

Nutritional Efficacy and Sensory Evaluation of Supplementary Foods Formulated from Tiger nut and Ground nut

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ABSTRACT

Supplementary foods are specially formulated foods, in milled form or ready-to-eat, which are modified in their nutrient density to help meet the nutritional requirements of children with moderate acute malnutrition (MAM). Current study evaluated the nutritional, functional and sensory attributes of supplementary foods formulated from tiger nut and groundnuts. Nutritional composition, functional properties and storage stability were investigated using standard analytical methods reported by Association of Official Analytical Chemist. Data was analyzed by one-way analysis of variance and results expressed as mean \pm standard error of mean. Results of proximate composition revealed that protein content is in ranged of (5.86-6.04%), moisture (2.50-4.50%), fat (26.50-29.50%), ash (1.50-2.00%), crude fibre (3.5-4.50%), and carbohydrate (56.14-57.20%). The physicochemical and functional analyses showed that bulk density ranged from (0.58-1.93 g/cm³), water absorption capacity (0.36-0.49 cm³/g), swelling index (0.13-0.50 cm³/g) reconstitution index (0.17-0.45 g/cm³) and pH (6.71-6.81). The sensory evaluations showed mean scores range of: taste (3.50-5.00), aroma (4.00-5.00), colour (3.00-5.00), Mouth feel (3.00-5.00), and overall acceptance (4.25-5.00). The amino acid compositions showed that all the essential amino acids were present in the three formulations within Food and Agricultural Organization recommended dietary allowance. This study indicated that the food products formulated from groundnut and tiger nut can meet the nutritional needs of infants and young children. Therefore, the formulated foods can be used in supplementary feeding program to combat the problem of malnutrition among infants and young children in Nigeria and other developing countries.

Keywords: Supplementary foods, moderate acute malnutrition and Children.

INTRODUCTION

Childhood malnutrition is still a major disabler and serious public health problem in low-income countries (WHO, 2013). It can be best viewed as a syndrome of developmental impairment characterized by growth faltering, delayed motor, cognitive, and behavioural development; decrease immunity; increased morbidity and mortality, suboptimal adult work capacity and even increased risk of disease in adulthood (Helen and Demewez, 2017; Shashidhar, 2018). One such form of malnutrition is protein energy malnutrition (PEM).

Protein energy malnutrition refers to a group of pathological disorders that include marasmus, kwashiorkor and intermediate states of marasmic kwashiorkor. These terms have been replaced by WHO with moderate acute malnutrition (MAM) and severe acute malnutrition (SAM) depending on the degree of wasting (marasmus) or presence of oedema (kwashiorkor); or oedema superimposed on severe wasting (marasmic kwashiorkor) (WHO, 2013; Helen and Demewez, 2017).

Severe acute malnutrition is the most common nutritional disorder affecting children in Nigeria and Kebbi State in particular. Many children in Kebbi state suffer from varying degree of acute and chronic malnutrition (NNHS, 2018). Children with severe acute malnutrition are treated at nutritional rehabilitation centres; however, there is no

intervention for management of MAM in the state except for nutritional counseling. This approach is not yielding the expected result, as many of these children graduate from MAM to SAM.

WHO (2012) posit that children with MAM have nutritional requirements that differ from non-malnourished and severely malnourished children, they require increased intake of energy and essential nutrients above those required by non-malnourished children and, where applicable, treatment of any associated medical complication. Dietary management of MAM is based on the optimal use of locally available nutrient-dense foods to improve the nutritional status of children and prevent them from becoming severely acutely malnourished or failing to thrive (Ashworth and Ferguson, 2009; Golden, 2009). Dietary management of children suffering from MAM result in recovery with reduced risk of morbidity (WHO, 2012). The utilization of locally accessible nutrient-dense food is highly encouraged (Ashworth and Ferguson, 2009). Tiger nut and groundnut are readily available and affordable food materials and yet contain essential nutrients required for successful recovery of children with MAM. Therefore, the aim of this study was to formulate and evaluate the nutritional, functional, sensory attributes and storage stability of supplementary foods formulated from tiger nut and groundnut.

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MATERIALS AND METHODS

Procurement and Processing of Food Materials

The food materials (Groundnut and Tiger nut) were purchased from Birnin Kebbi New Market, Kebbi State. They were manually sorted to remove stones and dirt. This was followed by roasting for about 10 to 15 minutes at 80°C. The groundnuts were dehulled after roasting. This was followed by milling and storage in air tight containers for subsequent analysis.

Chemicals and reagents

All chemicals and reagents used were of analytical grade and manufactured by British Drug House (BDH) Limited, England; Sigma Aldrich Chemical Company Incorporation, Milwaukee, Wisconsin, USA and Randox Laboratories, Northern Ireland.

Formulation of the Supplementary Foods

The supplementary food formulations of tiger nut and groundnut were blended in the ratio as indicated in Table 1 to enhance nutritional quality and sensory attributes.

Table 1: Proportion of Ingredients in the Formulations

Sample	Blending ratio
TG1	2:1
TG2	3:1
TG3	4:1

T= tiger nut, G= groundnut

Nutrient Analysis

Proximate composition was determined in triplicate using standard procedures of Association of Official Analytical Chemists (AOAC, 2005). The moisture content was determined by oven drying method. Crude protein was determined by Micro-Kjeldahl Method. Fat was determined by soxhlet extraction utilizing hexane as solvent. Crude fibre was determined by neutralization method (Method 962.09). Ash content was determined by dry ashing method of AOAC (Method 923.03) (AOAC, 2005). Carbohydrate content was determined by difference (%Carbohydrate) = [100-(%Protein + %Moisture+ %Ash+% Fibre% + %Crude Lipid)] (Mathew *et al.*, 2015).

Determination of Selected Micronutrient content

Selected mineral content (Iron, Zinc, Magnesium, Potassium and Calcium) were determined by means of atomic absorption spectrophotometer (AAS) (Shimadzu AA-6200 Tokyo, Japan) according to AOAC (2005).

Determination of Amino Acid Profile and Essential Amino Acid Index (EAAI)

The Amino acid profile was determined according to AOAC, 2005 using Technicon sequential Multi-Sample Amino Acid Analyser (TSM). The essential amino acid index was determined according to (Riza *et al.*, 2015).

$$EAAI = \frac{EAA}{NEAA}$$

Computation of Protein Efficiency Ratio (PER) and Corrected PER (C-PER)

The PER and C-PER were computed according to Alsmeyer *et al.* (1974) cited by Mune *et al.* (2011) using the equation: PER = -0.468 + 0.454(LEU) - 0.105(TYR)

$$C-PER = -0.684 + 0.456 (LEU) - 0.047 (PRO)$$

Where LEU= leucine, TYR= tyrosine and PRO= proline.

Biological value (BV) was calculated according to Oser (1959) using the equation:

$$BV = 1.09 \times \text{Essential amino acid index} - 11.7$$

Storage stability analyses

The products were packaged in laminated aluminum foil. Freshly prepared formulations were subjected to microbial count, moisture, peroxide value and free fatty acid determination immediately after preparation and at 15 days interval for a period of 60 days (AOAC, 2005; Amankwah *et al.*, 2009).

Estimation of Peroxide value

The peroxide value was determined according to Ebunoluwa *et al.* (2017). From the sample, 2.0g was weighed into a clean dry flask and 22 cm³ of the mixture of 10 cm³ of acetic acid and 12 cm³ of chloroform was added, then 0.5 cm³ of potassium iodide was also added. The flask was closed and allowed to stay with constant shaking for 1 minute. 30cm³ of distilled water was then added and titrated against 0.1 M of sodium thiosulphate (Na₂S₂O₃) solution until an initial yellow colour disappeared and a faint blue colour appeared. The titration continued after the addition of 0.5 cm³ of starch indicator until there was a sudden disappearance of the blue colour, which signifies the end point. The peroxide value was calculated using equation:

$$\text{Peroxide value (meq/kg)} = \frac{S \times N \times 100}{W}$$

S = Volume in cm³ of sodium thiosulphate solution used up by the sample, N = Normality of sodium thiosulphate solution; W = Weight in grams of the sample

Estimation of Free Fatty Acid

Free fatty acid was determined according to the method of Ebunoluwa *et al.* (2017). From the sample, 2.0 g was transferred into a 250 cm³ Erlenmeyer flask followed by the addition of 100 cm³ of ethanol and 2 cm³ of phenolphthalein indicator. After mixing the content properly, it was titrated against 0.04 M NaOH. The shaking continued until a slight pink colour was observed, which was steady for about 30 seconds and signified the end point. The percentage of free fatty acids was calculated using Equation:

$$\%FFA = \frac{V \times M \times 28.2}{W}$$

V= average volume of NaOH used (cm³), M = molarity of NaOH, 28.2g/mol = Molecular weight of oleic acid; W = weight of the flour sample

Moisture content Determination

Moisture content was determined by oven drying according to Association of Official Analytical Chemist (2005). The moisture dishes were washed and placed in an oven drier at 105°C for one hour. They were then placed in a desiccator to cool and the initial weight of the dishes recorded (W1). Three grams of samples were taken and placed in the moisture dish and weight recorded (W2). The dishes were then placed in an oven drier overnight. After drying, the moisture dishes with dried samples were removed from the oven, cooled in a desiccator and the final weight recorded (W3). The percentage moisture content was calculated using the formula:

$$\text{Moisture content(\%)} = \frac{W3 - W1}{W2 - W1} \times 100$$

Microbial load count

Serial dilutions were made from 1g of each sample dissolved in 9 cm³ of distilled water in a Mac Cartney bottles to give 10⁻¹ dilution. Serial dilutions were made up to 10⁻³. Each diluent was plated out in duplicate using the pour plating technique by transferring 1cm³ from each Mac Cartney bottle into 2 different Petri dish and pouring 15cm³ of the nutrient agar media on each sample as described by Speck (1992). The plates were incubated at 37°C for 48 hours for bacterial growth and at 27°C for 5 days for yeasts and mould. The average colony obtained from duplicate plates were expressed as colony forming unit per gram (Cfu/g) using the formula: N = A × D. Where N = Number of colonies, (cfu/g), A = Average count of colonies in petri plates and D = Dilution factor

Sensory Evaluation of the Composite Blends

Sensory evaluation was determined according to (USAID, 2015). The test formulations were judged by 15 semi trained panelists. Five points hedonic rating scale was used. Scores were defined as: 1 for dislike extremely or bad, 2 for like slightly only or tolerable, 3 for like or good, 4 for like very much, 5 for like extremely or excellent.

Determination of Functional Properties

Bulk Density

Bulk density was determined according to Onwuka (2005) using the formula

$$\text{Bulk density} \left(\frac{\text{g}}{\text{cm}^3} \right) = \frac{\text{Weight of sample}}{\text{Volume of sample}}$$

Reconstitution Index (RI)

From the ground sample, five grams of each sample was dissolved in 50 cm³ of boiling water. The mixture was agitated for 90 seconds and was transferred into a 50 cm³ graduated cylinder and the volume of the sediment was recorded after settling for 30 minutes (Onwuka, 2005).

$$\text{RI}(\text{cm}^3/\text{g}) = \frac{\text{Volume of sediment}}{\text{Weight of sediment}}$$

Water Absorption Capacity (WAC) Determination

From the ground sample, 1g was weighed into conical graduated centrifuge tubes of known weights and mixed with 10cm³ of distilled water for one minute with a glass rod. The tubes were centrifuged at 5000 rpm for 30 min. The volume of the supernatant was discarded and each tube together with its content was reweighed as water absorbed per gram of sample. The gain in mass was the water absorption capacity of the flour sample. The volume difference gave the volume of water absorbed per gram sample. Absorption capacity is expressed in grams of water absorbed per gram of sample (Onwuka, 2005).

$$\text{WAC} = \frac{\text{Density of water} \times \text{Volume absorbed}}{\text{Weight of sample}}$$

Swelling Index (SI) Determination

Swelling index was determined according to Ukpabi and Ndimele (1990). From each sample, 3g were transferred into clean, dry, and graduated (50cm³) cylinders. The samples were gently levelled and the volumes noted. Distilled water (30 cm³) was added to each sample. The cylinder was swirled and allowed to stand for 60 min while the change in volume (swelling) was recorded every 15 min. The ratio of the initial volume to the final volume gave the swelling index.

$$\text{Swelling Index}(\text{cm}^3/\text{g}) = \frac{\text{Change in volume of sample}}{\text{Change in weight of sample}}$$

Determination of Wettability

Triplicate samples were weighed and, in each case, 1.00 g was introduced into a 25 cm³ measuring cylinder with a diameter of 1 cm and a finger was placed over the end of the cylinder. The mixture was inverted and clamped at a height of 10 cm from the surface of a 250cm³ beaker containing 100 cm³ of distilled water. The finger was removed to allow the test material to be dumped. Wettability was taken as the time required for the sample to become completely wet (AOAC, 2005).

pH Measurement

The pH of the samples was determined according to Mathew *et al.* (2015). The samples (10%W/V) were suspended in distilled water. The suspensions were mixed thoroughly in 100cm³ beaker before the pH was taken. This was repeated three times and the average was calculated (Mathew *et al.*, 2015).

Determination of Iodine Value

Iodine value was determined according to the method of Bailey (1951). To 5cm³ of chloroform solution of the fat, 5cm³ of Dam's reagent was added. The mixture was kept in fume cupboard for 10 min. and 5cm³ of 10% KI and 20cm³ of water were added. The mixture was thoroughly mixed and titrated to a colourless end point with 0.025M Na₂S₂O₃ solution.

Statistical Analysis

Data were reported as means ± standard error of mean of triplicate determination. One-way analysis of variance (ANOVA) was used to establish significant difference (*P*<0.05). Values were analyzed statistically

using Graph Pad PRISM (Statcon, Witzenhausen, Germany).

RESULTS

The nutrient compositions (dry weight basis) for all the formulations are presented in Figure 1. The

formulations met the WHO specified requirement for fat, energy, ash, moisture and fibre for supplementary foods used in the management of moderate acute malnutrition in children. However, none of the formulations met the specification for protein proposed by for children with MAM (WHO, 2012).

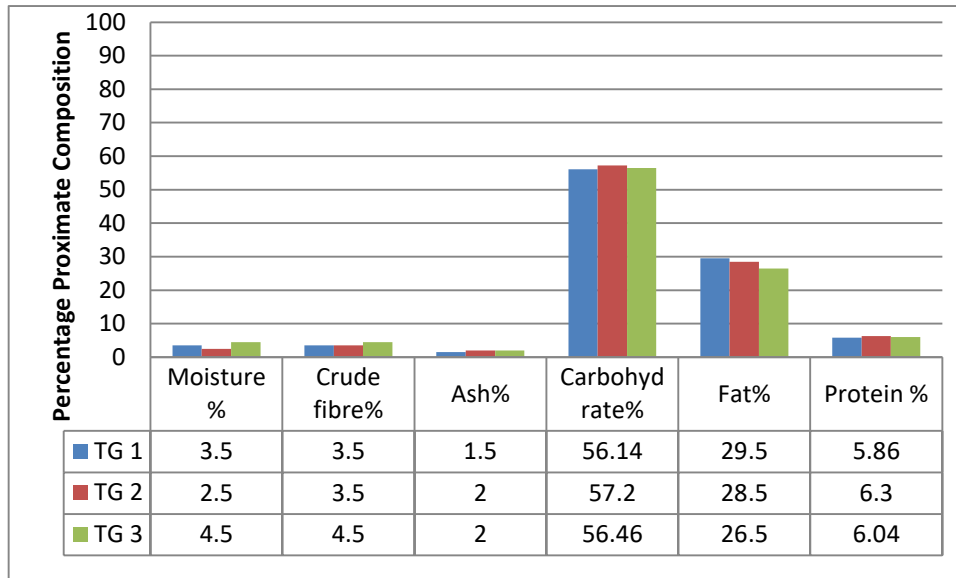


Figure 1: Percentage Proximate Composition of Tiger nut-groundnut based Supplementary food
 TG 1: Tiger nut and groundnut 2:1, TG 2: Tiger nut and groundnut 3:1, TG 3: Tiger nut and groundnut 4:1. Values are mean ± standard error of mean (SEM) of triplicate determinations.

Table 2: Selected mineral content of the formulated Supplementary foods

Samples	Zinc	Iron	Calcium	Magnesium	Sodium
TG1	2.55 ^a ±0.26	2.80 ^b ±0.12	397 ^b ±4.04	344 ^a ±0.23	120 ^b ±0.76
TG2	2.60 ^a ±0.23	2.67 ^b ±0.57	368 ^b ±5.77	320 ^a ±0.57	115 ^b ±0.57
TG3	2.96 ^a ±0.02	2.42 ^b ±0.05	310 ^a ±5.57	333 ^a ±0.58	132 ^b ±0.28

Values are mean ± standard error of mean (SEM) of triplicate determinations.

The result of the amino acid contents of the composite blends is presented in Table 3. The test formulations were found to contain all the 20 naturally occurring amino acids. Arginine and methionine had highest and

lowest values respectively. Arginine and histidine met 100% of the recommended values for infant and young children (FAO/WHO, 2004).

Table 3: Essential amino acid profile of the composite blends

Amino acid	TG 1 (g/100g)	TG2 (g/100g)	TG3 (g/100g)
Histidine	1.92±0.01	2.40±0.01	2.30±0.03
Isoleucine	2.29±0.57	2.62±0.03	2.36±0.02
Lysine	3.02±0.29	4.32±0.23	4.03±0.57
Methionine	0.85±0.01	0.91±0.01	0.96±0.01
Threonine	2.05±0.23	2.83±0.03	3.00±0.29
Tryptophan	0.79±0.01	0.81±0.01	0.89±0.01
Valine	2.89±0.10	2.98±0.27	2.46±0.23
Phenylalanine	3.19±0.14	2.48±0.06	2.31±0.10
Arginine	4.04±0.33	3.97±0.10	3.87±0.57
Leucine	3.03±0.10	4.02±0.35	3.57±0.42

TG 1: Tiger nut and groundnut 2:1, TG 2: Tiger nut and groundnut 3:1, TG 3: Tiger nut and groundnut 4:1

Values are mean ± standard error of mean (SEM) of triplicate determinations.

Table 4 present percentage chemical scores of essential amino acids of the supplementary foods. The score for methionine indicates that it is the first limiting amino acid.

Table 4: Percentage Chemical Scores of Essential Amino Acids of the Supplementary food formulations

Amino acid	TG1 (%)	TG2 (%)	TG3 (%)
Phenylalanine	50.63	59.36	56.67
Valine	82.57	85.14	70.28
Tryptophan	71.81	73.63	80.90
Histidine	100.0	100.0	100.0
Arginine	100.0	100.0	100.0
Leucine	50.00	63.63	54.09
Lysine	51.07	53.55	50.45
Threonine	80.45	82.65	88.24
Isoleucine	81.79	93.57	84.29
Methionine	34.00	36.40	38.40

TG 1: Tiger nut and groundnut 2:1, TG 2: Tiger nut and groundnut 3:1, TG 3: Tiger nut and groundnut 4:1
 Values are mean ± standard error of mean (SEM) of triplicate determinations.

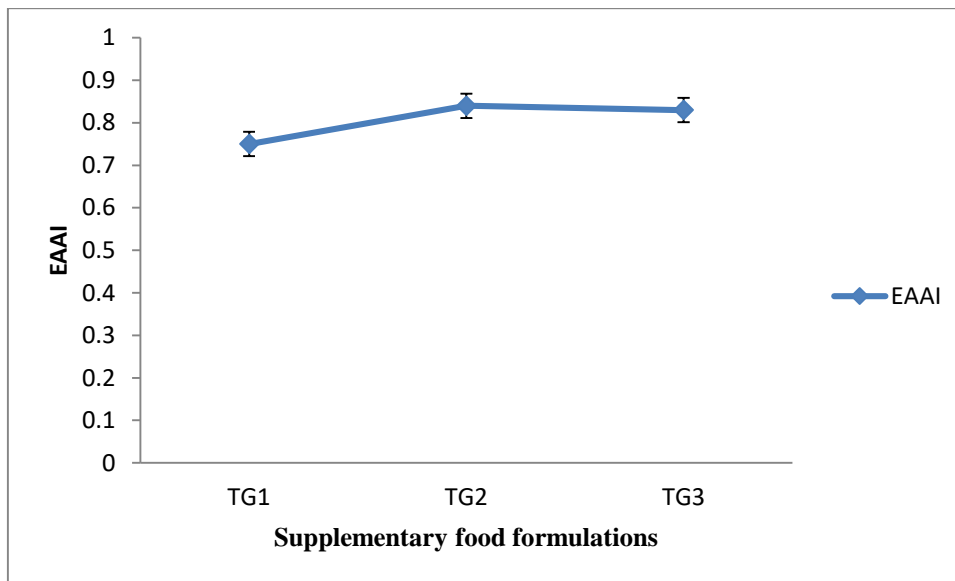


Figure 2: Essential amino index of the supplementary food formulations

TG 1: Tiger nut and groundnut 2:1, TG 2: Tiger nut and groundnut 3:1, TG 3: Tiger nut and groundnut 4:1. Values are mean ± standard error of mean (SEM) of

triplicate determinations. Values are mean ± standard error of mean (SEM) of triplicate determinations. EAAI ≥ 0.95: indicate high quality; 0.86-0.95: good quality; 0.75-0.86: useful; ≤ 0.75: inadequate (Riza *et al.*, 2015).

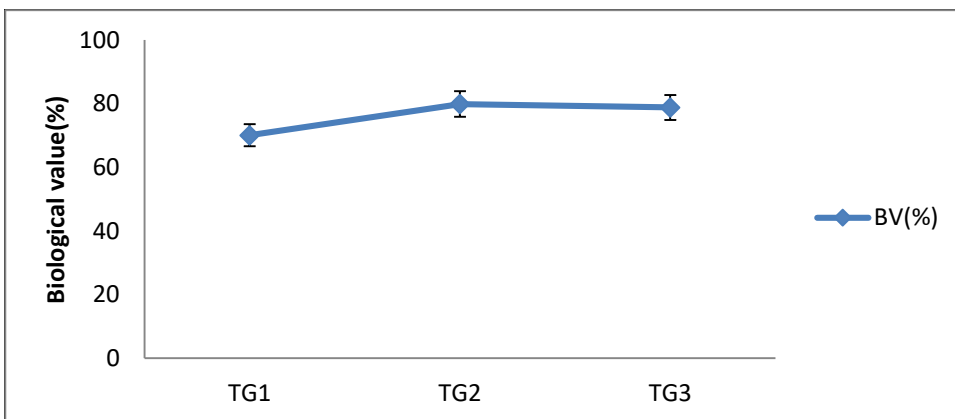


Figure 3: Biological value of the Supplementary food formulations

Values are mean ± standard error of mean (SEM) of triplicate determinations. Values are mean ± standard error of

mean (SEM) of triplicate determinations.

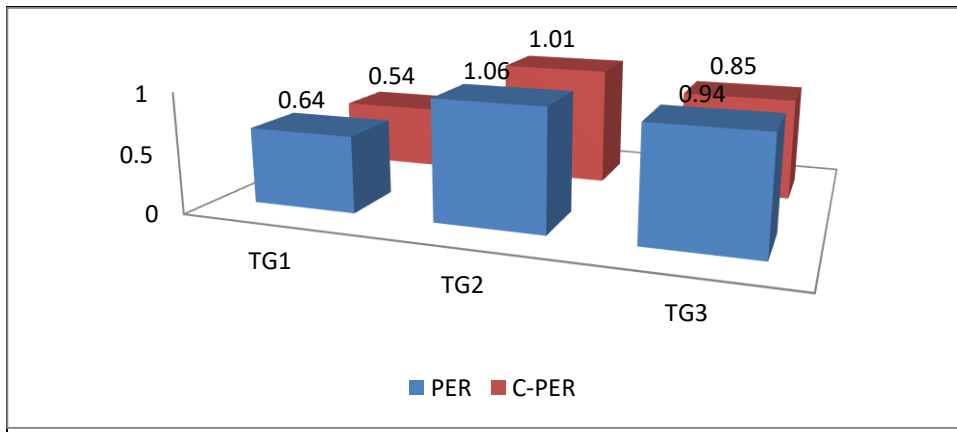


Figure 4: Efficiency of the proteins of the composite blends
 PER= protein efficiency ratio and C-PER is corrected protein efficiency ratio; TG 1: Tiger nut and groundnut

2:1, TG 2: Tiger nut and groundnut 3:1, TG 3: Tiger nut and groundnut 4:1. Values are mean ± standard error of mean (SEM) of triplicate determinations.

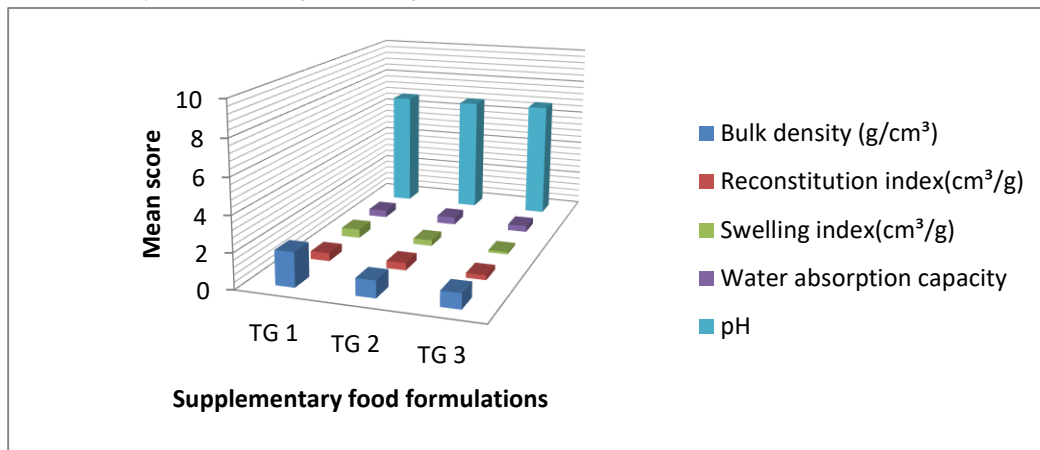


Figure 5: Functional properties of the Supplementary food formulations

TG 1: Tiger nut and groundnut 2:1, TG 2: Tiger nut and groundnut 3:1, TG 3: Tiger nut and groundnut 4:1. Values are mean ± standard error of mean (SEM) of triplicate determinations. Functional properties determine the application and use of food materials for various food products.

Figure 6 is the mean sensory score of organoleptic attributes evaluated. While aroma was the most liked sensory attribute, there was no significant difference in overall acceptability of the supplementary foods.

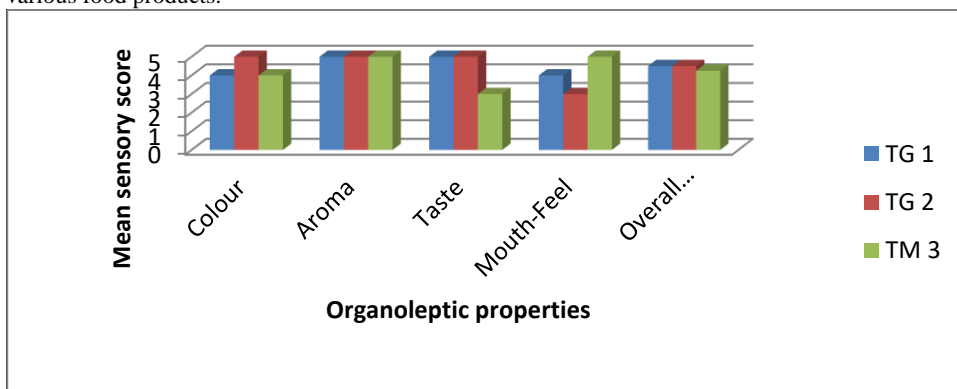


Figure 6: Mean sensory score of the Supplementary food formulations

TG 1: Tiger nut and groundnut 2:1, TG 2: Tiger nut and groundnut 3:1, TG 3: Tiger nut and groundnut 4:1. Values are mean \pm standard error of mean (SEM) of triplicate determinations.

The results for Iodine values of the formulation are presented in Table 4 Samples TG 1 and TG3 recorded the highest and lowest values respectively.

Table 5: Iodine Values of the Supplementary Food Formulations

Food Samples	Iodine Value
TG1	32.53 ^a \pm 0.02
TG2	40.13 ^b \pm 0.08
TG3	53.38 ^c \pm 0.01

Values are mean \pm standard error of mean (SEM) of triplicate determinations. Values with different superscripts are significantly different at ($P < 0.05$).

Table 6: Moisture Content of the Supplementary Food Formulations during storage

Days of Storage	TG1 (%)	TG2 (%)	TG3 (%)
0	2.20 ^a \pm 0.10	2.15 ^a \pm 0.55	2.55 ^a \pm 0.23
15	3.50 ^a \pm 0.06	3.00 ^a \pm 0.19	3.10 ^a \pm 0.33
30	4.30 ^b \pm 0.57	3.90 ^b \pm 0.28	4.55 ^b \pm 0.29
45	5.00 ^b \pm 0.01	4.50 ^a \pm 0.01	5.35 ^b \pm 0.02
60	5.60 ^b \pm 0.01	5.00 ^a \pm 0.01	5.80 ^b \pm 0.01

Values are mean \pm standard error of mean (SEM) of triplicate determinations. Values in the same row with different superscripts are significantly different at ($P < 0.05$).

At baseline, all the samples had FFA value of $\leq 0.17\%$. These values gradually increased during the 60 days of

storage probably due to hydrolysis of fat. The lower FFA values observed in sample TG3 after 60 days of storage may be attributed to lesser proportion of ground nut used in the formulation. This may translate to better keeping quality.

Table 7: Percentage free fatty acids of the Supplementary Food Formulations

Days of Storage	TG1 (%)	TG2 (%)	TG3 (%)
0	0.17 \pm 0.01 ^b	0.14 \pm 0.01 ^b	0.16 \pm 0.02 ^b
15	0.27 \pm 0.01 ^a	0.23 \pm 0.01 ^a	0.25 \pm 0.01 ^a
30	0.90 \pm 0.01 ^a	0.64 \pm 0.01 ^a	0.76 \pm 0.01 ^a
45	1.79 \pm 0.01 ^b	1.27 \pm 0.02 ^a	1.24 \pm 0.01 ^a
60	2.57 \pm 0.02 ^c	2.02 \pm 0.04 ^a	2.00 \pm 0.04 ^a

Values are mean \pm standard error of mean (SEM) of triplicate determinations.

The peroxide value of the optimized complementary cereal-based foods remained < 1.4 meq/kg for the 60 days of storage. This may be attributed to partial

inactivation of the lipolytic enzymes that are responsible for degradation of triglycerides due to roasting before milling.

Table 8: Peroxide value of the Supplementary Food Formulations

Day(s)	TG1 (meq/kg)	TG2 (meq/kg)	TG3 (meq/kg)
0	0.50 \pm 0.01	0.55 \pm 0.01	0.57 \pm 0.01
15	0.70 \pm 0.01	0.77 \pm 0.02	0.90 \pm 0.01
30	1.00 \pm 0.00	1.01 \pm 0.00	1.11 \pm 0.00
45	1.26 \pm 0.00	1.19 \pm 0.01	1.20 \pm 0.01
60	1.35 \pm 0.03	1.28 \pm 0.02	1.23 \pm 0.03

Values are mean \pm standard error of mean (SEM) of triplicate determinations.

Table 9: Microbial Count of the Supplementary Food Formulations during 60 days Storage

Food Samples	Bacterial count(cfu/g)	
	Baseline	End line
TG1	5.0± 0.02 ^a ×10 ⁻³	25±0.23 ^b ×10 ⁻³
TG2	4.0±0.01 ^b ×10 ⁻³	20±0.57 ^a ×10 ⁻³
TG3	4.0±0.02 ^b ×10 ⁻³	22±0.29 ^c ×10 ⁻³

Values are mean ± standard error of mean (SEM) of triplicate determinations. Values in the same row with different superscripts are significantly different at ($P < 0.05$).

Table 10: Fungal Count of the Supplementary Food Formulations during 60 days Storage

Food Samples	Fungal count(cfu/g)	
	Baseline	End line
TG1	6±0.06 ^b ×10 ⁻³	30±0.57 ^d ×10 ⁻³
TG2	3±0.24 ^a ×10 ⁻³	15±0.10 ^a ×10 ⁻³
TG3	4±0.12 ^a ×10 ⁻³	20±0.23 ^a ×10 ⁻³

Values are mean ± standard error of mean (SEM) of triplicate determinations. Values in the same row with different superscripts are significantly different at ($P < 0.05$).

DISCUSSION

In formulating supplementary foods, the focus is on the nutritional adequacy and acceptability. This is particularly important in a developing country like Nigeria, where childhood malnutrition has largely been attributed to poor infant and young child feeding practices (NNHS, 2015). The nutrient composition of the supplementary food blends under investigation have shown that the formulations met the WHO specified requirement for fat, energy, ash, moisture and fibre for supplementary foods used in the management of moderate acute malnutrition in children. However, none of the formulations met the specification for protein content proposed for children with MAM (WHO, 2012). Further study may focus on improving the protein content by including ingredients with high protein content like Cray fish or soya beans. There was no significant difference ($P > 0.05$) in the selected minerals of the test formulations evaluated except for calcium. TG1 and TG3 had the highest and lowest values for calcium respectively. Minerals participate in several biochemical roles in the body. They are constituents of skeletal tissues, cofactors to enzymes and hormones (Golden, 2009). Acute malnutrition is often associated with hidden hunger hence the need to ensure that supplementary foods contain adequate micronutrients. The micronutrient content of the formulations can be improved by inclusion of vegetable ingredients rich in micronutrient like moringa.

The test formulations were found to contain all the 20 naturally occurring amino acids. Hence, they can provide essential amino acids needed for growth and maintenance. It is pertinent to note that the amino acid content of supplementary food is very important for catch up growth particularly for children with MAM (WHO, 2012). Amino acids arginine and histidine were the most abundant; methionine was the most limiting amino acid.

The essential amino acid index (EAAI) indicates that the protein content of the supplementary foods is of good quality (Riza *et al.*, 2015). The protein efficiency ratio (PER) did not reveal any significant

difference ($P > 0.05$) in nutritional value of the supplementary foods. PER is a reliable and commonly used method of assessing quality of protein in infant and non-infant food products (Oibiokpa *et al.*, 2018). The biological values also corroborate the EAAI and PER; and suggest that the test formulations may support growth and recovery in children with MAM. Therefore, further study may evaluate the efficacy of these formulations in children with MAM

Peroxide test is commonly used to assess in rancidity food product with unsaturated fatty acids. Peroxide test is typically used in conjunction with other tests to determine the level of deterioration of food products (USAID, 2015). In the current study, peroxide value at end line did not differ significantly ($P < 0.05$) from the values at baseline. The low peroxide value recorded for the formulations may be attributed to partial inactivation of the lipolytic enzymes that are responsible for degradation of triglycerides due to roasting before milling.

Free fatty acids are a measure of the extent to which glycerides in a food sample have been decomposed by lipase or other actions (USAID, 2015). Rancidity is accompanied by free fatty acids formation, and is used as a criterion to ascertain edibility. TG3 recorded the Lowest FFA values at end line (60 days of storage). This may be attributed to lesser proportion of ground nut used in the formulation which translates to better keeping quality.

The moisture content is a function of the drying time before storage. Higher moisture content indicates increased susceptibility to spoilage and thus reduces shelf life. Low moisture contents recorded will ensure better storage stability and shelf life (Okaka and Potter, 1977); as higher moisture contents of foods encourages microbial growth and spoilage. At end line, there was gradual uptake of moisture by all the samples. This could be attributed to extrinsic factors such as temperature, relative humidity, and duration of storage.

Sensory evaluation is an important tool to assess consumer acceptability because Organoleptic attributes can change over time (USAID, 2015). Sensory evaluation conducted at baseline and end line by visual observation did not reveal any significant difference ($P>0.05$) in the consistency, odour, appearance and overall acceptability of the test formulations. This translates to good keeping quality of the supplementary food formulations.

Microbial spoilage of foods is an economically significant problem for food manufacturers, retailers, and consumers. Depending on the product, process, and storage conditions, the microbiological end of shelf life can be determined by either the growth of spoilage or pathogenic microorganisms. Microbial analysis was conducted on freshly prepared diets to determine if blends are wholesome for consumption. Bacterial counts and fungal count at baseline and end line were within specification of International microbiological standard for supplementary foods (ICMSF, 1996). The low microbial count obtained is as a result of high standard of personal hygiene and heat treatment during processing.

CONCLUSION

Acute malnutrition is still a serious public health problem affecting so many children in Nigeria and Kebbi State in particular. It accounts for the morbidity and mortality in children under the age of five. While children with severe acute malnutrition are treated at nutritional rehabilitation centres ready to use therapeutic foods (RUTF), there is no intervention for management of MAM in the state except for nutritional counseling. This approach is not yielding the expected result, as many of these children eventually graduate from MAM to SAM.

The current study has revealed that Groundnut/Tiger nut blend could be used for supplementary foods due to its nutritional composition. The sensory evaluations of the blends indicate consumer acceptability. This study indicated that the food products formulated from groundnut and tiger nut can meet the nutritional needs of infants and young children. Therefore, the formulated foods can be used in supplementary feeding program to combat the problem of malnutrition among infants and young children in Nigeria and other developing countries.

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