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# Chemical Functional and Sensory Properties of Complementary Diets from Blends of Fermented Millet (*Penniselum glaucum*) with Groundnut (*Arachis hypogeae*) and *Moringa oleifera* Seed Flours

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**Abstract:** Malnutrition resulting mostly from poor infant feeding practices is a major public health problem in Nigeria. This study evaluated the nutritional and functional properties of flour blends prepared from fermented millet, groundnut and *Moringa oleifera*, as well as attributes of the gruel obtained from the composite flour. Seven blends were formulated using NutriSurvey for Linear Programming Software and compared with *Ogi* (traditional complementary food) and cerelac (commercial flour). Data were analyzed using statistical packages, means values separated using Ducan's New Multiple Range (DNMR) test at P<0.05. Protein, fat, fibre and ash content of the formulated samples ranged from 18.18-20.46, 10.89-20.72, 3.44-3.89, and 1.62-3.30g/100g, respectively, and all were significantly higher (P<0.05) than in *ogi* (7.08, 5.61, 0.92 and 1.18), while energy values (Kcal/100g) ranged between 427.17 and 481.16. Calcium, phosphorous, zinc and iron content of the formulated samples were significantly higher P<0.05) than in *ogi*, but lower to cerelac. Bulk density, water absorption capacity, least gelation and swelling capacity of the blends ranged from 0.75-0.81g/ml, 2.81-4.24ml/g, 12.33-18.67% and 3.01-5.91% respectively. Sensory evaluation indicated that the samples were highly rated (P 0.05) with sensory scores of above 5.00 for all the sensory attributes investigated. The study shows that the formulated samples are of high nutrient dense products and possess good functional and sensory properties which are needed for the production of complementary foods for infants and older children.

**Keywords:** Millet, *Moringa oleifera*, Fermentation, Functional Properties

## 1. Introduction

Malnutrition resulting mostly from poor feeding practices of infants and young children aged 6 months to two years is a major public health problem in Nigeria [1, 2] According to recent Nigeria Demographic and Health Survey (NDHS) report, the prevalence of stunting, underweight and wasting reached 37%, 23% and 7% respectively [3] Only 29% of infants aged less than six months are exclusively breast fed and 11% of children 6-23 months received minimum acceptable diet. Furthermore, the risk of a newborn dying before the age of five years in Nigeria is thirty times higher than a baby born in the developed countries [4]. The onset of malnutrition can be attributed to a range of factors such as poor food quality, insufficient food intake, severe and repeated infectious diseases or combination of the three factors [5]. The most widely consumed complementary foods in Nigeria, are local cereal-based gruels (ogi) prepared from food materials like maize, sorghum, millet, or starchy foods such as yams, cassavas, coco yams and sweet potatoes [6].

The nutritional values of these gruels is very low [7], protein, lipid and energy contents are well below the recommended values for complementary foods in developing countries [7]. The traditional complementary foods are also often associated with high viscosity which may lead to choking and suffocation of infant during feeding [8].

Considering the high prevalence of Protein Energy Malnutrition (PEM) among the under five children as well as poor complementary food quality, several strategies have been employed in the formulation of complementary foods [9, 10]. The use of two or more plant-based food materials such as cereal and legume in the preparation of complementary foods in order to improve the nutritional quality of the food combinations in terms of essential amino acid profile have been proven by various scientific studies [11-14, 10, 8]. The aims of this study is to produce and evaluate the nutritional qualities of composite blends from locally available food materials such as pearl millet, groundnut and *Moringa oleifera*.

## 2. Materials and Methods

### *2.1. Sources of Food Materials*

The food materials used Millet (*Pennisetum glaucum*), Groundnut (*Arachis hypogeae*) and *Moringa oleifera* were bought from a local market in Lafia, Nasarawa State capital, Nigeria. It was ensured that the food materials were fresh and of good quality and viable.

### *2.2. Preparation of Materials*

Pearl millet was cleaned by hand picking and steeped in cold water for 24 hours. It was then washed and spread on a wire gauze on a raised platform. The dried grains were then milled into powder using laboratory hammer mill and sieved to fine powder using a 150 µm mesh sieve. Groundnut were cleaned by hand picking and then roasted in an oven at 70°C FOR 30 minutes and the seed coat removed to obtained clean roasted groundnut.

*Moringa oleifera* seeds flour was prepared according to the method described by [15]. *Moringa oleifera* seeds were sorted, dehulled, boiled for 1 hour, wrapped in blanched banana leaves for 72hrs (3days) at room temperature to ferment. Then oven dried at 50°C for 20 hrs (model T121, Gen lab Widnes, UK), the fermented seeds were milled using a Philips laboratory blender (HR2811 model), and sieved using a 60-mm mesh sieve (British Standard). The food materials were blended into different formulation of appropriate ratio after which the food samples were milled, sieved and packed in plastic container and stored at room temperature (25°C prior to analyses).

### *2.3. Formulation of Food Samples*

Food formulations were done by blending different components of food samples in the appropriate ratios according to their nutrient contributions in order to achieve the desired food balancing that meets the energy and protein needs of infants between 6 and 24 months of age. The ratios of the corresponding flour samples (Table 1) were blended in a ratio obtained using NutriSurvey for Linear Programming Software developed by [16] to optimize nutrient density of the novel formulations [17]. The NutriSurvey Linear Programming Software was used to target 18% protein, 9% fat [18] and minimum energy value of 380 kcal /100 g dry matter requirement specifications in the weaning blend formulation for the age group of 6 to 18 months. From the processed flours in ratio of 50:35:15, 50:30:20, 55:25:20, 60:20:20, 70:10:30, 55:20:25. 55:15:30 of pearl millet, groundnut and *Moringa oleifera* to obtain FGMG1, FGMG2, FGMG3, FGMG4, FGMG5, FGMG 6 and FGMG7 respectively.

***Table 1.*** *Recipe formulation.*

| Samples | FMGM1 | FMGM2 | FMGM3 | FMGM4 | FMGM5 | FMGM6 | FMGM7 |
|---|---|---|---|---|---|---|---|
| Pearl Millet (%) | 50 | 50 | 55 | 60 | 70 | 55 | 55 |
| Groundnut (%) | 35 | 30 | 25 | 20 | 10 | 20 | 15 |
| *M. oleifera* (%) | 15 | 20 | 20 | 20 | 20 | 25 | 30 |

Key: FGMG: Fermented Pearl Millet+ Groundnut + *Moringa oleifera*.

### *2.4. Determination of Proximate Composition Flour Blends*

The standard method was used to determined nutrients composition of the formulated samples [19]. Oven method was used for moisture determination, fat was determined by ether extraction using soxhlet extractor, crude protein microkjedahl method using 6.25 as a conversion factor while ash was determined by drying ashing method. The carbohydrate content was determined by difference, that is subtracting the total of %moisture content, % crude protein, %crude fiber, % ash, and % fat from the total dry weight (100%) of the food sample difference as follows:

$$\text{Total Carbohydrate (\%)} = 100\% - \% \text{ (Moisture + Protein + Fat + Ash + Crude Fibre)}$$

The energy content was determined by the method of [7]

$$\text{Energy value} = (P * 4.0) + (F * 9.0) + (C * 4.0) \text{ in Kcal/100g of the sample}$$

Where; *P=Protein content (%); F=Fat content (%); C=Available total carbohydrate (%).*

*Mineral composition determination of formulated diets blends*

The Atomic Absorption Spectrophotometer (AAS Model SP9) was used to determine the mineral compositions of iron (Fe), zinc (Zn), calcium (Ca), copper (Cu), iodine (I) and magnesium (Mg) while Sodium (Na) and potassium (K) in the samples were determined using flame emission photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK) with NaCl and KCl as the standards [19]. Phosphorus was determined using Vanodo-molybdbate method.

Calculation of mineral molar ratios and bioavailability index

The Na/K, Ca/P, Ca/K, Zn/Cu, Fe/CU, Phytate: Zn, Ca: Phytate, Phytate: Fe and [Ca] [Phytate]/[Zn] molar ratios were calculated as described by [20].

### 2.5. Determinations of Anti-nutritional Composition of Formulated Flour Blends

The Spectrophotometric procedure of [19] was used for the determination of phytate. Total oxalate content of samples was assayed using the standard method of [19]. The casein digestion method was used in the determination of Trypsin Inhibitor Activity (TIA) [21]. Heamagglutinin (Lectin) determined using the method of [22] and saponin was done using the method described by [23].

### 2.6. Determination of Functional Properties of Formulated Blends

The functional properties of the flour samples were also determined. The least gelation properties and Swelling capacity were determined according to the method described by [24] and modified by [25]. The bulk density was determined using the procedure of [26] and The water absorption capacity of the flours was determine by the method. [27]

### 2.7. Sensory Evaluation of Complementary Foods

The formulated food samples were prepared into light gruels, using about 20 g and 60 ml of water. The reconstituted formulated food samples and the control food samples (i.e., *Cerelac*, a commercial weaning food and Ogi, a traditional weaning food) were coded and presented to 30 untrained panelists (Nursing mothers) that were familiar with the existing complementary foods (i.e., *Cerelac* and Ogi). The panel members were assigned individually to well illuminate laboratory booths and the gruels prepared were served at 40°C in white and transparent glass cups coded with random three digits. The panelists were instructed to rank the gruels on the basis of appearance (color), taste, odour, texture (mouth feel) and overall acceptability using a nine point Hedonic scale as described by [28] (where, 1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much and 9=like extremely).

### 2.8. Statistical Analysis

Data collected were analyzed by Statistical Package for Social Sciences (SPSS) version 16.0. The means and standard deviation of the results were calculated. The data generated were subjected to one-way analysis of variance (ANOVA)). Duncan's Multiple Range Test (DMRT) was used for separation of means to determine whether Significant differences existed between the means at $p<0.05$.

## 3. Results and Discussion

### 3.1. Proximate Compositions of Fermented Millet, Groundnut and Moringa Oleifera Blends

Proximate compositions of formulated samples from fermented Millet, Groundnut and *Moringa oleifera* blends are presented in Table 2. The moisture content of flour samples ranged between 5.50 g/100g in FMGM3 to 8.29 g/100g in FMGM5. The moisture content in the formulated food samples was comparatively lower than [29] recommended value (<10 mg/100g) for flour samples and the values were comparatively similar to the values (7.18 – 7.80 g/100 g) reported by [30] for plantain-based dough meal enriched with soybean and cassava fibre. The results obtained showed that low moisture content of the formulated samples flour may inhibits the growth of microorganisms and thereby prolong the shelf life of the flour products. To inhibits the development of microorganism growth such as mould and bacterial the moisture content of food commodities intended to be used in the preparation of dry weaning foods should be low [11].

The crude protein content of the formulated food samples ranged from 18.18–20.46g/100g; and significantly different ($p<0.05$) from cerelac and ogi, which recorded 17.36g/100g and 7.08g/100g respectively. FMGM5 recorded the highest value (20.46g/100g) while FMGM4 recorded the least value (g/100g). There was significant difference ($p<0.05$) between all the samples.. The crude protein values obtained for the formulated food samples were significantly higher than the 13 to 14g RDA [3] recommended for infants up to one year. The crude protein content was also observed to be significantly ($p<0.05$) higher than Ogi (a local complementary food) but have a similar value with Cerelac. The protein content in formulated food samples are higher than 1.38g/100g to 3.15g/100g reported by [31] for commonly used complementary foods in North-western Nigeria. The high crude protein values observed in this study may be attributed to the supplementation of flour from pearl millet with other protein rich source such as groundnut and *Moringa oleifera seed* flour as affirmed by [32]. This findings is in agreement with observations from other researchers that the protein content of two or more plant-based food materials, particularly cereal-legume combinations, are usually better than those produced from a single cereal or other plant based food materials [33, 34].

***Table 2.*** *Proximate compositions (g/100g dry weight matter) of fermented Millet, Groundnut and Moringa oleifera seed blends.*

| samples | Moisture | Ash | Crude Fat | Crude Protein | Crude Fibre | Carbohydrate | Energy (Kcal) |
|---|---|---|---|---|---|---|---|
| FMGM 1 | 7.40bc±0.06 | 2.71b±0.06 | 11.73d±0.32 | 20.18a±0.07 | 3.54cd±0.06 | 61.53d±0.13 | 432.14f±2.17 |
| FMGM 2 | 7.00c±0.12 | 2.68b±0.06 | 10.89e±0.52 | 18.46b±0.09 | 3.58cd±0.07 | 63.83c±0.59 | 427.17f±2.72 |
| FMGM3 | 5.50d±0.06 | 1.62d±0.09 | 19.28a±0.09 | 19.85a±0.03 | 3.89b±0.06 | 55.23e ±0.03 | 473.84a±0.55 |
| FMGM 4 | 7.07c±0.03 | 2.60b±0.06 | 17.57c±0.03 | 20.46a±0.07 | 3.72c±0.03 | 56.63e±0.10 | 466.49d±0.12 |
| FMGM 5 | 8.23a±0.38 | 2.38c±0.09 | 19.04b±0.07 | 18.18c±0.07 | 3.44d±0.12 | 56.92e±0.20 | 471.76cd±1.33 |
| FMGM 6 | 7.00c±0.06 | 3.30a±0.07 | 20.72a±0.03 | 18.41b±0.09 | 3.58cd±0.07 | 55.26f±0.06 | 481.16b±0.38 |
| FMGM 7 | 6.97c±0.09 | 3.30a±0.07 | 18.96ab±0.07 | 18.38b±0.06 | 3.51cd±0.07 | 55.88ef±0.067 | 467.68bc±0.18 |
| CERELAC | 4.03e±0.01 | 2.51b±0.01 | 9.87f±0.01 | 17.36c±0.01 | 5.43a±0.12 | 69.11b±0.12 | 434.71e±0.61 |
| OGI | 7.80ab±0.12 | 1.18e±0.01 | 5.61g±0.01 | 7.08d±0.12 | 0.92e±0.01 | 86.28a±0.12 | 423.93e±1.03 |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P< 0.5. *RDA (Recommended Daily Allowance) [29].*
Key: FMGM1 50%Fermented Millet +35%Groundnut + 15%*Moringa Oleifera,* FMGM2 50%Fermented Millet +30%Groundnut + 20%*Moringa 0leifera,* FMGM3: 55%Fermented Millet +25%Groundnut + 20%*Moringa 0leifera,* FMGM4 60%Fermented Millet +20%Groundnut + 20%*Moringa Oleifera* FMGM5 70%Fermented Millet +10%Groundnut + 20%*Moringa 0leifera,* FMGM6 55%Fermented Millet +20%Groundnut + 25%*Moringa 0leifera*FMGM7 55%fermented Millet +15%Groundnut + 30%*Moringa Oleifera.*

Crude fat contents formulated samples ranged between 10.89g/100g in FMGM2 to 20.72g/100g in FMGM6. The crude fat contents of all the formulated samples were found to be significantly higher ($p<0.05$) than ogi (5.61g/100g) and cerelac (9.87g/100) (control samples). the fat content of the samples were within the range (10-25g/100g) recommended by [29]. The high content in the formulated food samples may be attributed to the contribution of groundnut and *Moringa oleifera* seed as well as due to increase in activities of lipolytic enzymes, which hydrolyze fat to glycerol and fatty acid [35, 15]. Comparatively, the fat content of food samples in this study were within the range of values reported by [38, 8]. Energy values of fermented complementary foods ranged from 432.14 kcal in FMGM1 to 481.16 kcal in FMGM6. Statistically, the energy values of formulated food samples were significantly ($p<0.05$) higher when compared with ogi (423.93 kcal/100 g), cerelac (434.71kcal/100 g. The results observed for the formulated samples foods also showed that the energy density per 100g were higher than the energy (400-425kcal/100g) recommended in the Codex Alimentarus standards for weaning [29] these formulated food samples were found to be more energetic compared to the energy contents of Ogi' and Cerelac. This high-energy content of the formulated complementary food samples observed in this study can be explained by the high content of carbohydrates and Lipids. According to [36], foods fed to infants and children should be energy dense because low-energy foods tend to limit total energy intake and the utilization of other nutrients. [11] also observed that due to their stomach size children requires energy dense diets to meet their needs. The result of this study indicated that when compare to 'Ogi' children may need to consume less quantity of the complementary foods to meet their daily energy recommended intake of 200, 300 and 550 kcal for ages 6 to 8, 9 to 11 and 12 to 23 months respectively [7, 35, 37]

### *3.2. Mineral Compositions of Fermented Millet, Groundnut and Moringa Oleifera Blends*

The mineral compositions of formulated samples fermented millet, groundnut and *Moringa oleifera* blends are presented in Table 3. Results showed potassium as the most abundant mineral and the value ranged between 640.00 mg/100g in FMGM5 and 685.50 mg/100g in FMGM2 while the mineral with the least concentration was copper and the value ranged from 0.50 mg/100g in FMGM5 to 0.87mg/100g in FMGM2. The results further revealed that the formulated food sample contains essential elements that are important for blood, synthesis, bone and teeth formation and cognitive development in children such as iron, potassium, phosphorous, calcium, sodium, magnesium and zinc. According to [7] complementary foods should provide approximately 50-75% of Calcium, 75-100% of Phosphorous, Zinc and Iron. It is noteworthy that the formulated food samples meet the daily requirement (%RDA) of Calcium (62-78%), Phosphorous (46-59%), Zinc (83-100%) and iron (71-92%). Based on the [29] recommendation the formulated diets would meet the daily requirements for these essential minerals except for Phosphorous. However, since the formulated complementary foods are intended to complement breast milk, therefore continuous breastfeeding as recommended by [36] would go a long way in meeting infants daily requirement. Furthermore, fruits and vegetables are therefore recommended to be included in infants diets to increase micronutrients intakes as well as meet the daily needs.

The molar ratios of Na/K and Ca/P in formulated food samples were higher than that of Ogi but had comparable values with Cerelac while Ca/K molar ratios in fermented complementary foods were lower when compared with the control food samples (ogi and Cerelac). According to [38] a food is considered "poor" if Ca/P ratio is less than 0.5 and "good"if the ratio is above one, while Ca/P ratio above two helps to increase the absorption of calcium in the small intestine The results of Ca/P ratios in this study for the formulated diets can be said to be not only good but also an indication that could help to increase the intestinal absorption of calcium as well as promote bone and teeth development in children.

### 3.3. Anti-nutritional Composition of Fermented Millet, Groundnut and Moringa Oleifera Blends

Table 4 shows the anti-nutritional composition of fermented millet, groundnut and *Moringa oleifera* blends. The phytate content ranged from 2.57 (FMGM5) to 3.10mg/100g (FMGM2). The present study results showed that phytate content of the formulated samples was significantly (P<0.05), when compared to cerelac and ogi. The phytate levels observed for these food samples are well below the established safe permissible limits of 0-5% for phytates in foods [39]. The oxalate concentration of the formulated food samples ranged between 0.18 (FMGM3) and 0.24 mg/100g ((FMGM2). The results revealed that the oxalate of the formulated food samples were comparable to ogi but significantly (P<0.05) higher than cerelac. However, for all the food samples the oxalate concentration were low and less than than the 1% reported to interfere with mineral availability [31].

***Table 3.*** *Mineral compositions (mg/100g) of fermented millet, groundnut and M. oleifera seed blends.*

| Parameters | FMGM 1 | FMGM 2 | FMGM 3 | FMGM 4 |
|---|---|---|---|---|
| Na | 149.50$^{c}$±0.00 | 163.00$^{c}$±0.00 | 135.00$^{c}$±0.00 | 144.00$^{c}$±0.00 |
| K | 662.50$^{a}$±0.001 | 685.50$^{a}$±0.001 | 648.00$^{a}$±0.00 | 664.00$^{a}$±0.001 |
| P | 250.50$^{bcd}$±0.00 | 270.50$^{b}$±0.00 | 236.50$^{cd}$±0.05 | 252.50$^{bc}$±0.00 |
| Ca | 332.50$^{b}$±0.00 | 355.00$^{b}$±00 | 319.95$^{b}$±0.00 | 336.50$^{b}$±0.00 |
| Fe | 12.75$^{c}$±0.01 | 13.83$^{a}$±0.02 | 11.87$^{f}$±0.01 | 12.42$^{d}$±0.01 |
| Mg | 25.90$^{bc}$±0.00 | 27.67$^{a}$±0.02 | 25.0$^{cd}$±0.02 | 26.05$^{abc}$±0.01 |
| Zn | 2.90$^{de}$±0.02 | 3.13$^{b}$±0.01 | 2.79$^{f}$±0.03 | 2.95$^{cd}$±0.02 |
| Cu | 0.71$^{cd}$±0.02 | 0.87$^{b}$±0.02 | 0.61$^{e}$±0.02 | 0.70$^{cd}$±0.02 |
| Mn | 1.10$^{e}$±0.02 | 1.28$^{b}$±0.01 | 0.97$^{g}$±0.01 | 1.23$^{c}$±0.02 |
| Na/K | 0.23$^{a}$ | 0.24$^{a}$ | 0.21$^{b}$ | 0.22$^{a}$ |
| Ca/P | 1.33$^{c}$ | 1.31$^{d}$ | 1.35$^{b}$ | 1.33$^{c}$ |
| Ca/K | 0.5$^{c}$ | 0.52$^{c}$ | 0.49$^{d}$ | 0.51$^{c}$ |
| Zn/Cu | 4.08$^{e}$ | 3.6$^{g}$ | 4.57$^{b}$ | 4.21$^{d}$ |
| Fe/Cu | 17.96$^{d}$ | 15.9$^{f}$ | 19.46$^{b}$ | 17.74$^{e}$ |

***Table 3.*** *Continued.*

| Parameters | FMGM 5 | FMGM 6 | FMGM7 | CERELAC | OGI |
|---|---|---|---|---|---|
| Na | 126.50$^{c}$±0.00 | 147.50$^{c}$±0.0 | 154.50$^{c}$±0.0 | 145.10$^{a}$±0.10 | 14.5.75$^{b}$±0.02 |
| K | 640.00$^{a}$±0.002 | 660.50$^{a}$±0.00 | 666.00$^{a}$±0.00 | 636.50$^{b}$±1.50 | 102.55$^{c}$±0.15 |
| P | 227.50$^{d}$±0.00 | 245.50$^{cd}$±0.00 | 254.50$^{bc}$±0.00 | 400.10$^{a}$±0.10 | 85.97$^{e}$±0.02 |
| Ca | 310.50$^{b}$±0.00 | 328.00$^{b}$±00 | 339.50$^{b}$±0.00 | 600.01$^{a}$±0.02 | 68.68$^{c}$±0.02 |
| Fe | 11.63$^{g}$±0.01 | 12.15$^{e}$±0.02 | 13.27$^{b}$±0.01 | 7.51$^{h}$±0.01 | 0.28$^{i}$±0.02 |
| Mg | 23.35$^{e}$±0.02 | 25.55$^{c}$±0.01 | 26.35$^{abc}$±0.02 | - | 27.50$^{ab}$±0.01 |
| Zn | 2.64$^{g}$±0.02 | 2.85$^{e}$±0.02 | 2.98$^{c}$±0.01 | 5.01$^{a}$±0.01 | 0.81$^{h}$±0.01 |
| Cu | 0.50$^{f}$±0.02 | 0.67$^{d}$±0.02 | 0.74$^{c\pm}$0.02 | - | 1.30$^{a}$±0.02 |
| Mn | 0.02$^{h}$±0.00 | 1.06$^{f}$±0.02 | 1.17$^{d}$±0.02 | - | 1.9$^{5a}$±0.02 |
| Na/K | 0.20$^{b}$ | 0.22$^{a}$ | 0.23$^{a}$ | 0.23$^{a}$ | 0.14$^{c}$ |
| Ca/P | 1.36$^{b}$ | 1.34$^{b}$ | 1.33$^{c}$ | 1.5$^{a}$ | 0.8$^{e}$ |
| Ca/K | 0.49$^{d}$ | 0.5$^{c}$ | 0.51$^{c}$ | 0.94$^{a}$ | 0.67$^{b}$ |
| Zn/Cu | 5.28$^{a}$ | 4.25$^{c}$ | 4.01$^{f}$ | - | 0.62$^{h}$ |
| Fe/Cu | 23.26$^{a}$ | 18.13$^{c}$ | 17.93$^{d}$ | | 0.21$^{g}$ |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.5.

Key: FMGM1 50%Fermented Millet +35%Groundnut + 15%*Moringa Oleifera,* FMGM2 50%Fermented Millet +30%Groundnut + 20%*Moringa 0leifera,* FMGM3: 55%Fermented Millet +25%Groundnut + 20%*Moringa 0leifera,* FMGM4 60%Fermented Millet +20%Groundnut + 20%*Moringa Oleifera* FMGM5 70%Fermented Millet +10%Groundnut + 20%*Moringa 0leifera,* FMGM6 55%Fermented Millet +20%Groundnut + 25%*Moringa 0leifera*FMGM7 55%fermented Millet +15%Groundnut + 30%*Moringa Oleifera.*

The low phytates and oxalate concentration observed in may be due to fermentation process. Studies have shown that various food processing techniques such as dehulling, soaking, boiling, blanching and microbial activities results in decrease in anti-nutritional composition of food products [40, 15]. The low concentration of anti-nutrients such as phytates and oxalates observed in this present study have both nutritional and health advantages. For instance high level of phytates in food are known to inhibit iron absorption in a dose dependent fashion [41] while low level of oxalate is reported to enhance the bioavailability of protein and minerals such as iron, calcium and Zinc [42]. Researches have suggested that the absolute effect of high levels of anti-nutrients on bioavailability of mineral not only depends on relative concentration of minerals in foods but also on the anti-nutritional factors: mineral molar ratio [43, 11]. The relationship between the phytate and the bioavailability of selected minerals such as calcium, zinc and iron in the blend of formulated food samples is presented in Table 4. The range values of phytate: zinc (0.917-0.933), phytate: calcium (0.005), phytate: iron (0.180-0.193) and phytate: calcium: zinc (7.437-8.636). The calculated molar ratios were observed to be lower than that of critical values [43]. Consequently, phytate would not affect the bioavailability of minerals rather the gastrointestinal tract bioavailability and utilization of minerals like iron, calcium, and zinc would be enhanced [42]. Nutritionally, iron plays an important role in maintenance of specific brain cells, forms a vital component of certain enzymes and substances that aid in metabolism as well as has protective function by helping in preventing infections while calcium together with phosphorus and other elements gives rigidity to bones and teeth. Hence, these minerals play important roles in the growth and development of children.

### *3.4. Functional Properties of Fermented Millet, Groundnut and Moringa Oleifera Blends*

Functional properties of food materials are very important for appropriateness of diet, especially for growing children [44]. The functional properties of the formulated food samples are shown in Table 5. The results showed that bulk density ranged from 0.75 g/ml (FMGM5 and FMGM7) to 0.81 g/ml (FMGM2 and FMGM4). Comparatively, the bulk density formulated food samples were within the same ranged values, however, they were higher than Ogi, 0.67 g/ml and *Cerelac*, 0.57 g/ml). Water absorption capacity (WAC) of the formulated food samples was found to be highest in FMGM7 (4.24 ml/g), while FMGM7 (2.81 ml/g) had the lowest value.. Water absorption capacities of the formulated diets were higher than the values for 'Ogi' and *Cerelac.* Swelling capacity (SC) of formulated food samples ranged between 2.92% (FMGM3) and 5.91% (FMGM2). Comparatively, swelling capacity of the formulated food samples were observed to be higher than in 'Ogi' and *Cerelac*. The least gelation ranged from 12.33% (FMGM2, FMGM3, FMGM4, FMGM5) to 18.67% (FMGM1).

***Table 4.*** *Anti-nutritional compositions (mg/100g) of fermented millet, groundnut and Moringa oleifera seed flour blend.*

| Parameters | FMGM 1 | FMGM 2 | FMGM 3 | FMGM 4 | FMGM 5 | FMGM 6 | FMGM 7 | Cerelac | Ogi |
|---|---|---|---|---|---|---|---|---|---|
| Phytate | 2.70±0.00$^{g}$ | 3.10±0.00$^{c}$ | 2.70±0.00$^{g}$ | 2.83±0.00$^{e}$ | 2.57±0.00$^{h}$ | 2.78±0.00$^{f}$ | 2.86±0.00$^{d}$ | 3.73±0.02$^{b}$ | 16.44±0.02$^{a}$ |
| Oxalate | 0.20±0.00$^{c}$ | 0.24±0.00$^{a}$ | 0.19±0.00$^{d}$ | 0.21±0.00$^{b}$ | 0.18±0.00$^{e}$ | 0.20±0.00$^{c}$ | 0.21±0.00$^{b}$ | 0.05±0.01$^{f}$ | 0.20±0.02$^{bc}$ |
| Tannin | 0.07±0.00$^{c}$ | 0.09±0.00$^{a}$ | 0.05±0.00$^{d}$ | 0.07±0.00$^{c}$ | 0.04±0.00$^{e}$ | 0.07±0.00$^{c}$ | 0.08±0.00$^{b}$ | 0.01±0.00$^{g}$ | 0.03±0.00$^{f}$ |
| Saponin | 0.21±0.00$^{b}$ | 0.24±0.00$^{a}$ | 0.18±0.00$^{d}$ | 0.20±0.00$^{c}$ | 0.18±0.00$^{d}$ | 0.20±0.00$^{c}$ | 0.21±0.00$^{b}$ | - | - |
| phenols | 25.19±0.03$^{c}$ | 31.90±0.03$^{a}$ | 23.88±0.02$^{e}$ | 24.20±0.02$^{d}$ | 21.92±0.03$^{e}$ | 25.26±0.02$^{c}$ | 29.37±0.02$^{a}$ | - | - |
| Trypsin Inhibitor | 0.24±0.02$^{f}$ | 0.32±0.02$^{c}$ | 0.33±0.02$^{c}$ | 0.35±0.02$^{b}$ | 0.38±0.02$^{a}$ | 0.29±0.03$^{d}$ | 0.27±0.02$^{e}$ | 0.29±0.02$^{d}$ | 0.28±0.01$^{d}$ |
| Chymotrypsin Inhibitor | 0.24±0.02$^{g}$ | 0.28±0.03$^{f}$ | 0.39±0.02$^{c}$ | 0.40±0.02$^{b}$ | 0.43±0.02$^{a}$ | 0.36±0.03$^{d}$ | 0.33±0.03$^{e}$ | - | - |
| **Phytate/mineral (Zn, Ca &Fe) molar ratios** | | | | | | | | | |
| *[Phy]: [Zn] | 0.917$^{d}$ | 0.973$^{a}$ | 0.953$^{b}$ | 0.943$^{c}$ | 0.958$^{b}$ | 0.959$^{b}$ | 0.945$^{c}$ | - | - |
| *[Phy]: [Ca] | 0.005$^{a}$ | 0.005$^{a}$ | 0.005$^{a}$ | 0.005$^{a}$ | 0.005$^{a}$ | 0.005$^{a}$ | 0.005$^{a}$ | | |
| *[Phy]: [Fe] | 0.180$^{e}$ | 0.190$^{b}$ | 0.192$^{a}$ | 0.193$^{a}$ | 0.187$^{c}$ | 0.193$^{a}$ | 0.183$^{d}$ | | |
| *[Phy]: [Ca/Zn] | 7.623$^{e}$ | 8.636$^{a}$ | 7.626$^{e}$ | 7.931$^{c}$ | 7.437$^{f}$ | 7.863$^{d}$ | 8.024$^{b}$ | | |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.5.

Key: FMGM1 50%Fermented Millet +35%Groundnut + 15%*Moringa Oleifera,* FMGM2 50%Fermented Millet +30%Groundnut + 20%*Moringa 0leifera,* FMGM3: 55%Fermented Millet +25%Groundnut + 20%*Moringa 0leifera,* FMGM4 60%Fermented Millet +20%Groundnut + 20%*Moringa Oleifera* FMGM5 70%Fermented Millet +10%Groundnut + 20%*Moringa 0leifera,* FMGM6 55%Fermented Millet +20%Groundnut + 25%*Moringa 0leifera*FMGM7 55%fermented Millet +15%Groundnut + 30%*Moringa Oleifera.*

*Sources phytate: calcium/zinc > 200 [7].

The least gelation values of the formulated food samples were similar, and they were higher than 'Ogi'; but lower than that of *Cerelac* except for FMGM1 and FMGM7. The observation in this study indicated that the samples possess bulk density comparable to the 0.8g/ml recommended for complementary foods flour [45, 24], which is of advantage in the preparation of high density complementary foods child feeding [42] because high bulk density limits the caloric and nutrient per feed of a child [25]. The water absorption capacity gives an indication of maximum amount of water that a food product would absorbed or available for gelatinization [13]. The differences in the water absorption capacities of the formulated complementary foods could be explained by their respective protein contents with hydrophilic properties, which bind more water than lipids. Therefore the low water absorption capacity observed in some of the formulations could be attributed to high content of fat in the foods that usually combined with protein or carbohydrate to form a complex substance with reduced ability to absorb water [46]. Lower water absorption capacity is desirable for making thinner gruel and also the microbial activities of food products with low water absorption capacity would be reduced. Hence, the shelf life of such food product would be extended [13, 25].

***Table 5.*** *Functional properties of fermented millet, groundnut and Moringa oleifera seed flour blends.*

| Samples | Bulk density (g/ml) | Least gelation% | Water absorption capacity (ml/g) | Swelling capacity% |
|---|---|---|---|---|
| FMGM1 | 0.78±0.01$^{b}$ | 18.67±0.58$^{a}$ | 3.83±0.01$^{b}$ | 4.41±0.01$^{d}$ |
| FMGM2 | 0.81±0.01$^{a}$ | 12.33±0.58$^{d}$ | 3.27±0.01$^{c}$ | 5.91±0.01$^{a}$ |
| FMGM3 | 0.79±0.01$^{b}$ | 12.33±0.58$^{d}$ | 3.07±0.01$^{d}$ | 2.92±0.01$^{e}$ |
| FMGM4 | 0.81±0.01$^{a}$ | 12.33±0.58$^{d}$ | 3.27±0.01$^{c}$ | 5.02±0.01$^{b}$ |
| FMGM5 | 0.75±0.01$^{c}$ | 12.33±0.58$^{d}$ | 3.07±0.01$^{d}$ | 4.21±0.01$^{f}$ |

| Samples | Bulk density (g/ml) | Least gelation% | Water absorption capacity (ml/g) | Swelling capacity% |
|---|---|---|---|---|
| FMGM6 | 0.78±0.01$^{b}$ | 14.33±0.58$^{c}$ | 4.24±0.01$^{a}$ | 3.01±0.01$^{g}$ |
| FMGM7 | 0.75±0.01$^{c}$ | 16.33±0.58$^{b}$ | 2.81±0.01$^{e}$ | 4.51±0.01$^{d}$ |
| CERELAC | 0.57±0.01$^{e}$ | 14.67±0.58$^{c}$ | 2.33±0.01$^{f}$ | 2.45±0.01$^{h}$ |
| OGI | 0.67±0.01$^{d}$ | 10.00±0.58$^{e}$ | 1.83±0.01$^{g}$ | 0.91±0.01$^{i}$ |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P<0.5.
Key: FMGM1 50%Fermented Millet +35%Groundnut + 15%*Moringa Oleifera,* FMGM2 50%Fermented Millet +30%Groundnut + 20%*Moringa 0leifera,* FMGM3: 55%Fermented Millet +25%Groundnut + 20%*Moringa 0leifera,* FMGM4 60%Fermented Millet + 20%Groundnut + 20%*Moringa Oleifera* FMGM5 70%Fermented Millet +10%Groundnut + 20%*Moringa 0leifera,* FMGM6 55%Fermented Millet + 20%Groundnut + 25%*Moringa 0leifera*FMGM7 55%fermented Millet +15%Groundnut + 30%*Moringa Oleifera.*

### *3.5. Sensory Evaluation of Fermented Millet, Groundnut and Moringa Oleifera Blends*

Presented in Table 6 is the results of sensory evaluation of the panelist who assessed the formulated food samples. The results showed that in all the attributes tested for the samples, there are significant (P<0.05) differences. All the samples were acceptable to the nursing mothers however, sample FMGM3 was more acceptable to the panelist. Furthermore, both ogi and cerelac were rated higher than the formulated diets. The disparity observed in this present study between the formulated complementary food samples and control food samples (Cerelac and 'Ogi') in terms of taste, aroma and overall acceptability may be due to the familiarity of the panelists with the 'Ogi' and cerelac over the new formulated products.

***Table 6.*** *Sensory attributes of formulated complementary food samples from fermented millet, groundnut and Moringa oleifera seed blends.*

| SAMPLES | TASTE | COLOUR | CONSISTENCY | AROMA | OVERALL ACCEPTABILITY |
|---|---|---|---|---|---|
| FMGM 1 | 6.05$^{cd}$±0.32 | 5.81$^{cd}$±0.25 | 5.50$^{de}$±0.32 | 6.02$^{cd}$±0.32 | 5.76$^{c}$±0.34 |
| FMGM 2 | 5.85$^{cd}$±0.21 | 6.10$^{cd}$±0.34 | 6.10$^{cd}$±0.30 | 5.82$^{cd}$±0.21 | 6.05$^{c}$±0.20 |
| FMGM3 | 6.65$^{c}$± 0.35 | 6.25$^{bc}$±0.27 | 6.90$^{b}$±0.28 | 6.62$^{c}$±0.35 | 6.20$^{bc}$±0.25 |
| FMGM 4 | 5.60$^{d}$±0.40 | 5.80$^{cd}$±0.37 | 6.90$^{b}$±0.24 | 5.58$^{d}$±0.40 | 5.75$^{c}$±0.32 |
| FMGM 5 | 5.65$^{d}$±0.37 | 6.20$^{cd}$±0.37 | 6.80$^{bc}$±0.25 | 5.63$^{d}$±0.36 | 6.00$^{c}$±0.40 |
| FMGM 6 | 6.55$^{c}$±0.30 | 6.30$^{bc}$±0.21 | 5.90$^{d}$±0.40 | 6.52$^{c}$±0.30 | 6.25$^{bc}$±0.20 |
| FMGM 7 | 5.40$^{d}$±0.41 | 5.40$^{d}$ ±0.36 | 5.45$^{e}$±0.27 | 5.37$^{d}$±0.41 | 5.75$^{c}$±0.40 |
| CERELAC | 8.95$^{a}$± 0.05 | 7.85$^{a}$±0.13 | 7.90$^{a}$±0.19 | 8.92$^{a}$± 0.05 | 7.80$^{a}$±0.10 |
| OGI | 7.60$^{b}$±0.28 | 7.05$^{ab}$±0.14 | 7.55$^{ab}$±0.20 | 7.57$^{b}$±0.28 | 7.00$^{ab}$±0.15 |

Means (±SEM) with different alphabetical superscripts in the same row are significantly different at P< 0.5.
Key: FMGM1 50%Fermented Millet +35%Groundnut + 15%*Moringa oleifera,* FMGM2 50%Fermented Millet +30%Groundnut + 20%*Moringa 0leifera,* FMGM3: 55%Fermented Millet +25%Groundnut + 20%*Moringa 0leifera,* FMGM4 60%Fermented Millet +20%Groundnut + 20%*Moringa Oleifera* FMGM5 70%Fermented Millet +10%Groundnut + 20%*Moringa 0leifera,* FMGM6 55%Fermented Millet +20%Groundnut + 25%*Moringa 0leifera*FMGM7 55%fermented Millet +15%Groundnut + 30%*Moringa oleifera.*

# 4. Conclusion

This study has shown the possibility of producing acceptable complementary food from blends of millet, groundnut and *Moringa oleifera* seed. The findings showed that the protein contents, energy and minerals values of the formulated food samples were better than in 'Ogi', (a local complementary food), and comparable with the Nestle Cerelac, (a commercial complementary food). This study has further shown that the formulated samples are high nutrient dense products and possess good functional and sensory properties which are needed for the production of complementary foods for infants and older children. Moreover, it also offers opportunity to increase the utilization of the underutilized food plants such as *Moringa Oleifera*.

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