View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

Croatian Journal of Food Science and Technology

journal homepage: www.ptfos.unios.hr/cjfst/

Original scientific paper

DOI: 10.17508/CJFST.2020.12.2.14

Nutritional composition of formulated complementary food produced from blends of malted and unmalted yellow maize (*Zea mays*), soybean (*Glycine max*), and tiger nut (*Cyperus esculentus*) flour

FUNKE T. ALAKA[1*], ABIODUN, V. IKUJENLOLA[1] AND OLUWASEUN, P. BAMIDELE[2]

[1]*Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, Nigeria*
[2]*Department of Food Technology, Federal Polytechnic Offa, Kwara State, Nigeria*

ARTICLE INFO

Article history:
Received: January 1, 2020
Accepted: June 10, 2020

Keywords:
tiger nut
soybean
maize
proximate
complementary food

ABSTRACT

Protein-energy malnutrition (PEM) and micronutrient deficiencies among infants and children in developing countries have been a major concern of the World Health Organization. Formulation of complementary food from local sources of raw materials can be of great help in solving the problems of protein energy malnutrition. This study determined the nutritional composition of four formulated complementary foods from malted yellow maize, pre-gelatinized yellow maize, soybean, and tiger nut flour. The results showed an increase in protein content (17.6, 16.9, 20.4 & 19.7 %), crude fat (14.9, 12.9, 13.0 & 12.9 %) and energy (433.1, 419.4, 421.5 & 426.6 %) when compared with the control sample. The functional properties also competed favourably with the control sample, with the formulated samples having water absorption capacity (171.9, 169.0, 184.1 & 167.4 %), swelling power (27.9, 25.2, 29.8 and 28.1 %), and bulk density at the same level for all the formulated samples (0.5 g/ml). The formulated samples contained a higher amount of iron and magnesium, and the anti-nutritional factors fell below the hazard level. In conclusion, formulated complementary food made from locally sourced raw materials has enough nutritional composition to be able to combat PEM and micronutrient deficiencies among infants and children.

Introduction

Malnutrition persists in many developing countries despite abundant global food supplies. The World Health Organization has been concerned about this trend, particularly PEM (Protein-Energy Malnutrition) and micronutrient deficiencies among infants and children (WHO, 2001a, and UNICEF, 2004). Undernutrition is associated with at least 35% of the near 10 million deaths of children under 5 years of age seen each year in developing nations (Black et al., 2008). Higher rates of exclusive breastfeeding during the first six months of life, thereafter continued with complementary foods, can potentially decrease under-five deaths each year by 13% (Jones et al., 2003). Complementary foods in most developing countries are based on staple cereals or root crops; they are often of low nutritional quality and given in an insufficient amount. The feeding practice in both developed and developing countries, considering the performance of cereals and plant foods, does not complement these recognized nutritional gaps (Temesgen, 2013). In line with this, the development of low cost, high protein complementary food from underutilized and readily available raw materials is a constant challenge for developing nations (Ikpeme-Emmanuel et al., 2012). Yellow maize (*Zea mays*) has been found very useful as food in most African countries. It is used for making *Ogi* in Nigeria, *Kenkey* in Ghana, *Koji* in Cameroon, and *Ugali* in Kenya (Iken et al., 2002). It constitutes an important source of carbohydrates, protein, Vit B and A (yellow maize), and minerals. It is complete in nutrients compared to other cereals (Iken et al., 2002).

*Corresponding author E-mail: fprecious1@yahoo.com

Soybean (Glycine max), being a leguminous plant, has a highly available protein content and is very cheap. Wang et al. (2008) described soybean as ideal for protein (32%) substitution in starchy foods, being superior to that of cowpea protein (20%). It has been found widely useful because of its distinctive properties, both functional and physicochemical.
Tiger nut (*Cyperus esculentus*) is one of the underutilized crops and it contains 8% protein with 30% oil (Alobo and Ogbogo, 2007). It is useful in tissue and bone repair because it contains essential minerals like calcium, magnesium, iron, sodium, and potassium. It is also abundant in vitamin B, which is essential in balancing the central nervous system (Oladele and Aina, 2007). The use of this underutilized, rich, and readily available tiger nut to produce a complementary food with legumes (soybean) and cereals (maize) will be of great importance in providing solution to PEM (Protein Energy Malnutrition) and the infant mortality rate. Hence, this study aims at analysing the nutritional composition and the consumers' acceptability of formulated complementary food from maize (*Zea may*), soybean (*Glycine max*), and tiger nut (*Cyperus esculentus*).

Materials and methods

Materials

Yellow maize, soybeans, the yellow variety of tiger nut, and commercial complementary food (Control) were purchased from a local market in Ile-Ife, Osun State Nigeria. They were all processed in the processing laboratory of the Department of Food Science and Technology Obafemi Awolowo University, Ile-Ife.

Methods

Production of pre-gelatinized maize flour

About 750 g of yellow maize grains were cleaned and washed thoroughly to remove adhering dirt and dust. The washed grains were steamed for 10 minutes to pre-gelatinize the starch. The maize grains were then dried at 60 °C for 20 hours in a cabinet dryer. The dried maize grains were milled (Hammer mill, Perten, UK), sieved (500 μm, sieve), and packaged into polyethylene bags until needed; Marero et al. (1988).

Production of malted maize flour

The yellow maize grains (500 g) were cleaned separately by hand sorting and floatation to remove broken grains and extraneous materials. The grains were steeped in tap water for 8 hours at ambient temperature. The steeped seeds were spread evenly in a germinating chamber (locally made) at about 1.5 cm depth, for a period of 72 hours with watering four times daily. The germinated seeds were thereafter thoroughly washed. This was followed by steaming the grains for 10 minutes to pre-gelatinize the starch. The germinated grains were subsequently dried in the dryer at 60 °C for 20 hours and then milled (Hammer mill, Perten, UK), sieved (500 μm), packaged in polythene bags, and kept until required Akingbala et al. (1981).

Production of soybean flour

Soybean seeds were cleaned of dirt and extraneous materials. The seeds were soaked in warm water (into which 0.2% $NaHCO_3$ was added for easy dehulling) for 3 hours. The soaked seeds were decorticated, thoroughly washed, and steamed for 1 hour. These were dried in a cabinet dryer at 60 °C for 12 hours. The dried seeds were milled (Hammer mill, Perten, UK), sieved (500 μm), and packaged in polyethylene bags until needed (Iwe, 2003).

Production of tiger nut flour

The method of Ade–Omowaye et al. (2007) was used in the preparation of tiger nut flour. Dry tiger nuts were sorted to remove unwanted materials like stones, pebbles, and other foreign seeds, before washing with tap water. The cleaned nuts were dried in a cabinet, milled, packed, and stored.

Complementary food formulation

Four different formulations were used in the production of the complementary foods based on the target age group. The commercial brand of complementary food sold in the market was used as control for this study. Sample A contained unmalted pre-gelatinized yellow maize, soybean, and tiger nuts in the ratio of 60:30:10% (w/w), while sample B contained the same raw materials in the ratio of 50:30:20% (w/w). Sample C contained malted pre-gelatinized yellow maize, soybean, and tiger nuts in the ratio of 60:30:10% (w/w), while sample D contained the same raw materials in the ratio of 50:30:20% (w/w). Basal food for the animals was formulated using the formula of Ikujenlola, 2010. Maize flour 800 g/kg, sugar 60 g/kg, vegetable oil 100 g/kg, vitamin mix 30 g/kg, and cod-liver oil 10 g/kg.

Proximate composition

The nutrient composition of the food samples was determined using the standard procedures of Association of Official Analytical Chemists (2006).

The total carbohydrates were calculated as the difference of 100- (% moisture + crude protein + crude fat + ash + crude fibre). The gross energy was determined with a Gallenkamp ballistic bomb calorimeter (Gallenkamp ccb-330-010L UK).

Functional properties

The bulk density of each of the flours was determined by the method described by Ikujenlola (2010). The water absorption capacity (WAC) and swelling capacity were determined at room temperature and at temperatures ranging between (60 °C – 90 °C) using a combination of AOAC (2010) and Adepeju *et al*. (2010). The least gelling concentration was determined using the method of Sathe and Salunkhe (1981).

Mineral analysis

The mineral content of all the samples was analysed using the method of Fasakin and Ogunsola (1982). Exactly 0.5 g of the sample was transferred into a 75ml digestion tube. About 5 ml of the digestion mixture was added, swirled, and placed in a fume cupboard; digestion was made for 2 h at 150 °C. These were removed from the digester, cooled for 10 min., and then 3ml of 6 M HCl was added to each tube. These mixtures were digested for another 1 h 30 mins. They were then removed from the digestor, cooled, and 50 ml of distilled water was added to each tube and stirred vigorously using a vortex mixer. The mineral content was analysed using the atomic absorption spectrophotometer- model Perkin Elmer 403 and by comparing the blank to the standard curve.

Anti-nutrient determination

Determination of phytate

Phytic acid was extracted from each 3 g flour sample with 3% trichloro-acetic acid by shaking at room temperature, followed by high speed centrifugation as described by Adepeju et al. (2010). This method depends on an iron to phosphorus ratio of 4:6. Five grams of the test sample was extracted with 3% trichloroacetic acid. The phytate was precipitated as ferric phytate and converted to ferric hydroxide and soluble sodium phytate by adding sodium hydroxide. The precipitate was dissolved in hot 3.2 N HNO_3 and the colour read immediately at 480 nm^3. The standard solution was prepared from Fe $(NO_3)_3$ and the iron content was extrapolated from a Fe $(NO_3)_3$ standard curve. The phytate concentration was calculated from the iron results assuming a 4:6 iron: phosphorus molecular ratio. The phytic acid was estimated by multiplying the amount of phytate-phosphorus by the factor 3.55, based on the empirical formula $C_6P_6O_{24}H_{18}$.

Determination of trypsin inhibitors

The trypsin inhibition activity was assayed in terms of the extent to which an extract of defatted flour inhibited the action of bovine trypsin (EC 3.4.21.4) on the substrate benzoyl-DL-arginine-p-nitrianilide (BAPNA) hydrochloric (Kakade et al., 1974; Ikujenlola, 2010). The samples (1g each) were extracted continuously at ambient temperature for 3 h with 50 ml, 10 M NaOH, using a mechanical shaker (GallenKamp orbital shaker Surrey, UK). The pH of the resulting slurry was adjusted to 9.4 - 9.6 with 1 M NaOH. After extraction, the suspension was shaken and diluted with distilled water such that 1 cm^3 of the extract produced trypsin inhibition of 40 - 60% at 37 °C. The respective dilutions were noted. Consequently, TIA (Trypsin inhibition activity) was calculated in terms of mg of pure trypsin [Sigma type lll, lot 20H0868]:

$$\text{TIA}=\frac{2.632\ \text{DA mg pure trypsin inhibited g -1 g sample}}{\text{S}}$$

where, D – dilution factor, A- change in absorbance at 410 mm due to trypsin inhibition / cm^3 of diluted sample extract, and S is the weight of the sample.

Biological assessment

White rats weighing between 55 g – 70 g at the beginning of the experiment were weighed, randomly distributed into metabolic cages, and subjected to laboratory conditions for a period of five days. During this period, the animals were fed normal pellet foods as they had been previously fed during the breeding period.

At zero day of the experiment, the animals were re-weighed and re-grouped such that the average weight of animals in each group was approximately the same. One group of animals served as baseline control for the experimental groups, which was sacrificed at zero day and tissue samples from liver, kidney, and the plantaris muscle of the hind leg were removed, weighed, and frozen (-10 °C) until nitrogen content was determined. The remaining animals were placed on the experimental foods for a period of 28 days. Food and water were supplied ad libitum, the formulated foods were made such that each sample contained 15% protein.

The feed intakes and growth were recorded during the period. At the expiration of the experimental period, the animals were anaesthetized and sacrificed. Tissue specimens from liver, kidney, and the plantaris muscles were obtained, weighed, and frozen (-10 °C) until nitrogen was determined by the modified micro-Kjedhal method. The body weights of the animals were measured at three-day intervals. The total faeces and urine voided during the last five days of the experiment were collected, weighed, and preserved. The urine collected was preserved by adding H_2SO_4 to prevent any ammonia loss, while the corresponding feed consumed was also recorded for nitrogen determination. The information collected during the feeding experiment was used in determining the following parameters.

Nitrogen retention

The nitrogen retained in the experimental animal was calculated as the algebraic difference between the foods and the sum of both the faecal and urinary nitrogen for the collection period.

NR = Ni – (FN + UN);
NR = nitrogen retained; Ni = nitrogen intake in foods;
FN = faecal nitrogen;
UN = urinary nitrogen

Protein efficiency ratio (PER) and food efficiency ratio (FER) were calculated as follows:

$$\text{PER} \quad \frac{weight\ gain}{protein\ consumed}$$

$$\text{FER} \quad \frac{weight\ gain}{feed\ consumed}$$

True digestibility (TD) and biological value (BV) were calculated as follows:

$$TD = \frac{Ni - (NF1 - NF2)\ x\ 100}{Ni}$$

$$BV = \frac{(\text{Ni} - \text{NF2}) + (\text{NU1} - \text{NU2})\ \text{x}\ 100}{Ni - (NF1 - NF2)}$$

where,
Ni = Nitrogen intake of animals that were fed test food
NF1 = Nitrogen excreted in the faeces of animals that were fed test food
NF2 = Nitrogen excreted in the faeces of animals that were fed protein - free food
NU1 = nitrogen excreted in the urine of animals that were fed test food
NU2 = nitrogen excreted in the urine of animals that were fed protein - free food

Net protein utilization (NPU) was determined according to the method of Dahiya and Kapoor (1993):

$$NPU = \frac{\text{BV}\ \times \text{TD}}{100}$$

Net protein retention (NPR) and protein retention efficiency (PRE) were calculated according to the following formulae:

$$NPR = \frac{weight\ gain\ of\ test\ group + weight\ loss\ of\ protein\ free\ groups}{weight\ of\ test\ protein\ consumed}$$

$$PRE = NPR\ \times 16$$

Statistical analyses

All experimental results are the averages of three measurements. Quantitative data was expressed as means and standard deviation (SD) of at least three measurements. Each experimental set was compared with the one-way Analysis of Variance (ANOVA) procedure using Statistical Package for Social Sciences (SPSS) version 16 (SPSS Inc., Chicago, IL, USA). Duncan's new multiple range test was used to separate means. P values <0.05 were regarded as significant.

Results and discussion

Proximate Composition

Table 1 shows the proximate composition results of formulated complementary food from malted and unmalted pre-gelatinized yellow maize, soybean, and tiger nut. The moisture content of the four formulated samples was higher (7.2, 7.4, 7.6 & 7.3 %) than the control (4.5%). This may be due to the combination of different raw materials used in producing complementary food.
The protein and the crude fat content were also higher (17.6, 16.9, 20.4 & 19.7 %) when compared with the control sample (15.0%). The increase in protein content of the formulated complementary food may be attributed to the presence of soybean, which serves as a protein source in the formulated sample. The differences in protein content and crude fat in the formulated samples may be due to the ratio of malting pre-gelatinized yellow maize and malted pre-gelatinized yellow maize to tiger nut. The crude fibre, ash, and carbohydrate content of sample B were slightly higher (1.4, 2.2 and 59.1 %) than samples A, C & D, respectively. The formulated samples were lower than the control in crude fibre (2.9%), ash (2.6%), and carbohydrate content (67.9%).

The energy content of the formulated samples was higher (433.1, 419.4, 421.5 & 426.6 kcal/100 g) than the control (404.6 kcal/100 g). These results showed the positive influence of tiger nut and malted and unmalted pre-gelatinized yellow maize in improving the nutritional quality of the formulated complementary food, which makes them compete favourably with commercially sold complementary food (Control). Although there were differences in the proximate composition of the formulated samples, the difference may be attributed to the combining ratio of the raw materials and the malting effect.

The quantity present in the formulated samples was good enough for children between 6 months and two years of age in line with WHO (2015) recommendation regarding daily protein (15%) for complementary foods. This result was similar to the finding of Ade-omowaye et al. (2008), who reported an increase in ash and crude fibre content of wheat, tiger nut composite flour, and bread. Also, Solomon (2005) reported the importance of locally sourced raw materials in making weaning (complementary) food. In the study, the author reported a higher nutritional value in the diet formulated with yellow maize, soybean, and groundnut.

Functional Properties

The functional properties of the formulated complementary food samples are shown in Table 2. The water absorption capacity of the formulated samples was lower (171.0, 169.0, 184.1 & 167.4 %) than the control (219.9%). Sample A absorbed more water than the rest of the samples (B, C & D). The difference in water absorption capacity (WAC) of the samples may be attributed to the variation in the ratio of pre-gelatinized and malted yellow maize starch to tiger nut. Pre-gelatinization of the yellow maize starch influenced the WAC, since the starch granules have been disintegrated, which may influence the absorption of water experienced in the samples. Yellow maize starch has been reported to be higher in starch content than tiger nut (Ejigui et al., 2005; Oladele and Aina, 2007). This can also be confirmed by the report of Mbofong et al. (2006), that a higher amount of starch improves the water absorption capacity of food materials.

The least gelation concentration shows that the formulated samples form a gel at a higher concentration (10 & 10%) than the control (8%). The gelation capacity of cereals and legumes is influenced by the competition for water between proteins and starch granules (Singh, 2001). The control and sample C formed a relatively firm gel at a significantly lower concentration (8%) when compared with the rest of the formulated samples. This may be due to the variation in proximate composition such as protein, crude fat, crude fibre, and carbohydrate. This result was in line with Schmidt (1981), who reported that the protein-polysaccharide complex may be involved in the gelation of legumes.

The result of the swelling capacity of the formulated samples was lower (27.9, 25.2, 29.8 & 28.1 %) when compared with the control (31.6%). Sample A recorded a higher value (27.9%) than the rest of the samples. The higher swelling capacity of sample A may be due to the effect of pre-gelatinization of the yellow maize starch, which helped starch granules to entrap water molecules, which resulted in swelling of the sample. Ezeocha et al. (2011) reported that water molecules entrapped by food substance (Starch granules) help in swelling.

The packed and loose bulk density of the samples (Table 2) showed no significant difference ($p < 0.05$). The values for packed bulk density were 0.6 g/ml for control and 0.7, 0.6 g/ml for the formulated samples (A, B, C & D). Loose bulk density was 0.5 g/ml for the control and the formulated samples. Bulk density helps in determining the packaging requirement for material handling and transportation in various food companies. Higher bulk density value is an indication of the high cost of packaging and transportation.

Table 1. Proximate composition of the formulated complementary food (%) dry basis

Nutrients	Control	A	B	C	D
Moisture	$4.5^{a}\pm0.1$	$7.2^{b}\pm0.2$	$7.4^{b}\pm0.2$	$7.6^{b}\pm0.2$	$7.3^{b}\pm0.4$
Protein	$15.0^{a}\pm0.1$	$17.6^{c}\pm0.3$	$16.9^{b}\pm0.1$	$20.4^{d}\pm0.7$	$19.7^{c}\pm0.4$
Crude fat	$9.0^{a}\pm0.3$	$14.9^{c}\pm0.1$	$12.9^{b}\pm0.3$	$13.0^{b}\pm0.2$	$12.9^{b}\pm0.6$
Crude fibre	$2.9^{b}\pm0.2$	$1.2^{a}\pm0.2$	$1.4^{a}\pm0.2$	$1.1^{a}\pm0.1$	$1.3^{a}\pm0.1$
Ash	$2.6^{c}\pm0.1$	$2.0^{a}\pm0.1$	$2.2^{a}\pm0.3$	$2.1^{a}\pm0.3$	$2.2^{c}\pm0.1$
Carbohydrate	$65.9^{e}\pm0.5$	$57.2^{c}\pm0.4$	$59.1^{d}\pm0.6$	$55.7^{a}\pm1.2$	$56.6^{b}\pm0.8$
Energy (Kcal/100g)	$404.6^{a}\pm5.3$	$433.1^{d}\pm7.3$	$419.4^{b}\pm6.5$	$421.5^{c}\pm2.6$	$426.6^{c}\pm1.5$

Values are mean ± SD for three determinations. Values with different superscripts on the same row are significantly different $P\leq 0.05$. **A** – Yellow maize: Soya beans: Tiger nut (60:30:10 % w/w); **B** – Yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w); **C** – malted yellow maize: Soya beans: Tiger nut (60:30:10 % w/w) and D – malted yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w)

Mineral content

Mineral content, calcium (Ca), iron (Fe), magnesium (Mg), potassium (K), and sodium (Na) were determined as shown in Table 3. All the samples were higher in potassium content, with the control and sample A having the same value of 70 mg/kg, and sample D having 69.8 mg/kg. The iron content of sample D (77.9 mg/kg) was higher than the rest of the formulated samples and the control sample had the lowest value (10.0 mg/kg).

The control sample recorded the highest value of calcium (39.0 mg/kg), followed by sample B (23.4 mg/kg), while samples A and D had the lowest value (20.4 & 20.5 mg/kg). The sodium content of the control was also higher (22.0 mg/kg) than the formulated samples (14.4, 20.2, 14.9 & 15.0 mg/kg), respectively. The magnesium content of the control sample was not determined due to lower concentration, but the formulated samples contained 23.6, 21.9, 21.8 & 22.6 mg/kg for sample A, B, C & D. The contribution of malting and pre-gelatinized yellow maize and tiger nut to the mineral content of the formulated samples cannot be overemphasized. Although the control sample was higher in some minerals (Ca and Na), Fe and Mg were found to be lower in the control sample. The variation in the mineral contents of the formulated samples occurred based on the ratio of pre-gelatinized yellow maize flour, malted yellow maize to tiger nut flour.

Anti-nutritional content

The results in Table 4 show that the control sample has the least value for both determined anti-nutritional factors (1.05% for phytic acid and 0.6% for trypsin inhibitor). The formulated samples have higher phytic acid and trypsin inhibitor values which may be due to the addition of soybean. The level of anti-nutritional factors found in the formulated samples was lower and may not be harmful to humans when consumed. The reduction in the content of anti-nutritional factors may be due to pre-processing like gelatinization, malting, dehulling, milling, and pasteurization of each raw material before formulation (Iwe, 2003). The lower amount of phytic acid in the samples may still be of good health benefit, since research shows that phytic acid has anti-oxidant and anti-carcinogenic properties (Bhat et al., 2007).

Table 2. Functional properties of the formulated complementary food

Sample	Water Absorption Capacity (%)	Least Gelation Concentration (%)	Swelling Capacity (%)	Bulk Density (Packed)	Bulk Density (Loose)
Control	$219.9^{d}\pm1.3$	$8.0^{a}\pm0.3$	$31.6^{e}\pm0.5$	$0.6^{a}\pm0.1$	$0.5^{a}\pm0.1$
A	$171.0^{c}\pm1.8$	$10.0^{b}\pm0.2$	$27.9^{d}\pm0.5$	$0.7^{b}\pm0.1$	$0.5^{a}\pm0.1$
B	$169.0^{b}\pm1.1$	$10.0^{b}\pm0.2$	$25.2^{c}\pm0.4$	$0.7^{b}\pm0.1$	$0.5^{a}\pm0.1$
C	$154.1^{a}\pm1.24$	$8.0^{a}\pm0.1$	$23.8^{b}\pm0.3$	$0.6^{a}\pm0.1$	$0.5^{a}\pm0.1$
D	$167.4^{b}\pm0.58$	$10.0^{b}\pm0.3$	$22.1^{a}\pm0.5$	$0.6^{a}\pm0.1$	$0.5^{a}\pm0.1$

Values are mean ± SD for three determinations. Values with different superscripts on the same row are significantly different P≤ 0.05. **A** – Yellow maize: Soya beans: Tiger nut (60:30:10 % w/w); **B** – Yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w); **C** – malted yellow maize: Soya beans: Tiger nut (60:30:10 % w/w) and D – malted yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w)

Table 3. Mineral contents of the formulated complementary food (mg/kg)

Samples	Ca	Fe	Mg	K	Na
Control	$39.0^{d}\pm0.3$	$10.0^{a}\pm0.1$	ND	$70.0^{c}\pm0.3$	$22.0^{c}\pm0.3$
A	$20.4^{a}\pm0.2$	$75.2^{d}\pm0.1$	$23.6^{c}\pm0.4$	$70.0^{c}\pm0.2$	$14.4^{a}\pm0.2$
B	$23.4^{c}\pm0.2$	$65.5^{c}\pm0.3$	$21.9^{a}\pm0.3$	$68.1^{b}\pm0.3$	$20.2^{b}\pm0.4$
C	$22.2^{b}\pm0.4$	$57.3^{b}\pm0.3$	$21.8^{a}\pm0.4$	$61.4^{a}\pm0.4$	$14.9^{a}\pm0.2$
D	$20.5^{a}\pm0.1$	$77.9^{e}\pm0.5$	$22.6^{d}\pm0.3$	$69.8^{c}\pm0.4$	$15.0^{a}\pm0.2$

Values are mean ± SD for three determinations. Values with different superscripts on the same row are significantly different P≤ 0.05. **A** – Yellow maize: Soya beans: Tiger nut (60:30:10 % w/w); **B** – Yellow maize: Soya beans: Tiger nut (50: 30: 20% w/w); **C** – malted yellow maize: Soya beans: Tiger nut (60:30:10 % w/w) and D – malted yellow maize: Soya beans: Tiger nut (50: 30: 20% w/w)

Biological assessment of the formulated complimentary foods

Table 5 shows the influence of protein quality in the control sample, formulated samples, and the basal food that was fed to the animals. The weight gained by the experimental animals was a result of the nutritional composition of various feeds given to them, in which protein may be the major determining factor. The experimental animals fed with basal feed recorded the least weight gain (9.2 g), followed by sample B (34.3 g), A (39.8 g), and the control (40.5 g). The experimental animals fed with formulated samples C and D had the highest weight gain (42.1 & 43.0 g). The experimental animals fed with the control sample have higher values of other determined parameters, except in the few parameters where the experimental animals that were fed with formulated samples have a higher value. The slight variations recorded between the control sample and the formulated samples showed that there is hope for locally sourced raw material in complementary food formulation. From the results, one could say that sample A competed favourably with the control sample, although there was a significant difference at $p<0.05$. Fig. 1 was used to confirm the relationship between the weight gains by experimental animals fed with basal feed, formulated feed, and control feed. The weight gained by all the experimental animals remained unchanged till the sixth day and this may be due to the nutritional composition of the animals before being given the feeds. The changes started reflecting on day 9 and continued throughout the feeding days. There was a slight difference between the weights of experimental animals that were fed formulated samples. The weight of experimental animals fed with sample C was higher than the rest of the experimental animals fed between days 9 and 15. The reverse happened to the experimental animals fed with samples A, B, and C on the last day (28th day). The weight gained by the experimental animals fed with sample D was higher from day 21 to 28 than the rest of the experimental animals fed with formulated samples A, B & C. The initial differences that occurred between the formulated samples may be attributed to the metabolism rate of the experimental animals. Also, the equal weight of the animals fed with sample D to that of the animals fed with the control may be attributed to the accumulation of the nutrients in the feeds which the metabolism mechanism in the experimental animals was utilizing in the same way. The experimental animals fed with the basal feed lost weight from day 6 till the last day (28th day) of feeding. This may be attributed to the absence of protein from the feed. Protein is required among other nutrients for good growth. This finding was similar to the report of Ijarotimi and Ayantokun (2003) and Ikujenlola (2010) on formulated food made from malted maize.

Table 4. Anti-nutritional content of formulated complementary food

Samples	Phytic Acid (%)	Trypsin inhibitors (%)
Control	$1.0^{a}\pm0.2$	$0.6^{a}\pm0.2$
A	$1.9^{c}\pm0.1$	$0.6^{a}\pm0.1$
B	$1.9^{c}\pm0.1$	$0.7^{b}\pm0.1$
C	$1.8^{b}\pm0.1$	$0.9^{d}\pm0.1$
D	$1.8^{b}\pm0.1$	$0.8^{c}\pm0.2$

Values are mean ± SD for three determinations. Values with different superscripts on the same row are significantly different $P\leq 0.05$. **A** – Yellow maize: Soya beans: Tiger nut (60:30:10 % w/w); **B** – Yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w); **C** – malted yellow maize: Soya beans: Tiger nut (60:30:10 % w/w) and D – malted yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w)

Table 5. Protein quality parameters of formulated foods

Parameter	**A**	**B**	**C**	**D**	**Control**	**Basal Food**
Weight gain(g)	$39.8^{c}\pm1.3$	$34.3^{b}\pm1.5$	$42.1^{d}\pm1.3$	$43.0^{e}\pm0.5$	$40.5^{c}\pm3.6$	$9.2^{a}\pm3.1$
Carcass nitrogen(g)	$1.8^{c}\pm0.2$	$1.7^{b}\pm0.2$	$1.9^{d}\pm0.3$	$1.9^{d}\pm0.1$	$1.9^{d}\pm0.2$	$0.2^{a}\pm0.2$
Carcass protein	$11.0^{b}\pm0.1$	$10.7^{b}\pm1.0$	$12.0^{c}\pm0.4$	$11.6^{c}\pm0.3$	$11.0^{b}\pm0.3$	$1.4^{a}\pm0.1$
Faecal nitrogen(g)	$0.7^{c}\pm0.0$	$0.7^{c}\pm0.0$	$0.4^{a}\pm0.3$	$0.4^{a}\pm0.2$	$0.7^{c}\pm0.0$	$0.5^{b}\pm0.3$
Urinary nitrogen(g)	$0.3^{c}\pm0.1$	$0.2^{b}\pm0.1$	$0.3^{c}\pm0.2$	$0.3^{c}\pm0.2$	$0.4^{d}\pm0.1$	$0.1^{a}\pm0.1$
Protein intake(g)	$17.9^{b}\pm0.6$	$17.2^{b}\pm0.4$	$19.2^{d}\pm0.3$	$18.4^{c}\pm0.3$	$19.6^{d}\pm0.4$	$0.3^{a}\pm0.4$
Nitrogen intake(g)	$2.9^{b}\pm0.5$	$2.8^{b}\pm0.31$	$3.1^{c}\pm0.5$	$2.9^{b}\pm0.3$	$3.1^{c}\pm0.5$	$0.1^{a}\pm0.4$
PER	$2.2^{c}\pm0.1$	$2.0^{a}\pm0.1$	$2.1^{b}\pm0.3$	$2.3^{d}\pm0.5$	$2.1^{b}\pm0.6$	-----
FER	$0.3^{b}\pm0.1$	$0.3^{b}\pm0.3$	$0.3^{b}\pm0.7$	$0.4^{b}\pm0.2$	$0.3^{b}\pm0.1$	$0.1^{a}\pm0.1$
NPR	$2.2^{a}\pm0.1$	$2.2^{a}\pm0.1$	$2.6^{c}\pm0.8$	$2.8^{d}\pm0.2$	$2.5^{b}\pm0.1$	-----
TD(%)	$81.9^{a}\pm0.1$	$83.1^{b}\pm0.3$	$92.1^{d}\pm0.6$	$91.1^{c}\pm0.3$	$91.1^{c}\pm0.4$	-----
BV(%)	$74.3^{a}\pm0.1$	$80.7^{b}\pm0.5$	$87.5^{c}\pm0.8$	$88.5^{d}\pm0.7$	$97.3^{e}\pm0.1$	-----
NPU(%)	$60.9^{a}\pm0.1$	$67.07^{b}\pm0.2$	$80.6^{c}\pm0.6$	$80.6^{c}\pm0.5$	$88.6^{d}\pm0.2$	-----

Values are mean ± SD are from three different measurements. Values with different superscripts on the same row are significantly different $P\leq 0.05$. **A** – Yellow maize: Soya beans: Tiger nut (60:30:10 % w/w); **B** – Yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w); **C** – malted yellow maize: Soya beans: Tiger nut (60:30:10 % w/w) and D – malted yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w)

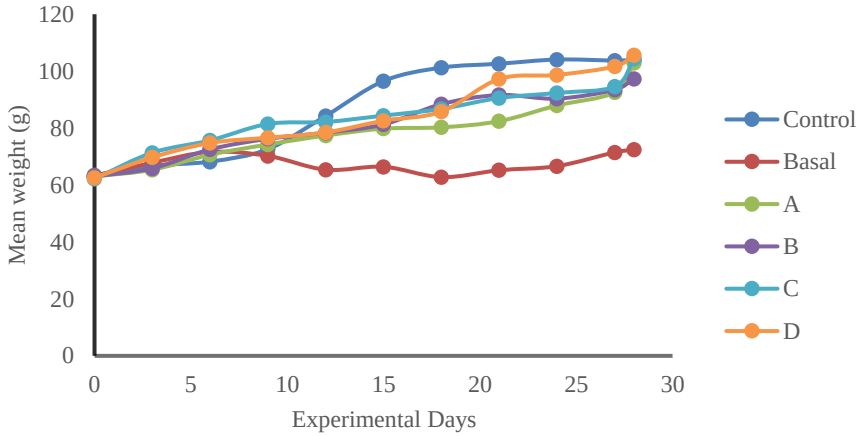

Fig. 1. Mean growth rate of the experimental animals. Keys: **A** – Yellow maize: Soya beans: Tiger nut (60:30:10 % w/w); **B** – Yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w); **C** – malted yellow maize: Soya beans: Tiger nut (60:30:10 % w/w) and D – malted yellow maize: Soya beans: Tiger nut (50: 30: 20 % w/w)

Conclusion

It can be concluded from this study that locally sourced raw materials contain sufficient nutrients to produce complementary food which can combat PEM and micronutrient deficiency among children and infants. Malting and pre-gelatinization of yellow maize starch improved the nutritional quality of the formulated complementary food. Other processing methods, like fermentation of both tiger nut and yellow maize, can still be considered to improve the nutritional quality of any formulated complementary food.

References

Ade-Omowaye, B.I.O., Akinwande, B.A., Bolarinwa, I.F. and Adebiyi, A.O. (2008): Evaluation of tiger nut (*Cyperusesculentus*) –wheat composite flour and bread. *Afri. J. Food Sci.* 2, 087-091.

Adepeju, A.B, Gbadamosi, S.O, Adeniran, A.H and Omobuwajo, T.O. (2010): Functional and pasting characteristics of breadfruit (*Artocarpusaltilis*) flour. *Afri. J. Food Sci.* 5 (9), 529-535.

Alogo, A. P. and Ogbogo, P. O. (2007): Selected properties of tiger nut starch as affected by physical and chemical modifications. Proceeding of the 31st annual NIFST Conference, Abuja, Nigeria 22nd -25th October 2007.

AOAC (2006): Official methods of analysis 14th Edition. Association of Official Analytical Chemist. Washington DC, USA. https://doi.org/10.1007/978-3-642-31241-0.

Bhat, R., Sridhar, K. R, and Yokotani, K. T. (2007): Effect of ionizing radiation on Anti-nutritional features of velvet bean seeds (*Mucunapruriens*). *Food Chem.* 103, 860-866. https://doi.org/10.1016/j.foodchem.2006.09.037.

Black, R.E., Allen, L.H., Bhutta, Z.A., Caufield, L.E., De Onis,M., Mathers, C. and Rivera, J. (2008): Maternal and Child Under nutrition: Global and Regional Exposures and Health Consequences. *Lancet* 371 (9608), 243-260. https://doi.org/10.1016/S0140-6736(07)61690-0.

Dahiya, S. and Kapoor, A. C. (1993): Biological evaluation of protein quality of home processed supplementary foods for pre-school children. *Foods Chem.* 48, 183-188. https://doi.org/10.1016/0308-8146(93)90055-K.

Earp, C. F., Akingbala, J. O., Ring, S. H. & Rooney, L. W. (1981): Evaluation of several methods to determine tannins in sorghums with varying kernel characteristics. *Cereal Chem.* 58 (3), 234-238.

Ejigui, J., Savoie, L., Mavin, J. and Desrosiers, T. (2005): Beneficial changes and drawback of a traditional fermentation process on chemical composition and antinutritional factors of yellow maize (Zea may). *J. Biol. Sci.* 5, 590-596.

Ezeocha, V. C., Omodamiro, R. M., Oti, E. and Chukwu, G. O. (2011): Development of trifoliate yam: cocoyam composite flour for fufu production. *J. Stored Prod. Posthar Res.* 2, 184 – 188.

Fashakin, J. B. and Ogunsola, F. (1982): The Utilization of Local foods in the Formulation of Complementary foods. *J. Trop. Pediatri* 28, 93-96.

Ijarotimi, O. S., and Ayantokun, O. A. (2003): Nutritional composition, sensory and biological evaluation of a potential weaning food from low cost food materials (*Sorghum bi Colour* and *Cajanus Cajan*). *J. Food Technol.* 4 (3), 178-184.

Ikpeme – Emmanuel, C.A., Ekpeyoung, I.O. and Igile, G.O. (2012): Chemical and Protein quality of Soya beans and Tiger nuts based weaning food. *J. Food Res.* 1, 246-254. http://dx.doi.org/10.5539/jfr.v1n2p246.

Ikujenlola, A.V. (2010): Effect of Malting and Fermentation on the Nutritional Quality of Complementary foods From Maize Varieties and soya beans Grains. Ph.D. Thesis, Obafemi Awolowo University, lle- lfe.

Iwe, M. O. (2003): The science and technology of soybean. *Rejoint communication services Ltd. Enugu, Nigeria*.

Jideani, V. A. (2011): Functional properties of soybean food ingredients in food systems. *Soybean-Biochemistry, Chemistry and Physiology*, pp. 345-366.

Jones, G., Steketee, R. W., Black, R. E., Bhutta, Z. A., Morris, S. S. & Bellagio Child Survival Study Group. (2003). How many child deaths can we prevent this year? L*ancet* 362 (9377), 65-71. https://doi.org/10.1016/S0140-6736(03)13811-1.

Coscueta, E. R., Pintado, M. E., Picó, G. A., Knobel, G., Boschetti, C. E., Malpiedi, L. P. & Nerli, B. B. (2017): Continuous method to determine the trypsin inhibitor activity in soybean flour. *Food Chem*. 214, 156-161. https://doi.org/10.1016/j.foodchem.2016.07.056.

Marero, I. M., Payumo, E. M. and Aguinado, A.R. (1999): Nutritional characteristics of weaning foods prepared from germinated cereals and legumes. *J. Food Sci.* 53 (5), 1399-1402. https://doi.org/10.1111/j.1365-2621.1988.tb09286.x.

Mbofung, C. M. F., Aboubakar, N. Y., Njintang, Y. N., Abdou, B. & Balaam, F. (2006): Physicochemical and functional properties of six varieties of taro (Colocasia esculenta L. Schott) flour. *J Food Technol*, *4* (2), 135-142.

Obatolu, V. A. and Cole, A. H. (2000): Functional Properties of complementary blends of soya beans and cowpea with malted and unmalted maize. *Foods Chem.* 70, 147-153. https://doi.org/10.1016/S0308-8146(99)00248-4.

Oladele, A.K., Aina, J.O. (2007): Chemical composition and functional properties of flour produced from two varieties of tiger nut (*Cyperus esculentus*) Afri. *J. Biotechnol.* 6 (21), 2473-2476. http://dx.doi.org/10.589/AJB2007.000-2391.

Sathe, S. K. and Salunkhe, D. K. (1981): Isolation, partial characterization and modification of Great Northern Bean (P*haseolous vulgaris L*.) starch. *J. Food Sci.* 46, 617-621. https://doi.org/10.1111/j.1365-2621.1981.tb04924.x.

Schmidt, R. H. (1981): Gelation and coagulation. *Protein Functionality in Foods* 147, 131-147. https://doi.org/10.1021/bk-1981-0147.ch007.

Singh, U. (2001): Functional properties of grain legume flours. *J. Food Sci. Technol.* 38 (3), 191–199.

Solomon M (2005): Nutritive Value of three potential complementary foods based on cereals and legumes. *Afri. J. Food Nutri. Sci.* 5 (2), 1-14.

SPSS 16.0 (2008): Statistical package for the social science. Command syntax reference. SPSS Inc., Chicago, IL.

UNICEF., UNICEF. Nutrition Section, UNICEF. Programme Division, & UNICEF. Division of Communication. (2008): *Sustainable elimination of iodine deficiency: Progress since the 1990 World Summit for Children*. UNICEF.

Wang, X. S., Tang, C. H., Li, B. S., Yang, X. Q., Li, L. & Ma, C. Y. (2008): Effects of high-pressure treatment on some physicochemical and functional properties of soy protein isolates. *Food Hydrocoll.* 22 (4), 560-567. https://doi.org/10.1016/j.foodhyd.2007.01.027.

WHO (2001a): The Optimal of exclusive breastfeeding: a systematic review. Geneva: World Health Organization. WHO/NHD/01.08; WHO/FCH/CAH/0/.23.