Evaluation of the chemical composition, anti-nutrients and mineral element level of a composite meal from pearl millet, wheat, cowpea and groundnut

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Weaning foods were formulated in a cereal-legume combination using pearl millet, wheat, cowpea and groundnut. The pearl millet SOSAT C-88 and the wheat ATILA GAN ATILA were obtained from Lake Chad Research Institute (LCRI) while the cowpea (Borno Red) and the Groundnut (Dakar) were obtained through a seed breeder at LCRI. The pearl millet was fermented to produce “Akamu”, the wheat was germinated while the cowpea and groundnut were roasted separately. The weaning foods were formulated as follows: Pearl millet (60%)-cowpea (30%)-wheat (10%)-groundnut (10%) (PCWG); Pearl millet (60%)-cowpea (30%)-wheat (10%) (PCW); Pearl millet (60%)-groundnut (30%)-wheat (10%) (PGW). Standard procedures were used for analysis. Data obtained were subjected to Analysis of Variance (ANOVA). Duncan’s multiple range test was used to separate the means. Significance was accepted at p ≤ 0.05. The low moisture content of PCWG (3.49 ± 0.05%), PCW (3.51 ± 0.01%) and PGW (3.56 ± 0.05%) is within the moisture content of flour blends (3.60%). Protein content of PCWG (15.61 ± 0.17 g/100g), PCW (13.52 ± 0.01 g/100g) and PGW (14.33 ± 0.28 g/100g) met the Recommended Dietary Allowance (RDA) of infants 0 - 1 year (13 - 14g/100g) and was comparable to that of Cerelac® (15 g/100g). The fat content of PCWG (10.29 ± 0.24%) and PGW (12.91 ± 0.18%) met the RDA of infants 0 - 1 year and is comparable to that of Cerelac® (10.00%) while the fat content of PCW (4.98 ± 0.02%) was below the RDA and lower than that of cerelac®. The energy content of PCWG (405.77 ± 1.30 Kcal/100g) and PGW (423.63 ± 0.22 Kcal/100g) met the RDA (400 - 425 Kcal/100g) while PCW had the lowest energy content (385.90 ± 0.22 Kcal/100g) which was below the RDA. The levels of iron, zinc and magnesium in the weaning food formulations met the RDA while the levels of sodium, potassium and calcium were below the RDA. Results indicated that the process of fermentation, germination and roasting resulted in significant percentage reduction in phytic acid (pearl millet (71.25%), wheat (64.91%), cowpea (69.23%), groundnut (70.01%)) and tannins (pearl millet (70.85%), wheat (63.55%), cowpea (71.62%), groundnut (70.00%)). Reduction in the phytic acid and tannin improved the in vitro protein digestibility of PCWG (84.52 ± 0.28 %), PCW (80.02 ± 0.09 %) and PGW (82.25 ± 0.06%); and also improved the in vitro carbohydrate digestibility of PCWG (96.17 ± 0.06%). PCW (93.13 ± 0.07%) and PGW (91.45 ± 0.12).

Key words: Complementary weaning foods, fermentation, germination, pearl millet, wheat, cowpea, groundnut, commercial weaning food.

INTRODUCTION

The best food for an infant is the breast milk which has been designed by nature to contain all of the necessary nutrients that a developing infant needs (WHO, 2003). In many West African countries, exclusive breast feeding is usually adequate up to 3 - 4 months of age, but after this period it may become increasingly inadequate to support the nutritional demands of the growing infant (Onofio and Nnanyelugo, 1992). When the child is undergoing rapid growth, physiological maturation and development breast milk is no longer sufficient to meet the nutritional needs of the infants, there is the need to introduce other foods to the infant alongside breast milk (Onweluozo and Nwabugwu, 2009).
The infant is gradually introduced to a semi solid gruel which should ideally be easily digestible, of high energy density and low bulk to supplement the infants’ feeding early in life (Onweluzo and Nwabugwu, 2009). Poor nutrition during this critical period of life may increase the risk of growth faltering and may have adverse health and mental development in the infant (Ijarotimi and Keshinro, 2013).

Traditional weaning foods in Nigeria and most parts of West Africa consist of single monocereal grains prepared from either fermented millet, maize or sorghum into gruels referred to as “Akamu” or ‘Ogi’ which is of poor nutritional value (Modu et al., 2010). About 40% of the Nigerian population live below poverty line and cannot afford commercial weaning foods for their infants or good quality animal source of protein (Adebayo-Oyetoro et al., 2012). Protein energy malnutrition is a major problem that frequently occurs during the important transitional phase of weaning in infants, thereby affecting the physical and mental growth of many infants in developing countries. Protein energy malnutrition is a syndrome characterized by its progressive onset and a series of symptoms and signs that encompass a continuum from clinically undetected manifestations to the full clinical picture of marasmus or kwashiorkor. WHO (2003) estimates that about 150 million children less than five years of age in developing countries are malnourished and additional 200 million have stunted growth. The problem of protein energy malnutrition can be prevented by introducing weaning foods of the correct protein quality and quantity at the right stage of the weaning period (FAO/WHO, 1985).

Cereals are often used as the main ingredients in complementary weaning food because they are highly digestible. Cereal grains are rich in carbohydrate but deficient in essential amino acids such as lysine thus making their protein quality poorer than that of animals (Magda et al., 2013). The present study is designed to evaluate the proximate composition, mineral element composition, in vitro carbohydrate and protein digestibility and ant-nutritional factors of complementary weaning foods from pearl millet, wheat, cowpea and groundnut.

**MATERIALS AND METHODS**

**MATERIALS**

**Sources of raw materials**

Improved varieties of pearl millet SOSAT C-88 and wheat Atilla Gan Atilla were obtained from Lake Chad research institute (LCRI) while the cowpea seeds (Borno red) and groundnut (Dakar) were obtained through a seed breeder at LCRI. The grains and legumes were authenticated by a seed breeder at LCRI.

**Commercial weaning food**

The commercial weaning food (maize based Cerelac®) was selected on the basis of popularity. This weaning food was purchased from a supermarket in Maiduguri. It is recommended for infants of 6 months and above and it is a product of Nestle Nigeria Plc.

**METHODS**

**Sample preparation**

The “Akamu” was prepared by method described by Akingbala et al. (1981).

**Preparation of wheat**

One hundred grams (100 g) of wheat grains were cleaned to remove dirt. The grains were washed three times with water and then soaked (1:3 w/v) for 2 h at room temperature after soaking the grains were drained and wrapped in the damped cotton cloth. Germination was carried out at room carried out at room temperature for 48 h. The mouldy seeds were removed by hand and sprouted grains were washed before sun drying to a constant weight. The dried grains were ground into a fine powder and sieved using a 1 mm pore sieve to obtain a fine powder. (Chaturvedi and Sarajini, 1996).

**Preparation of cowpea**

Cowpea seeds were cleaned of dirt and soaked in water for 20 min. The cowpea seeds were dehulled using a mortar and a pestle. The seeds were washed to separate the coat and dried to a constant weight. The dried seeds were roasted at temperature of 120°C for 30 min. The seeds were continually stirred until a characteristic slightly brown colour was obtained. The seeds were allowed to cool and then ground into a fine powder. The ground seeds were sieved using a 1 mm pore sieve (Udensi et al., 2007).

**Preparation of groundnut**

The groundnut was cleaned of dirt, washed, soaked, dried, roasted at low temperature, dehulled to remove the testa and milled (Nkama et al., 2001).

**Preparation of the weaning food blends**

The formulation of the weaning foods was done in the following ratios:

i.) 60 parts of pearl millet, 20 parts of roasted cowpea, 10 parts of germinated wheat and 10 parts of roasted groundnut i.e. 60:20:10:10- PCWG.
ii.) 60 parts of pearl millet, 30 parts of roasted cowpea and 10 parts of germinated wheat i.e. 60:30:10 – PCW.

iii.) 60 parts of pearl millet, 30 parts of roasted groundnuts and 10 parts of germinated wheat i.e. 60:30:10 - PGW.

**Proximate composition**

Proximate composition of the raw and processed cereals and legumes and the weaning food formulations was determined by the standard methods of AOAC (2005).

**Mineral element composition**

Atomic absorption Spectrophotometer (AAS) AA series 6800 series Shimazo Corp was used for determination of Ca, P, K, Na, Fe, Zn and Mg. Two grams (2g) of sample was weighed into a crucible and incinerated at 600°C for 2 h. The ashed sample was transferred into 100 ml volumetric flask and 100 ml of distilled water was added into it and readings were taken on the AAS. The appropriate lamps and correct wavelength for each element were specified in the instruction manual.

**In vitro carbohydrate digestibility**

The method of Shekib et al. (1988) was used for in vitro carbohydrate digestibility. Into four sets of test tubes labelled as I, II, III and IV (0.30, 60 min and 6 h), 1 ml of α-amylase, 4 ml of phosphate buffer and 1 ml of sodium chloride was added and allowed to equilibrate at room temperature. After equilibrium, 5 ml of 1% sample was added and mixed thoroughly. At intervals of 10, 30 and 60 min, 3 drops of Lugol’s iodine was introduced into the reaction mixture and absorbance of starch-iodine complex was measured calorimetrically at 620 nm with Corning colorimeter 253 long side the blank (Lugol’s iodine). Unit of amylase activity was calculated as:

$$\frac{A_0 - A_t \times 100}{A_0}$$

Where

$A_0$ = Absorbance of iodine-starch complex at zero time.

$A_t$ = Absorbance of iodine-starch at specified time intervals.

Specific activity of amylase is expressed in unit /mg protein/minute.

**In vitro protein digestibility**

The in vitro protein digestibility of the samples was determined according to the method described by Nills (1979). One millilitre (1 ml) of 11% trypsin was introduced into 3 test tubes, 4 ml of phosphate buffer at pH 7.5 was added into each test tube and 1 ml of 1% sample was added to all the test tubes (labelled as digestibility at 0 h, 1 h and 6 h). The reaction in each test tube was stopped with 5 ml of neutralised formalin at 1 and 6 h. The content of the test tubes were filtered using filter papers. The filter papers were dried in an oven at 180°C for 3 h. The nitrogen of the undigested sample was determined by Kjedahl method.

$$\% \text{ in vitro protein digestibility} = \frac{CP_1 - CP_2 \times 100}{CP_1}$$

Where

$CP_1$ = Total protein of unprocessed grain.

$CP_2$ = Total protein after digestion with trypsin.

**Anti-nutritional factors**

**Tannins**

Tannin content of the raw and processed pearl millet and wheat were determined by the method described by Price and Butler (1977). 0.2 g of sample was weight into Erlenmeyer flask, and 10 ml of 4% HCl in methanol was pipetted into the flask. The flask was closed with parapilus and shaken for 20 min on a wrist actron shaker. 1 ml of extract was pipetted and 1 ml of 1% vanillin and 0.5 ml of conc. HCl was added. Five test tubes were labelled I, II, III, IV and V to prepare the standard solutions. Into the five test tubes, 0.1, 0.3, 0.5, 0.7 and 1, 0 ml of phenol reagent was added respectively. The test tubes was made up to 1 ml with methanol (8% HCl in methanol). 1.0 ml of 1% vanillin and 0.5 ml conc. HCl was added to the tubes and made up to 5.5 ml with 4% HCl in methanol. Blank sample was prepared by using 5 ml of 4% HCl in methanol. The absorbance of the standard solutions, sample extract and blank sample were read using a spectrophotometer at 500 nm 20 min after incubation.

**Calculation:**

$$Au = Astd$$

$$Cu = Cstd$$

$$Cu = \frac{Au \times Cstd}{Astd} = mg/g$$

Where

$Au$ = Absorbance of unknown.

$Astd$ = Absorbance of standard.

$Cu$ = Concentration of unknown.

$Cstd$ = Concentration of standard.

**Phytic acid**

Phytic acid content of the raw and processed pearl millet and wheat samples were determined according to the
method described by Davies and Reid (1979). One gram (1g) of sample was extracted by taking 40 ml of 0.5 M nitric acid in a conical flask and shaken for 1 h on a shaker at 30°C and 80 revolutions per minute. The samples were filtered and 5 ml of 0.08M ferric chloride was added and boiled for 20 min and filtered. The free iron (Fe³⁺) remaining in the solution was determined colorimetrically by adding 2 ml of 0.005M ammonium thiocynate and the iron binding capacities of the extract was determined by difference. The results were expressed in terms of MgFe bound per gram of sample.

STATISTICAL ANALYSIS

Data obtained were analysed using Analysis Of Variance (ANOVA). Duncan multiple range test was used to compare the differences between the means. Significance was accepted at p ≤ 0.05.

RESULTS

Proximate composition

The proximate composition of the raw and processed pearl millet, wheat, cowpea and groundnut are presented in Table 1. Significant decreases (P ≤ 0.05) in moisture and ash contents were observed in the processed pearl millet, wheat, cowpea and groundnut. The fibre content of the raw and processed pearl millet, wheat, cowpea and groundnut did not show any significant difference (P > 0.05). The fat and protein contents of the fermented pearl millet (“Akamu”) and germinated wheat showed significant decreases (P ≤ 0.05) while Significant increases (P ≤ 0.05) were observed in the carbohydrate and energy contents of the fermented pearl millet (“Akamu”) germinated wheat, roasted cowpea and roasted groundnut. The fat content of the raw and roasted cowpea did not show any significant difference (P > 0.05) while the fat content of the roasted groundnut showed a significant difference (P ≤ 0.05).

The proximate composition of the complementary weaning food blends are presented in Table 2. The moisture content of the weaning food blends ranged between 2.49 ± 0.01 - 2.56 ± .05. No significant differences (P > 0.05) were observed in the moisture contents of the three weaning food blends. The fat content of the weaning food blends PCWG and PGW met the RDA of infants 0 - 1 year while the energy content of PCW was below the RDA and below the level of that of Cerelac®.

Mineral element composition

The mineral element composition of the raw and processed pearl millet, wheat, cowpea and groundnut are presented in Table 3. There were significant decreases (P ≤ 0.05) in the levels of sodium, potassium, magnesium and phosphorus in the fermented pearl millet (“Akamu”) and the germinated wheat while significant increases (P ≤ 0.05) were observed in the levels of calcium, iron and zinc in the fermented pearl millet (“Akamu”) and germinated wheat.

There were significant differences (P ≤ 0.05) in the levels of sodium, potassium and calcium content of the raw and processed cowpea and groundnut while no significant differences (P > 0.005) were observed in the levels of iron, zinc, magnesium and phosphorus of the raw and processed cowpea and groundnut.

The mineral element contents of the three weaning food blends PCWG, PCW and PGW are presented in Table 4. The levels of sodium, potassium and calcium in the three weaning food blends are lower than that of Cerelac® and below the RDA of infants 0 - 1 year. The iron, zinc and magnesium content of the three weaning food blends met the RDA of infants 0 - 1 year and are comparable to that of Cerelac®.

In vitro protein digestibility

The in vitro protein digestibility of the raw and processed pearl millet, wheat, cowpea and groundnut are presented in Table 5. There were significant differences (P ≤ 0.05) between the raw and processed pearl millet, wheat, cowpea and groundnut at one (1) hour digestibility with the processed pearl millet, wheat, cowpea and groundnut showing higher values. The same trend was observed for the raw and processed pearl millet, wheat, cowpea and groundnut at six (6) hours digestibility. Table 6 presents the in vitro protein digestibility of the weaning food blends. Significant differences (P ≤ 0.05) were observed between the three weaning food blends PCWG, PCW and PGW both at 1 and 6 h digestibility. PCWG had higher digestibility followed by the groundnut based weaning food PGW then the cowpea based weaning food PCW.

In vitro carbohydrate digestibility

The in vitro carbohydrate digestibility of the raw and processed pearl millet, wheat, cowpea and groundnut are presented in Table 7. Significant increases (P ≤ 0.05) were observed in the fermented pearl millet (“Akamu”), germinated wheat, roasted cowpea and roasted groundnut at 30, 60 and 360 min digestibility. The
Table 1. Proximate composition of raw and processed pearl millet, wheat, cowpea and groundnut.

<table>
<thead>
<tr>
<th>Nutrient /Sample</th>
<th>PEARL MILLET</th>
<th>WHEAT</th>
<th>COWPEA</th>
<th>GROUNDNUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>“Akamu”</td>
<td>Raw</td>
<td>Germinated</td>
<td>Raw</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>4.96±0.10a</td>
<td>2.46±0.05c</td>
<td>4.16±0.34d</td>
<td>2.06±0.04d</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>3.21±0.15a</td>
<td>1.73±0.05b</td>
<td>3.39±0.04a</td>
<td>1.37±0.04b</td>
</tr>
<tr>
<td>Fibre (%)</td>
<td>2.83±0.23a</td>
<td>2.66±0.05a</td>
<td>4.35±0.52a</td>
<td>4.0±0.10d</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>7.96±0.58a</td>
<td>5.23±0.05c</td>
<td>4.97±0.10b</td>
<td>2.8±0.10d</td>
</tr>
<tr>
<td>Energy (Kcal/100g)</td>
<td>395.80±0.70a</td>
<td>309.76±0.72b</td>
<td>376.78±0.01c</td>
<td>384.28±0.82c</td>
</tr>
</tbody>
</table>

Values are recorded as mean± SD of three determinations. Values in the same row with different superscript are significantly different (P ≤ 0.05).

Table 2. Proximate composition of the weaning food blends

<table>
<thead>
<tr>
<th>Nutrient/Sample</th>
<th>PCWG</th>
<th>PCW</th>
<th>PGW</th>
<th>Cerealc (Maize)</th>
<th>RDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>3.49±0.05a</td>
<td>3.51±0.01c</td>
<td>3.56±0.05a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>3.00±0.01a</td>
<td>2.08±0.01b</td>
<td>2.01±0.01b</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fibre (%)</td>
<td>4.93±0.05a</td>
<td>4.16±0.05a</td>
<td>4.66±0.05a</td>
<td>4.30</td>
<td>-</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>10.29±0.24d</td>
<td>4.98±0.02d</td>
<td>12.91±0.18c</td>
<td>10.0</td>
<td>10-25</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>15.61±0.17d</td>
<td>13.52±0.01b</td>
<td>14.33±0.28ba</td>
<td>15.0</td>
<td>13-14</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>62.68±0.17d</td>
<td>71.75±0.60b</td>
<td>6.25±0.48b</td>
<td>65.00</td>
<td>-</td>
</tr>
<tr>
<td>Energy (kcal/100g)</td>
<td>405.77±1.30c</td>
<td>385.90±0.22b</td>
<td>423.63±1.12e</td>
<td>410.00</td>
<td>400-425</td>
</tr>
</tbody>
</table>

Values are recorded as mean± SD of three determinations. Values in the same row with different superscript are significantly different (P≤0.05).
RDA – Recommended Dietary Allowance of infants 0-1 year (1989).
Cerealc – Nestle Nigeria Plc.
PCWG - 60 parts of Pearl millet, 20 Parts of Cowpea, 10 parts of wheat and 10 parts of groundnuts
PCW - 60 parts of Pearl millet 30 parts of cowpea, 10 parts of wheat.
PGW - 60 parts of Pearl millet, 30 parts of groundnut, 10 parts of wheat.

Table 3. Mineral element composition of the raw and processed pearl millet, wheat, cowpea and groundnut (mg/100g).

<table>
<thead>
<tr>
<th>Nutrient /Sample</th>
<th>Pearl millet</th>
<th>Wheat</th>
<th>Cowpea</th>
<th>Groundnut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>“Akamu”</td>
<td>Raw</td>
<td>Germinate</td>
<td>Raw</td>
</tr>
<tr>
<td>Sodium</td>
<td>112.12±0.29a</td>
<td>109.10±0.22b</td>
<td>121.50±0.14c</td>
<td>115.12±0.01a</td>
</tr>
<tr>
<td>Potassium</td>
<td>325.36±0.23a</td>
<td>320.31±0.01b</td>
<td>485.30±0.01b</td>
<td>480.15±0.19c</td>
</tr>
<tr>
<td>Calcium</td>
<td>50.07±0.31a</td>
<td>57.29±0.14a</td>
<td>35.45±0.37c</td>
<td>37.32±0.09b</td>
</tr>
<tr>
<td>Iron</td>
<td>9.27±0.24a</td>
<td>11.30±0.30b</td>
<td>4.51±0.03d</td>
<td>7.34±0.13a</td>
</tr>
<tr>
<td>Zinc</td>
<td>6.43±0.74a</td>
<td>10.52±0.03b</td>
<td>2.57±0.15a</td>
<td>5.65±0.24d</td>
</tr>
<tr>
<td>Magnesium</td>
<td>177.45±0.04a</td>
<td>130.49±0.42b</td>
<td>173.27±0.25c</td>
<td>150.34±0.12a</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>399.23±0.04a</td>
<td>385.07±0.53a</td>
<td>412.32±0.16c</td>
<td>396.59±0.20d</td>
</tr>
</tbody>
</table>

Values are recorded as mean± SD of three determinations. Values in the same row with different superscript are significantly different (P≤0.05).
increase in digestibility was higher in the fermented pearl millet and germinated wheat than the roasted cowpea and roasted groundnut. Table 8 presents the in vitro carbohydrate digestibility of the weaning food blends. The weaning food blend PCWG had a significantly (P ≤ 0.05) higher digestibility at 30, 60 and 360 min than PCW and PGW. The groundnut based weaning food blend PGW had the lowest digestibility. Increase in in vitro carbohydrate digestibility with increase in incubation time was observed. The result indicates that the maximum increase in carbohydrate digestibility was observed in the fermented pearl millet followed by the germinated wheat.

Antinutritional content

The result of the antinutritional content of the raw and processed Pearl millet and wheat is shown in Table 9.

Phytic acid

Significant decreases (P ≤ 0.05) in phytic acid were observed in the fermented pearl millet ("Akamu") and the germinated wheat. A reduction of 71.25% and 64.91% were observed in the phytic content of "Akamu" and germinated wheat respectively. Significant decreases (P ≤ 0.05) were also observed in the roasted cowpea (69.23%) and the roasted groundnut (70.21%).

Tannins

Significant reduction (P ≤ 0.05) in the tannin content of fermented pearl millet ("Akamu") and germinated wheat were observed. A reduction of 70.85% for "Akamu" and 63.55% for germinated wheat were observed. The roasted cowpea and roasted groundnut also showed significant reduction of 71.61% and 70.00% in the tannin content.

DISCUSSION

Proximate composition

The decrease observed in the protein content during fermentation of pearl millet and germination of wheat was attributed to a possible increase in the number of microorganisms that use protein for metabolism. During fermentation and germination, microorganisms hydrolyze protein and it complexes to release free amino acid for synthesis of new proteins (Frazier and Westhoff, 1978), this result agree with the reports of Onwuluzo and Nwabugwu (2009), Modu et al. (2010), Chavan and Kadam (1989) who reported that fermentation and or germination did not change the protein content but the protein quality of cereals. The process of roasting of the cowpea and groundnut did not alter their protein content and this is in agreement with the report of Griffith et al. (1998).

The decrease in the fat content of the fermented pearl millet and germinated wheat might be due to the increased activities of the lipolytic enzymes which hydrolyze fat to fatty acid and glycerol. Similar observations were made by Obizoba and Atti (1994), Inyang and Zakari (2008).

An increase in carbohydrate content was noticed during the fermentation of pearl millet and germination of wheat and this is in agreement with the report of Ikemefuna (1998).

The weaning food blends had moisture content within the normal moisture content of dried food (3.6). The low moisture content observed is a good indicator of their potential to have longer shelf life. This is in line with the findings of Adebayo-Oyetoro et al. (2012). The low moisture content of food products inhibits biochemical activities of invading microorganisms and therefore prevent food spoilage during storage (Ijarotimi and Keshinro, 2013).
Table 5. *In vitro* protein digestibility of the raw and processed pearl millet, wheat, cowpea and groundnut.

<table>
<thead>
<tr>
<th></th>
<th>Pearl millet</th>
<th>Wheat</th>
<th>Cowpea</th>
<th>Groundnut</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw</td>
<td>Germinate</td>
<td>Raw</td>
<td>Roasted</td>
</tr>
<tr>
<td>Digestibility at one (1) hour (%)</td>
<td>39.33±0.15(^a)</td>
<td>58.35±0.54(^b)</td>
<td>39.38±0.33(^a)</td>
<td>59.01±0.81(^a)</td>
</tr>
<tr>
<td>Digestibility at six (6) hour (%)</td>
<td>52.96±0.70(^a)</td>
<td>75.33±0.35(^b)</td>
<td>52.60±0.30(^a)</td>
<td>75.70±0.40(^b)</td>
</tr>
</tbody>
</table>

Values are recorded as mean± SD of three determinations. Values in the same row with different superscript are significantly different (P ≤ 0.05).

Table 6. *In vitro* protein digestibility of the weaning food blends.

<table>
<thead>
<tr>
<th></th>
<th>PCWG</th>
<th>PCW</th>
<th>PGW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestibility at one (1) hour (%)</td>
<td>57.43±0.44(^a)</td>
<td>54.27±0.03(^b)</td>
<td>55.25±0.04(^c)</td>
</tr>
<tr>
<td>Digestibility at six (6) hours (%)</td>
<td>84.52±0.28(^a)</td>
<td>81.05±0.09(^b)</td>
<td>82.25±0.06(^c)</td>
</tr>
</tbody>
</table>

Values are recorded as mean± SD of three determinations. Values in the same row with different superscript are significantly different (P≤0.05).

PCWG - 60 parts of Pearl millet, 20 Parts of Cowpea, 10 parts of wheat and 10 parts of groundnuts.
PCW - 60 parts of Pearl millet 30 parts of cowpea, 10 parts of wheat.
PGW - 60 parts of Pearl millet, 30 parts of groundnut, 10 parts of wheat.

Table 7. *In vitro* carbohydrate digestibility of raw and processed pearl millet, wheat, cowpea and groundnut.

<table>
<thead>
<tr>
<th></th>
<th>Pearl millet</th>
<th>Wheat</th>
<th>Cowpea</th>
<th>Groundnut</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw</td>
<td>&quot;Akamu&quot;</td>
<td>Raw</td>
<td>Germinate</td>
</tr>
<tr>
<td>Digestibility at 30 mins(%)</td>
<td>8.34±0.67(^a)</td>
<td>10.17±1.9(^b)</td>
<td>6.53±0.76(^c)</td>
<td>8.81±0.45(^a)</td>
</tr>
<tr>
<td>Digestibility at 60 mins(%)</td>
<td>33.60±0.40(^a)</td>
<td>35.53±0.20(^b)</td>
<td>30.60±0.17(^c)</td>
<td>32.70±0.23(^a)</td>
</tr>
<tr>
<td>Digestibility at 360 mins(%)</td>
<td>93.24±0.05(^a)</td>
<td>95.31±0.23(^b)</td>
<td>90.11±0.01(^c)</td>
<td>93.56±0.48(^a)</td>
</tr>
</tbody>
</table>

Values are recorded as mean± SD of three determinations. Values in the same row with different superscript are significantly different (P ≤ 0.05).

The protein content of the three weaning food blends compared favourably with Cerelac® and met the RDA of infants 0 - 1 year. The blending of two or more cereals and legumes that complement each other (co-supplementation) is a key feature of weaning food formulations which increases the protein content of weaning foods as reported by Solomon (2005), Eka et al. (2010). The fat content and energy content of the weaning food blends PCWG and PGW compare favourably with Cerelac® and met the RDA of infants 0 - 1 year. This could be due to the addition of groundnut in
Table 8. *In vitro* carbohydrate digestibility of the weaning food blends.

<table>
<thead>
<tr>
<th></th>
<th>PCWG</th>
<th>PCW</th>
<th>PGW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestibility at 30mins(%)</td>
<td>15.96±0.78(^a)</td>
<td>14.34±0.65(^b)</td>
<td>13.12±0.21(^c)</td>
</tr>
<tr>
<td>Digestibility at 60mins(%)</td>
<td>35.32±0.13(^a)</td>
<td>34.27±0.14(^b)</td>
<td>30.13±0.08(^c)</td>
</tr>
<tr>
<td>Digestibility at 360(mins%)</td>
<td>96.17±0.06(^a)</td>
<td>93.13±0.07(^b)</td>
<td>91.45±0.12(^c)</td>
</tr>
</tbody>
</table>

Values are recorded as mean± SD of three determinations. Values in the same row with different superscript are significantly different (P≤0.05).

PCWG - 60 parts of Pearl millet, 20 Parts of Cowpea, 10 parts of wheat and 10 parts of groundnuts

PCW - 60 parts of Pearl millet 30 parts of cowpea, 10 parts of wheat.

PGW - 60 parts of Pearl millet, 30 parts of groundnut, 10 parts of wheat.

Table 9. Antinutritional content of raw and processed pearl millet, wheat, cowpea and groundnut.

<table>
<thead>
<tr>
<th></th>
<th>Pearl millet</th>
<th>Wheat</th>
<th>Cowpea</th>
<th>Groundnut</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw</td>
<td>“Akamu”</td>
<td>Raw</td>
<td>Germinated</td>
</tr>
<tr>
<td>Phytic acid mg/g</td>
<td>0.80±0.52(^a)</td>
<td>0.23±0.20(^b)</td>
<td>0.57±0.60(^c)</td>
<td>0.20±0.10(^d)</td>
</tr>
<tr>
<td>Percentage decrease</td>
<td>71.25</td>
<td>64.91</td>
<td>69.23</td>
<td>70.21</td>
</tr>
<tr>
<td>Tannin mg/g</td>
<td>1.75±0.20(^a)</td>
<td>0.51±0.33(^b)</td>
<td>2.36±0.45(^c)</td>
<td>0.89±0.13(^d)</td>
</tr>
<tr>
<td>Percentage decrease</td>
<td>70.85</td>
<td>63.55</td>
<td>71.62</td>
<td>70.00</td>
</tr>
</tbody>
</table>

Values are recorded as mean± SD of three determinations. Values in the same row with different superscript are significantly different (P≤0.05).

The weaning foods PCWG and PGW. The use of groundnut not only increased protein but also increased fat which provides a more concentrated caloric source (Anyabor et al., 2009). This attribute tends to agree with the recommendations of FAO/WHO (1998) guidelines that vegetable oils be included in foods meant for infants and children, which will not only increase energy density but also a transport vehicle for fat soluble vitamins (Solomon, 2005). Even though the fatty acid composition of the three weaning food blends were not carried out, the fat content can also provide essential fatty acid like linoleic acid (which is a polyunsaturated fatty acid) since groundnut is rich in linoleic acid.

Mineral element composition

The loss in the content of sodium, potassium, magnesium and phosphorus in the raw pearl millet and wheat could be attributed to the loss in the ash content during fermentation and germination of the pearl millet and wheat respectively. Akingbala et al. (1981) report that more than 50% of the ash in sorghum was leached out of the steep water and wash water.

The increase in the level of iron in the raw pearl millet and wheat is in consistence with the result of Nnam (2000) who reported two fold increases in iron level of hungry rice (acha) during germination and fermentation.

This is also in agreement with the work of Inyang and Zakari (2008). In quantitative terms, this means the process of fermentation and (or) germination can change a diet of low iron bioavailability into a diet of intermediate to high iron availability (Svanberg and Sandberg, 1988). Sripiya et al. (1997) reported that phytate complexes with essential elements such as zinc, iron and calcium reduces their bioavailability which can be enhanced by degradation of phytate. Increase in the levels of calcium, iron and zinc during fermentation of pearl millet and germination of wheat could be as a result of increased activity of the enzyme phytase. The enzymes hydrolyse the bond between protein-enzymes-mineral to free these essential minerals (Nnam, 2000).

Zinc plays a role in normal growth and development of immunity, gene expression, cell regulation and cell differentiation (Hambige, 2000). Magnesium is important in DNA and RNA synthesis, while iron is an essential element for the formation of red blood cells and also plays an important role in the transport of oxygen (Kumkum et al., 2010).

The low levels of sodium, potassium and calcium in the three weaning food blends when compared with Cerelac could be attributed to the fact that commercial weaning foods are usually fortified with micronutrient in order to meet the FAO/WHO guidelines for infant complementary food formulations (Ijarotimi and Keshinro, 2013).
In vitro protein digestibility

The improvement in the protein digestibility may be due to the fact that the micro flora may have produced proteolytic enzymes during fermentation of pearl millet and germination of wheat. The proteolytic enzymes activity promotes the breakdown of proteins into smaller polypeptides which are easily digested (Singh et al., 2012). In addition, the reduction of antinutrients may have contributed to the improvement in protein digestibility (Heseltine, 1983; Laminu et al., 2011). Griffith et al. (1998) and Onyango et al. (2013) reported improved in vitro protein digestibility with germination and fermentation of pearl millet.

In vitro carbohydrate digestibility

The increase in in vitro carbohydrate digestibility may be due to the degradation of starch into smaller fragments and formation of reducing sugars during fermentation and germination (Madhuri et al., 1988; Liu et al., 2004; Jyothy and Reddy, 1981; Veny and Kiran, 2012). The process of fermentation and germination led to changes in the endosperm protein fractions and this makes starch more accessible to the digestive enzymes (Singh et al., 2012). The low carbohydrate digestibility of roasted cowpea and roasted groundnut may be due to the formation and other substances present in the grain itself, thereby reducing accessibility of carbohydrates to enzymes, action (Birch et al., 1974; Jane, 2004).

Antinutritional content

Phytic acid

The reduction in the phytic acid contents during fermentation of pearl millet and germination of wheat could be attributed to inherent phytase activity in the pearl millet and wheat which may hydrolyse phytic acid thereby reducing the phytic acid content of germinated and fermented products (Laminu et al., 2011; Khetarpaul and Chauhan, 1990; Archana and Kawatra, 1998). Mahajan and Chauhan (1987) reported acidic pH of fermented product and temperature provide favourable conditions for phytase activity, similar findings. The removal of seed coat (dehulling) of soaked cowpea and groundnut may have attributed to the reduction of the phytic acid content of the roasted cowpea and roasted groundnut. Soaking of cereals and legumes usually forms an integral part of processing methods such as germination, fermentation and roasting (Komal and Darshen, 2000).

Tannins

The reduction of the tannin content of Pearl millet during fermentation may be due to microbial activity which may hydrolyse the condensed tannins to lower molecular weight phenols. Khetarpaul and Chauhan (1991) reported similar findings. Reduction of tannins during germination may be attributed to the presence of polyphenol oxidase and to the hydrolysis of tannins-protein and tannin-enzyme complexes which results in the removal of tannins (Rao and Deosthale, 1982).

The reduction of tannins in the fermented pearl millet, germinated, roasted cowpea and roasted groundnut could also be as a result of soaking. Tannins are polyphenolic compounds that are water soluble in nature (Kumar et al., 1979); therefore reduction in tannin content may be attributed to leaching out of phenols into the medium which can be eliminated with the discarded soaking water. Since polyphenolic compounds are present on the outer periphery of the grain, their passing out in the soaking medium is possible. (Akande and Fabiyi, 2010; Vijayakumani et al., 1992).

Conclusion

The protein content of the three weaning food blends PCWG, PCW and PGW met the RDA of infants 0 - 1 year and were comparable to that of Cerelac® while the energy content of the weaning food blends PCWG and PGW met the RDA of infants 0 - 1 year. The reduction in the level of antinutrients contributed to the improvement of the in vitro carbohydrate and protein digestibility of the three weaning food blends and also increased the bioavailability of mineral elements such as iron zinc and magnesium.

REFERENCES


