple processing treatments are employed.

Table 4: Vitamin content of maize-millet-soybean complementary food

Vitamin	SC	SFR	SGR	SGFR
β-Carotene (µg/100g)	2691 ± 0.63^{a}	3129 ± 0.65^{b}	3126 ± 0.77^{b}	3137 ± 0.20^{b}
Calculated Vitamin A (RE*)	448.0 ± 0.03^{a}	522.0 ± 0.00^{b}	521.0 ± 0.22^{b}	523.0 ± 0.31^{b}
Thiamin (µg/100g)	0.28 ± 0.07^{a}	0.57 ± 0.11^{c}	0.43 ± 0.16^{bc}	0.51 ± 0.06^{c}
Riboflavin (µg/100g)	0.02 ± 0.01^{a}	0.06 ± 0.01^{ab}	0.08 ± 0.01^{ab}	0.06 ± 0.03^{ab}
Pyridoxine (µg/100g)	0.21 ± 0.10^{ab}	0.24 ± 0.07^{ab}	0.33 ± 0.09^{ab}	0.26 ± 0.09^{ab}
Cobalamine (µg/100g)	0.07 ± 0.04^{ab}	0.16 ± 0.06^{bc}	0.21 ± 0.01^{c}	0.15 ± 0.04^{bc}
Ascorbic acid (mg/100g)	3.92 ± 0.17^{c}	2.24 ± 0.14^{ab}	2.76 ± 0.10^{b}	2.09 ± 0.04^{a}

Values are means of trplicate determination. Mean values in the same row with different superscript are significantly different ($p< 0.05$)

SC: Control sample; SFR: Fermented-Roasted maize-millet-soybean flour; SGR: Germinated-Roasted maize-millet-soybean flour; SGFR: Germinated maize-Germinated millet-Fermented soybean.

*: 6µg of β-carotene equal 1 retinol activity equivalent and 1 retinol equivalent of vitamin A activity equivalent to 1µg of retinol (FAO/WHO, 1988).

4. CONCLUSIONS

The protein quality results obtained from this study showed that the formulated complementary foods based on maize-millet-soybean were nutritionally balanced and possess good growth promoting quality for old infants and young children. Combined processing methods such as fermentation-roasting and germination-roasting could easily be adapted to prepare complementary foods from maize-millet-soybean with an optimum mixing ratio. The processing methods are found not only to improve nutrients quality, but also provide more than RDA in zinc, potassium, selenium, and magnesium for old infants and young children. The results from this study indicated that the adoption of germination and roasting processing methods in the production of maize-millet-soybean complementary foods would not only bring about generally improved complementary foods, it will also give rise to the production of complementary foods that is nutritious, and easy to be formulated and produced. Furthermore, the introduction of appropriate combination of two cereal grains with one legume crop with these processing methods (fermentation-roasting or germination-roasting) may constitute one of the major steps towards providing nutritional, complementary foods for mothers of low socio-economic status.

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