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Macronutrient composition, amino acid profiles and acceptability of maize-based complementary foods enriched with defatted white melon seed and *Moringa oleifera* leaf powder

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ABSTRACT

The study evaluated nutrient composition (protein, mineral & amino acid profile), energy value and sensory attributes of complementary foods from the following flour blends: 100% maize (MAI, control); 70% maize, 30% defatted melon seed flour (MTH); 70% maize, 27.5% defatted melon seed flour, 2.5% moringa leaf powder (MAT); 70% maize, 25% defatted melon seed flour, 5% moringa leaf powder (MET); and 70% maize, 20% defatted melon seed flour, 10% moringa leaf powder (MIT). Protein and energy values of the foods varied from 14.98 - 16.60 g/100 g and 352.53 - 374 kcal/100 g, respectively. Calcium/phosphorous (5.14 - 12.55) and sodium/potassium (0.009 - 0.012) molar ratios were higher than >0.5 and lower than (<1) recommended values, respectively. Essential amino acids ranged from 30.61 to 42.84 g/100 g protein. Predicted-biological value and essential amino acid index were 54 - 79.28% and 59.85 - 83.47%, respectively and were significantly ($p<0.05$) higher than MAI (49.47% & 56.12%). The MTH and MIT were rated higher than MAI in overall acceptability. However, MET sample was ranked the best in nutrient composition and biological value. Hence, it may be suitable as complementary food.

Introduction

African traditional complementary foods are mostly cereal-based, and are usually not adequate, in terms of protein content and energy values, to meet the nutritional requirement of children for proper growth and development (Ijarotimi and Keshinro, 2012). Traditional maize-based complementary food has been implicated as the main risk factor for the aetiology of protein and micronutrient deficiency among the infants, particularly in the communities where they are solely used as the complementary food (Ijarotimi and Keshinro, 2012). Protein deficiency is the major nutritional problem in developing countries, which leads to high prevalence of morbidity, mortality, stunting and mental retardation in children (Michaelsen et al., 2009).

Recent efforts have been shifted to the formulation of complementary foods from affordable and locally available food materials like cereals, legumes and oil seeds (Yohannes et al., 2020; Gemede, 2020). These efforts have led to overshooting of the nutrient and energy density of some of these infant foods beyond the daily protein and energy requirements of infants. Evidence-based study found that an early introduction of complementary foods (before the 4th month of life), together with complementary foods high in protein and energy density, was implicated as the main risk factor to childhood overweight and obesity (Pearce et al., 2013; Wang et al., 2016; Laving et al., 2018). Epidemiological studies have shown that an obese child remains obese in adulthood, hence, early prevention is necessary to reduce the prevalence and risks associated with obesity in adulthood (Ahmad et al., 2010; Raychaudhuri and Sanyal, 2012).

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Therefore, production of healthy complementary foods by judiciously selecting and combining locally available food materials may improve biological values and prevent childhood malnutrition.

Maize (*Zea mays*) is a cereal crop that is grown widely throughout the world, and it is rich in essential micronutrients, dietary fibers and is a good source of energy (Linda, 2013). In many parts of Africa, maize is consumed in different dishes like *pap*, *tuwo*, *masa*, *waina*, *ibier*, *choko*, *mumu*, *couscous*, *gwate* and popcorn, and it is also used for medicine and as a raw material for industries.

White melon seed (*Cucumeropsis mannii*) is a tropical African plant, which belongs to the cucurbitaceae family (Sanjur et al., 2002). In most developing countries, white melon kernel is commonly used for preparing 'egusi' soup in Cameroon, Nigeria and Benin, and pistachio soup in Cote d'Ivoire, where it functions as thickening, emulsifying, fat binding and flavouring agent (Enujiugha and Ayodele-Oni, 2003; Loukou et al., 2007). In today's food product development, melon seeds could become a functional ingredient as well as the vegetable protein source.

Moringa oliefera is a "miracle plant" that contains essential nutrients like proteins, minerals and vitamins, which the body needs for vibrant and good health. The leaves, pods and flowers of moringa are used for nutritional and medicinal purposes in many parts of the world (Fuglie, 2001). The leaves are a valuable source of nutrients for people of all ages and have beneficial pharmacological effects in the treatment of a variety of diseases due to their anti-hyperglycaemic, antimicrobial, anti-inflammatory, and antioxidant properties (Jaiswal et al., 2009; Mahajan et al., 2009; Atawodi et al., 2010).

In recent decades, efforts have been geared towards the utilization of locally available and inexpensive high protein food sources, like legumes, to complement the amino acid pattern of cereals in the production of qualitative complementary foods (Yohannes et al., 2020; Gemede, 2020). However, there is little information on the combination of yellow maize, white melon seed and moringa leaves powder in infant food formulation. Hence, the present study aimed to formulate and evaluate nutrient composition and acceptability of complementary food from maize, white melon seed and moringa leaves powder.

Materials and methods

Processing of food materials

Yellow maize flour processing

Yellow maize was processed into flour as described by Ijarotimi and Keshinro (2013). Yellow maize grains were sorted to remove unwanted materials like stones, pebbles and other foreign materials, washed under running clean water and soaked in water for three (3) days. After soaking, they were thoroughly rinsed with clean water and drained. The clean maize grains were oven dried at 60 °C for 20 h using a hot-air oven (Plus11 Sanyo Gallenkamp PLC, Loughborough, Leicestershire, UK), milled with a laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK) and passed through a 60 mm mesh sieve (British Standard) to obtain yellow maize fine flour. The flour was packed in plastic zip lock bag, sealed and stored at room temperature (~27 °C) until analysis.

Moringa leaf powder processing

The moringa leaf was processed into powder as described by Gernah and Sengev (2011) with slight modifications. The leaf samples were thoroughly washed with distilled water to remove unwanted materials, shade dried at room temperature for four days, milled into powder using a laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK), and sieved with a fine sieve (500 μm). The powder was stored in airtight plastic containers away from light.

Defatted white melon seed flour (DMF) processing

Defatted white melon seed was processed into flour by defatting 500 g of raw melon seed flour using Soxhlet apparatus for 6 h with n-hexane as solvent. How was the melon seed flour produced before defatting? The defatted flour was oven dried at 60 °C for 2 h using the hot-air oven (Plus11 Sanyo Gallenkamp PLC, Loughborough, Leicestershire, UK) and passed through a 60 mm wire mesh sieve (British Standard) to obtain defatted white melon seed flour (DMF). The flour was packed in a plastic container, sealed and stored at room temperature (~27 °C) until analysis.

Formulation of maize-based complementary food samples

The yellow maize flour, defatted white melon seed flour and moringa leaf powder were blended by using the NutriSurvey Linear programming to obtain the following food blends: MAI-maize 100%; MTH-maize 70% and defatted melon seed flour 30%; MAT-maize 70%, defatted melon seed flour 27.5% and moringa leaf flour 2.5%; MET-maize 70%, defatted melon seed flour 25% and moringa leaf flour 5%; and

MIT-maize 70%, defatted melon seed flour 20%, moringa leaf flour 10%.

Chemical analyses of maize-based complementary foods

Determination of proximate composition of maize-based complementary foods

Proximate composition, that is, moisture content, ash, crude fiber, crude fat and crude protein content of maize-based breakfast meal samples, was determined by using the standard methods (AOAC, 2012). Carbohydrate content was determined by difference as follows:

Carbohydrate (%) = 100 - (%Moisture + %Fat + %Ash + % Crude fibre + %Crude protein)

The gross energy content was determined by calculation from fat, carbohydrate, and protein contents by using the Atwater conversion factors; 4 kcal/g for protein, 9 kcal/g for fat, and 4 kcal/g for carbohydrates cited by (Guyot et al., 2007).

Food energy (kcal/100g) = (Carbohydrate x 4) + (Fat x 9) +(Crude protein x 4)

Determination of mineral composition of maize-based complementary foods

Mineral composition, that is, calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu) and zinc (Zn), was determined by using Atomic Absorption Spectrophotometer (AAS Model SP9). Sodium (Na) and potassium (K) in the food samples were determined by using flame emission photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK) with NaCl and KCl as the standard (AOAC 2012). Phosphorus (P) was determined by using Vanodo-molybdate method. Mineral molar ratios (bioavailability index of minerals), such as Na/K and Ca/P, were calculated.

Determination of amino acid composition of maize-based complementary foods

The amino acid profiles of the complementary food samples were determined according to the method described by AOAC (2012). The food samples were digested by using 6N HCl for 24 h. Amino acids were determined by 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 data were calculated as grams of amino acid per 100 g crude protein of flour sample.

Protein quality indices of the formulated maize-based complementary foods

Protein quality of the complementary foods was determined on the basis of the amino acid profiles. The Essential Amino Acid Index (EAAI) was calculated by using the method of Labuda et al. (1993), according to the equation below:

$$\text{EAAI} = \sqrt[9]{\frac{[\text{lys x try x isoleu x val x threo x leu x phenylal x hist x meth}]a}{[\text{ [lys x tryp x isoleu x val x threo x leu x phenyla x hist x meth] b}}} \text{ x } 100$$

where:
[lysine, tryptophan, isoleucine, valine, threonine, leucine, phenylalanine, histidine and methionine] in test sample and [lysine, tryptophan, isoleucine, valine, threonine, leucine, phenylalanine, histidine and the sum of methionine and cystine] b content of the same amino acids in standard protein (%) (egg or casein), respectively.

The nutritional index of the food samples was calculated by using the formula below:

$$\text{Nutritional index (\%)} = \left[\frac{EAAI \; x \; \%protein}{100}\right]$$

The biological value was calculated according to Oser (1959), cited by Mune-Mune et al. (2011) by using the following equation:
BV = 1.09 x Essential amino acid index [EAAI] – 11.7
the protein efficiency ratio (PER) was estimated according to the regression equations developed by Alsmeyer et al. (1974), cited by Mune-Mune et al., (2011) as given below:

$$PER = -0.468 + 0.454(LEU) - 0.105(TYR)$$

Determination of anti-nutritional factors of maize-based complementary foods

Determination of tannin content

Tannin content of the sample was determined as described by the method of Jaffe (2003), with slight

modifications. The sample was measured (1.0 g) and dispersed in distilled water (10 mL), shaken vigorously and centrifuged at 3000 *x g* for 20 min. The filtrate (2.5 mL) and standard tannic acid solution (2.5 mL) were separately dispersed into 50 mL flask, respectively, and Folin-Denis reagent (1.0 mL) and saturated Na_2CO_3 solution (2.5 mL) were poured into each of the volumetric flasks. Thereafter, the mixture was diluted with distilled water to mark in the volumetric flask (50 mL) and incubated for 60 min. at room temperature. The absorbance was measured at 250 nm in an electronic spectrophotometer (Genway model 6000i). Readings were taken with the reagent blank at zero. The tannin content was calculated.

$$\text{Tannin (mg/g)} = \frac{\text{Ab x Conc. x Vf}}{\text{Ast x Wt of sample x Vol.}}$$

where:
Ab =Absorbance of test sample, Ast =Absorbance of standard solution, Conc. = Concentration of standard solution, W = Weight of sample used Vf = Total volume of extract Vol. = Volume of extract.

Determination of saponin

The saponin in the flour samples was determined as described by the method of Obadoni and Ochuko (2001). The flour sample (20 g) was poured into a 250 mL conical flask containing 100 mL of 20% aqueous ethanol. The mixture was transferred into a hot water bath maintained at 50 °C for 3 h with continuous stirring. The residue of the mixture was re-extracted with another 100 mL of 20% aqueous ethanol after filtration. Thereafter, the combined mixture was filtered and concentrated in a water bath at 90 °C for 30 min. To the concentrated filtrate, 20 mL diethyl ether was added and mixed vigorously to separate the aqueous layer from the ether layer, which was discarded. This purification process was repeated twice. The separated aqueous solution was mixed with 60 mL of n-butanol. The mixture was then washed twice with 10 mL of 5% aqueous sodium chloride, and the sodium chloride layer was separated and discarded, while the leftovers were re-concentrated in a water bath at 90 °C for 30 min. The filtrate was then transferred into a crucible, and thereafter oven dried in the hot-air oven (Gallenkamp, England) at 60 °C to a constant weight. The saponin content was calculated.

$$\text{Saponin } \left(\frac{\text{mg}}{\text{g}}\right) = \frac{\text{weight of saponin}}{\text{weight of sample}}$$

Determination of oxalate

The oxalate was determined as described by the modified method of Munro (2000). The sample (2.5 g) was digested with 10 mL 6 M HCl at a temperature of 60 °C for 60 min. with continuous stirring using a magnetic stirrer, and then filtered. To 5.0 mL of the filtrate, 1.0 mL of 5 M ammonium hydroxide solution was added (to adjust pH) until the colour of the solution changed from salmon pink to a faint yellow colour. Phenolphthalein indicator (2 drops), glacial acetic acid (3 drops) and 5% calcium chloride (5.0 mL) were added to the solution to precipitate insoluble oxalate, and the solution was allowed to incubate for 120 min. at room temperature before centrifuged at 2500 *x g* for 20 min. The precipitate was washed with distilled hot water, 5.0 mL of 3 M tetraoxosulphate (VI) acid was added and incubated in a water bath at 60 °C for 20 min. Freshly prepared 0.01 M potassium permanganate ($KMnO_4$) was titrated against 12.5 mL of the filtrate until a faint pink colour, which persisted for about 30 sec. and the volume of $KMnO_4$ used was read from the burette reading. The oxalate content was calculated (mg/g).

$$\text{Oxalate } \left(\frac{\text{mg}}{\text{g}}\right) = V_{\text{T}} \text{ x } 0.9004$$

where: V_T = Titre volume (ml).

Determination of trypsin inhibition activity

Trypsin inhibition activity was assayed by the procedure of AOAC (2005). Sample extract (0.1 mL) and 0.9 mL of 0.1 mol/L phosphate buffer pH 8.0 were mixed with the same volume of trypsin solution and preincubated at 37 °C for 5 min. 1 ml of 0.03% (w/v) Bovine Serum Albumin (BSA) was added to the mixture and incubated for 30 min at 37 °C. After that, the reaction was stopped by the addition of 2 ml of 5% (w/v) Trichloroacetic acid (TCA) solution, and the mixture was filtered. The filtrate (1 ml) was mixed with 5 mL of 0.55 mol/L Na_2CO_3 and 0.1 mL of Folin-Ciocalteu reagent. The resulting colour absorbance was determined at 660 nm wavelength. Standard sample was prepared in the absence of the inhibitor.

$$\%\text{Trypsin inhibition activity} = T - T\circ T \times 100$$

where:
T, absorbance in the absence of the inhibitor;
T°, absorbance in the presence of the inhibitor.

Calculation of molar ratio of phytate, oxalate and minerals (Ca, Fe & Zn)

The molar ratio was predicted by dividing the mole of antinutrient (phytate or oxalate) by the mole of minerals (Ca, Fe & Zn) (Norhaizan and Norfaizadatul, 2009).

Determination of functional properties of maize-based complementary foods

Water absorption capacity (WAC)

The method described by Onwuka (2005) was used to determine WAC. One gram of the samples was weighed into a 15 mL centrifuge tube and suspended in 10 mL of water. It was shaken on a platform tube rocker for 1 min at room temperature. The sample was allowed to stand for 30 min and centrifuged at 1200 x *g* for 20 min. The volume of free water was read directly from the centrifuge tube.

$$\text{WAC} = \frac{\text{Amount of water added} - \text{Free water}}{\text{Weight of Sample}} \text{ x Density of Water x } 100$$

Bulk Density (BD)

A 50 g flour sample was put into a 100-mL measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g/ cm^3) was calculated as a weight of flour (g) divided by flour volume (cm^3) (Okaka and Potter, 1979)

$$\text{Bulk Density} = \frac{\text{Weight of Sample}}{\text{Volume of Sample after Tapping}}$$

Swelling Index (SI)

The swelling index was determined by the method described by Alawode et al. (2017) with slight modifications. One gram of the samples was mixed with 10 mL distilled water in a centrifuge tube and heated at 80 °C for 30 min. The mixture was continually shaken during the heating period. After the heating, the suspension was centrifuged at 1000 *x g* for 15 min. The supernatant was decanted and the weight of the paste taken. The swelling index was calculated as follows:

$$\text{Swelling Index}(\%) = \frac{\text{Weight of Sample Paste}}{\text{Weight of Dry Flour}} \text{x} 100$$

Evaluation of Sensory Attributes of Maize-based Complementary Foods

The formulated complementary foods were prepared into porridges. The flour (100 g) of each of the samples was mixed with 600 mL of boiled water (100 °C), and the slurry was heated in a thermostatically controlled water bath at 100 °C for 25 min. The gruel was maintained at a temperature of 40 °C, coded with random three digits and then served to the panelists comprising nursing mothers who were familiar with the local complementary food (*ogi*) (Nnam and Baiyeri, 2008). The sensory analyses were conducted in a sensory laboratory with adequate lighting and no odour environment. The nursing mothers were selected based on their familiarity with the control samples and the recognition and perception of common odours. The reconstituted formulated complementary foods and the control food samples were coded and presented to 20 untrained panelists (nursing mothers). Water at room temperature was provided for mouth rinsing in between successive evaluations. Sample attributes (appearance, aroma, taste, texture, consistency) were rated on a scoring scale of 1 to 9, where 1 = dislike extremely and 9 = like extremely. Panelists made their responses on score sheets that were designed in line with the test procedures (Olapade, 2014).

Statistical Analysis

All data were expressed as mean ± standard error of mean (SEM), using the statistical analysis programme for social sciences (SPS) (version 21). Significant differences among the means were determined by using New Duncan's Multiple Range Test (NDMRT). Graphs were plotted by using GraphPad Prism. Results were considered to be significant at $p \leq 0.05$

Results and discussion

Nutrient Composition and Energy Value of Maize-based Complementary Foods

Protein, energy and moisture contents of the developed complementary foods varied from 14.98 to 16.60 g/100 g, 352.53 to 374 kcal/100 g and 7.13 to 8.90 g/100 g, respectively (Table 1). The protein content of the developed food products was significantly ($p<0.05$) higher than MAI (100% maize) (7.86 g/100 g). This finding could be attributed to the inclusion of defatted white melon seed flour and moringa leaf powder into the formulated complementary foods. The protein and caloric value of maize-based complementary foods in this study agreed with previous studies, which reported that traditional complementary foods were usually low in protein content, but high in energy value (Kulwa et al., 2015; Alamu et al.,

2018). Similar studies have reported that inclusion of legumes with cereal-based food products usually increased protein content of the formulated food products (Adepeju et al., 2016; Noah, 2017). Nutritionally, the complementary foods (100 g) in this study could be adequate in providing daily protein (14g/day) (FAO/WHO/UNU, 1985) and energy (200 - 300 kcal/day) requirements for infants (Dewey and Brown, 2003). It is well established that adequate nutrition, particularly during the childhood, is a major determinant of growth and development and subsequently better health wellbeing and productivity in adulthood (WHO, 2000).

The mineral composition of the complementary foods ranged from 1.80 - 2.93, 1.46 -1.79 and 0.83 - 1.25 mg/100g for Cu, Zn and Fe, respectively, while Ca, K, P and Na were 92 - 220, 139.9 - 179, 13.84 - 15.25 and 0.78 - 1.29 mg/100g, respectively. Statistically, the minerals in MIT sample were significantly ($p<0.05$) higher than other food products including MAI (100% maize). This observation could be due to the inclusion of moringa leaf powder, which previous studies have reported to contain large amount of micronutrients (Gopalakrishnan et al., 2016). The essential minerals such as Zn, Ca and Fe are vital to the development of cognitive, bone and hemoglobin formation in children. The Ca/P molar ratio (5.14 - 12.55) of the complementary food products was higher than critical levels (>0.5) (Jacob et al., 2015). It is evident that food is always considered as a good source of calcium and phosphorous when the Ca/P molar ratio is >1 and poor if the value is <0.5 (Alinnor and Oze, 2011). The high Ca/P molar ratio observed in this study indicates that the formulated complementary foods could adequately provide calcium and phosphorous for infants and young children who require a high intake of calcium and phosphorus for bone and teeth formation, and for the prevention of osteoporosis, (Ijarotimi and Keshinro, 2013). The Na/K molar ratios of the formulated complementary diets ranged from 0.009 to 0.012, and the values were lower than the report of Gemede (2020) for the complementary foods formulated from maize, pea, and anchote flours. The Na/K molar ratios were very low in all the complementary foods. This/ It indicates that the food samples were low in sodium, but higher in potassium. Hence, these complementary foods could be of nutritional benefit particularly for the hypertensive patients and the children with immature kidney and/ or heart. Na/K ratio plays a very important role in the diet as it reduces high blood pressure and the risk of stroke in man (Jacob et al., 2015). According to the previous study, Na/K molar ratio is of great importance for the prevention and treatment of high blood pressure (Perez and Chang, 2014).

The essential, non-essential and total amino acid profile of the developed complementary foods ranged from 30.61 to 42.84, 36.99 to 49.88 and 67.6 to 88.49 mg/100 g protein, respectively (Table 2). The total essential amino acid composition of the developed food products was comparatively higher than FAO/WHO (1991) recommended values (28.9) for infants. The histidine (2.26 - 4.22 g/100 g) and arginine (4.95 - 8.58 g/100 g) in developed complementary foods were higher than FAO/WHO (1991) recommendations of 1.9 and 2.0 g/day for infants. Histidine and arginine are essential amino acids for infants, because the guts (intestines) of infants cannot synthesize these amino acids.

Table 1. Proximate (g/100 g), energy values (Kcal/100 g) and mineral (mg/100 g) composition of complementary foods from maize, white melon seed and moringa leaf powder

Parameters	MAI	MTH	MAT	MET	MIT	*Standard
Moisture	8.60±0.04^{b}	8.66±0.03^{b}	8.71±0.08^{ab}	7.13±0.11^{c}	8.90±0.12^{a}	<5
Ash	1.14±0.07^{e}	1.37±0.12^{d}	1.67±0.11^{c}	2.25±0.06^{b}	2.68±0.09^{a}	<3
Crude Fibre	2.48±0.06^{d}	0.73±0.14^{e}	3.04±0.11^{c}	3.85±0.14^{b}	4.65±0.10^{a}	<5
Crude Protein	7.86±0.14^{c}	15.34±0.10^{b}	14.98±0.50^{b}	15.75±0.65^{ab}	16.60±0.10^{a}	15
Fat	3.46±0.12^{c}	3.48±0.36^{c}	3.67±0.13^{a}	3.27±0.70^{d}	3.49±0.07^{b}	10-25
CHO	76.48±0.17^{a}	70.44±0.04^{b}	68.33±0.93^{c}	67.75±1.13^{d}	63.68±0.10^{e}	60-75
Energy	368.5±3.22^{b}	374.44±2.45^{a}	366.27±1.99^{b}	363.43±3.09^{c}	352.53±2.34^{d}	400-425
Copper	0.65±0.07^{e}	1.80±0.11^{d}	2.30±0.11^{c}	2.60±0.06^{b}	2.93±0.04^{a}	-
Zinc	1.24±0.06^{e}	1.46±0.06^{d}	1.67±0.12^{c}	1.71±0.06^{b}	1.79±0.06^{a}	3.2
Iron	0.68±0.36^{d}	0.83±0.04 ^{c}	1.13±0.06^{b}	1.21±0.02^{a}	1.25±0.06^{a}	16
Calcium	79±1.73^{e}	92±1.73^{d}	175.00±1.73^{c}	203±1.73^{b}	220±1.73^{a}	250
Potassium	50.07±0.02^{e}	139.91±0.13^{d}	146.50±0.02^{c}	167±0.06^{b}	179±0.17^{a}	516
Phosphorus	10.55±0.17^{e}	13.84±0.04^{c}	14.37±0.01^{b}	12.50±0.17^{d}	15.25±0.06^{a}	356
Sodium	0.55±0.03^{d}	0.78±0.01^{c}	0.93±0.04^{b}	1.15±0.03^{ab}	1.29±0.12^{a}	296
Ca/P	5.79±0.01^{d}	5.14±0.00^{e}	9.41±0.11^{c}	12.55±0.05^{a}	11.15±0.21^{b}	>0.5
Na/K	0.019±0.01^{a}	0.009±0.00^{c}	0.011±0.00^{b}	0.012±0.01^{b}	0.012±0.00^{b}	<1

Values are mean± standard deviation. Values with the same superscript in the same row are not significantly different ($p<0.05$). *CODEX CAC/GL 08 (1991). KEY: MAI-Maize 100%; MTH-Maize 70%, Defatted melon seed flour 30%; MAT-Maize 70%, Defatted melon seed flour 27.5%, Moringa Leaf Flour 2.5%; MET-Maize 70%, Defatted melon seed flour 25%, Moringa Leaf Flour 5%; MIT-Maize 70%, Defatted melon seed flour 20%, Moringa Leaf Flour 10%

Table 2. Amino acid profile (g/100 g protein) of complementary foods from maize, defatted white melon seed and moringa leaf powder

Amino Acid	MAI	MTH	MAT	MET	MIT	*RDA
Non-Essential Amino Acid						
Tyrosine	1.44±0.01^{d}	1.40±0.00^{d}	2.42±0.03^{c}	3.95±0.14^{b}	4.05±0.41^{a}	-
Proline	4.26±0.11^{a}	4.29±1.01^{a}	4.23±0.03^{a}	4.06±0.04^{b}	3.08±0.03^{c}	-
Serine	3.11±0.03^{d}	2.39±0.00^{e}	3.64±0.00^{c}	3.92±0.07^{b}	6.15±0.11^{a}	-
Aspartic acid	6.12±0.21^{c}	6.71±0.22^{c}	8.1±0.21^{b}	8.61±0.21^{b}	9.44±1.02^{a}	-
Glutamic acid	13.76±2.03^{c}	13.44±1.04^{c}	14.3±2.05^{b}	14.42±3.01^{b}	17.44±2.03^{a}	-
Glycine	3.97±0.01^{c}	3.21±0.00^{c}	5.4±0.45^{a}	4.9±0.03^{b}	4.89±0.24^{b}	-
Alanine	2.98±0.00^{d}	3.3±0.03^{c}	5.7±0.33^{a}	4.36±0.44^{b}	3.03±0.22^{c}	-
Cysteine	1.35±0.01^{c}	1.54±0.00^{a}	1.33±0.00^{c}	1.43±0.01^{b}	1.8±0.04^{d}	-
∑NEAA	36.99±3.07^{c}	36.28±2.03^{c}	45.02±4.02^{b}	45.65±3.19^{b}	49.88±2.71^{a}	-
Essential Amino Acids for Infant						
Arginine	4.77±0.22^{c}	5.44±0.31^{b}	8.58±0.22^{a}	5.33±0.06^{b}	4.95±0.09^{c}	2
Histidine	3.43±0.00^{b}	4.22±0.33^{a}	2.92±0.00^{bc}	2.32±0.00^{c}	2.26±0.00^{c}	1.9
Isoleucine	2.63±0.01^{bc}	2.77±0.01^{b}	4.08±0.05^{a}	2.72±0.12^{b}	4.21±0.14^{a}	2.8
Leucine	5.31±0.25^{c}	5.45±0.05^{c}	7.68±1.22^{b}	8.94±1.11^{a}	5.46±0.55^{c}	6.6
Lysine	3.86±0.31^{c}	4.54±0.1^{b}	6.21±0.33^{a}	5.35±0.65^{b}	4.52±0.25^{b}	5.8
Methionine	1.24±0.00^{c}	1.34±0.00^{a}	1.27±0.00^{b}	1.29±0.00^{b}	2.29±0.00^{b}	2.2
Phenylalanine	4.95±0.07^{b}	4.42±0.34^{c}	2.83±0.01^{d}	5.26±0.21^{a}	2.67±0.00^{e}	2.8
Threonine	3.28±0.11^{d}	4.3±0.09^{a}	3.63±0.00^{b}	3.42±0.09^{c}	3.08±0.03^{d}	3.4
Tryptophan	1.14±0.03^{c}	1.19±0.00^{c}	1.33±0.00^{b}	8.21±0.43^{a}	1.28±0.00^{b}	1.4
Valine	3.23±0.00^{c}	3.6±0.03^{b}	4.58±0.04^{a}	3.2±0.02^{c}	4.61±0.06^{a}	3.5
∑EAA	30.61±4.01^{d}	33.67±1.11^{c}	38.53±2.91^{b}	42.84±3.04^{a}	30.72±4.33^{d}	28.9
Predicted Nutritional Quality						
∑Aas	67.60±3.03^{e}	69.95±2.22^{d}	83.55±2.43^{c}	88.49±2.66^{a}	80.6±3.03^{b}	-
∑EAA+His+Arg/∑AA%	57.41±2.21^{c}	61.94±4.11^{a}	59.88±2.43^{b}	57.06±3.14^{c}	47.06±2.11^{d}	-
TEAA/∑AA%	45.28±0.99^{c}	48.13±1.87^{a}	46.12±0.98^{b}	48.41±2.33^{a}	38.11±0.98^{d}	-
∑NEAA/∑AA%	54.72±3.72^{b}	51.87±2.45^{c}	53.88±0.59^{b}	51.59±2.17^{c}	61.89±2.02^{a}	-
∑EAA/∑NEAA	0.83±0.00^{b}	0.93±0.00^{a}	0.86±0.00^{b}	0.94±0.00^{a}	0.62±0.01^{c}	-
PER	1.99±0.00^{c}	2.20±0.01b^{c}	2.57±0.00^{a}	2.76±0.01^{a}	2.08±0.00^{b}	-
EAAI (%)	56.12±3.43^{e}	60.99±1.77^{c}	63.22±4.01^{b}	83.47±2.33^{a}	59.85±3.03^{d}	70
BV (%)	49.47±2.01^{d}	54.79±3.03^{c}	57.21±2.25^{b}	79.28±4.06^{a}	53.53±2.22^{c}	70
Nutritional index (%)	8.61±0.11^{c}	4.79±0.33^{d}	9.47±0.99^{b}	13.15±0.83^{a}	9.94±0.45^{b}	
Arginine/Lysine	1.24±0.00^{c}	1.20±0.00^{b}	1.38±0.00^{a}	0.99±0.01^{e}	1.09±0.01^{d}	
BCAAs	11.17±0.09^{c}	11.82±0.77^{c}	16.34±0.67^{a}	14.86±1.01^{b}	14.28±1.11^{b}	

Mean± standard deviation. Values with the same superscript in the same row are not significantly different ($p<0.05$). KEY: MAI-Maize 100%; MTH-Maize 70%, Defatted melon seed flour 30%; MAT-Maize 70%, Defatted melon seed flour 27.5%, Moringa Leaf Flour 2.5%; MET-Maize 70%, Defatted melon seed flour 25%, Moringa Leaf Flour 5%; MIT-Maize 70%, Defatted melon seed flour 20%, Moringa Leaf Flour 10%

Besides, studies have shown that inadequate intake of arginine has been associated with many neonatal diseases, including persistent pulmonary hypertension (Vosatka et al., 1994). The predictedbiological values (p-BV) and essential amino acid index (EAAI) of the complementary food products were 54 - 79.28% and 59.85 - 83.47%, respectively, and these values were significantly ($p<0.05$) higher than that of MAI (49.47% & 56.12%, respectively). The p-BV and EAAI of MET (70% maize, 25% defatted melon seed flour & 5% moringa leaf flour) were comparable to the recommended values for ideal food products (>70). This finding could be due to the inclusion of defatted white melon seed flour and moringa leaf powder. This observation agrees with previous studies, which reported that melon seed and moringa leaf are rich in protein content and other vital nutrients that could improve nutritional quality of food products (Alozie, 2017).

Antinutrient Composition and Phytate/Minerals Molar Ratio of Maize-based Complementary Foods

The antinutrient composition (mg/g) of the complementary foods showed that trypsin inhibitor (26.73 - 33.87), saponin (10.36 - 13.97, tannin (1.08 - 1.44), phytate (7.0 - 10.3) and oxalate (0.5 -0.68) were higher than MAI sample. The differences in antinutrient composition of these food products could be due to the variation in the food sample components and processing methods. However, the values were low and within the tolerable levels. The phytate and mineral molar ratios (an index of mineral bioavailability) of the complementary food samples were <0.0001, 0.004 - 0.007, 0.005 - 0.011 and 0.016 - 0.025 for phytate/Ca, Phytate:zinc, Phytate:iron and phytate:calcium/zinc, respectively. These phytate/minerals (Ca, Fe & Zn) molar ratios were lower when compared to the critical levels reported by Gemede (2020). This indicates high bioavailability and

absorption of calcium, iron and zinc in the formulated food samples, hence preventing their deficiency that may lead to bone deformation, anemia and poor cognitive development. Calcium, iron and Zinc are important minerals required for optimal growth and development in children and their deficiency may lead to rickets, anaemia and poor brain development (Haimi and Lerner, 2014). Adequate complementary foods in terms of nutrient-energy density and micronutrients, coupled with appropriate feeding practices, are needed to ensure optimal growth and development in children (Lutter and Rivera, 2003). Traditional complementary foods in Africa, including Nigeria, have been implicated as the risk factor in child malnutrition due to lack of essential nutrients that are needed for normal child growth and development (Udoh and Amodu, 2016).

Functional Property of Maize-based Complementary Foods

The functional property of the developed food products showed that bulk density (BD), swelling index (SI) and water absorption capacity ranged from 0.84 - 0.91 mg/mL, 2.75 - 3.58% and 23 - 40%, respectively. The BD, SC and WAC of the developed food products were comparable to that of MAI (100% maize flour), and agreed with the report of Jude-Ojei et al. (2017) for the complementary food produced from maize and moringa seed flour. The BD, SC and WAC of the food products in this study were generally low, and this could be of nutritional benefit, particularly to the children. According to previous studies, it is evident that low WAC, BD and SC are desirable in infant foods, because these make it possible to prepare a thinner gruel with high nutrient-density, high caloric density per unit volume and ability to associate with water (Omueti et al., 2009; Onuoha et al., 2014; Jude-Ojei et al., 2017). Studies have established that a complementary food should have low water absorption capacity and bulk density in order to have high nutrient-energy density that could meet nutrient and energy requirements of the children, because of their small stomach size (Theodore et al., 2009; Jude-Ojei et al., 2017).

Table 3. Anti-nutritional composition of maize-based complementary food fortified with defatted white melon seed flour and moringa leaf powder

SAMPLE	MAI	MTH	MAT	MET	MIT	*Ref.
Trypsin (%)	26.20±0.20^{d}	35.58±0.20^{a}	33.87±0.20^{b}	29.28±0.20^{c}	26.73±0.20^{d}	-
Saponin (mg/g)	9.18±0.27^{d}	13.97±0.03^{a}	10.36±0.27^{c}	12.91±0.27^{b}	13.18±0.27^{a}	-
Tannin (mg/g)	1.06±0.01^{d}	1.44±0.01^{a}	1.36±0.01^{b}	1.18±0.01^{c}	1.08±0.01^{d}	-
Phytate (mg/g)	5.77±0.00^{d}	10.3±0.41^{a}	8.71±0.41^{b}	8.65±0.41^{b}	7.00±0.41^{c}	-
Oxalate (mg/g)	0.41±0.05^{d}	0.68±0.05^{a}	0.62±0.05^{b}	0.54±0.00^{c}	0.50±0.05^{cd}	-
Phytate/minerals molar ratio						
Phytate/Calcium	0.00002±0.0^{b}	0.00007±0.0^{a}	0.00003±0.0^{b}	0.00003±0.0^{b}	0.00002±0.0^{b}	<0.24
Phytate/Zinc	0.004±0.001^{c}	0.007±0.001^{a}	0.005±0.001^{b}	0.005±0.0^{b}	0.004±0.0^{c}	<10
Phytate/iron	0.005±0.000^{d}	0.011±0.002^{a}	0.007±0.001^{b}	0.006±0.0^{c}	0.005±0.0^{d}	>0.15
Phytat*Ca/Zn	0.021±0.002^{b}	0.016±0.0^{c}	0.022±0.001^{b}	0.025±0.002^{a}	0.021±0.001^{b}	0.5
Oxalate/Calcium	0.002±0.000^{c}	0.007±0.001^{a}	0.004±0.001^{b}	0.003±0.000^{bc}	0.002±0.000^{c}	<1

Values are mean± standard deviation. Values with the same superscript in the same row are not significantly different ($p<0.05$). *Gemede (2020). KEY: MAI-Maize 100%; MTH-Maize 70%, Defatted melon seed flour 30%; MAT-Maize 70%, Defatted melon seed flour 27.5%, Moringa Leaf Flour 2.5%; MET-Maize 70%, Defatted melon seed flour 25%, Moringa Leaf Flour 5%; MIT-Maize 70%, Defatted melon seed flour 20%, Moringa Leaf Flour 10%

Table 4. Functional properties of maize-based complementary food fortified with defatted white melon seed flour and moringa leaf powder

SAMPLE	MAI	MTH	MAT	MET	MIT
BD (g/ml)	0.86±0.55^{b}	0.85±0.02^{b}	0.91±0.00^{a}	0.84±0.04^{b}	0.91±0.04^{a}
SI (%)	3.63±0.83^{a}	3.58±0.25^{b}	3.11±0.07^{c}	3.50±0.14^{b}	2.75±0.03^{d}
WAC (%)	42±2.05^{a}	22.5±1.5^{d}	32±2.03^{c}	40±3.03^{b}	23±1.00^{d}

Mean± standard deviation. Values with the same superscript in the same row are not significantly different ($p<0.05$). SAMPLES: MAI-Maize 100%; MTH-Maize 70%, Defatted melon seed flour 30%; MAT-Maize 70%, Defatted melon seed flour 27.5%, Moringa Leaf Flour 2.5%; MET-Maize 70%, Defatted melon seed flour 25%, Moringa Leaf Flour 5%; MIT-Maize 70%, Defatted melon seed flour 20%, Moringa Leaf Flour 10%

Table 5. Sensory attributes of complementary foods from maize, defatted white melon seed and moringa leaf powder

Sample	MAI	MTH	MAT	MET	MIT
Colour	4.5±1.54^{b}	7.0±1.84^{a}	2.8±1.51^{c}	3.9±1.07^{bc}	8.20±0.77^{a}
Appearance	4.4± 1.05^{b}	7.2±2.14^{a}	2.2±1.64^{c}	3.4±1.05^{bc}	6.9±1.48^{a}
Aroma	5.7±O.66^{a}	5.8±1.36^{a}	3.7±1.66^{b}	5.0±0.79^{a}	5.6±0.82^{a}
Flavour	5.1±0.55^{ab}	5.8±1.11^{a}	4.0±1.72^{c}	4.6±0.94^{bc}	5.6±1.47^{ab}
Texture	5.9±1.48^{ab}	6.6±2.68^{a}	4.7±1.95^{b}	5.1±2.02^{ab}	6.8±1.70^{a}
Taste	5.7±0.47^{ab}	6.4±1.47^{a}	4.6s±2.06^{b}	4.6±1.31^{b}	6.4±1.14^{a}
Overall acceptability	5.5±0.51^{b}	7.4±1.85^{a}	3.8±1.51^{c}	4.30±0.92^{c}	6.8±1.11^{a}

Values are mean± standard deviation. Values with the same superscript in the same row are not significantly different ($p<0.05$). KEY: MAI-Maize 100%; MTH-Maize 70%, Defatted melon seed flour 30%; MAT-Maize 70%, Defatted melon seed flour 27.5%, Moringa Leaf Flour 2.5%; MET-Maize 70%, Defatted melon seed flour 25%, Moringa Leaf Flour 5%; MIT-Maize 70%, Defatted melon seed flour 20%, Moringa Leaf Flour 10%

Sensory Attributes of Maize-based Complementary Foods

The sensory attributes of developed food products are presented in Table 5. The results show that MTH (70% maize & 30% defatted melon seed flour) was rated higher in terms of appearance, aroma, taste, texture and overall acceptability than MAI (100% maize), including samples enriched with moringa leaf powder. However, MIT (70% maize, 20% defatted melon seed flour, 10% moringa leaf powder) was rated equally as MTH in all the sensorial attributes. This finding agrees with the reports of Abioye and Aka (2015) and Boateng et al. (2019), who established that an acceptable complementary food with moringa leaf powder could only be achieved at 10% inclusion. It is well established that sensory attributes and nutritional quality of food products are essential factors to be considered in infant food formulation (Egounlety et al., 2002).

Conclusion

This study developed and evaluated complementary foods from locally available food materials like maize, defatted white melon seed and moringa leaf powder. The findings showed that the developed food products, particularly MET, were nutritiously adequate in terms of protein, energy value, mineral content, total essential amino acid and biological value. Therefore, this food product (MET, 70% maize, 25% defatted melon seed flour & 5% moringa leaf powder) may be a good substitute to traditional complementary foods that are low in nutritional quality. However, there is a need to improve the sensorial attributes of the product.

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