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<td>NNAM, N. M.</td>
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<td>Author 2</td>
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<td>Title</td>
<td>Chemical, Sensory and Rheological Properties of Porridges from Processed Sorghum (<em>Sorghum biocolo</em>), Bambara Groundnut (<em>Vigna subterranean</em> L. Verdc) and Sweet Potato (<em>Ipomoea batatas</em>) Flours</td>
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<td>Bambara groundnuts, Nutrient, Sensory properties, Sorghum, Sweet potatoes, Viscosity</td>
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Chemical, sensory and rheological properties of porridges from processed sorghum (*Sorghum bicolor*), bambara groundnut (*Vigna subterranea* L. Verdc) and sweet potato (*Ipomoea batatas*) flours

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Abstract. The chemical, sensory and rheological properties of porridges made from blends of sprouted sorghum, bambara groundnuts and fermented sweet potatoes were examined. Sorghum and bambara groundnuts were sprouted for 48 h while sweet potatoes were fermented for the same period. Blends were formulated from the processed ingredients in the ratio of 60:40:0, 57:42:1, 55:44:1 and 52:46:2 (protein basis) of sorghum, bambara groundnuts and sweet potatoes. Porridges were prepared from the composite flours and the traditional sorghum complementary food. Standard assay methods were used to evaluate the flours for nutrient composition. The porridges were also tested for sensory properties and viscosity. Processing increased the levels of most of the nutrients evaluated. Relative to the sorghum traditional complementary food, the composite flours had higher levels of lipids, protein, ash, crude fiber and minerals ($p < 0.05$). The porridges from the composite flours were generally liked slightly by the panelists and were about seven times less viscous than the porridge from the traditional sorghum complementary food. Use of the composite flours, particularly the 52:46:2 blend, as a traditional complementary food should be encouraged in Nigeria especially with the increasing cost of commercial complementary foods.

Key words: Bambara groundnuts, Nutrient, Sensory properties, Sorghum, Sweet potatoes, Viscosity

Introduction

Childhood malnutrition in the form of protein-energy malnutrition (PEM) is the most common deficiency disease in the world, especially in developing countries [1]. The precipitative factors are related to poor food quality, insufficient food intake and severe and repeated infections [2]. Often infants are weaned too abruptly onto starchy foods with low energy and nutrient densities. In Nigeria, the traditional complementary foods are mainly porridges from maize, sorghum and millet, which do not satisfy the energy and other nutrient needs of infants [1]. The gruels are either too watery (liquid gruel)
and, thus, have a low energy density or too bulky (thick porridge), which cannot be consumed in sufficient quantity by young children [3]. Bulkiness of gruels is due to the effect of heat on the starch structure. On cooking, the starch granules swell and bind large amounts of water. This results in gruels of high viscosity which need to be further diluted with water to give a consistency that is appropriate for child feeding. The dilution decreases the energy and nutrient densities of the gruel and makes it practically impossible for the child to meet his/her requirements due to the limited functional gastric capacity of children (200-250 ml) [1, 3]. Because of this, the traditional complementary foods need to be modified to meet the needs of infants without unrealistically high food intakes.

Germination, a simple household-level food processing technique, has been identified as one of the means of reducing volume/viscosity (dietary bulk) of traditional complementary foods [4, 5]. It has been observed that on sprouting, alpha- and beta-amylases become active. They act on starch granules to break down the amylose chains, which will form the gel network. This reduces the water-holding capacity of the gruels and the inherent problem of dietary bulk associated with the traditional complementary foods. Fermentation is another household-level food process, which could be used to improve nutritional quality, flavor, aroma and safety of traditional foods [6-8]. Both processes have promise and could be employed to modify the existing traditional complementary foods in Nigeria. Supplementation is necessary, however, to insure nutrient balance.

Sorghum, bambara groundnuts and sweet potatoes are cheap and readily available staples in Nigeria, with promising nutritional attributes. Sorghum and bambara groundnut (cereal and legume) proteins have a complementary and supplementary effect on each other, when appropriately blended. Sweet potatoes are rich in lysine and tryptophan which will further enhance the protein quality of sorghum-bambara blends and improve the amino acid and nutrient balance. Judicious blending and processing of the foods could result in improvement of the traditional complementary food made from sorghum (‘ogi’ or ‘akamu’). The objectives of this study, which is part of a series of exploratory works on the use of cheap and locally available staples in Nigeria for the improvement of traditional complementary food, were designed to:

1. formulate composite flours from sprouted sorghum, bambara groundnuts and fermented sweet potatoes,
2. evaluate the unprocessed and processed foods and their composites for nutrient composition, and
3. prepare porridges from the composites and evaluate their sensory properties and viscosity.
Materials and methods

Materials. White sorghum (Sorghum bicolor) (S), cream bambara groundnuts (Vigna subterranea (L) Verdc) (BG) and reddish-purple sweet potatoes (Ipomoea batatas) (SP) were used for the study. They were all purchased from the Nsukka market in Enugu State.

Preparation of materials. Five kg of sorghum were cleaned and divided into two portions of 3 and 2 kg. The three kg portion was soaked in deionized water in a ratio of 1:3 (w/v) (grain to water) for 8 h at an average room temperature of 28 ± 2°C. After soaking, the water was drained. The grains were spread on wet jute bags and covered with moistened muslin cloth. They were allowed to germinate for 48 h at an average room temperature of 28 ± 2°C. The grains were washed twice daily with deionized water to avoid the growth of mold. The vegetative parts were carefully removed after sprouting. The sprouted grains were dried separately in an air oven (Gallenkamp BS Oven 250°C, Model No. 320) at 55°C for 12 h to 96% dry matter. They were milled in a laboratory hammermill (Thomas Wiley Mill, Model ED-5) to a fine flour (70 mm mesh screen). The remaining two kg portion was divided into two parts of one kg each. One portion (1 kg) was steeped in deionized water in a ratio of 1:3 (w/v) (grain to water) and allowed to ferment in a bell jar at 28 ± 2°C for 48 h to produce the traditional sorghum complementary food. At the end of the fermentation, the grains were separated from the steeping water by decanting. The fermented sorghum was dried as noted for sprouted. The fermented sorghum and the unprocessed one kg sample were separately milled in a laboratory hammermill (Thomas Wiley Mill, Model ED-5) to a fine powder (70 mm mesh screen).

Two kg of bambara groundnuts were cleaned and divided into two portions of one and half kg and five hundred grams. The five hundred gram portion was not sprouted. The larger portion (1.5 kg) was sprouted as in sorghum for 48 h. The sprouted seeds were dried in an air oven (Gallenkamp BS oven 250°C, Model No. 320) at 55°C for 12 h to 96% dry matter. The unsprouted and sprouted bambara groundnuts were dehulled mechanically using a laboratory dehulling machine (Bental Superb, Model 200 L 090). The dehulled samples were separately milled in a laboratory hammermill (Thomas Wiley Mill, Model ED-5) to a fine flour (70 mm mesh screen).

One kg of sweet potatoes were hand-peeled and divided into two parts of eight hundred and two hundred grams. The two hundred gram portion was dried in an air oven (Gallenkamp BS oven 250°C, Model No. 320) at 55°C for 12 h to 96% dry matter. The other portion (800 gm) was wet-milled using a Gallenkamp mixer (Model MPR201). It was left to ferment in a bell jar using the microflora present in the paste for 48 h at 28 ± 2°C. The resulting product
was dried as described earlier. The unfermented and fermented samples were separately milled in a laboratory hammermill (Thomas Wiley Mill, Model ED5) to a fine powder (70 mm mesh screen). All the flours were stored separately in Kilner jars for analysis and formulation of the composites. 

Composite flour formulation. The protein level of each flour was estimated by the microKjeldahl procedure [9]. Composites were formulated from the processed foods in ratios of 60:40:0, 57:42:1, 55:44:1, 52:46:2 of sorghum, bambara groundnuts and sweet potatoes on protein basis. The fermented sorghum, which is used as a traditional complementary food ('ogi' or 'akamu'), served as the control for evaluation of the composite flours.

Chemical analyses. Proximate and mineral compositions of the composite flours and the unprocessed and processed foods were determined by the standard assay methods of AOAC [9] (Method Nos. 981.10, 960.02, 960.39, 984.27). Starch and total sugar were determined by the sulphuric-phenol method of Dubois et al. [10]. Residual moisture was determined by the hot air oven method [11]. All analyses were done in triplicate.

Preparation of porridges. Porridges were prepared from the composite flours and the traditional sorghum complementary food (fermented sorghum). One hundred grams of each flour were mixed with 660 ml of deionized water. The slurry was heated in a thermostatically controlled water bath at 75°C. It was allowed to boil for 20 min. Two grams of white sugar were added and the gruel was allowed to cool at room temperature to 40°C (serving temperature). The samples were kept separately in Thermos flasks to maintain a serving temperature of 40°C.

Sensory evaluation. A nine point hedonic scale, where 9 was the highest score and 1 the lowest, was used to test for flavor, texture, color and general acceptability of the porridges [12]. The degree to which a product was liked was expressed as like extremely (9 points), like very much (8 points), like moderately (7 points), like slightly (6 points), neither like nor dislike (5 points), dislike slightly (4 points), dislike moderately (3 points), dislike very much (2 points) and dislike extremely (1 point). Like extremely to like slightly constituted good while dislike slightly to dislike extremely constituted poor. Neither like nor dislike showed that the product was neither good nor poor. One hundred mothers were selected through random sampling from the Mother and Child Health (MCH) Clinic of the Bishop Shanahan Hospital, Nsukka, for the sensory evaluation. The judges were divided into four groups of twenty-five. Morning and afternoon evaluation sessions were organized for two days. Each group participated in one of the evaluation sessions. The
testing was conducted in the food research laboratory of the Department of Home Science and Nutrition, University of Nigeria, Nsukka. Each judge was seated in an individual compartment with fluorescent lighting and free from distractions. The porridges which were appropriately coded (NMN, FAN, CBN, CFN, CNN), were presented to each of the panelists in a Thermos flask (20 ml of sample). Each panelist was given five transparent dessert bowls and plastic teaspoons for use in the sensory test. Room temperature of 28 ± 2 °C was maintained throughout the testing sessions. Each panelist evaluated the five porridges using the hedonic scale. A column for each sample in the hedonic instrument was coded to correspond with the sample code.

Viscosity test. The viscosities of porridges prepared from composite flours and fermented sorghum flour were determined using the Gallenkamp Universal Torsion Viscometer, VHA-200-M. The viscometer is comprised of a vertical torsion wire, a flywheel mounted above a graduated scale and a cylinder suspended below the scale. Five milliliters of sample were poured into the viscometer tube. The flywheel was rotated through 360° and released. The damping effect of the sample on the overswing of the cylinder gave a measure of its viscosity. The porridges were kept separately in Thermos flasks to maintain the serving temperature (40 °C) during the determinations.

Statistical analysis. The chemical and sensory evaluation results were statistically analyzed. The means and standard error of the means were calculated. T-tests, Analysis of Variance and Duncan’s New Multiple Range Test were used [13]. Significance was accepted at $p < 0.05$.

Results and discussion

The nutrient compositions of the unprocessed and processed sorghum, bambara groundnuts and sweet potatoes are shown in Table 1. Processing influenced the lipid levels of the ingredients. Sprouting decreased the percent lipid in sorghum and increased ($p < 0.05$) that in bambara groundnuts. Fermentation of sweet potatoes caused increases ($p < 0.05$) in lipid content. The observed decreases and increases were most likely due to lipolytic enzyme activities which hydrolyzed fat to glycerol and fatty acids. The free fatty acids might have reacted with other products of hydrolysis to form esters. This would account for the decrease. The fatty acids might also have been used for synthesis of new lipids during the metabolic activities of the microflora. This would explain the observed increases in lipid levels of bambara groundnuts and sweet potatoes.
Table 1. Nutrient composition of unprocessed and processed sorghum, bambara groundnuts and sweet potatoes (dry weight basis)

<table>
<thead>
<tr>
<th>Nutrient (100 g sample)</th>
<th>USS</th>
<th>SS₄₈</th>
<th>USBG</th>
<th>BGS₄₈</th>
<th>UFSP</th>
<th>SPF₄₈</th>
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</thead>
<tbody>
<tr>
<td>Lipid (%)</td>
<td>2.81 ± 0.01a</td>
<td>2.50 ± 0.02a</td>
<td>3.62 ± 0.01a</td>
<td>5.97 ± 0.01a</td>
<td>4.26 ± 0.01b</td>
<td>8.01 ± 0.00a</td>
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<tr>
<td>Protein (%)</td>
<td>3.65 ± 0.01b</td>
<td>5.67 ± 0.09a</td>
<td>5.94 ± 0.07b</td>
<td>7.71 ± 0.04a</td>
<td>14.71 ± 0.01b</td>
<td>18.50 ± 0.02b</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>3.64 ± 0.01a</td>
<td>2.91 ± 0.04b</td>
<td>1.42 ± 0.02b</td>
<td>2.27 ± 0.01a</td>
<td>3.33 ± 0.02b</td>
<td>4.55 ± 0.00a</td>
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<tr>
<td>CHO (%)</td>
<td>84.70 ± 0.06a</td>
<td>87.80 ± 0.06a</td>
<td>81.02 ± 0.04a</td>
<td>78.79 ± 0.02b</td>
<td>70.41 ± 0.04a</td>
<td>65.62 ± 0.02b</td>
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<tr>
<td>Phosphorus (ppm)</td>
<td>83.17 ± 0.04b</td>
<td>91.73 ± 0.01a</td>
<td>65.75 ± 0.02a</td>
<td>66.60 ± 0.04a</td>
<td>65.75 ± 0.01b</td>
<td>78.89 ± 0.02a</td>
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<td>Iron (ppm)</td>
<td>49.05 ± 0.09b</td>
<td>48.17 ± 0.02a</td>
<td>36.58 ± 0.09a</td>
<td>38.14 ± 0.07a</td>
<td>20.26 ± 0.04b</td>
<td>29.69 ± 0.01a</td>
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<td>Copper (ppm)</td>
<td>24.05 ± 0.02b</td>
<td>16.54 ± 0.11b</td>
<td>17.09 ± 0.05a</td>
<td>17.33 ± 0.04a</td>
<td>15.33 ± 0.04b</td>
<td>18.54 ± 0.02a</td>
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<td>Calcium (ppm)</td>
<td>217.63 ± 0.03a</td>
<td>101.12 ± 0.04b</td>
<td>97.16 ± 0.08a</td>
<td>151.98 ± 0.03a</td>
<td>168.40 ± 0.09b</td>
<td>170.41 ± 0.00a</td>
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<td>Starch (g)</td>
<td>54.40 ± 0.04a</td>
<td>23.30 ± 0.09b</td>
<td>74.23 ± 0.01a</td>
<td>28.42 ± 0.04b</td>
<td>36.31 ± 0.01a</td>
<td>23.50 ± 0.00b</td>
</tr>
<tr>
<td>Sugar (g)</td>
<td>25.32 ± 0.02b</td>
<td>8.36 ± 0.01b</td>
<td>34.30 ± 0.02a</td>
<td>11.31 ± 0.02b</td>
<td>21.23 ± 0.01a</td>
<td>20.14 ± 0.00a</td>
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</table>

For each nutrient, values with similar letter in each row are statistically (p > 0.05) similar while those with different letter are statistically (p < 0.05) different.

USS = Unsprouted sorghum,
SS₄₈ = Sorghum sprouted for 48 h,
USBG = Unsprouted Bambara groundnut,
BG₄₈ = Bambara groundnut sprouted for 48 h,
UFSP = Unfermented sweet potatoes,
SPF₄₈ = Sweet potatoes fermented for 48 h.
Treatment influenced the protein levels of the foods. Relative to the unsprouted, the sprouted sorghum and bambara groundnuts had higher \( p < 0.05 \) protein contents. This may be attributed to net synthesis of enzymic protein during germination. The fermented sweet potatoes contained more protein than the unfermented. The increase might have been due to proteolytic enzyme activities of the microorganisms involved in fermentation. They hydrolyze protein and its complexes with the release of free amino acids, which could then be used for the synthesis of new proteins.

Processing had varied effects on the ash levels. Sprouting decreased \( p < 0.05 \) the ash of sorghum and increased \( p < 0.05 \) that of bambara groundnuts. Fermentation increased \( p < 0.05 \) the ash in sweet potatoes. The increases in ash of bambara groundnut and sweet potatoes were likely due to synthetic activities of microorganisms during the metabolic processes. The decrease in the ash of sorghum might be attributed to the removal of the vegetative part after sprouting of the seeds.

Sprouting increased \( p < 0.05 \) the carbohydrate level of sorghum and decreased \( p < 0.05 \) that of bambara groundnuts. These changes are attributed to the metabolic activities of the hydrolytic enzymes within the seeds during germination, and structural differences of the seeds. The observed decrease in carbohydrate level of the fermented sweet potatoes was not surprising. It is known that during fermentation, complex carbohydrates are hydrolyzed to simple sugars, which are used for metabolic processes [14].

The treatments had varied effects on the crude fiber levels of the flours. Sprouting decreased fiber in sorghum and bambara groundnuts while fermentation caused a slight increase in the crude fiber level of sweet potatoes. The decreases in the sprouted samples might have been due to use of the nutrient for metabolism by the growing embryo. It is likely that the microbial enzyme activities of the fermenting sweet potatoes led to synthesis of the complex carbohydrate from the carbon skeleton.

Sprouting and fermentation increased the levels of the minerals tested (phosphorus, iron, copper and calcium) except for the decrease in copper and calcium of sprouted sorghum. The increases were due to losses in dry matter which caused apparent increases in mineral concentrations of the foods. Similar observations have been made in germinated [15] and fermented [16] legume seeds.

Processing decreased starch levels of the foods. The decreases might have been due to increased activities of alpha- and beta-amylases during the metabolic processes. The enzymes degrade starch molecules to simple sugars. Sprouting caused a much higher decrease than fermentation. This was probably due to higher activities of the amylases in sprouting seeds than in the fermenting mash.
The treatments decreased total sugar in all the foods. This was probably due to (1) use of this nutrient for metabolic processes by the germinating seeds and a source of energy by the fermenting microflora, (2) use of the sugar to provide carbon skeleton for the synthesis of other complex compounds. This explains the lower sugar level in the processed foods despite the conversion of starch to simple sugars.

The nutrient compositions of traditional sorghum complementary food (fermented sorghum) and composite flours from sprouted sorghum, sprouted bambara groundnuts and fermented sweet potatoes are shown in Table 2. The lipid levels of the flours varied. The 52:46:2 composite contained more lipids than the others. This might have been due to the increased proportion of bambara groundnuts in the composite. Bambara groundnuts are known to contain a higher level of oil relative to other pulses [17]. However, there was no significant (p < 0.05) difference in lipid content among the composites. The fermented sorghum flour (control) used as a traditional complementary food had the least (p < 0.05) lipid content.

The protein levels of the flours were influenced by supplementation. The composites contained more protein (p < 0.05) than the traditional complementary food (fermented sorghum). The poor protein levels of the traditional complementary foods have been a major concern in infant feeding [1]. Use of the composites could serve as a practical means of upgrading the protein levels of the traditional sorghum based complementary food. Protein levels of the composite flours increased as sweet potato levels increased. This demonstrated the beneficial effect of supplementing more than two foods. The 52:46:2 blend had the highest protein (p < 0.05).

The ash levels varied and were a function of supplementation. The composites had lower ash content (p < 0.05) than the control. The lower ash content of the fermented sorghum flour might have been due to the increased microbial enzyme activities during fermentation which hydrolyzed nutrients and led to losses in dry matter content of the flour.

The carbohydrate (CHO) levels of the flours differed. The composites had lower CHO (p < 0.05) than the control. This was likely due to hydrolysis of this nutrient during the metabolic process, and the lower CHO level of the sprouted bambara groundnuts. During sprouting of seeds, there is increased activities of the alpha- and beta-amylases which reaced the CHO level of the sprouted bambara groundnuts. The 52:46:2 blend had the least CHO (p < 0.05).

The composite flours had comparable crude fiber levels (p > 0.05) which were higher (p < 0.05) than that of the control. The lower crude fiber of the fermented sorghum flour relative to the composites might have been due to in-
Table 2. The nutrient compositions of traditional sorghum complementary food (fermented sorghum) and composite flours from sprouted sorghum, sprouted bambara groundnuts and fermented sweet potatoes (dry weight basis)

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<tbody>
<tr>
<td>Lipids (%)</td>
<td>5.73 ± 0.02a</td>
<td>5.70 ± 0.04a</td>
<td>5.79 ± 0.08a</td>
<td>6.12 ± 0.02a</td>
<td>3.74 ± 0.01b</td>
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<tr>
<td>Protein (%)</td>
<td>12.03 ± 0.04b</td>
<td>12.23 ± 0.01b</td>
<td>12.44 ± 0.04b</td>
<td>13.65 ± 0.04a</td>
<td>4.62 ± 0.02c</td>
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<tr>
<td>Ash (%)</td>
<td>2.42 ± 0.06a</td>
<td>2.53 ± 0.01a</td>
<td>2.65 ± 0.01a</td>
<td>2.83 ± 0.01a</td>
<td>0.44 ± 0.02b</td>
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<tr>
<td>Crude fiber (%)</td>
<td>5.78 ± 0.01a</td>
<td>5.76 ± 0.01a</td>
<td>5.76 ± 0.01a</td>
<td>5.72 ± 0.01a</td>
<td>2.59 ± 0.01b</td>
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<tr>
<td>Carbohydrate (%)</td>
<td>74.40 ± 0.04b</td>
<td>73.78 ± 0.04b</td>
<td>73.36 ± 0.04b</td>
<td>71.68 ± 0.06c</td>
<td>88.61 ± 0.03a</td>
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<tr>
<td>Starch (g)</td>
<td>26.35 ± 0.02b</td>
<td>26.21 ± 0.07b</td>
<td>30.11 ± 0.04b</td>
<td>25.94 ± 0.04b</td>
<td>42.23 ± 0.04a</td>
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<tr>
<td>Sugar (g)</td>
<td>14.78 ± 0.01a</td>
<td>14.93 ± 0.02a</td>
<td>15.11 ± 0.02a</td>
<td>15.28 ± 0.02a</td>
<td>15.61 ± 0.02a</td>
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<tr>
<td>Phosphorus (ppm)</td>
<td>71.52 ± 0.04a</td>
<td>72.01 ± 0.04a</td>
<td>72.26 ± 0.01a</td>
<td>72.75 ± 0.04a</td>
<td>55.61 ± 0.04b</td>
<td></td>
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<tr>
<td>Iron (ppm)</td>
<td>347.64 ± 0.09a</td>
<td>346.95 ± 0.07a</td>
<td>344.86 ± 0.02a</td>
<td>344.77 ± 0.06b</td>
<td>336.54 ± 0.03c</td>
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<tr>
<td>Copper (ppm)</td>
<td>17.65 ± 0.02a</td>
<td>17.75 ± 0.04a</td>
<td>17.78 ± 0.08a</td>
<td>17.88 ± 0.04a</td>
<td>16.02 ± 0.02b</td>
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<tr>
<td>Calcium (ppm)</td>
<td>126.46 ± 0.04d</td>
<td>129.13 ± 0.06c</td>
<td>130.59 ± 0.08b</td>
<td>133.16 ± 0.16a</td>
<td>95.01 ± 0.04c</td>
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</table>

Means not followed by the same letters in the same row are significantly (p < 0.05) different.

SS = Sorghum sprouted for 48 h.
SSB = Bambara groundnut sprouted for 48 h.
FSP = Sweet potato fermented for 48 h.
FS = Sorghum fermented for 48 h.
* Control.
creased enzyme activities during fermentation of the grain, which hydrolyzed the complex carbohydrates to simpler compounds.

| The starch values varied. The unsupplemented sorghum complementary food (fermented sorghum) contained more starch ($p < 0.05$) than the composite flours which had high proportions of sprouted sorghum and sprouted bambara groundnut flours. The lower starch levels of the composites could be attributed to enzymatic activities which increase rapidly in germinating seeds. In sorghum seeds, the amylase activity is especially high at $46\%$ of germination [3]. The alpha-amylases are synthesized in the cell within the aleurone layer, from where they migrate into the starchy endosperm and hydrolyze starch granules to simple sugars. The starch granules will, therefore, not swell to the same extent during cooking because the amylose chains needed to form the gel network have been broken down. This will reduce the water-holding capacity and, subsequently, the bulk or consistency (viscosity) of gruels prepared from the germinated flours.

| The lower starch levels of the composites are of interest because starch has been implicated in dietary bulk and high viscosity of fermented traditional complementary foods. This is because fermentation techniques do not appear to cause sufficient starch hydrolysis to significantly influence the dietary bulk of the gruels [18]. This results in either (a) a thin gruel with very low energy and nutrient density and the required volume to meet the child’s requirement would be too large and practically impossible for the child to consume, or (b) a very stiff and sticky porridge which is difficult to consume, especially for young children who may not have developed their full capacity to masticate and to swallow stiff, solid foods. Although the energy density may be acceptable, the consistency (viscosity) may be a major constraint in providing young children with enough food.

| The flours had comparable ($p > 0.05$) sugar levels contrary to expectation. Higher ($p < 0.05$) levels of sugar were expected in the composite flours than in the control (fermented sorghum). This is because the activities of alpha- and beta-amylases, which hydrolyze starch to simple sugars, increase more rapidly during germination of seeds than in fermentation [18]. The comparable ($p > 0.05$) sugar levels for the control and the composites were probably due to the balance between synthetic and degradative processes during the sprouting process. The high level of sugar resulting from the degradation of starch might have been translocated for use by the developing axis.

| The phosphorus (P) concentrations of the composites were comparable ($p > 0.05$) but higher ($p < 0.05$) than that of the control. This might have been due to leaching of this mineral into the fermenting medium. The iron (Fe) levels varied and were influenced by supplementation. The bambara-sorghum com-
3. The sensory properties of porridges from composite flours and fermented sorghum flour

<table>
<thead>
<tr>
<th>Flavor</th>
<th>Texture</th>
<th>Color</th>
<th>General</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS-SBG-FSP</td>
<td>6.73 ± 0.20</td>
<td>5.24 ± 0.21</td>
<td>5.13 ± 0.15</td>
<td>5.18 ± 0.23</td>
</tr>
<tr>
<td>SS-SBG-FSP</td>
<td>6.01 ± 0.12</td>
<td>5.73 ± 0.26</td>
<td>5.40 ± 0.18</td>
<td>5.15 ± 0.18</td>
</tr>
<tr>
<td>SS-SBG-FSP</td>
<td>6.21 ± 0.27</td>
<td>5.92 ± 0.22</td>
<td>5.71 ± 0.26</td>
<td>5.51 ± 0.21</td>
</tr>
<tr>
<td>SS-SBG-FSP</td>
<td>6.94 ± 0.21</td>
<td>7.16 ± 0.06</td>
<td>7.16 ± 0.21</td>
<td>7.43 ± 0.19</td>
</tr>
<tr>
<td>SS-SBG-FSP</td>
<td>5.26 ± 0.19</td>
<td>7.43 ± 0.19</td>
<td>7.43 ± 0.19</td>
<td>7.16 ± 0.21</td>
</tr>
</tbody>
</table>

Means ± SEM of 100 replications. Means not followed by the same letter in a row are significantly (p < 0.05) different.

Scores are based on a point hedonic scale where scores of
9 - Like extremely
6 - Like slightly
3 - Neither like nor dislike
0 - Neither like nor dislike
- Dislike much
- Dislike very much
- Dislike extremely

SS = Sorghum sprouted for 48 h.
SBG = Bambara groundnut sprouted for 48 h.
FSP = Sweet potato fermented for 48 h.
FS = Sorghum fermented for 48 h.
Control.

The composite (60:40:0) had the highest (p < 0.05) Fe, while the unsupplemented sorghum contained the least (p < 0.05). Again, this might be attributed to leaching of the nutrient during fermentation and also to the higher level of Fe in the sprouted sorghum which constituted the greater proportion of the composite. Supplementation improved the copper (Cu) levels. The unsupplemented sorghum flour had the least Cu. The calcium (Ca) values varied with supplementation level. The blends containing sorghum, bambara groundnuts and sweet potatoes contained more Ca (p < 0.05) than others. The 52:46:2 blend had the highest Ca (p < 0.05) while the unsupplemented sorghum contained the least. The mineral results appear to suggest that fermentation of sorghum to produce the traditional complementary food leads to significant losses in minerals.

The sensory scores associated with the porridges made from the composite flours and the fermented sorghum flour are shown in Table 3. The flavors of the porridges were liked slightly by the panelists except for the 57:42:1 mixture which was neither liked nor disliked. However, there was no significant (p > 0.05) difference in flavor among the porridges.

Supplementation influenced the texture of the porridges. There was a significant (p < 0.05) difference between the texture of the composites porridges and the supplemented sorghum flour product. The textures of the porridges...
Table 4. Viscosity of porridge from composite flours and fermented sorghum flour

<table>
<thead>
<tr>
<th>Sample</th>
<th>SS:SBG:FSP SS:SBG:FSP SS:SBG:FSP FS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>60:40:0</td>
<td>57:42:1 55:44:1 52:46:2 100%</td>
</tr>
</tbody>
</table>

Viscosity (cps) 358.26 362.28 281.88 394.36 3,100.68

SS = Sorghum sprouted for 48 h.
SBG = Bambara groundnut sprouted for 48 h.
FSP = Sweet potato fermented for 48 h.
FS = Sorghum fermented for 48 h.

*Control.

Ridges from the composite flours were neither liked nor disliked while the control was liked moderately. The preference for the texture of the porridge from fermented sorghum over those made from the composites was due to treatment. The composites contained sprouted flours. It is known that sprouting activates the alpha- and beta-amylase to act on the starch granules and breakdown the amylase chains which would typically form a gel network [3]. This reduces the water-holding capacity and accounts for the low gel properties of the composites.

Relative to color, the porridges made from the composites were neither liked nor disliked while the control was liked moderately. The preference for the color of the porridge from fermented sorghum was probably because the panelists were familiar with the color of the product which is used as a traditional complementary food.

The general acceptabilities of the porridges was influenced by the organoleptic attributes of flavor, texture and color. There was a significant ($p < 0.05$) difference in the degree of acceptance among the porridges. The porridge from fermented sorghum flour was liked moderately while those from the composites were neither liked nor disliked. The preference for the porridge from fermented sorghum over those from the composite flours was not surprising. The panelists were familiar with the organoleptic properties of porridges from fermented sorghum, which is popularly used as a traditional complementary food in Nigeria. Use of sprouted cereal-legume flour blends for porridges is not common in Nigeria. Promotion will be required to popularize the composites, which have a lot of nutritional benefits over the traditional complementary sorghum food.

The viscosities of the porridges from the composite flours and fermented sorghum flour are shown in Table 4. The viscosity of the porridges varied with the porridges from the composite flours having lower ($p < 0.05$) viscosities than the porridge from the fermented sorghum flour. The blends produced porridges which were on the average more than seven times thinner than the
control. This facilitates easier consumption, digestion and greater nutrient intake. The amount of flour in the porridges prepared from the composite flours was increased more than three times before attaining the viscosity of the control. These findings are in accordance with the results of previous workers [3, 5], who reported reduced viscosity and increased nutrient and energy intake with the use of germinated flour in preparing gruels.

The lower viscosity of porridges from the composite flours was due to processing (sprouting). The blends contained sprouted sorghum and bambara groundnut flours. Germination of sorghum flour is known to reduce viscosity of porridges [5] due to increased activities of alpha-and beta-amylases that develop on sprouting of the seeds. These enzymes degrade the starch granules and breakdown the amylose chains which would normally form a gel network [3]. This reduces the gel properties and the water-holding capacity of porridges prepared from the flours. Because of this, germinated sorghum flour is termed power flour (PF).

The processed sorghum, bambara groundnuts and sweet potatoes showed nutritional superiority over their unprocessed counterparts in most of the nutrients evaluated. The composite flours had better nutritional attributes than the traditional sorghum complementary food. The composites had higher concentrations of protein, lipids and all the minerals tested. Porridges from the composite flours were not disliked by the panelists. They were more than seven times less viscous than the porridge from the traditional sorghum complementary food. This could result in greater nutrient and energy intake from porridge made with the composite flours. Use of the composites, particularly the 52:46:2 mixture, could offer a method for improving the nutrient composition of the traditional sorghum complementary food in Nigeria. Promotion will be needed to popularize the use of this composite for its nutritional advantages over the traditional sorghum complementary food.

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References


