Creating and Assessing the Nutritional and Physicochemical Properties of Millet Based Composite Mixed Complementary Food: An Innovative Approach

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ABSTRACT

The study developed millet-based composite complementary mixes in the form of convenience foods for children, as cost effective and easy approaches that offer variety, convenience and quality food that combat micro nutrient deficiencies. A complete randomized designed was used for the experiment. The household recipes with supplementation of nutrients rich food sources: millet, toasted soybean and sesame seeds flour samples were blended at the ratios of 6:2:1 while cray fish, orange flesh sweet potatoes, dried moringa leaves and baobab fruit pulp were supplemented at the ratio 2:1:1:1 using varying proportions 10% (MBF), 15% (MCF), 20% (MDF) respectively while millet alone served as control (MAF).Functional properties (bulk density, water and oil absorption capacity, swelling capacity) and proximate composition, micro nutrient composition were carried out on the individual flour samples. The proximate composition of flour samples showed increased in crude protein from 9.13±0.09 to 14.21±0.13, fat content 5.38±0.09 to 7.79±0.08, fibre from 3.05±1.03 to 5.68±2.43, ash from 2.17±0.79 to 3.41±0.42. There was decreased moisture content from 10.71±0.42to 7.61±0.25 and carbohydrates from 69.56±0.40to 61.65±0.28%. There was an increase in the micro nutrient composition with increasing incorporation level of other flours. The sensory evaluation revealed 15% (MCF) menu showed promising results, presenting a high level of acceptance and good protein digestibility (85.98%). These results suggest significant potential for development opportunities that enhanced dietary diversification and improved nutritional outcomes of malnourished children.

Key words: Millet-based, composite mixed, children under five, food resources, complementary food, physicochemical

INTRODUCTION

The scourge of under-nutrition is a threat to human health and remains alarming especially among children under five years old in many developing countries (Kramer & Allen,2015). Complementary foods play a crucial role in ensuring the nutritional needs of infants and young children as they transit from exclusive breastfeeding to varied diet. Various local and regional long-established complementary foods practices common in developing countries produced from cereals are typify with low protein, energy density and micro nutrients (Adepoju and Ayenitaju, 2021). Consequently, inferior and inadequate complementary foods have been implicated as the main causes of growth and intellectual development impediment, therefore increasing the risk of morbidity and mortality in children (Yamashiro, 2021). A strategy to manage all forms of malnutrition is food based, with sufficient amounts of energy and various macro and micronutrients for proper human body's growth and development. In recent times, scientific report has emphasized the use of local complementary food formulated in the home rather than centrally produced fortified foods for mothers with limited access to commercial complementary foods, thereby promoting dietary diversification and bio-economy (Masanja, Jumbe& Pacific, 2021; Ijarotimi, Fatiregun & Oluwajuyitan, 2022). These formulated products should consist of energy-dense, micronutrient enhanced nutrients necessary for rapid catch-up growth for those at risk (UNICEF, 2012). Several research reports have shown the effect of therapeutic complementary diet using diverse local foods and staples for treatment of mild, moderate and severe acute wasted children in various countries e.g in Indonesia (Scherbaum, Purwestri, Stuetz et al.,2015; Fetriyuna, Purwestri, Susandy, Kohler et al.,2021), Ethiopia (Guimon & Guimon, 2012), Nigeria (Uhiara & Onwuka, 2014) to support the development of underutilized local foods.

Traditional Nigerian complementary food recipes including several tubers, cereals, beans, fruits, and vegetables consumed in various forms with different taste. Among many commodities, pearl millet (*Pennisetumglaucum*), soybean (*Glycine max*), sesame (*Sesamumindicum*), moringa (*Moringa oleifera*) leaves, orange-fleshed sweet potato (OFSP) (*Ipomoea batatas*), baobab (*Adonsonia digitata*) and cray fish can potentially be used as an ingredient to produce an enriched complementary food due to their high energy, vitamin and mineral contents.

The local millet-based infant food is low in essential nutrients like protein and micronutrients, which has been implicated as the main cause of high prevalence of protein-energy malnutrition among the weaning-aged children (6–24 months) in Africa. Using locally available crops to formulate affordable but nutrient-dense complementary food can alleviate malnutrition resulting from the high rate of poverty in Nigeria. The incorporation of cereals and legumes with fruits or vegetables can increase the protein and vitamin content of cereal fruit blends hence their functionality and nutritional values (Garg, Sharma, Vat, Tiwari et al., 2021). Orange fleshed sweet potato, baobab fruit pulp and moringa leaf are underutilized in this part of the world. Therefore, they should be complemented with legumes and/or cereals when used for complementary foods. In view of this, there is need to formulate complementary food using local food resources following the guideline for management of malnutrition among children under five years of age. To optimize the nutrition profile of the developed complementary food, millet were mixed with soybeans, sesame seeds, moringa leaves, orange flesh sweet potatoes, baobab fruit powder and cray fish as a promising option to improve both the macro and micro nutrient profile and functional properties of millet based food; thereby promoting dietary diversification and biobased economy. This study therefore aimed at developing and evaluating the blends of complementary foods produced from millet, soybean, sesame seed, crayfish, orange fleshed sweet potato, moringa leaf powder and baobab pulp.

MATERIALS AND METHODS

Source of Material

Porridge was selected as the carrier of new developed product from the blends of the local foods because the Nigeria children favoured different types of porridges including gruel. The common food resources used in the study are millet (*Pennisetumglaucum)*, soybeans (*Glycine max*), sesame *(Sesamumindicum)*, baobab (*Adonsonia digitata*) fruit pulp and cray fish were purchased from Monday market in Pankshin, Plateau state while moringa (*Moringa oleifera*) leaves and Orange fleshed sweet potatoes (*Ipomoea batatas*) were obtained from Research Farms of Agricultural Science Department, Federal College of Education Pankshin. The chemicals and equipment/facilities used were up to standard and were obtained from Chemistry laboratory of Chemistry Department Federal College of Education Pankshin. The crops were subjected to pre-cleaning operations with the aim of producing a safe and wholesome product.

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Sample Processing

Millet grains were cleaned sorted and washed with tape water to remove traces of dirt, soaked for eight hours, drain and sundry. Soya beans seeds were cleaned sorted, washed, soaked overnight, strain, wash, remove the seed coat, sun dried and toasted at low heat until golden brown. Sesame seeds were cleaned, sorted, sprinkled with some water and pounded gently using mortar and pestle for easy removal of testa, washed, dried and toasted on low heat. Stones and sand were handpicked; other dirt and particles were separated from dried crayfish and toasted at low heat. Fresh moringa leaves were plucked, blanched, drained, and dried under shade. Orange fleshed sweet potatoes tubers washed, peeled, flaked and dried in hot air oven at 60^0C for 12 hours. Baobab fruit pulp was obtained in powdered form. Each of the samples was packaged separately in polythene bag and stored in refrigerator.

Formulation of the Composite Flour

Pearl millet was chosen as base for the study as it has been reported to be rich in nutrients and their intake can promote health as well as prevent and treat various non – communicable diseases (Bhat, Rao &Tonapi, 2018). The pearl millet, soybean, sesame seeds samples were blended at the ratios of 6:2:1 while cray fish, orange flesh sweet potatoes, dried moringa leaves and baobab fruit pulp were supplemented at the ratio 2:1:1:1 using varying proportions 10%(MBF), 15%(MCF), 20%(MDF) respectively in order to meet the protein and energy requirements for children of age 6–59 months (WHO, 2021) while millet alone served as control (MAF) (Table 1). The formulated samples were weighed with electronic chemical balance and milled using locally fabricated harmer mill. Each of the four milled samples obtained were subjected to sieving process with 1mm pore sieve size and packed for analysis.

Table 1: Formulation of millet-based composite mixed complementary foods

	MAF	MBF	MCF	MDF
Millet	100	78	67	57
Soybeans	00	9	17	25
Sesame	00	3	6	8
Crayfish	00	4	4	4
OFS	00	2	2	2
Moringa leaves	00	2	2	2
Baobab fruit pulp	00	2	2	2
Total	100	100	100	100

Nutrient Composition of Millet and Millet-Based Flours

Proximate compositions: The millet and millet-based composite flours were analyzed for moisture, crude protein, crude fat, crude fiber, and ash contents according to the Method described by Association of Official Analytical Chemists (AOAC, 2012). Total carbohydrate was determined by difference and energy content was determined using Art water factor (% Protein x 4, % Carbohydrate x 4, % Fat x 9) kcal/100 g.

Mineral content analysis: The amount of iron, calcium and zinc in the millet and millet-based composite flour was measured by an atomic absorption spectrophotometer according to the method of AOAC (2012) were expressed as mg/100 g.

Concentration (mg/100g) =

$$\frac{(\text{Slope} \times \text{Absorbance}) - \text{Y}) \times \text{D} \times \text{V}}{\text{Sample weight (g)} \times 10}$$

where *y* = intercept on *y*-axis; *D* = Dilution factor; 10 = a conversion factor from mg/kg to mg/100 g; *V* = volume of sample in ml.

In-vitro protein digestibility: Protein digestibility was measured using the method developed by Mert *et al* (1984) with modifications as reported by Gulati, Li, Holding, Santra., Zhang & Rose (2017). The powder (0.2g) was measured into 60ml of phosphate butter (pH 2.0) containing pepsin (1.5mg/ml) and digested for 2hrs at 37^{0}C with intermittent mixing. After 2hrs, the reaction was stopped by adding 6ml of 2N NaOH and content of the flask were centrifuged and pellet washed twice with distilled deionized water. The pellet was oven dried at 40^{0}C overnight and use to measure protein digestibility according to the following equation:

In-vitro protein digestibility

PD (%) = $\left[\frac{Ni - Nf}{Ni} \text{ x } 100\right]$, where N$i$ was the total concentration of Nitrogen in the sample before digestion and Nf was the concentration of Nitrogen in the recovered pellet after digestion

Determination vitamins: Vitamins A, B9, C, E were analyzed in duplicate using the high-performance liquid chromatography (HPLC) with the methods, developed and optimized by Wald, Nohr & Biesalsk (2018). Vitamin A was calculated based on retinol equivalent (RE) conversion factors (Scott & Rodriquez-Amaya, 2000) where: 1 RE = 1 µg retinol = 6 µg beta-carotene = 12 µg other carotenoids.

Determination of microbial load: The microbial load of the samples was analyzed for staphylococcus aureus, yeast, mould coliforms (Escherichia coli) and total plate count.

Functional Properties of Millet-Based Composite Flour

The bulk density was determined using the method of Akinsola, Opreh & Hammed (2014), water and oil absorption capacities of the millet flours were determined according to the method described by Onwuka (2005). Swelling capacity of the flour blends was determined using the modified method of: Swelling power (%) = weight of sediment paste (g)×100/ weight of sample (g) × (100/% Solubility).

Solubility (%) = weight of soluble starch (g) × 100/ weight of sample (g)

Preparation of Complementary Food

Method described by Olapade, Babalola & Aworh (2012) was adopted. The blends of breakfast cereal flour were thoroughly blended using a warring blender. Each blend (100g) was reconstituted with 25ml water and stirred into smooth slurry followed by addition of boiling water (100ml) and stirring to obtain consistent paste, which was sweetened sugar.

Sensory Analysis

The sensorial acceptability of the products was conducted by a panel of twenty semi-trained breastfeeding mothers and their children selected from staff and students of Federal College of Education Pankshin. Four coded samples of porridge were presented to each panelist at each session and the children remark was observed through facial expressions. The mothers assessed the sensory attributes of the porridge for appearance, consistency, flavour, mouthfeel and overall acceptability using a seven point Hedonic scale, with 1 and 7 representing the lowest score (dislike very Much) and highest score (like very much) respectively (Lim, 2011) for each of the food items prepared.

Statistical Analysis

The experimental design was completely randomized design. All determinations were performed in duplicates and subjected to one-way analysis of variance using SPSS (IBM version 20.0). The results were presented as means (±SD). Comparisons between mean were done using Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT). Values of $p < 0.05$ were considered as statistically significant.

RESULTS

Proximate Composition of Composite Mixed Complementary Food

The macronutrients and minerals composition of developed complementary foods are presented in Table 2, on a dry weight basis. The crude protein, fat, crude fibre, ash, carbohydrate and energy values of the complementary foods varied from 9.13 to 14.21g/100g, 5.38 to 7.79g/100g, 3.05 to 5.33g/100g, 2.17 to 3.41g/100g, 363.18 to 373.55.2kcal/100g respectively. Crude protein, crude fat, crude fibre, ash content and energy values of formulated samples were significantly (p< 0.05) higher than MAF (100% millet flour) while the moisture content and carbohydrate decreases 10.71 to 7.61, 69.56 to 61.65% respectively. This could be ascribed due to incorporation level of soybean, sesame and cray fish in the blends. The mineral elements in composite blends were Ca (3.237 – 6.909mg/100g), Fe (0.081 – 0.131mg/100g), Zn (0.026 – 0.034mg/100g). The observed variation in the mineral elements of these sample products could be attributed to the blending proportion of food materials. The concentration values for vitamins A, B9, C and E in the samples were 0.532 to 0.719, 0.350 to 0.589, 0.057 to 0.092, 0.325 to 0.441 respectively. Vitamin A values ranged from 0.540 to 0.719µg RE/100g for formulated samples while 0.532 for traditional sample were significantly different (p<0.05). The formulated complementary flour had the vitamin C values ranging from 0.060 to 0.092 while the traditional sample recorded 0.057 were significantly differently (p<0.05). The presence and adequacy of vitamin A and C in complementary food cannot be overemphasized. The values for folate (B9) varied from 0.350 to 0.589; vitamin E from 0.325 to 0.44 respectively. The observed variation in vitamins B9 and C values were significantly differently (p<0.05), and could be attributable to the addition of fruits and vegetables proportion in the blends. The higher values recorded for Vitamins A and E in the formulated products could be attributed to the fortification proportion of soybean and sesame seeds. Predicted values for protein digestibility ranged from 37.9% (100% millet) to 85.98% (composite blend). Significant (p<0.05) differences existed in the protein digestibility between formulated samples and the traditional sample.

Table 2: Nutrient composition of millet-based composite mixed complementary recipe and controls

PARAMETERS	MAF mean ± SD	MBF mean ±SD	MCF mean ±SD	MDF mean ±SD
Moisture Content (%)	10.71±0.42^{a}	7.91±0.08^{a}	7.77±0.08^{a}	7.61±0.25^{a}
Crude Protein (%)	9.13±0.09^{b}	13.13±0.08^{ab}	13.87±0.19^{ab}	14.21±0.13^{a}
Crude Lipid (%)	5.38±0.09^{a}	6.5±0.03^{a}	7.53±0.15^{a}	7.79±0.08^{a}
Crude Fibre (%)	3.05±1.03^{b}	5.68±2.43^{a}	5.56±0.76^{a}	5.33±0.49^{a}
Ash Content (%)	2.17±0.79^{b}	2.79±0.41^{ab}	3.00±0.08^{a}	3.41±0.42^{a}
Carbohydrate (%)	69.56±0.40^{a}	63.99±0.73^{ab}	62.27±0.29^{ab}	61.65±0.28^{b}
Energy (KCal)	363.18^{c}	366.98^{b}	372.32^{a}	373.55^{a}
Ca(mg/100g)	3.237±0.080^{c}	4.965±0.125^{b}	5.089±0.102^{b}	6.909±0.148^{a}
Fe(mg/100g)	0.081±0.016^{b}	0.093±0.019^{ab}	0.097±0.018^{ab}	0.131±0.018^{a}

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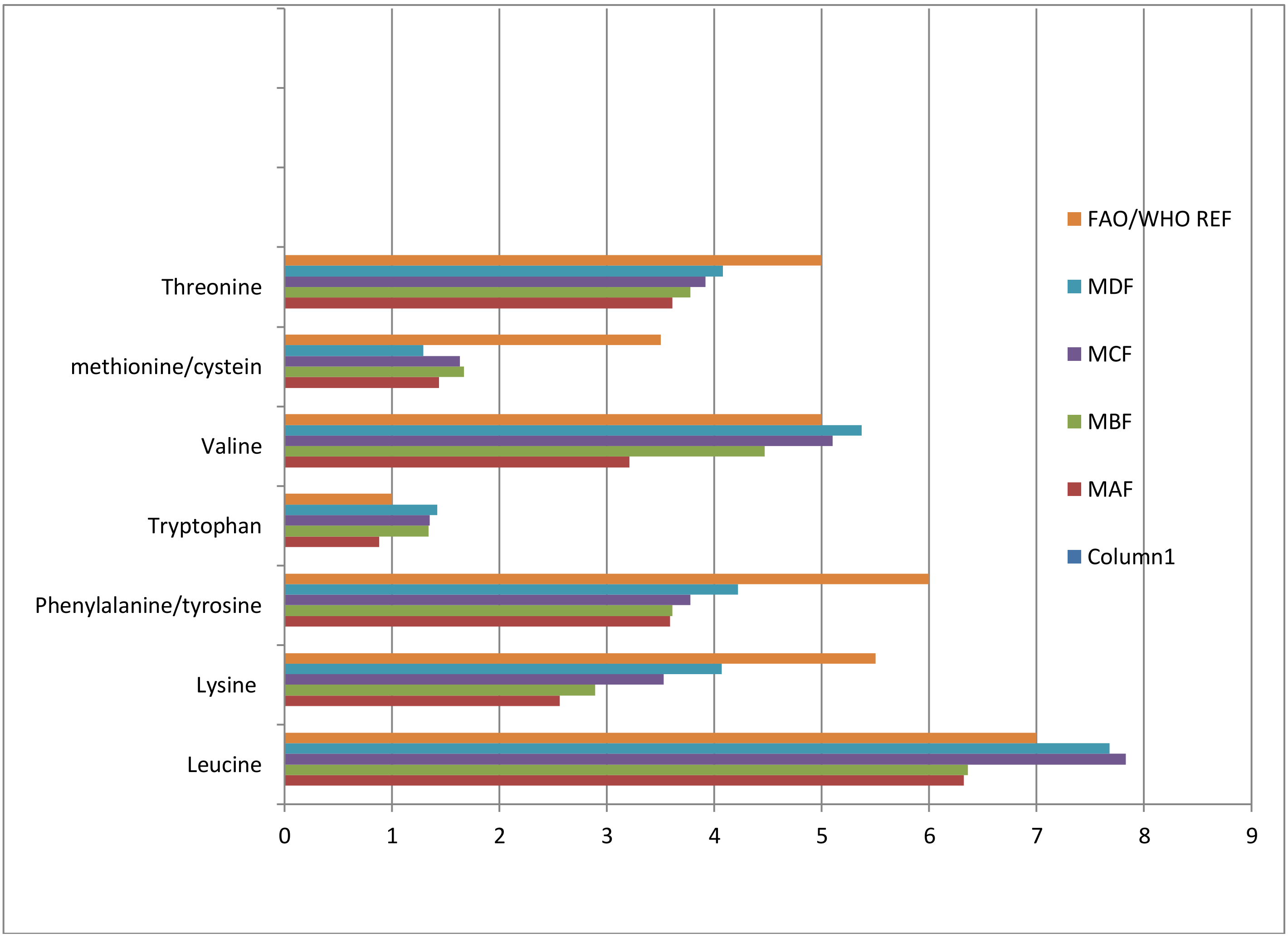
Zn(mg/100g)	0.026.±0.004[b]	0.027±0.004[b]	0.034±0.004[a]	0.034±0.004[a]
VIT A	0.532[b]	0.540[b]	0.629[ab]	0.719a
FOLATE	0.350[c]	0.426[b]	0.490[b]	0.589[a]
VITC	0.057[c]	0.060[b]	0.073[b]	0.092a
VIT E	0.325b	0.325b	0.363[ab]	0.441[a]
In vitro protein digestibility(IVPD)(%)	37.9	44.26	66.98	85.26

Mean values with the different superscript within the same row are significantly different from each other ($p<0.05$). Key: MAF=100% Millet flour, MBF=78% millet, 9% soybean, 3% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder; MCF= MBF=67% millet, 17% soybean, 6% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder; MDF= MBF=57% millet, 25% soybean, 8% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder

Essential amino acid profile (g/100g protein) of samples of millet-based composite mixed complementary food.



Values are mean of duplicate determination from each millet-based composite mixed sample. Key: MAF=100% Millet flour, MBF=78% millet, 9% soybean, 3% sesame, 4% crayfish, 2% moringa leafpowder, 2% OFS, 2% Baobab fruit pulp powder; MCF= MBF=67% millet, 17% soybean, 6% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder; MDF= MBF=57% millet, 25% soybean, 8% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder, FAO/WHO Reference.

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Figure 1. Essential amino acid profile (g/100g protein) of samples of millet-based composite mixed complementary food.

The amino acid profile of the millet and millet -based composite mixed complementary flour is presented in Figure 1. The concentration of essential amino acid Leucine, lysine, phenylalanine/tyrosine, tryptophan, valine, methionine/ cystein and threonine in the millet and millet-based composite mixed complementary samples ranged from 6.32 to 7.68, 2.56 to 4.07, 3.59 to 3.61, 1.42 to 0.88, 3.21 to 4.47, 1.44 to 1.29, 4.08 to 3.61 respectively. There was significant (<0.05) difference in the values of essential amino acids between traditional and formulated complementary compared to FAO/WHO Reference, which may be ascribed to increased supplementation levels of soybean, sesame, and crayfish in the blend. The observed values for lysine range from 2.89 to 3.61mg/gN, tryptophan 0.98 to 1.42mg/gN, threonine 3.61 to 4.08mg/gN, valine 4.44 to 5.37mg/gN increased as the rate of substitution increased. The leucine and methionine/cystein values decrease with increasing level of supplementation. This result show that there is a significant difference ($p<0.05$) existed in the range of essential amino acid in the formulated product.

Table 3: Physicochemical properties of millet-based mixed composite flour

Sample	Bulk density (g /ml)	Water absorption capacity (ml/100g)	Oil absorption capacity(ml/100g)	Swelling capacity (%)
MAF(control)	1.013 ± 0.045^{b}	134.42 ± 4.95^{b}	118.24 ± 2.18^{c}	7.70 ± 0.41^{a}
MBF	1.201 ± 0.087^{ab}	139.89 ± 4.84^{b}	135.54 ± 4.22^{b}	5.27 ± 0.83^{b}
MCF	1.441 ± 0.088^{ab}	155.60 ± 3.34^{a}	163.57 ± 8.95^{a}	4.57 ± 0.03^{c}
MDF	1.642 ± 0.070^{a}	161.04 ± 4.45^{a}	174.81 ± 6.49^{a}	4.45 ± 0.36^{c}

Mean Values are of duplicate determination. Mean values within a row with the same superscript are not significantly different ($p>0.05$). Key: MAF=100% Millet flour, MBF=78% millet, 9% soybean, 3% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder; MCF= MBF=67% millet, 17% soybean, 6% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder; MDF= MBF=57% millet, 25% soybean, 8% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder

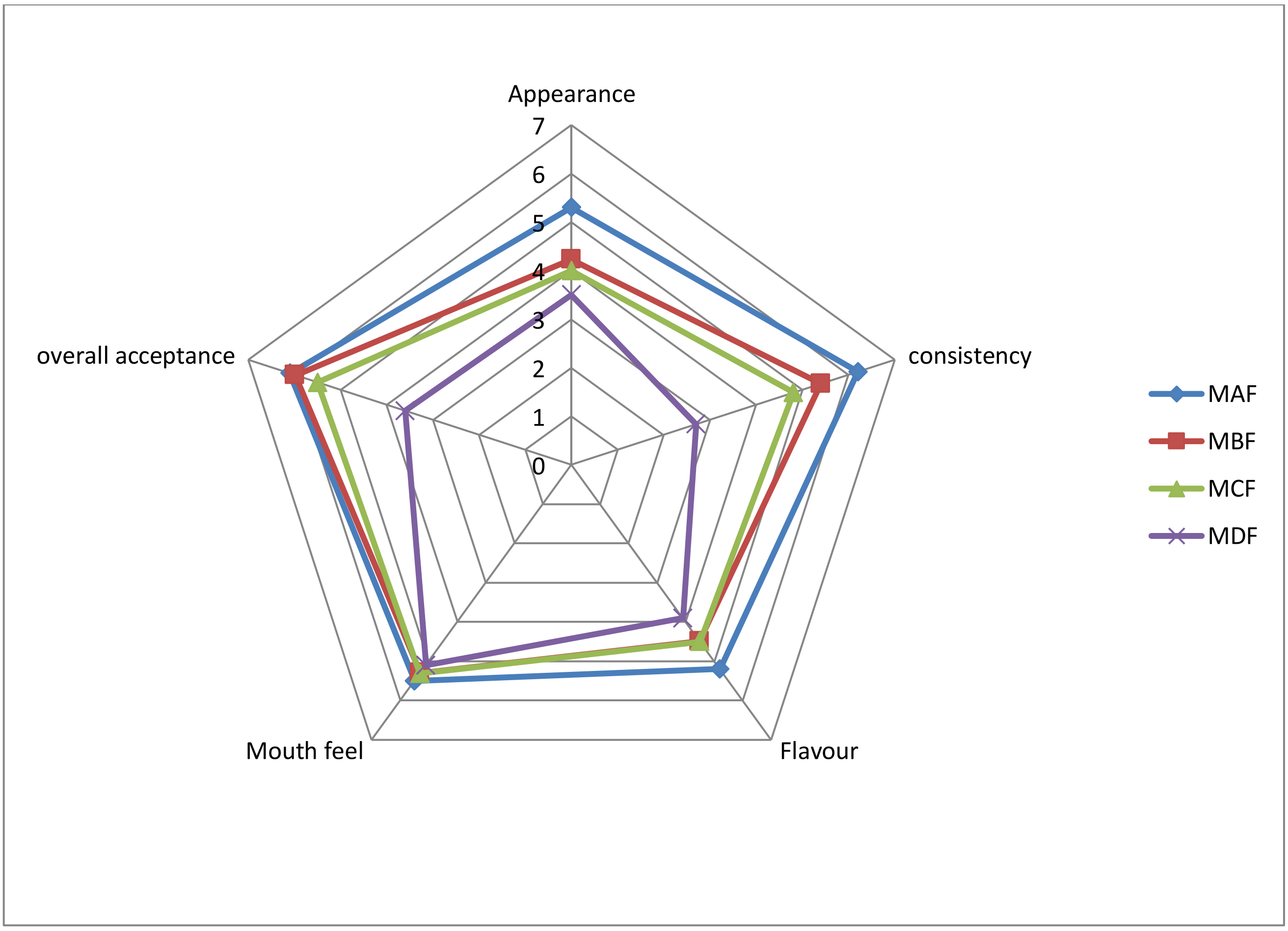
The functional properties (bulk density, water absorption capacity, oil absorption capacity and swelling capacity) of the complementary flour are presented in Table 3. The results vary from 1.013 g/ml to 1.642 g /ml, 134.42 g/ml to 161.04g/ml, 118.24 ml/100g to 174.81ml/100g,7.70% for bulk density, oil absorption capacity and water capacity respectively. For swelling capacity, the values ranged were 7.70 – 4.45%. There was significant difference ($p<0.05$) between the 100% millet flour and millet-based complementary composite mixed samples.

The comparison of the preference score by the panelist to all the parameters presented porridge overall choices from the millet (100%) and millet-based composite flour Figure 2. All the parameters showed a slight difference in panelist acceptance – appearance, consistency, flavor, mouth feel, overall acceptance as 6.1 to 4.7, 6.2 to 3.7, 6.5 to 4.3, 5.5 to 5.1, 6.1 to 4.6 respectively. All the porridges' sensory attributes obtained had similar scores within the range of 4 to 6 neither (like nor dislike to like moderately) except for sample (MDF) in consistency (3.7) (dislike moderately). The MAF (100%) was significantly ($p < 0.05$) rated highest in terms of appearance, consistency, flavour, mouthfeel and overall acceptability followed by MBF, MCF, MDF, respectively. However, the panelists rated the formulated complementary foods lower than the traditional complementary in all the sensory attributes.

Table 4: Bacterial composition of the complementary food blends

Microbial load(cfu/g)	Sample MAF	Sample MBF	Sample MCF	Sample MDF
Yeast and mold count	0.00^b	0.01^a	0.00^b	0.01^a
Staphylococcus aureus	0.01^a	0.00^b	0.01^a	0.00^b
Escherichia coli	0.00^b	0.01^a	0.00^b	0.01^a

The data are expressed as mean ± SD, with a sample size of n=3. Values marked with distinct superscripts within the same row indicate statistically significant differences ($p < 0.05$)



Key: MAF=100% Millet flour, MBF=78% millet, 9% soybean, 3% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder; MCF= MBF=67% millet, 17% soybean, 6% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder; MDF= MBF=57% millet, 25% soybean, 8% sesame, 4% crayfish, 2% moringa leaf powder, 2% OFS, 2% Baobab fruit pulp powder

Figure 2: Spiderweb of sensory evaluation scoring of millet-based composite mixed complementary diet

DISCUSSION

Millet-based composite mixed complementary food formulated were appreciably high in protein content and were capable of providing a daily protein requirement of the infant compare to traditional millet complementary food. This could be ascribed to the inclusion of soybean meal, sesame seed, moringa leaves and cray fish which studies have reported to be high in protein (Ibironke, Fashakin, &Badmus, 2012; Shiriki, Igyor & Genan, 2015; Mengeneh & Ariahu, 2022; Ariyo, Dudulewa & Atojoko, 2022). Findings of this study are in agreement with those of Tumwine, Atukwase, Tumuhumbise, Tucungwirwe & Linnemanu (2018) who reported an increase in the crude protein content due to the addition of skimmed milk powder and vegetables to millet flour. Increases in crude fat content of millet-based composite flour may be attributed to the addition of soybean and sesame seed meal, which are reported to contain high fat (Ayo, Nkama & Adewori, 2007; Ariyo et al; 2022). Results of this study are in agreement with the findings of Balasubramanyam & Lokesh (2000), Tumwine et al. (2019) who reported that supplementary foods prepared from cereals and pulses provide 10%–30% proteins and 350–380 kcal energy. The high protein and energy values of the present study food products could be advantageous over local complementary millet in supporting growth and development in children. The crude fiber values of millet-based composite products were comparatively higher than the traditional complementary food, this may be attributable to inclusion of moringa leaves and baobab fruit pulp (Shiriki et al., 2015; Nyam, Lau, & Tan, 2013). Rico, Martín-Diana, Barat, and Barry-Ryan (2007) reported that food preparations enriched with dried vegetables have higher values of fiber; and was within the ranged of 5 g per 100 g recommended by the Codex Alimentarius for complementary foods. The significant variations in ash content between the formulated samples and 100% millet were observed. The decrease in the carbohydrate content of the composite flour is attributed to the dilution effect of dried moringa leaves powder, baobab fruit powders and cray fish which are low in carbohydrates.

The essential minerals elements values like Ca, Fe and Zn in the millet-based composite were significantly ($p < 0.05$) higher than the values for the 100% millet flour sample. Increase in iron was not significant ($p > 0.05$). Addition of moringa leaves, baobab fruit pulp and sesame seeds powder to millet flour boosted the mineral content as they are reported to be rich in minerals (Adepoju, Bamigboye & Okafor, 2010; Shirika et al., 2015; Mounika et al.,2021; Ariyoet al., 2022). This implies that millet-based composite mixed were able to provide the desired amount for daily requirement that could improve growth and development in young children. The findings from this study are in agreement with those of Tumwine et al.(2018) who observed an increased in ash content of millet-based complementary diet fortified with skimmed milk powder and vegetables; and germinated wheat flour enriched with green gram and spinach (Mogra and Midha, 2013). Several studies have reported on deficiency of vital minerals like Ca, Fe, etc. in traditional complementary foods, which have resulted into increase in micronutrient deficiency among children in many parts of developing countries (Ferguson, Chege, Kimiywe, Wiesmann & Hotz, 2015; Abeshu, Lelisa &Geleta, 2016).

The vitamin A content of fortified samples had values ranging from 0.540 to 0.719mg/100g were significantly higher ($p<0.05$) than the unfortified samples and may be ascribed to the retinol in crayfish, carotenoids content in moringa leaves and orange fleshed sweet potatoes. Findings from this study were in agreement with several studies who reported an increase in vitamin A content after supplementing with moringa leaf powder (Shirika et al.,2015), skimmed milk powder and OFSP in millet–based complementary diet (Tumwine et al.,2019), maize-soybean complementary food fortified with crayfish, bonga fish and carrot flours (Okpalanma, Ukpong, Chude & Aba,2022). The higher vitamin C values in the formulated samples could be attributed to inclusion of OFSP, moringa leaves and baobab fruit pulp powder which are rich source of vitamin C in the form of ascorbic acid (Taylor, Adeola& Kruger, Ferruzzi & Hamaker, 2021). The finding in this study corroborate with 0.64 – 0.94mg/100g reported by Oyegoke, Adedayo, Fasuyi & Oyegoke (2018) for complementary flour formulated from yellow maize, soybean, millet and carrot composite flour. The folate content in both the samples were not significantly (>0.05) different. Folate is critically needed to produce healthy blood cells during period of rapid growth. The higher values observed for vitamin E was attributable to increased supplementation level of soybean and sesame seeds used. Vitamin E is critically needed to serve as antioxidant, keep immune system strong and help to form red blood cells. Increasing digestibility of protein with level of supplementation (Table 2) may be ascribed to the higher digestibility of crayfish. A high range of 77% to 98% digestibility in insect protein has been

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

reported (Ramos-Elorduy, Pino-Moreno, Prado, Perez, Otero,1997). The results of this study are similar to the results reported by Oti & Akobundu (2008), who reported high digestibility for cocoyam-soybean-crayfish mixture from 69.70 to 75.50%. Inclusion of crayfish in complementary food result in optimal nutrient composition suitable to provide caloric value for sustenance, met recommended dietary allowance (RDA) and sufficient to eradicate protein energy malnutrition (PEM) (Ibironke, Fashakin & Ige, 2014).

It is well established that cereal-based and other plant-based complementary foods are low in protein, especially lysine, tryptophan, threonine and biological values; therefore failed to provide sufficient nutrients for the growth and development of infant and young children (Ijarotimi and Keshinro 2012). The increased in values of essential amino acids with increasing supplementation in the form of convenience foods for children can be proven as a cost effective and easy approach that offer variety, convenience and quality food that combat micro nutrient deficiencies. Similar results have been reported by Ijarotimi, et al. (2022) on combination of quality-protein-maize, soybean and moringa (seed and leaf) flour and a therapeutic-complementary-food from locally available food materials with improved level of essential amino acid. Tryptophan is particularly required for infants' normal growth and development and abundantly present in the formulated complementary foods (Valentine, Morrow, Reisinger, Dingess, Morrow & Rogers, 2017).

Functional properties of complementary foods are very important, especially for growing children. Bulk density (BD) is generally affected by particle size and density of the flour and it is very important in determining the packaging materials and quantity of the powdery food for storage and transportation (Ijarotimi and Keshinro, 2013). High bulk density of flour suggests their suitability for use in food preparations, which can help to reduce paste thickness as an important factor in convalescence and child feeding. The observed variation in the water absorption capacity (WAC) among samples may be due to different protein concentration, their degree of interaction with water and conformational characteristics (Butt and Batool, 2010). A weaning food with low water absorption capacity and bulk density is suitable for reduce microbial activities and extended shelf-life (Mbata, Ikenebomeh & Ezeibe, 2009). The variation in the oil absorption capacity (OAC) could be attributed to the increasing level of incorporation of the fortificant which physically bind protein and fat by capillary attraction of both hydrophilic and hydrophobic parts (Aremu, Olaofe & Akintayo, 2007). High swelling capacity of composite flour gives it an advantage of being used as a thickener in liquid and semi-liquids foods since the flours has the ability to absorb water and swell for improve consistency.

The microbial count was minimal in every sample of complementary food, suggesting they are safe for consumption. The yeast and mold count fell below the figures documented by Ani, Alfa, Adeola, Ajuzie, Ajani, Omotoye & Akinlade (2022) and Nigusset, Hadero & Yoseph (2019). Standards for yeast and mold in complementary foods have been established to be less than 2.48 log cfu/g for ready-to-eat infant foods and 3 log10 cfu/g for foods requiring cooking (CAC, 2008). The presence of E. coli and Staphylococcus aureus was not observed. This aligns with the results reported by Ani et al (2022) and Laryea, Wireko-Manu &Oduro (2018). According to the standards outlined by CAC (2008), the E. coli count in complementary foods should ideally be zero.

Overall acceptability of the formulated complementary foods were significantly ($p<0.05$) rated lower when compared to 100% millet complementary food by the panelists. This could be attributed to the familiarity ofthe panelists with the product. Seemingly the panelist were used to millet porridge and addition of other food resources made it unique and less attractive. There was no significant difference in preference among under-five-year-old children between the fortification rates on dry weight. Low acceptability of foods enriched with edible insects and other food resources have been previously reported (Aboge, Orinda & Konyole, 2021; Maecel, Chacha & Ofoedo, 2022). The appearance of the porridge is good when the soybean ratio is low and the flavor of the product is better. The mouthfeel is high when the amount of soybean/sesame was optimum. The nutty and slightly sweet flavor of millet and soybean combine with the earthly vibrant green colour of moringa's fine powder, and the tangy natural hues of baobab pulp create a

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue IV April 2024

complex and enjoyable visual and taste experience responsible for acceptance of all the samples.

CONCLUSION

The incorporation of millet-based composite mixed meal holds great promise as a nutritional intervention for malnourished children. The diverse array of nutrients, improved protein quality, functional and organoleptic properties, and positive effects on gut health make it a valuable strategy for addressing nutritional deficiencies especially among under five years old children in developing countries. However, the formulated samples fall below recommended standards for rehabilitation, indicating that the effectiveness for the intervention may hinge not only solely on its nutritional composition but also on factors like cultural acceptability, accessibility and affordability. Further research and implementation studies are necessary to evaluate the enduring effects, enhanced formulations, and guarantee adoption.

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