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Research Article
Proteins, Amino Acid Profile, Phytochemicals and Antioxidative Activities of Plant-based Food Materials Blends

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Abstract

Background and Objective: The staple foods in developing countries are cereals, legumes and tuber-based and are low in essential nutrients. Hence, this study aimed to formulate and evaluate nutritional compositions of breakfast foods from locally available food materials. **Materials and Methods:** The food samples were formulated from the combinations of quality-protein-maize (Q), cassava starch (C), soycake (S) and *Moringa* (seeds (M_S) and leaves (M_L)) flour to obtain $QCSM_{LS}$ (55% Q, 15% C, 20% S, 5% M_S and 5% M_L), $QCSM_L$ (55% Q, 15% C, 20% S and 10% M_L) and $QCSM_S$ (55% Q, 15% C, 20% S and 10% M_S). The samples were evaluated for chemical compositions, antioxidant and sensory properties. Data were analyzed statistically and calculated Means±SD were separated using Duncan's new multiple range tests at significance level of $p<0.05$. **Results:** Protein and energy values of the food samples ranged from 14.0-16.49 g/100 g and ~436.89-459.52 kcal/100 g, respectively. The minerals in the food samples, except sodium, potassium and phosphorous, were significantly ($p<0.05$) higher than control sample. Essential amino acids (g/100 g protein) of the food samples ranged from 34.44-37.72 and were significantly ($p<0.05$) lower than control sample (41.94). Essential amino acids index and predicted biological values of the experimental food samples ranged from 53.99-60.84 and 47.10-54.54%, respectively and were comparable to control sample (55.94 and 49.21%). Water absorption capacity, oil absorption capacity and least gelation capacity values of the experimental food samples were higher than control sample, except for loose bulk density. The antioxidant activities of food samples showed that $QCSM_S$ samples had the highest metal chelating activities and $QCSM_L$ had higher free radical scavenging activities and were comparatively higher than control food sample. The sensory attributes of $QCSM_S$ sample in terms of colour, taste, mouth-feel, aroma and overall acceptability, were significantly ($p<0.05$) higher than $QCSM_{LS}$ and $QCSM_L$ samples, but lower than control sample. **Conclusion:** The present study experimental foods could be valuable and excellent source for low-priced functional foods and were characterized by high protein, essential amino acids, crude fiber, minerals and ability to scavenge free radicals.

Key words: Nutrient compositions, phytochemicals, free radical scavenging activities, organoleptic properties

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cereals are major staple foods, specifically in African dietaries. Cereals are rich sources of nutrients especially when used as whole grains and cereal-based foods are a major source of energy, protein and micronutrients. It is well known that complementation of cereal-based foods with legumes (i.e., plant-protein sources) has received considerable attention[1-3]. Legumes are important sources of low-cost vegetable proteins and micronutrients when compared to animal-based proteins, which are very expensive. Hence, indigenous legumes, are important sources of affordable alternative protein to poor people in many resource-poor countries where they are predominantly consumed[4].

Scientific studies have reported that consumption of whole grain cereals and legumes can protect against nutritional related diseases like diabetes, obesity, constipation, cardiovascular disease and other lifestyle disorders[5-7]. The ability of cereal and legume based foods to prevent diseases is associated with their antioxidant properties (i.e., capacity of food bioactive components to scavenge free-radicals), which are involved in the onset development of many of the chronic degenerative diseases like diabetes, cardiovascular diseases, cancer and ageing[8-10].

In the last few decades, evidence had shown that a dietary intake of foods rich in natural antioxidants correlates with reduced risk of coronary heart disease[11]. This has led to a change in the earlier idea of 'adequate nutrition' to the current concept of 'Optimal nutrition[12]. Optimal nutrition involves intakes of food which is intended not only to provide essential nutrients and satisfy hunger but also to prevent nutrient-related diseases and improve physical and mental wellbeing[13]. Functional foods play an exceptional role in this regard[14]. Functional food is usually derived from phytochemicals and bioactive proteins from plants or animal sources. In view of this, the present study formulated and determined the chemical compositions of breakfast foods from the combination of quality-protein-maize, cassava starch, soybean cake and *Moringa* (leaves and seeds) and also, to establish the nutritional efficacy of the formulated food samples.

MATERIALS AND METHODS

Sources of raw materials: *Moringa* leaves and seeds were obtained from Afe Babalola University research Farm, Ado-Ekiti, Ekiti State, Nigeria. Quality protein maize (Pool 18-SR) was procured from International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria. Cassava starch was obtained from Matna Foods Ltd, Ogbese along Akure-Owo road. Defatted soybeans were obtained from Jof Ideal family farm, Owo, Ondo State, Nigeria.

Processing of food materials into flour

Raw *Moringa oleifera* leave flour: The leaves were collected fresh, sorted and dried at room temperature for 7 days, milled using Phillips laboratory blender (HR2811 model), sieved with 60 mm wire mesh (British standard) to obtain the flour sample[15]. The flour was packed in a plastic container and stored at room temperature (~27°C) until required for use.

Raw *Moringa oleifera* seed flour: The raw seeds were sorted, dehulled, oven dried using hot air oven, at 60°C (Plus11 Sanyo Gallenkamp PLC, UK) for 12 h, milled using Phillips laboratory blender (HR2811 model), sieved with 60 mm wire mesh (British standard) to obtain the flour sample[16]. The flour was packed in a plastic container and stored at room temperature (~27°C) until required for use.

Quality-protein-maize flour: The kernels were sorted soaked in water for 24 h. The seeds were then wet milled into smooth slurry, sieved using muslin cloth, dewatered, the wet slurry starch was oven dried at 60°C (Plus11 Sanyo Gallenkamp PLC, UK) for 12 h, milled further using Phillips laboratory blender (HR2811 model), sieved with 60 mm wire mesh (British standard) to obtain the flour sample[17]. The flour was packed in a plastic container and stored at room temperature (~27°C) until required for use.

Soybean cake: The defatted soybean cake was further oven dried at 60°C (Plus11 Sanyo Gallenkamp PLC, UK) for 12 h, milled using Philips laboratory blender (HR2811 model) and sieved using a 60 mm mesh sieve (British Standard) to obtain flour sample[18]. The flour was packed in a plastic container and stored at room temperature (~27°C) until required for use.

Formulations of food samples: The quality-protein-maize, cassava starch, defatted soybean and *Moringa* (leaves and seeds) flour were mixed in different proportions using Nutri-Survey Linear Programming software version 2007 to obtain three formulations as shown in Table 1.

Proximate compositions determination: Proximate compositions of the multi-plant-based functional complementary food samples were determined using the standard procedures of AOAC[19]. Moisture content was

Table 1: Proportion of food materials in the formulated samples

Samples	Quality protein maize (%)	Cassava starch (%)	Soycake (%)	*Moringa* leaf (%)	*Moringa* seed (%)
$QCSM_{LS}$	55	15	20	5	5
$QCSM_{L}$	55	15	20	10	-
$QCSM_{S}$	55	15	20	-	10

$QCSM_{LS}$: Maize, cassava starch, defatted soybean, *Moringa* leaf and seed, $QCSM_{S}$: Maize, cassava starch, defatted soybean, *Moringa* seed, $QCSM_{L}$: Maize, cassava starch, defatted soybean, *Moringa* leaf

determined in a hot-air at 105°C for 3 h circulating oven (Galenkamp). Ash was determined by incineration (550°C) of known weights of the samples in a muffle furnace (Hotbox oven, Gallencamp, UK, size 3)[19]. Crude fat was determined by exhaustively extracting a known weight of sample in petroleum ether (boiling point, 40-60°C) using TecatorSoxtec (Model 2043(20430001), 69, Slandegarupgade, DK-3400, Hilleroed, Denmark)[19]. Protein content (N×6.25) was determined by the micro-Kjeldahl method (Method No 978.04)[19]. Crude fiber was determined after digesting a known weight of fat-free sample in refluxing 1.25% sulfuric acid and 1.25% sodium hydroxide[19]. Carbohydrate content was determined by difference, that is, addition of all the percentages of moisture, fat, crude protein, ash and crude fibre and subtracted from 100%. This gave the amount of nitrogen free extract otherwise known as carbohydrate.

$$\text{Carbohydrate (\%)} = \text{100-Moisture (\%)+Fat (\%)+Ash (\%)+ Crude fibre (\%)+Crude protein (\%)} \quad (1)$$

The energy value of the samples were estimated (kcal g^{-1}) by multiplying the percentages of crude protein, crude lipid and carbohydrate with the recommended factors 4.2, 9.0 and 4.2, respectively as proposed by Iombor *et al.*[20].

Mineral compositions determination: Calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn) were determined using Atomic Absorption Spectrophotometer (AAS Model SP9). Sodium (Na) and potassium (K) were determined using flame emission photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK) with NaCl and KCl as the standards[19]. Phosphorus was determined as phosphate by the vanadium phosphomolybdate (vanadate) colorimetric method reported by Atasie *et al.*[21].

Determination of amino acid compositions: The amino acid profiles of the experimental samples were determined according to the method described by Siswoyo *et al.*[22]. The experimental samples were digested using 6 N HCl for 24 h. Amino acids were determined using the Beckman Amino Acid Analyzer (model 6300, Beckman Coulter Inc., Fullerton, Calif., USA) employing sodium citrate buffers as step gradients with the cation exchange post-column ninhydrin derivatization method. The cysteine and methionine contents were determined after performic acid oxidation and tryptophan was determined as described by Spies and modified by Pianesso *et al.*[23]. The data were calculated as grams of amino acid per 100 g crude protein of flour sample.

Predicted nutritional quality: Protein efficiency ratio of the food samples was calculated using the equations developed by Alsmeyer *et al.*[24]. Essential Amino Acid Index (EAAI) was calculated using the equation described Labuda *et al.*[25]. Predicted biological values were computed according to the methods described by Oser[26], while nutritional index of the food samples was calculated using the formula described by Crisan and Sands[27].

Determination of anti-nutritional factors: Flavonoids, saponin, tannin, polyphenols and alkaloids were carried out according to the method described by Phillipson[28]. The oxalate content of the samples was determined using the method described by AOAC[29]. Cardiac glycosides of the samples were quantitatively determined according to Solich *et al.*[30].

Antioxidant determination of formulated food samples

Metal chelating: The ability of the samples to chelate Fe^{2+} was measured by the modified method of Puntel *et al.*[31]. About 200 mL of iron sulphate (1 mM) and 2 mL of diet samples extract were mixed and the reaction mixture was allowed to react for 2 min at room temperature. About1 mL of 0.5 mM phenanthroline was added and incubated for 10 min. the absorbance of was measured spectrophotometrically at 510 nm.

DPPH radical scavenging assay: The 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay quantitative measurements of radical scavenging assay were carried out according to the method described by Sreenivasan *et al.*[32]. A solution of 0.3 mM in methanol was prepared and 1 mL of this solution is added to 1 mL of extract in methanol. The reaction mixture was voltexed and left in dark at room temperature for 30 min the absorbance of the mixture was measured spectrophotometrically at 517 nm. Ascorbic acid and tannic acid were used as standard. The ability to scavenging DPPH radical was calculated using the Eq. 2:

$$\text{DPPH radical scavenging activity} = \frac{\text{abs}_{\text{control}} - \text{abs}_{\text{sample}}}{\text{abs}_{\text{control}}} \times 100 \quad (2)$$

Sensory evaluation of the formulated diets: The food samples were coded and presented to 18 panelists who were familiar with custard. They tested the formulated food samples based on the following attributes: Appearance, aroma, texture, taste and overall acceptability of the sample using a 9 point Hedonic scale, where 9 indicates extremely like and 1 extremely dislike[33].

Statistical analysis: Data were analysed in triplicate and the results were expressed as Means±Standard Deviation. The statistical analysis was performed using the SPSS statistical software version 17.0. Duncan Multiple Range Test (DMRT) was used to separate the means at p<0.05 level of significant[34].

RESULTS AND DISCUSSION

Proximate and energy compositions of the formulated breakfast food samples: The proximate compositions of the flour and composite flour blends are presented in Table 2 and 3, respectively. The moisture contents of the flour samples ranged from 3.52 in Raw *Moringa* Seed (RMS) flour to 7.07/100 g in Raw *Moringa* Leaf (RML) flour and the protein contents varied between 2.61/100 g in cassava starch and 43.14/100 g in soycake. In case of the formulated food samples, the moisture content and crude protein values ranged as 5.74-8.04/100 g and 14.0-16.49/100 g, respectively. Statistically, the moisture content of the formulated samples were significantly (p<0.05) lower than in control sample (custard) (10.36/100 g), whereas, the crude protein of the formulated food samples were significantly (p<0.05) higher than in control sample (CD). Energy values of the formulated food samples ranged from 436.89 kcal/100 g in $QCSM_L$ to 459.52 kcal/100 g in $QCSM_S$ and that the blend containing quality protein maize, cassava starch, soycake and *Moringa* seed flour blends (i.e., $QCSM_S$) had the highest energy value. This observation could be due to the high fat content in *Moringa* seed flour.

Comparatively, the moisture content, crude protein and energy values of the formulated food samples in the present study were similar to the values obtained for complementary foods formulated from cereal, legume, tuber, vegetable and crayfish reported by Achidi *et al.*[35]. However, these values (i.e., moisture content and crude protein) were higher than those obtained for complementary foods from cereal (maize), legume (soybean) and fruit (banana) reported by Ezeokeke and Onuoha[36]. Nutritionally, the moisture contents of the formulated foods were less than the recommended value (<10%)[37] and this property would enhance the storage ability of the food products. It is well established that moisture content of food is an important index of their susceptibility to

Table 2: Proximate compositions (g/100 g) of food material samples

Parameters	QPM	CSF	SBC	MLF	MSF
Moisture	5.79±0.40^c	9.57±0.03^a	5.22±0.09^d	7.07±0.05^b	3.52±0.30^e
Ash	0.10±0.02^d	0.05±0.01^d	7.70±0.13^b	9.63±0.11^a	3.04±0.20^c
Fat	14.59±0.50^b	11.18±0.09^c	10.78±0.90^c	14.98±0.11^{db}	42.40±0.20^a
Fibre	0.31±0.00^d	0.11±0.00^d	7.04±0.09^a	6.93±0.10^b	3.90±0.01^c
Protein	7.00±0.13^d	2.61±0.10^e	43.14±0.59^a	26.19±0.80^c	30.44±0.20^b
CHO	72.53±0.02^b	76.59±0.21^a	26.12±0.36^d	35.21±0.84^c	16.71±0.28^e

Values are expressed as Mean±Standard deviation, values with the same superscript in the same row indicate no significant difference at $p\leq 0.05$, QPM: Raw protein maize flour, MSF: Raw *Moringa* seed flour, CSF: Cassava starch flour, SBC: Soybean cake flour, MLF: Raw *Moringa* leaf flour

Table 3: Proximate compositions (g/100 g) and energy values (kcal/100 g) of formulated food samples

Parameters	$QCSM_{LS}$	$QCSM_S$	$QCSM_L$	CD
Moisture	6.71±0.18^c	5.74±0.07^d	8.04±0.08^b	10.36±0.17^a
Ash	2.14±0.08^b	2.19±0.09^b	2.44±0.16^a	0.05±0.00^c
Fat	16.38±0.48^{ab}	17.00±0.73^a	15.76±0.18^b	13.78±0.26^c
Fibre	2.86±0.09^b	2.10±0.01^c	3.52±0.03^a	0.00±0.00^d
Protein	15.41±0.11^b	16.49±0.30^a	14.00±0.21^c	4.27±0.30^d
CHO	56.50±0.20^b	56.49±0.43^b	56.25±0.12^b	71.54±0.39^a
Energy	449.44±4.20^b	459.52±3.30^a	436.89±2.40^d	442.42±5.20^c

Values are expressed as Mean±Standard deviation, values with the same superscript in the same row indicate no significant difference at $p\leq 0.05$, $QCSM_{LS}$: Maize, cassava starch, defatted soybean, *Moringa* leaf and seed, $QCSM_S$: Maize, cassava starch, defatted soybean, *Moringa* seed, $QCSM_L$: Maize, cassava starch, defatted soybean, *Moringa* leaf, CD: Custard (Control)

Table 4: Mineral compositions (mg kg^{-1}) of formulated food samples

Parameters	$QCSM_{LS}$	$QCSM_S$	$QCSM_L$	CD
Na	1.85 ± 0.01^c	1.72 ± 0.015^d	2.41 ± 0.00^b	2.51 ± 0.02^a
K	35.90 ± 0.00^a	28.80 ± 1.00^b	18.00 ± 0.5^d	19.30 ± 0.01^c
Zn	0.09 ± 0.01^b	0.08 ± 0.02^c	0.10 ± 0.01^a	0.01 ± 0.01^d
Mn	0.06 ± 0.03^b	0.04 ± 0.01^c	0.08 ± 0.01^a	0.01 ± 0.01^d
Cu	0.01 ± 0.01^c	0.03 ± 0.005^a	0.02 ± 0.01^b	0.00 ± 0.00^d
Fe	0.62 ± 0.03^b	0.57 ± 0.02^c	1.18 ± 0.00^a	0.05 ± 0.01^d
Co	2.20 ± 0.02^b	2.00 ± 0.001^c	3.60 ± 0.00^a	1.20 ± 0.01^d
Mg	2.52 ± 0.00^c	2.76 ± 0.004^a	2.64 ± 0.01^b	0.84 ± 0.00^d
Ni	0.06 ± 0.01^c	0.07 ± 0.003^a	0.06 ± 0.01^b	0.01 ± 0.00^d
P	2.40 ± 0.01^c	4.80 ± 0.02^b	9.92 ± 0.01^a	4.80 ± 0.02^b
Na/K	0.05 ± 0.01^c	0.06 ± 0.00^b	0.13 ± 0.02^a	0.13 ± 0.01^a

Values are expressed as Mean±Standard deviation, values with the same superscript in the same row indicate no significant difference at $p\leq0.05$, $QCSM_{LS}$: Maize, cassava starch, defatted soybean, *Moringa* leaf and seed, $QCSM_S$: Maize, cassava starch, defatted soybean, *Moringa* seed, $QCSM_L$: Maize, cassava starch, defatted soybean, *Moringa* leaf, CD: Custard (Control)

microbial spoilage. For instance, when moisture content is on the high side, it encourages the growth of microorganisms[38]. Moisture content would therefore indicate low growth of bacteria and fungi[38], hence, prolong the shelf life. In this study, the formulated food samples have higher protein content than in control sample (CD) and recommended value[39]. These diets may therefore be suitable for the treatment of protein deficiency.

Mineral composition of the Formulated food samples: The mineral composition of the food samples is shown in Table 4. The mineral composition show that potassium had the highest concentration ranging from 18.0 mg kg^{-1} in $QCSM_L$ to 35.90 mg kg^{-1} in $QCSM_{LS}$ while copper had the lowest concentration ranging from 0.01 in $QCSM_{LS}$ to 0.03 mg kg^{-1} in $QCSM_S$. Except for sodium, potassium and phosphorous, the values for zinc, manganese, copper, iron, cobalt, nickel of all the food samples were significantly ($p<0.05$) higher when compared with the control sample. This observation showed that the formulated food samples in this present study are suitable to provide some of the nutritionally important minerals which are required by the body for healthy living. For instance, zinc, iron, copper, calcium, sodium, potassium, etc. are needed for cognitive development, bone and blood formation and electrolyte balance[40].

Amino acid profile and predicted nutritional qualities of the formulated food samples: The amino acid profile of the formulated food samples is presented in Table 5. The amino acid profiles of the food samples showed that glutamic acid had the highest concentration with range values from 12.45/100 g protein in $QCSM_{LS}$ to 14.78/100 g protein in $QCSM_S$, while tryptophan had the least concentration ranging from 0.20/100 g protein in $QCSM_{LS}$ to 0.29/100 g protein in $QCSM_L$. The total amino acid of the formulated diets showed that $QCSM_L$ sample (87.03/100 g protein) had the highest concentration, while $QCSM_S$ samples (84.28/100 g protein) had the lowest concentration. For the essential amino acids, $QCSM_L$ sample (34.97/100 g protein) had the highest concentration, while $QCSM_S$ samples (31.77/100 g protein) had the lowest concentration. The total amino acids and essential amino acids of the formulated diets were significantly ($p<0.05$) lower than in control sample (CD) (98.11/100 g and 44.99/100 g). The Essential Amino Acids Index (EAAI) and predicted Biological Values (BV) of $QCSM_L$ (60.84 and 54.54%) were significantly ($p<0.05$) higher than $QCSM_{LS}$ (58.27 and 51.76%) and $QCSM_S$ (53.99 and 47.10%), respectively. In comparing with the control sample (CD), it was observed that the EAAI and BV of $QCSM_L$ and $QCSM_{LS}$ were significantly ($p<0.05$) higher than in the control sample (CD) (55.94 and 49.21%). Nutritional studies have shown that cereals and tuber-based foods constitute the main staples for most populations of the developing nations[41]. These local foods are characterised with poor protein and essential amino acids[38], hence, increased in protein-energy malnutrition[39]. Protein-energy malnutrition has been implicated as the major factor, which responsible for the high prevalence of morbidity and mortality, particularly among the children and mothers[42]. In order to prevent this nutritional disorder, development of supplementary foods from locally available foods has been suggested by the Integrated Child Development Scheme (ICDS) and Food and Agriculture Organization (FAO) to combat malnutrition among mothers and children of low socio-economic groups[43].

Functional properties of the formulated food samples: Functional properties of the formulated food samples are shown in Table 6. The Water Absorption Capacity (WAC), Oil Absorption Capacity (OAC), least gelation capacity, Loose Bulk Density (LBD) and Packed Bulk Density (PBD) of formulated food samples varied as follows: 9-10 g mL^{-1}, 11-17 g mL^{-1},

Table 5: Amino acid profiles (g/100 g CP) and predicted nutritional qualities of food samples

Parameters	$QCSM_{LS}$	$QCSM_S$	$QCSM_L$	CD
Non-essential amino acids				
Glycine	5.57±0.04^a	4.53±0.04^c	4.94±0.04^b	2.37±0.01^d
Alanine	4.46±0.03^b	4.08±0.03^c	4.68±0.04^a	3.66±0.03^d
Serine	5.12±0.04^b	4.15±0.03^d	4.88±0.04^c	5.83±0.04^a
Proline	3.19±0.02^c	2.37±0.01^d	3.67±0.03^b	9.35±0.06^a
Aspartate	9.49±0.06^b	9.92±0.07^a	8.48±0.06^c	7.46±0.05^d
Glutamate	12.45±0.08^d	14.78±0.11^b	13.16±0.09^c	19.12±0.13^a
Tyrosine	3.27±0.02^c	3.70±0.03^b	2.45±0.01^d	4.62±0.04^a
Cystine	1.22±0.01^c	1.31±0.01^a	1.25±0.01^b	0.74±0.01^d
Arginine	5.41±0.04^b	5.02±0.04^c	5.81±0.04^a	3.05±0.02^d
Histidine	2.64±0.02^b	2.67±0.02^b	2.75±0.02^a	2.78±0.02^a
Essential amino acids				
Valine	5.49±0.04^c	4.38±0.03^d	6.31±0.04^b	6.43±0.04^a
Threonine	4.23±0.03^a	3.09±0.02^d	3.48±0.02^c	3.94±0.03^b
Isoleucine	4.82±0.04^b	5.44±0.04^a	4.73±0.04^b	5.47±0.04^a
Leucine	6.07±0.04^c	6.25±0.04^b	5.83±0.04^d	9.10±0.06^a
Lysine	5.84±0.04^c	5.30±0.04^d	7.79±0.06^a	7.34±0.05^b
Methionine	1.84±0.01^c	2.13±0.01^b	1.70±0.01^d	2.60±0.02^a
Phenylalanine	5.20±0.04^a	5.09±0.04^b	4.88±0.04^c	4.32±0.03^d
Tryptophan	0.20±0.00^b	0.13±0.00^c	0.29±0.00^a	0.01±0.00^d
Nutritional qualities				
Amino acids	86.42±0.61^c	84.28±0.59^d	87.03±0.62^b	98.11±0.69^a
NEAA	52.78±0.35^b	52.50±0.35^b	52.06±0.35^b	58.95±0.40^a
EAA	33.64±0.25^c	31.77±0.24^d	34.97±0.27^b	39.16±0.30^a
Predicted-PER	2.48±0.01^c	2.34±0.01^d	2.60±0.02^b	2.70±0.02^a
EAAI (%)	58.27±0.41^b	53.99±0.38^d	60.84±0.43^a	55.94±0.40^c
Predicted-BV (%)	51.76±0.37^b	47.10±0.33^d	54.54±0.38^a	49.21±0.35^c
Nutritional Index (%)	8.99±0.06^a	8.91±0.06^a	8.51±0.06^b	2.39±0.01^c

Values are expressed as Mean±Standard deviation, Values with the same superscript in the same row indicate no significant difference at $p\leq 0.05$, $QCSM_{LS}$: Maize, cassava starch, defatted soybean, *Moringa* leaf and seed, QCSMS: Maize, cassava starch, defatted soybean, *Moringa* seed, QCSML: Maize, cassava starch, defatted soybean, *Moringa* leaf, CD: Custard (Control), NEAA: Non-essential amino acids, EAA: Essential amino acids, EAAI: Essential amino acids Index

Table 6: Functional Properties of formulated food samples

Parameters	$QCSM_{LS}$	$QCSM_S$	$QCSM_L$	CD
WAC (g mL^{-1})	10.00±0.05^a	9.00±0.10^b	10.00±0.5^a	3.00±0.10^c
OAC (g mL^{-1})	17.00±0.2^a	11.00±0.5^c	15.00±0.05^b	9.00±0.2^d
LGC (%)	0.30±0.00^a	0.30±0.00^a	0.25±0.5^b	0.10±0.00^c
LBD (g mL^{-1})	0.31±0.03^a	0.32±0.01^a	0.32±0.06^a	0.34±0.04^a
PBD (g mL^{-1})	0.67±0.02^a	0.69±0.04^a	0.67±0.01^a	0.66±0.01^a

Values are expressed as Mean±Standard Deviation, values with the same superscript in the same row indicate no significant difference at $p\leq 0.05$, $QCSM_{LS}$: Maize, cassava starch, defatted soybean, *Moringa* leaf and seed, $QCSM_S$: Maize, cassava starch, defatted soybean, *Moringa* seed, $QCSM_L$: Maize, cassava starch, defatted soybean, *Moringa* leaf, CD: Custard (Control), WAC: Water absorption capacity, OAC: Oil absorption capacity, LGC: Least gelation concentration, LBD: Loose bulk density, PBD: Pack bulk density

0.25-0.30%, 0.31-0.32 g mL^{-1} and 0.67-0.69 g mL^{-1}, respectively and were significantly ($p<0.05$) higher than the control sample except for loose bulk density. The values of WAC and OAC in this study were comparatively higher than in the complementary foods reported by Achidi *et al.*[35], but lower in the LBD and PBD for the same complementary foods. The high values of water absorption capacities that was observed in this present study could be attributed to their protein contents with hydrophilic properties, which has the tendency to bind with water[44]. Water absorption capacity is an index of the maximum amount of water that a food product would absorb and retain[45]. With respect to water absorption capacity, Roongruangsri and Bronlund[45] reported that the microbial activities of food products with high water absorption capacity would be high. Hence, the shelf life of such food products would be reduced. It was also observed in this present study that the food samples had low loose bulk densities indicating less quantity of the food samples packaged into a constant volume thereby ensuring an economical packaging. Nutritionally, loose bulk density promotes easy digestibility of food products[46].

Table 7: Anti-nutrient compositions of formulated food samples

Parameters	$QCSM_{LS}$	$QCSM_S$	$QCSM_L$	CD
Phytate ($\mu g\ g^{-1}$)	17.29 ± 0.12^b	14.87 ± 0.10^c	18.99 ± 0.13^a	11.56 ± 0.08^d
Steroid ($\mu g\ g^{-1}$)	7.94 ± 0.06^a	4.12 ± 0.03^c	6.13 ± 0.04^b	0.01 ± 0.00^d
Alkaloid (%)	29.16 ± 0.21^b	37.44 ± 0.26^a	26.01 ± 0.18^c	24.25 ± 0.17^d
Flavonoid ($mg\ g^{-1}$)	8.16 ± 0.06^c	6.46 ± 0.05^d	11.13 ± 0.08^a	10.64 ± 0.07^b
Cardiac glycosides ($mg\ g^{-1}$)	13.64 ± 0.10^b	12.97 ± 0.09^c	14.76 ± 0.10^a	11.52 ± 0.08^d
Oxalate ($mg\ g^{-1}$)	0.72 ± 0.01^a	0.36 ± 0.00^c	0.54 ± 0.00^b	0.18 ± 0.00^d
Cyanogenic glycoside ($mg\ kg^{-1}$)	5.77 ± 0.04^d	6.65 ± 0.05^b	6.86 ± 0.05^a	6.28 ± 0.04^c

Values are expressed as Mean$\pm$Standard deviation, values with the same superscript in the same row indicate no significant difference at $p \leq 0.05$, $QCSM_{LS}$: Maize, cassava starch, defatted soybean, *Moringa* leaf and seed, $QCSM_S$: Maize, cassava starch, defatted soybean, *Moringa* seed, $QCSM_L$: Maize, cassava starch, defatted soybean, *Moringa* leaf, CD: Custard (Control)

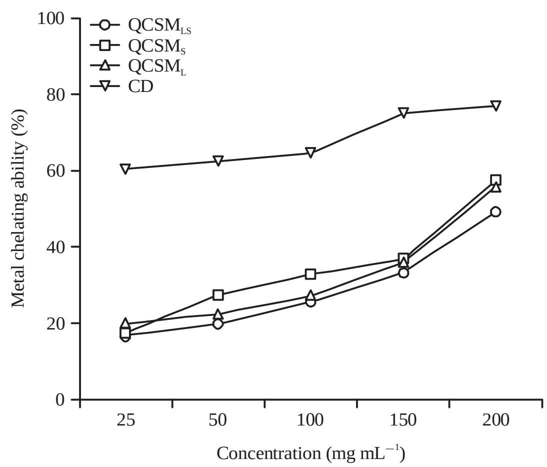

Fig. 1: Metal chelating ability of the formulated food samples

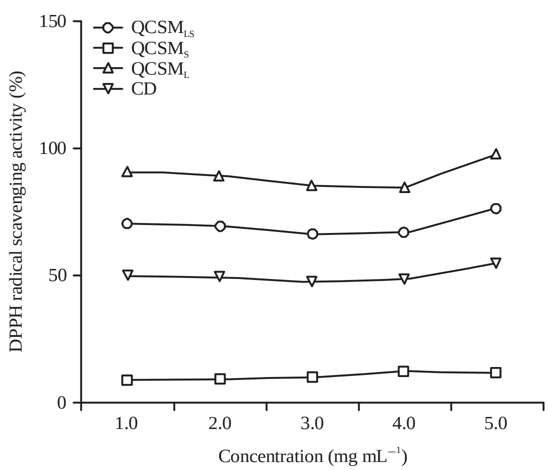

Fig. 2: DPPH free radical scavenging activities of the formulated diets

Anti-nutritional factors of the formulated food samples: The anti-nutrient compositions of the formulated food samples are presented in Table 7. The antinutrient compositions, that is, phytate, steroid, alkaloid and flavonoid in the formulated food samples varied as follows: 14.87-18.99 $\mu g\ g^{-1}$, 4.12-7.94 $\mu g\ g^{-1}$, 26.01-37.44% and 6.46-11.13 $mg\ g^{-1}$, respectively; while cardiac glycoside, oxalate and cyanogenic glycosides ranged from 12.97-14.76 $mg\ g^{-1}$, 0.36-0.72 $mg\ g^{-1}$ and 5.77-6.86 $mg\ kg^{-1}$, respectively. Comparatively, the composition of phytate, steroid, alkaloid, cardiac glycosides and oxalate in the formulated food samples were higher than in the control sample, however, these concentrations were still within the tolerable levels. Evidences have shown that intakes of anti-nutrients at lower concentration exhibit health benefits[47,48].

Antioxidant activity of the formulated food samples: The free radical scavenging activities of the formulated food samples are presented in Fig. 1 and 2. The metal chelating ability of the formulated food samples showed that $QCSM_{LS}$ samples had the lowest metal chelating activities, while $QCSM_S$ samples had the highest chelating activities, however, the chelating activities of these formulated diets were comparatively lower than in the control samples. With the exception of QCSMS, the free radical scavenging activities of the formulated food samples (i.e., $QCSM_L$ and $QCSM_{LS}$) in DPPH were higher when compared with the control food sample. The present study also established that the metal chelating and free radical scavenging activities in DPPH increased as the concentration of the food samples increased. This observation agreed with the reports of Biswas *et al.*[49].

Sensory attribute of the formulated food samples: The sensory attributes of the formulated food and control samples are shown in Table 8. The sensory attributes of $QCSM_S$ sample in terms of colour, taste, mouth-feel, aroma and overall acceptability, were significantly ($p<0.05$) higher than $QCSM_{LS}$ and $QCSM_L$ samples, but lower than the control sample. The least preference of $QCSM_{LS}$ and $QCSM_L$ samples could be due to the incorporation of *Moringa* leaf powder into these formulated food samples, which imparted greenish colour on the final food products thereby altering consumer choice of

Table 8: Sensory attributes of formulated food samples

Samples	Colour	Taste	Mouth feel	Aroma	Overall acceptability
$QCSM_{LS}$	6.50 ± 2.17^{b}	6.52 ± 2.32^{b}	6.20 ± 2.09^{b}	6.50 ± 1.9^{a}	6.54 ± 2.11^{b}
$QCSM_{S}$	6.90 ± 2.13^{ab}	6.71 ± 1.41^{b}	6.50 ± 2.32^{b}	6.53 ± 1.71^{a}	6.70 ± 1.79^{b}
$QCSM_{L}$	5.81 ± 2.09^{c}	5.42 ± 2.31^{c}	6.12 ± 1.85^{c}	6.40 ± 1.42^{a}	6.00 ± 2.21^{c}
CD	7.31 ± 1.05^{a}	7.50 ± 1.26^{a}	7.11 ± 1.33^{a}	6.41 ± 1.95^{a}	7.00 ± 1.56^{a}

Values are expressed as Mean$\pm$Standard Deviation, values with the same superscript in the same column indicate no significant difference at $p\leq0.05$, $QCSM_{LS}$: Maize, cassava starch, defatted soybean, *Moringa* leaf and seed, $QCSM_{S}$: Maize, cassava starch, defatted soybean, *Moringa* seed, $QCSM_{L}$: Maize, cassava starch, defatted soybean, *Moringa* leaf, CD: Custard (Control)

preference. This observation agreed with the reports of Abioye and Aka[50], who reported on the sensory properties of 'Ogi' fortified with *Moringa* leaves.

CONCLUSION

The present study demonstrated that the corn-cassava based diets supplemented with soycake and *Moringa oleifera* (leaf and seed) flours contained appreciable amounts of protein and minerals and besides, the food samples had the potentials to scavenge free radicals. Hence, it is concluded that these formulated diets could be valuable and excellent source for low-priced functional foods, which could provide adequate nutrients and prevention of certain diseases.

SIGNIFICANCE STATEMENTS

This present study utilized indigenous food materials to formulate low-cost breakfast foods with high nutrient-density and ability to scavenge free radicals. Hence, these formulations could be suitable as functional foods.

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