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EVALUATION OF THE NUTRITIONAL QUALITY OF COMPLEMENTARY FOOD FORMULATED FROM LOCALLY AVAILABLE GRAINS AND *MORINGA STENOPETALA* IN SOUTHERN ETHIOPIA

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ABSTRACT

Moringa stenopetala is an indigenous multipurpose tree grown in the back yard and crop lands with nutritional and medicinal value. This study aimed to produce *M. stenopetala* leaf powder supplementation on the macro and micronutrient nutritive values of maize–soybean–chickpea and sorghums–soybean–chickpea food formulations for use as a complementary food for infants and young children. The dried leaves of *M. stenopetala* and grains were ground and sieved to appropriate particle size. Proportions of grain flour and *M. stenopetala* leaf powder admixed in the formulations were determined using Nutri-Survey-Linear-Programming Software. Fourteen formulations were made from unprocessed and processed grains supplemented with 5% and 10% *M. stenopetala leaf* powder. A preferred ratio was selected based on the nutritional value (energy and protein) and sensory evaluation while using two unfortified formulations as control. Food analysis was performed with standard methods. Analysis of variance (ANOVA) with Turkey test was conducted to investigate the mean difference of nutritional values and sensory evaluation among different formulations. The crude protein and ash contents of the diets increased significantly with *M. stenopetala* leaf fortification and energy content. There was a significant decrease in carbohydrate content in the formulation of 10 and 12 compared to the controls as the percentage level of *M. stenopetala* leaf powder supplementation increased. This could be due to substitution effect of *M. stenopetala* as evidenced by the nutritional composition of the individual ingredients. The fat content of the formulation 10 and 12 that were selected by sensory evaluation was relatively higher (10.6%) than the control blend (9.85%) but not statistically significant, which fulfills the recommended dietary allowance by FAO/WHO. The product development study showed that the addition of *M. stenopetala* leaf powder to locally available food ingredients such as sorghum/maize, soybean and chickpea enhances nutrient value, such as energy, ash, protein, potassium and fat contents. Therefore, blending *M. stenopetala* with locally available food crops could be an option to mitigate protein–energy malnutrition (PEM) and micronutrient deficiency by improving traditionally used staple foods.

Key words: *Moringa stenopetala,* complementary food, malnutrition, sensory evaluation, micronutrient, bioavailability

INTRODUCTION

Protein Energy Malnutrition (PEM) and micronutrient deficiencies are the widest spread forms of malnutrition worldwide especially in developing countries including Ethiopia, with infant and pre-school children being particularly vulnerable. Different strategies have been employed, such as school feeding programs, nutrition education, exploring underutilized crops and even campaigns to give children high doses of vitamin A. One of the major problems with many of these approaches is the dependence on imported solutions which are not sustainable in the long- term. Progress quickly stops once the program winds up [1]. It is important to address this problem from a more holistic multidisciplinary approach through careful selection of locally available, inexpensive raw food materials.

The easiest and sustainable way of overcoming PEM and micronutrient deficiency for the vulnerable groups, especially young children, is the blending of locally available foods. The products should be high in protein, inexpensive and with high quantity/quality of micronutrients, to provide alternatives to the more expensive imported foods. The leaves, seeds and flowers of *Moringa stenopetala* (Baker f.) Cufod. have great nutritional and therapeutic value. The leaves of *M. stenopetala* are outstanding as a source of vitamins A, B group and C (when raw) and are among the best sources of minerals such as potassium, iron, calcium, phosphorus and zinc. They are also excellent sources of protein, which helps to overcome protein energy malnutrition, but are poor sources of carbohydrates and fats [2,3]. Thus, *M. stenopetala* leaves are one of the nutritious plant foods available in Ethiopia. It is widely grown and cultivated in parts of Ethiopia. In the Gamo and Gofa lowlands, Konso, Wolaita, Dherashe, Burji, Amaro and other moringa growing *woredas* of southern Rift Valley of Ethiopia, the leaves of moringa trees are used to prepare the famous local traditional food "*Kurkufa, Fosose* and *Dama.*" The leaves are also used to prepare the local drink "*Cheka*" [3,4]. The nutritional profile of the traditional food is unknown, and enhancing its nutritional content is valuable for the community. Also, the supplementation of *M. stenopetala* on a locally available maize/sorghum–soybean–chickpea food formulation, used as a complementary food, makes it rich in carbohydrates, fats, proteins and minerals [1].

The aim of this study was, therefore, to investigate the effect of *M. stenopetala* leaf powder supplementation on the macro and micronutrient contents of maize–soybean–chickpea and sorghums–soybean–chickpea food formulations. This will explore the possibility of its use as a complementary food for infants and young children to fill the calories, protein and micronutrient gap between the total nutritional need of the young child in addition to the amount provided by breastmilk.

MATERIALS AND METHODS

Collection of Food Materials

Maize (*Zea mays*), soybean (*Glycine max*) Wageye variety seeds, sorghum, chickpea and *Moringa stenopetala* leaves were used for the study. The maize, chickpea, sorghum and soybean were collected from Arba Minch Agricultural Research Institute and Bishoftu Agriculture research center. Leaves of *Moringa stenopetala* (Baker f.) Cufod.

were collected between February 2018 and February 2019 from the agro-forestry experimental site of Arba Minch University, Arba Minch located at 6^{O} 01'59" N and 37^{O} 32'59" E with an altitudinal range of 1100-1650 m above sea level at a distance of 505 km away from Addis Ababa, Ethiopia.

The local meals "*Kurkufa*/ *dama"* and "*Fosose*" were collected during the community-based cross-sectional study from some households of the study sites (Konso and Derashe). The samples were used for proximate composition analysis. Moringa- based dishes such as *kurkufa/dama and fosose* are prepared by mixing maize or sorghum flour and leaves of moringa.

Processing of Maize, soya, chick pea and sorghum flour
Sample materials were cleaned manually to remove husks, damaged grains, stones, dust, light materials, glumes, stalks, undersized and immature grains and other extraneous materials.

Processing of raw grains: The sorted maize, soya, sorghum and chickpea were washed then dried in hot air oven at a temperature of 60ºC. The cereals were then milled with an electrical mill, sieved through 150µm mesh. The powder sample was packed in a sealed airtight plastic container and stored at room temperature before formulations and chemical analysis.

Soaking: The sorted maize, soya, sorghum and chickpea were soaked in water for 2 to 3 days. The soaked grains were then decanted followed by dehulling (applicable only for soyabean) and dried in hot air oven at a temperature of 60^{O}C. The sample was milled after drying and sieved through a mechanical sieve with 150 µm mesh. The flour with the moisture content of <10% was packed in polyethylene bags and stored at room temperature until used for formulations and chemical analysis (Figure 1).

Roasting: The sorted maize, soya, sorghum and chickpea were cleaned, washed and soaked in water for 24 hours. It was then oven-dried in a hot air oven at a temperature of 60^{O}C. After drying, the sample was first roasted at 120^{O}C until the desired color was achieved (up to 10 minutes). It was then milled with an electrical mill, sieved through 150µm mesh and the milled sample was then packed in a sealed air-tight plastic container and stored at room temperature prior to formulations and chemical analysis (Figure 1).

Moringa stenopetala leaf flour
M. stenopetala leaves were sorted, washed with distilled water and dried at room temperature. The dried moringa leaves were milled using a laboratory blender, sieved through a 0.4mm wire mesh. The powdered *M. stenopetala* were then sealed in airtight container and stored at room temperature before formulations and chemical analysis (Figure 1).

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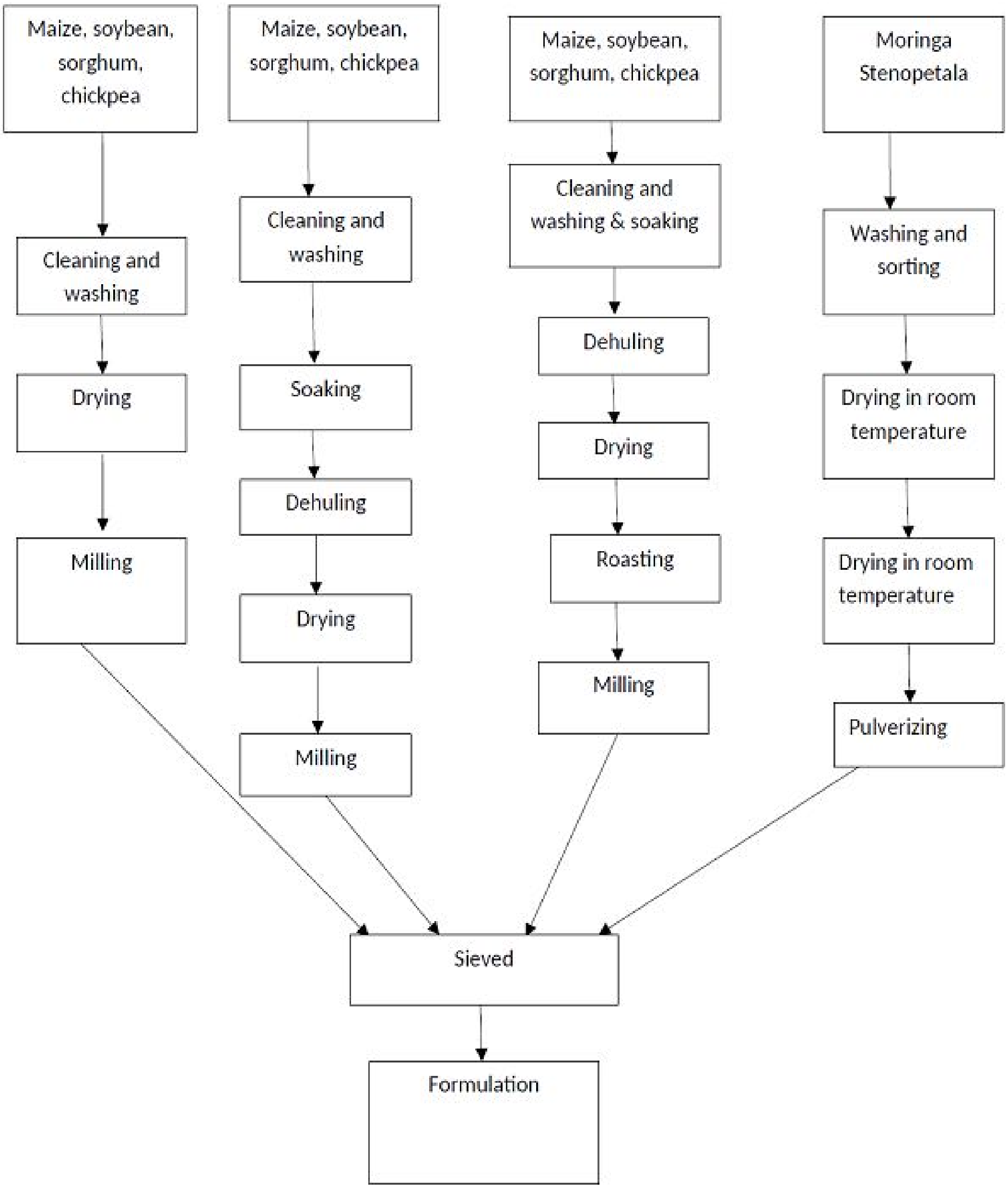

Figure 1: Flow diagram of the preparation for different formulation

Food Formulations

Proportions of grain flour and *M. stenopetala* leaf powder in the formulations were determined using Nutri-Survey-Linear-Programming Software. This facilitates obtaining their protein content in the course of material balancing [5] to give at least 16g protein/100g food as recommended by the protein advisory group [6] for infant and young children diets in different combinations [7]. A total of fourteen formulations were made from unprocessed and processed grains supplemented with 5% and 10% *M. stenopetala* powder. A preferred ratio was selected based on the nutritional value (protein and energy) and sensory evaluation while using two unfortified formulations as control.

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Porridge preparation for sensory evaluation

All samples were prepared with similar proportions of water to flour ratio of 3:1, and all samples were made in duplicate. The formulation recipe flour was mixed properly until it became uniform as observed by the naked eye. The blended flour was added to boiled water and cooked for 10 minutes by stirring occasionally.

Experimental design

Simple mixture design was used to determine the effect of blends of maize flour, soybean flour, chickpea, sorghum and M. *stenopetala* powder. The proportion of maize varied from 40% to 50%, sorghum from 40% to 50% and moringa leaf powder from 5% to 10%, keeping soybean flour and chickpea constant in the proportion of 30% and 20%, respectively; while no moringa supplement with 50% maize, 30% soya and 20% chickpea as one formulation; 50% sorghum, 30% soya and 20% chickpea as the second formulation were used as a control (Trial 5 and Trial 6). The ingredients were prepared in duplicate and analyzed for statistical validity.

Chemical Analysis

Proximate Analysis

The nutrient composition of the food sample was determined in duplicate using the standard procedures of the Association of Official Analytical Chemists [8]. Five grams of each formulated complementary foods were used to determine the moisture content in a hot-air circulating oven. Ash was determined by incineration of 2 grams each of the food samples in a muffle furnace at 550ºC [8]. Crude fat was determined by exhaustively extracting 2 grams of each sample in diethyl ether in a Soxhlet extractor. Protein was determined by the Kjeldahl method (Method No 978.04) using 0.5 grams each of the formulated complementary foods. Crude fiber was determined after digesting 2 grams each of fat-free complementary food samples in refluxing 1.25% sulfuric acid and 1.25% sodium hydroxide [8].

Carbohydrate Determination

The carbohydrate content was determined by subtracting the summed-up percentage compositions of moisture, protein, lipid, fiber and ash contents from 100 % [100 %-(moisture% + protein % + fat % and ash %)] [9].

Gross Energy

Energy was determined by calculating fat, carbohydrate and protein content using the Atwater's conversion factor; 4.0 kcal/g for protein, 9.0 kcal/g for fat and 4.0 kcal/g for carbohydrate [10].

Minerals Determination

Association of Official Analytics Chemistry (AOAC) methods were used to determine mineral compositions of the samples [8]. One gram of sample was ashed and digested with hydrochloric acid, filtered and the filtrate in a 50ml volumetric flask was loaded to Atomic Absorption Spectrophotometer (mode 7000 Shimadzu, Japan). Sodium and potassium values were determined using a Flame photometer. The phosphorus was determined spectrophotometrically using the molybdate method.

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Phytate content determination

Phytate was determined using a method by Latta and Eskin [11] as modified by Vaintraub and Lapteeva [12]. Freshly prepared 10ml of 2.4% HCl was added into 0.0300g sample to extract for 1 hour at room temperature and then centrifuged for 30 minutes at 3000 rpm. A clear solution was used for phytate determination. In a 3ml extract solution, 2ml of wade reagent was mixed on a Vortex for 5 seconds. The absorbance of the sample solution was measured at 500nm using UV-VIS spectrophotometer (Beckman DU-64spectrophotometer). A calibration curve solution prepared with 0, 5, 10, 20 and 40 µg/ml of phytic acid (analytical grade sodium phytate) in 0.2N HCl. One milliliter of the Wade reagent was added to 15ml test tube containing 3ml calibration solution, and the sample extract solution was mixed on a Vortex mixer for 20 seconds. The mixture was centrifuged for 10 minutes and the absorbance of the solution both the sample and standard were measured at 500nm by using deionized water as a blank. Absorbance versus concentration calibration curve was made and the slope and intercept were used for calculation. The concentration of phytate was calculated using phytic acid standard curve and results were expressed as of phytic acids in mg/100g fresh weight.

Tannin content determination

A 1.000g fresh sample was weighed in screw cap test tubes (in duplicate). Ten milliliters of 1% HCl in methanol were added to sample and extracted with a mechanical shaker for 24 hours. Then, the extraction was centrifuged for 5 minutes at 1000 rpm. One milliliter of extracted solution was taken and mixed with 5ml of Vanillin-HCl reagent (prepared by combining the equal volume of 8% concentrated HCl in methanol and 4% Vanillin in methanol). A standard calibration curve with D-catechin for condensed tannin determination, D-catechin (40 mg) was weighed and dissolved in 1L of 1% HCl in methanol, which it uses as stock solution. The stock solution 0, 0.2, 0.4, 0.6, 0.8 and 1ml was taken in test tubes and the volume was adjusted to 1.0 ml with 1% HCl in methanol for each test tube. Then, vanillin-HCl solution (5 ml) was added into each test tube.

After 20 minutes, the absorbance of the solutions and the standard solution were measured at 500 nm by using de-ionized water as blank, and the calibration curve was constructed from a series of standard solution using excel Version 16. Concentration of tannin was read in mg of D-catechin per gm of sample [13].

Sensory evaluation

The fourteen formulations were properly mixed and ready for nutrient analysis. Out of the fourteen formulations, seven products were selected based on the energy content of the formulation, which were used for sensory evaluation. The sensory analysis was measured by acceptability and preference tests employing 5 point hedonic scale through panelists and willing mothers based on Shrestha and Noomhorm [14]. Complementary food prepared as thick porridge for sensory analysis from both grain-based and supplemented moringa powder-based newly developed complementary food was tasted by a panel of judges. The seven formulations were used in duplicate to prepare the porridge in a proportion of water to flour ratio of 3:1 then cooked and ready

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for sensory evaluation. The prepared porridge samples were presented to 30 mother panelists. The panelists were selected from the staff of the Ethiopian Public Health Institute (EPHI), Addis Ababa, Ethiopia. The panelists were taken through the fundamental information about the purpose and objective of the test. The selection of panelists was based on essential requirements of a panelist, such as availability during the study period, experience on sensory evaluation in previous products, and willingness to participate. The health status of the panelists was also considered during panelist selection (not suffering from colds and allergies that affect their sensitivity to the product). The panel members were seated in an open well-laminated kitchen room and asked to rate the paste samples based on color, aroma, taste, texture and overall acceptance.

Statistical Analysis
The nutrient values of the formulation and sensory attribute score were analyzed using SPSS software version 20.0. Analysis of the mean and standard deviations were carried out. Analyses of variance (ANOVA) of the experimental result were also performed to determine significant differences between the means using Tukey Test at $P < 0.05$.

Ethical Consideration: This study's scientific and ethical approval was obtained from Institution Review Board of Ethiopian Public Health Institute (IRB of EPHI), approval letter EPHI 6.13/796.

RESULTS AND DISCUSSION

Nutrient and energy contents of traditional food, Control and Formulation
Results from the community-based cross-sectional study revealed that the majority consumed a handful or more parcels of moringa branches leaf daily, which is about 1kg and above. It could be of great importance in fighting the long overdue malnutrition problem in Ethiopia with appropriate processing. The results for the mean value of proximate composition analysis of *Kurkufa* collected from Konso and Derahse were moisture content 64.8 ±1.5 *versus* 67.2±0.6 %w/w, crude fiber 5.5 ±1.2 *versus* 8.1±4.1 %w/w, fat 4.5 ±0.4 *versus* 5.1±1.9 %w/w, ash 3.6 ±0.3 *versus* 4.1±0.7 %w/w, potassium 636.1±22.4 *versus* 614.9±99.4 mg/100g, sodium 410.7±37.3 *versus* 493.9±93.5 mg/100g and phosphorus 247.31 ±9.7 versus 232.2±1.530.6 mg/100g. *Fosose* was only collected from the households of Derashe study sites. Proximate composition analysis results showed moisture content 73.8 ±1.6 %w/w, crude fiber 4.3 ±0.2 %w/w, fat 4.0 ±0.9 %w/w, ash 3.3 ±0.2%w/w, potassium 715.9 ±0.3 mg/100g, sodium 198.8±155.8 mg/100g and phosphorus 313.6 ±146.5 mg/100g (Table 1).

Nutritive values of *Kurkufa/ Dama* and *Foso*se were analyzed to determine the nutrients gap and considering *M. stenopetala* based formulation as a complementary food for infant and young children.

The focus of this study was to explore the use of sorghum, maize, soybean, chickpea flours and *M. stenopetala* leaf powder as potential food ingredients that can add value to complementary foods. Malnourished young children are at a higher risk of mortality and morbidity due to protein–energy malnutrition and micronutrients. Malnutrition in children is more likely to face lifelong cognitive and faltering physical development and chronic health problems [15]. Children under two years of age are vulnerable to malnutrition [16]. In order to mitigate malnutrition in the country, different food-based approaches are needed, one of them could be to produce a cost-effective complementary food from local ingredients such as cereals and legumes with the supplementation of *M. stenopetala* leaves, which is cultivated in different parts of Ethiopia and used to make the indigenous foods '*Kurkufa/ Dama*, and *Fosose* in the Southern Nations, Nationalities, and Peoples' Region (SNNPR).

Tables 2 and 3 illustrate the proximate and mineral contents of the various ingredients that were used for different formulations in this study. *M. stenopetala* leaf powder had the highest crude fiber and ash contents of 13.9% and 9.2%, respectively and is rich in sodium and iron. It also had the highest concentration of condensed tannin and phytate that could hinder the bioavailability of minerals like iron and zinc. Roasted soya bean had the highest crude protein and fat content of 38.4% and 24.7%, respectively, while roasted maize and sorghum had the highest carbohydrate content of 73.2%, and soaked soya had the highest potassium content value of 2545.9 mg/100g. Roasted maize had the highest content of zinc (7.7 mg/100 gm).

A formulation of cereals, legumes, oil-seed and moringa leaf powder ingredients was expected to give balanced nutrient content in complementary foods in terms of macro- and micro–nutrients. The proximate composition of the food formulations is presented in Table 4. Formulation Trial 12 had the highest content of energy (404.6 kcal/100gm). There was no difference among formulation trials in moisture and fat contents. However, formulation trial 4 had highest concentration of protein (25%) and formulation trial 11 had highest content of ash (3.8%). Formulation trials 6 and 1 had the highest carbohydrate and fiber content, respectively. Comparing the raw and control formulation (Trial 1 to Trial 6), the energy, protein and ash content increased significantly with moringa based formulation. But, carbohydrate and fiber content are decreased in the formulation because of the substitution effect as evidenced by moringa have low carbohydrate content. The moisture content of the blended flour was in the limit of FAO/WHO recommended value (<10%) and ranged from 6% to 8.7%, which is a good indicator for long shelf life of a product since, moisture has an implication in terms of the consistency/texture and microbiological quality of food [17]. Complementary foods should be free of microbial contamination that might expose children to diarrhea. Olaoye *et al*. [18], reported that lower moisture content in food has an effect to prevent microbial contaminations. This finding agreed with the study of Nwosu *et al*. [19] and Abraham *et al*. [20] which reported decreasing moisture content as moringa powder level increased in their complementary food prepared from maize flour, soybean flour and moringa leaf powder [20]. The fat content of the formulations (Trial 10 and 12) that were selected by sensory evaluation was relatively slightly higher (10.6%) than the control blend (9.8%) but not statistically significant, which fulfills the recommended dietary allowance by FAO/WHO (>6%). Dietary fat provides energy, essential fatty acids, transport fat soluble vitamins (A, D, E and K) and promotes food palatability [17, 21]. Abraham *et al*. [20] reported an increase in fat content in his maize–soybean–moringa bread as the level of *M. stenopetala* leaf powder increased in the blend [20].

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There was an increase in protein content with an increasing level of *M. stenopetala* leaf powder in the selected formulation as compared to control. This could be due to the substitution effect caused by the high protein content of *M. stenopetala* leaf powder. Abraham *et al.* [20] reported that *M. stenopetala* leaf powder can increase the protein level in bread produced from wheat flour, soybean flour and *Moringa olifera* leaf powder. The protein value obtained in this formulation fulfills the requirements of FAO/WHO (that is, 16%).

The formulation Trial 10 and 12 showed significantly ($P < 0.05$) higher ash content (3.2% and 3.5%) than control (0.5% and 0.6%) (Table 4). The increase in ash content from 0.5% to 3.50% indicates an increase in mineral content of the formulations. Minerals are important to perform functions necessary for life. They have a role in nervous system functioning, other cellular processes, water balance, and structural (example, skeletal systems).

There was a slight decrease in carbohydrate content in the formulation (Trial 10 and 12) compared to controls. As the level of *M. stenopetala* leaf powder supplementation increased, the carbohydrate content of the formulation decreased. The differences observed could be due to low carbohydrate content in *M. stenopetala* leaf powder as compared to cereals and legumes (Table 2). Abraham *et al*. [20] reported a slight decreasing (about 1%) effect in his bread made from maize flour, soybean flour and *M. stenopetala* leaf powder [20].

The fiber content of the formulation decreased significantly ($p < 0.05$) from an average of 4.7% in control to 2.6% in Trial 10.

During complementary foods preparation one should consider the amount of fiber content in it, since a child's intestine is not mature enough to handle high fiber content [22]. Fiber may affect the absorption of various nutrients in diets with marginal nutrient content [22].

The energy content of the selected product was significantly higher than control. Still, the energy is higher than that recommended by WHO/FAO, where minimum energy requirements for infants (6–8 months of age) of developing countries is 200kcal and for 9–11 months of age is 300kcal. However, for 12–23 months, it is below the requirement, that is 550 kcal per day.

Table 5 demonstrates sodium, potassium and phosphorus concentrations. The highest concentration of sodium and phosphorus was found in raw formulation Trial 1 and control Trial 5, respectively. The highest concentration of potassium was found in formulation Trial 12 than the controls ($P<0.05$).
Table 6 shows the concentration of micronutrients (iron and zinc), antinutritional factors (phytate and tannin), phytate: iron molar ratio and phytate: zinc molar ratio. Iron concentration of the raw and control formulation was relatively higher than the processed formulation. Like the findings of this study, a study by Lestienne *et al.* [23] on the effect of soaking whole cereal and legumes seeds on iron and zinc content,

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showed a reduction of iron and zinc in both cereal and legumes after soaking, in addition to this, a study by Luo and Xie showed that, after soaking, the iron and zinc contents of the faba bean was significantly lower than raw faba bean ($P<0.05$) [24]. This happened due to leaching of iron and zinc ions into the soaking medium.
Still, there was no difference in zinc content among formulations, and no difference in phytate: iron and phytate: zinc molar ratio contents among different formulations due to the reduction of iron and zinc in soaking process as observed in Lestienne *et al*. [23]. On the other hand, processed formulation substantially had a decrease in tannin and phytate content than raw and control formulation. Also, in the selected formulation, the content of tannin and phytate were significantly reduced. This is due to food processing that may enhance the bioavailability of iron and zinc in the selected product (Table 6).

Sensory evaluation finding

Among the 14 formulations, seven formulations were selected based on energy and protein contents. As a result, codes for sensory evaluation were represented as follows: code 1 (Trial 2), code 2 (Trial 4), code 3 (Trial 5), code 4 (Trial 8), code 5 (Trial 10), code 6 (Trial 12) and code 7 (Trial 13). For sensory evaluation porridge from grains and moringa powder were prepared. Moringa-supplemented porridges were noticeably greener in color than raw and control, because moringa leaf powder had a green color. There was no significant difference among formulations in terms of color, aroma, texture and taste. However, in overall acceptability, Trial 5 and 6 were significantly different from other moringa-based and control porridges ($p < 0.05$). Moringa-based porridges had a low mean score in color and taste compared with control porridge. But in terms of odor and texture, the highest score was observed in codes 5 and 6 (Trials 10 and 12) with the overall acceptability (Figure 2). Based on sensory evaluation, trial 10 (code 5) and trial 12 (Code 6) were selected by overall acceptability result.

Different ingredients (maize, sorghum, chickpea and soyabean and *M. Stenopetala leaf powder*) in each formulation affected the recipe and the different sensory attribute ratings (Figure 2). Even though there were not any significant differences among formulations in color, odor, texture and taste, the results of sensory evaluation suggest that the slight bitter taste of moringa was retained irrespective of the fact that other ingredients were included in different blends. In addition, it was observed that incorporation of moringa in the porridges resulted in a greener color. Therefore, there is a need to mask the bitter taste and unfamiliar color of moringa based formulation porridge. This could be achieved through recipe modification, for example, by adding fruit extracts like orange juice, to reduce the bitterness. But the overall acceptability of 5% moringa leaf powder in code 5 (Trial 10) and code 6 (Trial 12) had a high score indicating that the product was acceptable for mitigation of malnutrition in the country with a slight modification of the product. In order to mitigate macro and micronutrient deficiency among under five children a nutrient dense complementary food product is required. Considering the recommended average daily nutrient intake for children, it seems that the nutrients in moringa leaf powder can contribute to the nutritional requirements of children aged 6 months to 2 years.

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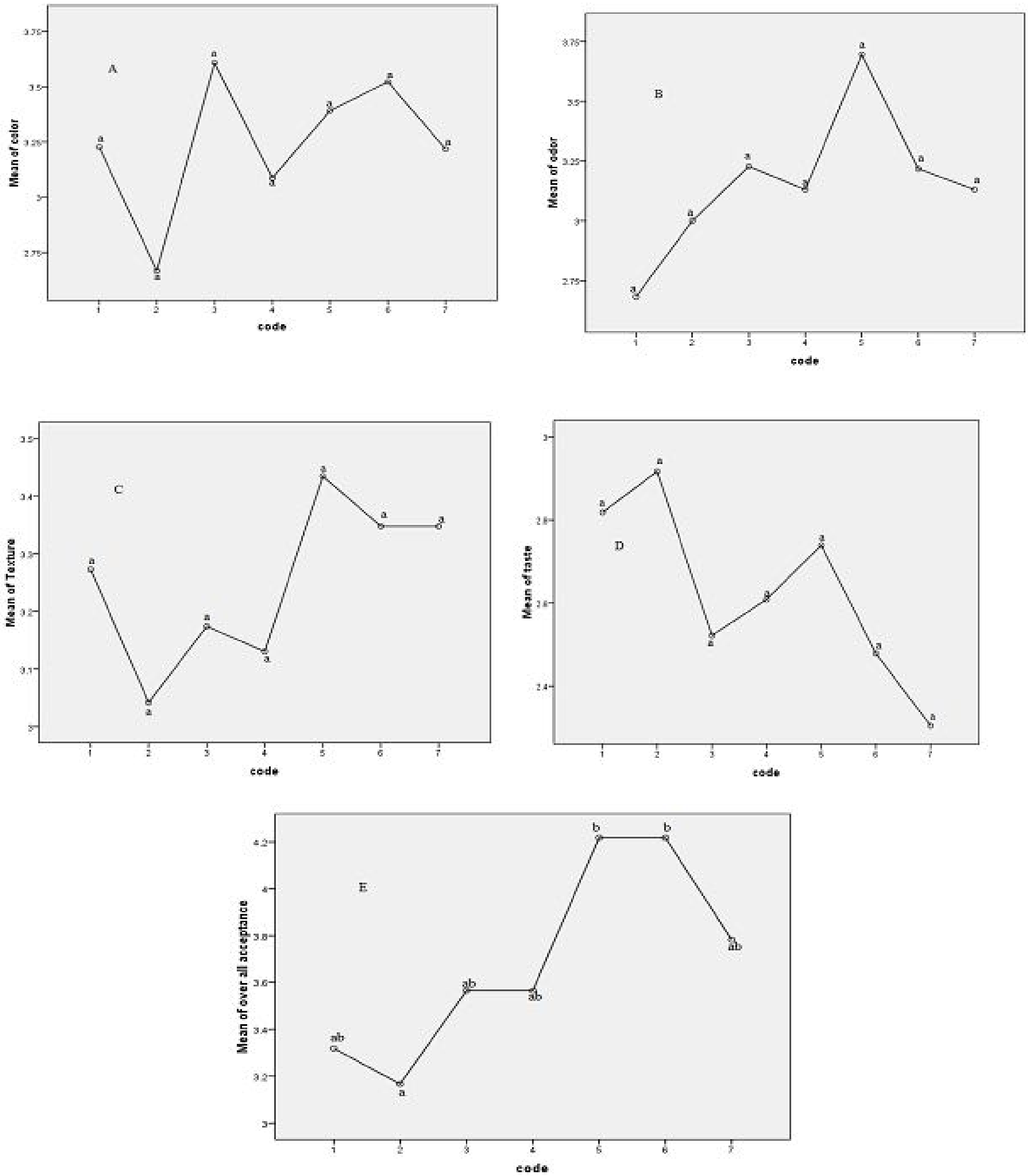

Note: Values within the same figure with different superscript letters are significantly different from each other (at $p<0.05$)

Figure 2: Sensory evaluation attributes A) color, B) Odor, C) Texture, D) Taste and E) Overall acceptability mean score of food formulation

CONCLUSION

The formulation Trial 10 (5% *M. stenopetala leaf* flour blended with 45% sorghum soaked + 20% chickpea soaked + 30% soybean soaked) and Trial 12 (5% *M. stenopetala* flour blended with 45% roasted maize + 30% roasted soyabean + 20% roasted chickpea) gives the best overall acceptability based on sensory evaluation. The study showed that addition of *M. stenopetala* leaf powder to locally available food ingredients such as sorghum/maize, soybean and chickpea enhances nutrient value, such as energy, ash, protein, potassium and fat contents. Iron concentration was relatively higher in the raw and control than other formulation due to leaching during soaking process, but the inhibitor effect of tannin and phytate substantially reduced. Therefore, the selected product could be an option to mitigate protein–energy malnutrition (PEM) and micronutrient deficiency in infants and young children.

Conflicts of interest

The authors declare that they have no conflicts of interest related to this article.

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Authors' contributions

A.B and A.D wrote the draft manuscript. All authors reviewed and edited the manuscript and agreed on the final version of the manuscript.

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Table 1: Proximate and mineral results of the local meals made from *M. stenopetala"Kurkufa* and *Fosose*"

Sample name	Sample code	Moisture % w/w	Crude fiber % w/w	Fat % w/w	Ash % w/w	Potassium mg/100g	Sodium mg/100g	Phosphorus mg/100g
Kurkufa	001	66.1	11.24	3.1	3.1	637.5	370.5	224.7
Kurkufa	002	66.3	4.67	5.6	4.1	712.0	423.2	239.1
Kurkufa	003	68.1	4.48	4.3	4.5	629.5	483.9	238.8
Kurkufa	004	58.7	4.46	5.6	2.5	599.0	267.5	248.3
Kurkufa	005	67.8	4.07	4.0	3.3	558.5	390.9	293.3
Kurkufa	006	61.5	3.95	3.9	4.2	679.8	527.8	239.4
Mean ±SEM		64.8 ±1.5	5.4 ±1.16	4.4 ±0.4	3.6±0.3	636.1±22.4	410.7± 37.2	247.3±9.7
Kurkufa	272-08	67.7	4	3.16	4.8	714	587.0	280.6
Kurkufa	272-31	66.6	12.15	7.13	3.4	515.77	400.7	183.6
Mean ±SEM		67.1±0.5	8.08±4.0	5.1±1.9	4.1±0.6	614.8±99.4	493.8±93.5	232.1±1.5
Fososse	272-73	72.2	4.5	3.09	3.56	716.28	354.1	167.0
Fososse	272-04	75.4	4.0	5	3.1	715.58	43.5	459.2
Mean ±SEM		73.8±1.6	4.34±0.2	4.05±0.9	3.33±0.2	715.93±0.35	198.8±155.8	313.6±146.5

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Table 2: Proximate and mineral results of different food items

Code	Food items	Protein %, w/w	Moisture %, w/w	Crude Fiber%, w/w	fat %, w/w	Ash %, w/w	CHO %, w/w	K mg/100g	Na mg/100g	P mg/100g	Phytate mg/100g	Tannin mg/100g
M	Moringa	29.5	8.5	13.9	5.5	9.2	36.8	1933.4	129.9	250.5	492.3	2176.6
C	Chickpea raw	9.4	9.2	2.8	4.1	1.4	73.0	71.8	13.2	256.2	116.5	1318.2
B	Maize raw	10.2	7.8	2.5	5.9	1.9	71.0	259.8	91.9	342.9	152.5	BDL
S	Soya raw	19.2	7.2	6.4	7.1	3.4	56.6	1800.4	35.9	660.2	350.0	50.0
DH	Sorghum raw	12.3	8.5	3.4	5.7	1.3	68.9	55.9	12.0	167.0	148.9	1.4
AA	Roasted chickpea	23.3	4.9	2.6	5.7	3.1	60.4	1191.8	15.2	303.6	105.6	23.2
BB	Roasted maize	9.9	7.0	2.2	6.0	1.7	73.2	1889.7	39.1	250.5	112.3	6.3
CC	Roasted soyabean	38.4	4.8	4.6	24.8	5.4	21.9	2070.3	72.7	519.5	289.7	41.2
BF	Roasted sorghum	9.4	9.4	1.2	5.9	1.7	72.2	267.9	8.8	307.4	167.8	BDL
CG	Chickpea soaked	37.6	6.1	3.9	2.6	5.2	21.1	1911.6	22.8	546.4	409.2	9.5
AE	Maize soaked	25.2	7.5	2.1	6.4	2.9	55.9	1159.3	12.4	300.3	111.6	2.6
A	Soya soaked	24.2	7.7	5.4	6.7	2.8	53.0	2545.9	26.4	260.9	103.3	19.4
DD	Sorghum soaked	16.2	10.6	4.8	5.1	1.1	62.1	31.9	4.0	178.8	125.9	12.6

Note: CHO, carbohydrate; BDL, below detection limit

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Table 3: Iron and zinc concentration of different food items

Code	Food items	Zinc (mg/100g)	Iron (mg/100g)
M	Raw Moringa	2.2	54.8
C	chickpea raw	7.1	10.7
B	Maize raw	6.1	11.2
S	Soya raw	5.2	21.5
DH	Sorghum raw	5.0	6.8
AA	Roasted chickpea	2.3	10.2
BB	Roasted maize	7.7	10.1
CC	Roasted soyabean	4.8	7.5
BF	Roasted Sorghum	4.6	16.0
CG	chickpea soaked	5.6	8.9
AE	maize soaked	1.6	1.9
A	soya soaked	0.8	1.11
DD	sorghum soaked	3.7	4.1

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Table 4: **Concentration of proximate analysis of different formulation of *M. stenopetala* blends with grains, % ± SD**

Trial No.	Treatment	Energy kcal/100g	Moisture %	Protein %	Fat %	Ash %	CHO %	Fiber %
Trial 1	Raw	379.5 ± 2.4^{ab}	8.1 ± 1.1^{a}	22.8 ± 1.4^{abcd}	9.9 ± 0.5^{a}	1.1 ± 0.1^{ab}	52.1 ± 1.2^{cde}	6.0 ± 0.1^{a}
Trial 2	Raw	384.3 ± 2.3^{bcd}	8.0 ± 1.2^{a}	21.9 ± 1.6^{abc}	10.1 ± 0.6^{a}	0.8 ± 0.2^{ab}	53.8 ± 1.3^{defg}	5.4 ± 0.1^{ab}
Trial 3	Raw	373.7 ± 2.6^{a}	8.6 ± 1.3^{a}	22.5 ± 1.3^{abcd}	9.2 ± 0.3^{a}	1.4 ± 0.1^{ab}	52.5 ± 1.5^{cdef}	5.8 ± 0.2^{ab}
Trial 4	Raw	377.9 ± 2.2^{ab}	8.7 ± 1.1^{a}	21.5 ± 1.5^{ab}	9.3 ± 0.2^{a}	0.9 ± 0.2^{ab}	54.4 ± 1.2^{defg}	5.2 ± 0.1^{ab}
Trial 5	Control	389.2 ± 2.7^{de}	8.0 ± 1.2^{a}	20.9 ± 1.7^{a}	10.3 ± 0.5^{a}	0.5 ± 0.1^{a}	55.5 ± 1.3^{fg}	4.8 ± 0.1^{ab}
Trial 6	Control	382.0 ± 2.9^{bc}	8.7 ± 1.3^{a}	20.5 ± 1.4^{a}	9.4 ± 0.4^{a}	0.6 ± 0.1^{ab}	56.2 ± 1.4^{f}	4.6 ± 0.2^{ab}
Trial 7	Soaked	395.8 ± 2.1^{efg}	7.6 ± 1.1^{a}	24.2 ± 1.3^{bcd}	11.6 ± 0.3^{a}	3.6 ± 0.1^{ab}	48.7 ± 1.2^{ab}	4.3 ± 0.1^{ab}
Trial 8	Soaked	400.4 ± 2.7^{gh}	7.6 ± 1.2^{a}	23.3 ± 1.8^{abcd}	11.7 ± 0.2^{a}	3.2 ± 0.3^{ab}	50.4 ± 1.3^{abc}	3.8 ± 0.1^{ab}
Trial 9	soaked	388.9 ± 2.0^{de}	8.1 ± 1.0^{a}	21.8 ± 1.2^{abc}	9.7 ± 0.6^{a}	3.5 ± 0.4^{ab}	53.6 ± 1.5^{cdefg}	3.3 ± 0.1^{ab}
Trial 10	Soaked	393.7 ± 2.5^{efg}	8.2 ± 1.3^{a}	20.8 ± 1.5^{a}	9.9 ± 0.4^{a}	3.2 ± 0.2^{ab}	55.3 ± 1.2^{efg}	2.6 ± 0.2^{a}
Trial 11	Roasted	399.5 ± 2.6^{fgh}	6.1 ± 1.5^{a}	23.1 ± 1.6^{abcd}	11.1 ± 0.2^{a}	3.8 ± 0.3^{b}	51.7 ± 1.2^{bcd}	4.2 ± 0.2^{ab}
Trial 12	Roasted	404.6 ± 2.3^{h}	6.0 ± 1.4^{a}	22.1 ± 1.4^{abc}	11.3 ± 0.4^{a}	3.5 ± 0.2^{ab}	53.5 ± 1.3^{cdefg}	3.6 ± 0.2^{ab}
Trial 13	Roasted	392.5 ± 2.9^{ef}	7.6 ± 1.3^{a}	25.0 ± 1.8^{cd}	10.9 ± 0.2^{a}	3.2 ± 0.3^{ab}	48.5 ± 1.1^{ab}	4.8 ± 0.1^{ab}
Trial 14	Roasted	388.7 ± 2.5^{cde}	7.5 ± 1.1^{a}	25.7 ± 1.9^{d}	10.8 ± 0.5^{a}	3.6 ± 0.1^{ab}	47.2 ± 1.0^{a}	5.2 ± 0.2^{ab}

CHO, carbohydrate, Values within the same column with different superscript letters are significantly different from each other (at $p<0.05$)

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Table 5: **Concentration of minerals content of different formulation of *M. stenopetala* blends with grains, mean ± SD**

Trial No.	Treatment	Na mg/100g	K mg/100g	P mg/100g
Trial 1	Raw	55.6 ± 1.2^{i}	1346.1 ± 15.3^{k}	425.7 ± 2.3^{g}
Trial 2	Raw	$53.7\pm1.4h^{i}$	1262.3 ± 12.7^{i}	430.3 ± 3.3^{h}
Trial 3	Raw	24.0 ± 0.8^{cd}	1270.2 ± 12.6^{j}	390.9 ± 3.2^{f}
Trial 4	Raw	18.1 ± 0.7^{b}	1177.4 ± 13.2^{h}	391.1 ± 2.8^{f}
Trial 5	Control	51.8 ± 1.3^{gh}	1178.1 ± 11.5^{h}	434.9 ± 3.4^{i}
Trial 6	Control	12.3 ± 0.6^{a}	1084.3 ± 11.5^{g}	391.4 ± 3.1^{f}
Trial 7	Soaked	27.1 ± 1.1^{d}	1021.1 ± 10.8^{d}	315.7 ± 2.1^{c}
Trial 8	Soaked	21.1 ± 0.9^{bc}	927.3 ± 9.5^{a}	311.5 ± 2.2^{ab}
Trial 9	soaked	24.8 ± 0.8^{d}	1031.5 ± 9.8^{e}	347.1 ± 2.4^{e}
Trial 10	Soaked	18.8 ± 1.0^{b}	947.9 ± 9.4^{b}	349.9 ± 3.2^{e}
Trial 11	Roasted	53.5 ± 1.8^{hi}	1809.3 ± 17.5^{l}	341.9 ± 2.8^{d}
Trial 12	Roasted	$49.01.6^{g}$	1807.4 ± 17.3^{l}	341.9 ± 2.4^{d}
Trial 13	Roasted	33.2 ± 1.0^{e}	971.2 ± 10.0^{c}	309.9 ± 2.3^{a}
Trial 14	Roasted	39.5 ± 1.1^{f}	1066.1 ± 11.3^{f}	313.5 ± 2.7^{bc}

Values within the same column with different superscript letters are significantly different from each other (at $p<0.05$)

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Table 6: Concentration of minerals, antinutritional and molar ratio of different formulation of *M. stenopetala* blends with grains, mean ± SD

Trial No.	Treatment	Fe mg/100g	Zn mg/100g	Phytate mg/100g	Tannin mg/100g	Phytate:Fe molar ratio	Phytate:Zn molar ratio
Trial 1	Raw	18.6±0.1[f]	5.7±0.2[a]	238.5±2.1[g]	496.3±2.9[j]	1.2±0.1[a]	4.5±0.6[a]
Trial 2	Raw	15.9±0.1[def]	5.9±0.2[a]	221.5±2.2[f]	387.4±2.6[i]	1.3±0.1[a]	4.0±0.7[a]
Trial 3	Raw	16.8±0.2[ef]	5.2±0.2[a]	237.0±2.3[g]	496.8±3.1[j]	1.3±0.1[a]	3.7±0.5[a]
Trial 4	Raw	14.4±0.2[cdef]	5.4±0.2[a]	219.9±1.9[f]	388.1±1.8[i]	1.4±0.1[a]	3.6±0.4[a]
Trial 5	Control	13.4±0.1[bcde]	5.6±0.2[a]	211.0±1.6[de]	150.3±0.5[a]	1.8±0.2[a]	6.8±0.8[a]
Trial 6	Control	12.0±0.1[abcde]	5.5±0.2[a]	202.7±1.8[c]	279.3±2.9[h]	2.2±0.2[a]	6.2±0.9[a]
Trial 7	Soaked	9.9±0.2[abc]	3.0±0.1[a]	206.6±1.9[cd]	225.0±2.1[e]	1.7±0.1[a]	5.4±0.4[a]
Trial 8	Soaked	7.2±0.2[a]	3.0±0.1[a]	187.6±1.5[a]	117.7±1.8[b]	1.6±0.1[a]	4.9±0.5[a]
Trial 9	soaked	10.8±0.1[abcd]	3.9±0.2[a]	212.4±2.0[e]	230.4±2.2[ef]	1.6±0.2[a]	6.0±0.4[a]
Trial 10	Soaked	10.1±0.1[abc]	3.9±0.2[a]	194.1±2.1[b]	122.2±1.3[bc]	2.0±0.1[a]	5.6±0.6[a]
Trial 11	Roasted	10.4±0.3[abc]	3.3±0.1[a]	202.1±1.9[c]	237.1±2.4[g]	1.7±0.2[a]	5.3±0.2[a]
Trial 12	Roasted	7.8±0.1[ab]	3.2±0.1[a]	183.1±1.7[a]	128.6±1.6[d]	1.5±0.1[a]	5.8±0.3[a]
Trial 13	Roasted	10.7±0.3[abc]	3.9±0.2[a]	208.2±2.1[cde]	125.8±1.3[cd]	1.2±0.1[a]	4.5±0.2[a]
Trial 14	Roasted	13.0±0.3[bcde]	3.8±0.1[a]	224.4±2.2[f]	234.6±2.8[fg]	1.3±0.1[a]	4.0±0.3[a]

Values within the same column with different superscript letters are significantly different from each other (at $p<0.05$)

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Description on the compositions of the fourteen formulations uses for Table 3, 4, 5 & 6:

Trial 1: 10% Moringa leaf powder+40% Maize raw+30% Soyabean raw+20% chickpea raw;

Trial 2: 5% Moringa leaf powder +45% Maize raw +30% Soyabean raw + 20%+ chickpea raw

Trial 3: 10% Moringa leaf powder +40% Sorghum raw+30% Soyabean raw +20% chickpea raw;

Trial 4: 5% Moringa leaf powder +45% Sorghum raw +30% Soyabean raw +20% chickpea raw;

Trial 5: 50% Maize raw +30% Soyabean raw +20%Sorghum raw;

Trial 6: 50% Sorghum raw +30%Soyabean raw +20% chickpea raw;

Trial 7: 10% Moringa leaf powder +40% Maize soaked +20% Chickpea soaked+30% Soyabean soaked;

Trial 8: 5% Moringa leaf powder +45% Maize soaked + 20%Chickpea soaked + 30% Soybean soaked;

Trial 9:10% Moringa leaf powder + 40% Sorghum soaked +20% Chickpea soaked +30% Soybean soaked;

Trial 10: 5% Moringa leaf powder +45% Sorghum soaked + 20% Chickpea soaked +30% Soybean soaked;

Trial 11: 10% Moringa leaf powder +40%Roasted maize+30% Roasted soyabin+20%Roasted chicken pea;

Trial 12: 5% Moringa leaf powder +45% Roasted maize+30% Roasted soyabean+20% Roasted chickpea;

Trial 13: 5% Moringa leaf powder + 45% Roasted Sorghum + 30% Roasted Soyabean + 20% Roasted chickpea

Trial 14: 10% Moringa leaf powder + 40% Roasted Sorghum + 30% Roasted Soyabean + 20% Roasted chickpea

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