

Formulation and nutritional evaluation of a complementary food blend made from fermented yellow maize (Improved variety), soybean and African cat fish meal

Mohammed, Z.K¹., Petrol, B.B²., and Ahmad, U²

¹Department of Biochemistry, Kaduna State University
²Department of Biochemistry, University of Maiduguri Nigeria

Abstract

Fermented cereal-based gruels with poor nutritional value form a major component of the diet of infants during the transition phase of childhood. With the recent security challenges affecting people in the north-east region of Nigeria, food security is at stake, malnutrition is common among infants and young children while reliance on UNICEF for supplies of ready-to-use therapeutic foods is not a long-term solution. A complementary food blend was prepared following the guideline of WHO/FAO on infants' nutritional requirements in a 60:20:20 ratio from fermented yellow maize (improved variety), roasted soybean and fishmeal respectively. All the sample materials were pre-processed by either fermentation, drying or roasting prior to food blend formulation. Standard methods (AOAC) were used to evaluate the nutritional values of the raw and processed materials and the formulated complementary food blend. Water absorption capacity of the fermented yellow maize significantly decreased ($P < 0.05$) with decrease in pH and increase in titratable acidity from 20% - 51% (0 – 72h). The carbohydrate ($64.35 \pm 0.03\%$) and protein contents ($14.55 \pm 0.03\%$) and energy value (351.64 ± 0.03 Kcal/100g) of the complementary food blend was closely comparable to the commercial complementary food blend cerelac[®] (Carbohydrate 69.00%, Protein 15.0%, and energy 426.00 Kcal/100g) and satisfied the needs of infants. The low moisture content ($3.1 \pm 0.02\%$) exhibited by the complementary food blend might give a good storage stability. The iron level of the complementary food blend ($40.33 \pm 0.03\%$) was higher than that of the commercial complementary food blend celerac[®] (10.0%), though the levels of potassium, zinc and calcium were lower. Microbial analysis showed no contamination with pathogenic organisms in the formulated food blend. The formulated complementary food blend met the WHO estimated requirements of infant 6 – 23 months in terms of nutritional quality and may therefore be a good substitute to the imported, expensive alternatives.

Keyword: Complementary, Fermentation, Food blend, Infant, Nutrition

Corresponding Author: zkammed24@gmail.com +2348020651436

Introduction:

The widespread infant malnutrition in Sub-Saharan African countries such as Nigeria has stirred efforts in research, development and extension by both local and international organizations. Infant nutrition in Nigeria is largely

supported by cereal-based foods which is often inadequate in nutritional qualities (Onofiok and Nnanyelugo, 1998). Infant malnutrition is often associated with poverty and ignorance. Protein-energy malnutrition generally occur during the phase when children transit from liquid to

semisolid or fully adult food (Foote and Marriott 2003). Nutritional problems such as protein energy malnutrition, kwashiorkor and marasmus are commonly seen among infants and young children. Malnutrition is attributable to ignorance and poverty in the developing nations of the world like Nigeria (Igbedioh, 1993; Nigeria Federal Ministry of Health, 2014; USAID, 2018). Among the six global nutrition targets of the World Health Assembly's (WHA) 2025 comprehensive implementation plan on maternal, infant and young child nutrition is, reducing stunting and wasting in children under five and increasing the rate of exclusive breastfeeding (WHO, 2016). Stunting and wasting in children is the outcome of poor nutrition and is preventable by appropriate infant and young child feeding (De Onis and Blössner, 2003). Ready to use therapeutic food (RUTF) for treating malnourished infants and children is provided only by the UNICEF.

The infants' dietary needs for energy and nutrients surpass that which can be provided by breast milk at the age of 6 months (WHO, 2018). Therefore, the need to supplement the infants with easily digestible, nutrient dense foods necessary for proper growth and development. Complementary foods are any foods, semi solid and liquids other than breast milk or infant formula which is intended to provide the adequate nutrients, minerals and vitamins needed by infants and young children. Cereals and legumes which are a source of energy, minerals and proteins form a staple food in the majority of households in Nigeria (Onimawo, 2010). These food products are utilized in preparation of complementary food blends for older infants and young children by processing them through one or more of these: boiling, fermentation, germination, sprouting, malting and toasting/roasting. Fermentation is an age-old technology whereby microorganisms help in improving the quality attributes of foods making it easily digested, palatable and beneficial to the gastrointestinal tract of the consumer. These functional microorganisms called probiotics, when present as live cultures in foods, help protect the gut lining and improve digestion and nutrient availability. However, the presence of microbial contamination needs to be taken seriously to avoid outbreak of nutritional related diseases. Cheaply available indigenous cereals

when subjected to some degree of processing can be supplemented with amino acid – rich food sources of protein and minerals suitable for complementary food blend. 'Akamu' is a well-known fermented gruel made from maize, millet, sorghum or mixes of two or all of the cereals. The fluidy nature or runny consistency of 'akamu' makes it one of the most suitable foods for complementary food blend infants. However, the lack of balanced nutrients in such foods makes it necessary to be supplemented with proteins, minerals, vitamins and other vital nutrients to support the growth of the weaned infant and young children. There is a need to complement the diet of this group of children with energy and nutrient dense foods for optimum growth and development. This study is aimed at formulating a complementary food blend from fermented yellow maize (*Zea mays*) (improved variety) supplemented with soybean (*Glycine max*) and fishmeal from African catfish (*Clarias gariepinus*).

Materials and Methods

All chemicals and reagents used were of analytical grade and purchased from Sigma Aldrich.

Source of Raw Materials: Yellow maize (*Zea mays*, improved variety) was obtained from Lake Chad Research Institute Maiduguri. Soybean (*Glycine max* L.) and fish (African catfish, *Clarias gariepinus*) were obtained from Maiduguri Monday Market, Nigeria. These materials were cleaned by removing stones, rotten grains and dirt. The cleaned materials were then stored in airtight bags until needed for the formulation.

Preparation of Fermented Yellow Maize Flour: One kilogram (1 kg) of clean yellow maize was soaked in about 2 L of distilled water for 72 hours. At the end of 72 hours the steep water which was naturally fermented was then decanted, another 2 L of clean water was added to the maize grains and milled into slurry. The obtained slurry was filtered through a muslin cloth. The filtrate was allowed to sediment for 24 hours after which the supernatant water was decanted. The sediment was then sun-dried to a constant moisture to obtain fermented yellow maize flour.

Preparation of Soybean Flour: As traditionally processed, one kilogram (1 kg) of cleaned soybeans was soaked in clean water for 3 hours. Thereafter, the pre-soaked soybeans were dehulled (husks discarded) and sundried to a constant moisture by confirming weight after

drying for a period of 4 – 6 h. The soybeans were roasted until golden brown with a sweet aroma. After cooling to room temperature, the roasted soybeans were milled to fine powder (using Moulinex Blender) and sieved with a fine mesh to obtain the soybean flour. This was stored at 4 °C in an airtight plastic jar until needed.

Preparation of Fish meal: Fresh African catfish was purchased from Monday Market in Maiduguri. About five hundred (500) grams of the fresh fish was thoroughly washed with salted water and cut to tiny pieces. These pieces of fish were dried at 40 °C to a constant dry weight approximately 243.7 g before milling to powder with a blender (Moulinex) to obtain the fishmeal flour. This was stored at 4 °C in an airtight plastic storage bag until needed.

Formulation of the Complementary Food Blend: The complementary food was formulated using fermented yellow maize, dehulled roasted soybean flour, fish meal powder in the ratio of 60:20:20 i.e. 60 g of yellow maize flour: 20 g of soybean flour: 20 g of fishmeal flour. Ratios were selected based on the recommendation of WHO/FAO and Codex (2006).

Water Absorption Capacity (WAC): Water absorption capacity was measured by method of Beuchart, (1977). One gram of sample was mixed with 10 mL distilled water for 30 seconds. The samples were then allowed to stand at room temperature (25 ± 2 °C) for 30 minutes after which they were centrifuged at 3000 rpm for 30 minutes. The volume of the supernatant was noted in a 10 mL graduated cylinder. Water absorption (mg mL⁻¹) was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant.

Total Titratable Acidity (TTA): The pH was measured using a pH meter. The titratable acidity of samples was measured by method of Egnan, (1981). Briefly, titratable acidity was determined using 0.1 N sodium hydroxide and phenolphthalein as an indicator and was expressed as % malic acid.

Determination of Proximate Composition: Proximate composition of raw and processed yellow maize, soybean, fish and formulated complementary food blend was determined by standard methods as previously described in AOAC, (2010).

Determination of Mineral Element Composition: Mineral element composition (Ca, P, K, Fe, Zn and Mg) of the raw materials and formulated complementary food blend was determined by Atomic Absorption Spectrophotometer (AAS) AA 6800 series Schmazo Corp. Two grams (2 g) of samples were weighed into a crucible and incinerated at 600 °C for 2 hours. The ashed samples were transferred into 1000 mL volumetric flask and 100 mL distilled water were added into while taking the reading on the AAS. The appropriate lamps and correct wavelength for each were specified in the instrumentation as follows: P= 213.6 nm, K= 766.5 nm, Ca= 422.7 nm, Mg= 85.23 nm, Zn= 213.9 nm, Fe= 248.3 nm, Na= 589 nm.

Microbial Analysis of Fermented Yellow Maize and Flour: This was done as previously described by (Bintu *et al.*, 2019). Growth media were prepared as per the guidelines in the laboratory manual. A loopful of the sample was smeared over one corner of the solidified medium which was sufficiently dried. A nichrome wire loop will be sterilized over a spirit lamp then cooled and used to make parallel streaks from the main inoculums. The plates were then incubated at 37 °C for 24 h. The colonies were separated from one another based on the difference of colony monopoly. One of the separated colonies was taken using a sterilized wire loop and inoculated in another media then incubated for 24 h at 37 °C. Colonies were obtained on the medium after 24 h incubation and isolates counted and expressed as cfu mL⁻¹.

Sensory Evaluation of the Formulated Complementary Food Blend: As previously described by Ruston *et al.*, (1996) 15 semi-trained panelists were asked to score the products for taste, appearance, texture, aroma and overall acceptability using a 5-point hedonic scale ranging from 1 (extremely dislike) to 5 (extremely like). The formulated complementary food blend was evaluated alongside the cereal only gruel 'Akamu'.

Statistical Analysis: All results are reported as means of triplicate determinations. Data collected were subjected to analysis of variance (ANOVA) using the SAS package. Differences among the means were separated using the DUNCAN multiple range test at 95% confidence limit.

Results

Functional Properties of Raw Materials and Formulated Complementary Food Blend

Table 1 shows the water absorption capacity of raw and processed maize, soya bean, fish meal and the complementary food blend food blend. A

significant difference was observed between the raw and processed yellow maize, soybean, fishmeal and also the complementary food blend with raw yellow maize having higher value and that of the processed soybean having lowest value.

Table 1: Water Absorption Capacity of Raw Materials and Formulated Complementary Food Blend

Functional Property	Yellow Maize		Soybean		Fishmeal	Formulated Food 60:20:20*
	Raw	Processed	Raw	Processed		
Water Absorption Capacity	3.5±0.01 ^a	3.00±0.02 ^b	2.8±0.04 ^c	2.5±0.03 ^c	2.8±0.04 ^c	3.0±0.02 ^a

Values are recorded as mean ± S.D three determinations. Values in the same rows with different superscript are significantly different (P<0.05)

*60 parts of processed maize: 20 parts of processed soybean: 20 parts of fishmeal.

Proximate composition of raw and processed food materials.

Table 2 shows the proximate composition of raw and processed yellow maize, soybean and fish meal. A significant difference was observed between the raw and processed yellow maize, soybean and fishmeal. There was a significant increase in protein, fibre was observed after the

preparation of the yellow maize which decreased in moisture content and no significant difference was observed in fat content. There was a decrease in fat, fibre and ash content with an increase in the protein of soybean after roasting. Fishmeal provides higher protein, higher value of protein and attained a lower moisture.

Table 2: Proximate composition of raw and processed food materials

Composition %	Yellow Maize		Soybean		Fishmeal
	Raw	Processed	Raw	Processed	Processed
Dry matter	96.18±0.06	93.35±0.04	97.61±0.03	97.93±0.03	97.34±0.05
Moisture	4.16±0.01	3.8±0.15	2.05±0.03	2.05±0.01	2.69±0.02
Protein	8.23±0.02	11.92±0.03	39.53±0.03	40.04±0.04	51.34±0.04
EE & Fat	4.04±0.04	4.04±0.04	5.04±0.04	3.01±0.02	7.02±0.02
Ash	1.12±0.02	1.03±0.02	2.02±0.02	1.01±0.02	1.02±0.03
Carbohydrate	78.42±0.02	79.17±0.02	22.43±0.03	22.97±0.02	13.94±0.04
Energy	382.96±0.02	392.72±0.02	300.0±0.0	134.84±0.0	324.13±0.0
	2	5	2	3	3

Values recorded as mean ± SD of three determinations

Proximate composition of complementary food blends

The proximate composition of formulated complementary food blend and the commercial complementary food (Nestle Celerac®) are

presented in Table 3. A significant difference in moisture and fat content was observed. The protein content of the complementary food blend is closely comparable to that of the commercial complementary food blend Celerac®.

Table 3: Proximate composition of complementary food blends

Parameters	Complementary Food Blend	
	Formulated (60:20:20)	Nestle Ceralac®
Dry Matter	97.95±0.04	ND
Moisture	3.18±0.02	2.5
Protein	14.55±0.03	15
EE & Fat	4.02±0.02	10
Ash	5.02±0.02	ND
Carbohydrate	64.35±0.03	69
Energy Kcal/J	351.65±0.03	426

Values recorded as mean ± SD of three determinations.

Composition of mineral elements of raw and processed food materials

The mineral element composition of raw and processed yellow, soybean and fish meal are presented in Table 4. A significant difference (P<0.05) in the level of mineral component of the

processed and unprocessed materials was observed. Mineral content increased after the production of "Akamu" whereas general decrease was observed in the soybean after roasting. Fishmeal provides higher value in iron, potassium and calcium with a lower value of magnesium.

Table 4: Composition of mineral elements of raw and processed food materials

Mineral (mg/g)	Yellow Maize		Soybean		Fishmeal
	Raw	Processed	Raw	Processed	
Iron	3.1±0.01 ^a	3.4±0.16 ^b	15.7±0.15 ^c	12.7 ±0.05 ^d	90.22±0.05 ^d
Phosphorus	1.68±0.02 ^a	1.91±0.05 ^b	10.12±0.02 ^a	10.24±0.04 ^c	90.02±0.04 ^c
Magnesium	80.54±0.03 ^a	91.73±0.13 ^b	40.30±0.27 ^c	38.14±0.05 ^d	10.22±0.06 ^e
Potassium	60.0±0.03 ^a	70.40±0.04 ^b	16.60±0.11 ^c	14.90±0.03 ^a	80.14±0.09 ^b
Zinc	0.4±0.11 ^a	0.63±0.04 ^b	4.89±0.17 ^c	4.1±0.03 ^d	9.6.22±0.11 ^a
Calcium	70.01±0.11 ^a	78.27±0.05 ^b	50.40±0.04 ^c	40.33±0.03 ^d	100.73±0.13

Values recorded as mean ± SD of three determinations, values in the same row with different superscript are significantly different (p<0.05)

Composition of mineral element in the formulated complementary food blend and commercial blend

Table 5 below shows the mineral element composition of complementary food blend and commercial complementary food. The complementary food blend recorded higher value

of iron than the commercial complementary food, but the levels of potassium, zinc and calcium were lower.

Table 5: Composition of mineral element in the formulated complementary food blend and commercial blend

Element (mg/g)	Complementary Food Blend 60:20:20*	Commercial Complementary Food (Celerac®)**
Iron	40.33±0.03	10
Phosphorus	85.42±0.05	ND
Magnesium	54.44±0.09	ND
Potassium	195±0.17	700.0
Zinc	2.7±0.18	7.0
Calcium	95.32±0.04	420

Values recorded as mean ± SD of three determinations.

*60 parts of yellow maize: 20 parts of soybean: 20 parts of fish meal

** Values as indicated by manufacturer ND not detected.

Sensory evaluation of the formulated complementary food blend and the cereal only 'Akamu'

The figure 1 below shows the results obtained from 5-point Hedonic scale sensory evaluation of

the formulated complementary food blend made from yellow maize, soybean and fishmeal from African catfish.

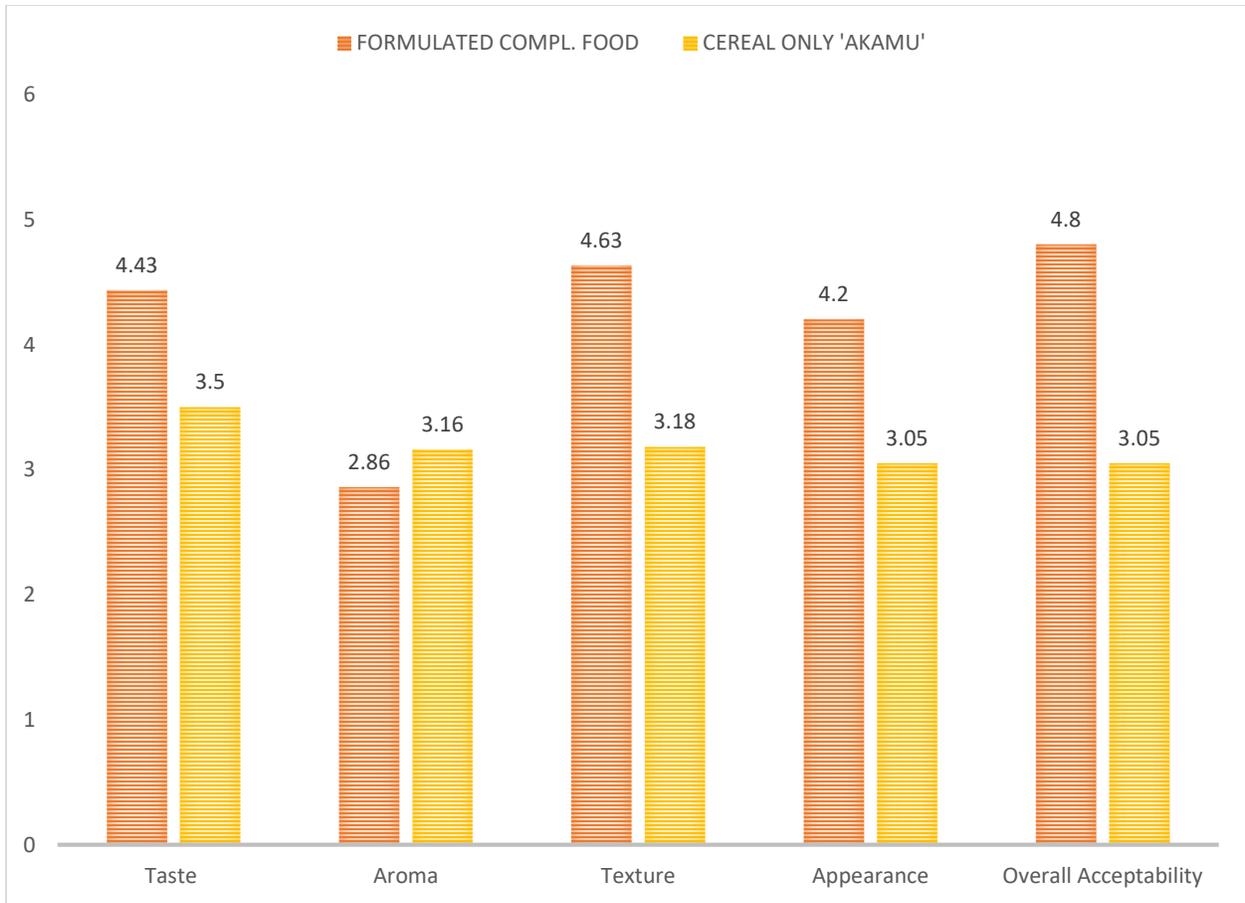


Figure 1: Bar graph showing results of 5 – point hedonic scale sensory evaluation of the formulated complementary food blend and the cereal only 'Akamu'

Discussion

Fermentation is widely accepted as a means of producing complementary foods (Tomkins *et al.*, 1988) and fermented food products from maize, millet and sorghum are very popular. Several works have explored the use of indigenous cereals, legumes and nuts for the production of a complementary food blend (Modu, 2004; Falmata *et al.*, 2014; Bintu *et al.*, 2019) for infants and young children that can no longer be adequately supported on breast milk. Food quality of yellow maize, soybean and fishmeal were employed through processing techniques such as fermentation, soaking, dehulling and roasting in formulating a complementary food blend in this study. The proximate composition of raw and processed yellow maize, soybean, fish meal and the formulated complementary food blend show significant differences ($p < 0.05$) between each

other (Table 1). No doubt fermentation and other processing methods have effects on end products. Microorganisms isolated from the fermented yellow maize in this study were of the lactobacillus species, *Lactococcus lactis* (formerly *Streptococcus lactis*) and *Bacillus subtilis*. These organisms are both non – pathogenic gram-positive bacteria which are generally regarded as safe, they are known to generate beneficial metabolites for well-being of the gastrointestinal tract (Won, 2020). During fermentation metabolites such as organic acids, carbon dioxide, hydrogen peroxides and antimicrobial peptides may be produced (Di Cagno *et al.*, 2013) which may increase acidity and be advantageous in reducing the chances of growth of pathogenic organisms. Besides preservation, fermentation imparts characteristic aroma, flavor, texture, and nutritional profile into food (Terefe, 2016). The presence of microorganisms might be responsible

for the decreases in pH and increase in total titratable acidity of the fermented samples in this study as similarly reported (Mensah *et al.*, 1990; Bintu *et al.*, 2019). Lactic acid bacteria lower pH, suppresses growth of pathogenic bacteria thereby increasing the shelf-life and safety of the food (Phiri *et al.*, 2019).

Fermentation and other processing techniques help increase the bioavailability of minerals and vitamins in foods, improve shelf life and palatability, lower the detrimental effects of anti-nutrients and enhance the quality of protein in foods by decreasing carbohydrate and increasing the availability of amino acids (Ogbonna *et al.*, 2012; Nkhata *et al.*, 2018 and Bintu *et al.*, 2019). Fermentation increased the protein content of the processed yellow maize flour in this study (Table 2). The carbohydrate, protein and energy value of the complementary food blend is closely comparable to that of the commercial complementary food blend (Nestle Cerelac®, Table 3). This may be suggestive of the suitability of the blend in providing adequate nourishment for infants and young children. The complementary food blend favorably compares with the recommended dietary allowance (RDA) for infant's nutrition. The fat composition of the formulated complementary food blend is lower than the commercial complementary food blend. Food with high fat and moisture content is more liable to spoilage than one with the lower contents (Laminu *et al.*, 2014).

Processing by fermentation significantly ($p < 0.05$) increased the mineral composition of yellow maize but significantly ($p < 0.05$) decreased the composition of minerals in roasted soybean (Table 4). Decreases in mineral composition of the soybean is the effect of roasting and dehulling which also caused a lowering of the ash contents (see Table 2). The fishmeal from African catfish in this study is an excellent source of iron, phosphorus, potassium, zinc and calcium with a significantly poor magnesium content (Table 4). Soybeans is a legume which is a good source of minerals, proteins and vitamins. However, the presence of anti-nutrients such as phytates and tannins cause digestive problems to children and even adults when raw. Processing techniques such as roasting, toasting, soaking and dehulling have been shown to reduce or eliminate such detrimental effects (Adeyemo and Onilude, 2018). Fortification with roasted soybeans have been shown to improve nutritional composition of

'ogi' as reported by Adeyemo and Onilude, (2019).

Iron deficiency anemia is a common micronutrient deficiency worldwide occurring as result of low socioeconomic status, low birth weight, low intake of iron – rich complementary foods (Magnus *et al.*, 2014). The iron content was significantly ($p < 0.05$) higher in the formulated complementary food blend than the commercial complementary food blend (Table 5). This increase may be attributable to the iron content of the fish meal. Iron is very important for the growing child and infant's needs; in fact, it is recommended that infants 6 months of age and under 5 years old children should receive iron – rich complementary foods (Magnus *et al.*, 2014) for growth and development and proper functioning of the body.

The levels of potassium, zinc and calcium were lower in the formulated complementary food blend. Mineral elements are sources of micronutrients essential for healthy brains, bones and bodies when consumed in adequate quantities. Rosa *et al.*, (2007) reported the presence of potassium, phosphorus, sodium, magnesium, calcium, zinc, iron, copper and manganese as mineral constituents of the African catfish thus contribute to increase in some elements than seen in the yellow maize and soybean flours. Minerals from plant sources have very low bioavailability because they are complexed with non-digestible materials and anti-nutrients. However, fermentation and other processing methods reduce the anti-nutrients and improve the bioavailability of iron and other mineral elements that would have been unavailable before processing, this is in line with earlier reports (Modu *et al.*, 2010).

Flescher *et al.*, (2003) published in a WHO regional document the age-specific estimate of energy in Kcal/day required from complementary foods in industrialized and developing countries assuming an average breast milk intake. According to WHO (2003) standard, infants from developing countries are often of low body weight, therefore require more energy estimates to meet the daily needs of the transiting infant. It is estimated that in developing countries at 6 – 8 months (269 Kcal/day), 9 – 11 months (451 Kcal/day) and 12 – 23 months (746 Kcal/day) is needed to meet the requirements of the transiting infant. This energy requirement can be

met in little frequent portions of 4 to 6 times meals per day given to the child. The formulated complementary food blend from an improved variety of yellow maize, soybean and fishmeal provides approximately 352kcal/100g which translates to about 7 tablespoons of the blend (a standard tablespoon is 15g; dividing this with 100g gives approximately 7 tablespoons full). Therefore, in order to provide the estimated energy requirement of an infant 6 – 8 months, about 3.5 tablespoons of the blend is needed to reconstitute the meal which can be given in little portions spread across throughout the day. About 15g of protein is needed from the complementary food according to WHO (2003) and the complementary food blend in this study provides just that right amount. Owing to the high incidence of iron deficiency, fortification of complementary foods with iron rich sources is very important. The iron content of the blend in this study is sufficient to the growing transiting infant.

On a 5 – Hedonic scale assessment, the formulated complementary food blend had an overall acceptability when compared to the cereal only based food 'Akamu' (Figure 1). The improvement of the nutritional quality of the food blend in this study by supplementation with roasted soybeans and fish meal from African catfish has significantly improved the taste, aroma, texture and appearance of the food blend. No doubt fermentation and other processing techniques help in enhancing the palatability and storage ability of foods as similarly reported by Muhimbula *et al.*, (2011); Bintu *et al.*, 2019).

Conclusion and Recommendations

The formulated complementary food blend met the energy needs and requirements of transition infants 6 – 23 months in terms of protein, fat, carbohydrate and energy (kcal/100g). The level of potassium, magnesium and phosphorus however, were low in the formulated food blend though the iron and calcium met the requirements of the transiting infants. It is therefore recommended that inclusion of fruits like bananas and vegetables in the formula may improve the potassium, magnesium and phosphorus contents of the complementary food blend.

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Conflict of Interest

The authors declare no conflict of interest in this work.

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