Original Research Article

Nutritional Quality of Complementary food blended with Moringa Leaf Powder.

Nutritional evaluation of a composite food based on dates, millet, orange-fleshed sweet potato and added Moringa leaf powder

ABSTRACT

Nutritional Quality of Complementary porridge made from Pearl millet, Orange-Fleshed Sweet Potato, Dates and blended with Moringa Leaf Powder was evaluated using standard methods. The objective of this study was to formulate highly nutritious food for young children. A total of 7 formulations were made, whose compositional proportions were calculated based on the Recommended Daily Allowances (RDA) for children aged 1-2 years. The Pearl millet grain flour, Moringa leaf powder and dates were blended in ratios of 90:2.5:7.5 [PmMD1], 95:2.5:2.5 [PmMD2] and 88:3:9 [PmMD3], forming three formulations, respectively. Also, Pearl millet grain flour, Moringa leaf powder and Orange fleshed sweet potato were blended in ratios of 95.5:2:2.5 [PmMP1], 88:2:10 [PmMP2], and 95:2.5:2.5 [PmMP3] forming three formulations, respectively. A control sample did not contain Moringa powder and was composed of Pearl millet, Dates and Orange fleshed sweet potato in a ratio of 50:15:35 [PmDP], respectively. The nutritional composition of the flour on dry weight basis was; crude fiber: 2.6-3.3 g/100g, ash: 1.9-2.13 g/100g, Crude fat: 0.66-1.38 g/100g, crude protein: 8.34-11.07 g/100g, Carbohydrates: 73-77 g/100g and Energy of 346-352g/100g. The content of iron, zinc and calcium was 4.5-6.3, 1.46-1.81, 183-240mg/100g, respectively and Vitamin A content was 3082-4975 µg/110g.The incorporation of Moringa leaf powder improved the nutritional quality of the complementary food.

Key words: Complementary food, Micronutrients, Moringa leaf, Recommended Daily Allowance.

Proposal

The aim of this study was to formulate highly nutritious infant foods. The nutritional quality of a complementary porridge based on pearl millet, orange-fleshed sweet potato, dates and mixed with Moringa leaf powder was assessed using standard methods. A total of 7 formulations were produced, with compositional proportions calculated on the basis of recommended daily allowances (RDAs) for children aged 1-2 years. The linear regression method was used to combine the samples into different formulations to meet FAO/WHO/UNICEF requirements. The results obtained revealed that the nutritional composition of the flour on a dry weight basis was as follows: crude fiber: 2.6-3.3 g/100g, ash: 1.9-2.13 g/100g, crude fat: 0.66-1.38 g/100g, crude protein: 8.34-11.07 g/100g, carbohydrates: 73-77 g/100g and 346-352 g/100g energy. Iron, zinc and calcium contents were 4.5-6.3, 1.46-1.81, 183-240mg/100g respectively, and vitamin A content was 3082-4975 µg/110g. The incorporation of Moringa leaf powder improved the nutritional quality of the supplementary feed.

Keywords: Composite flour, Formulation,Moringa leaves, micronutrients

INTRODUCTION

Child malnutrition remains a pressing problem worldwide, particularly affecting children under the age of 5, with a significant number of affected children residing in developing countries (UNICEF, 2009).The problem of malnutrition often arises in infants during or after the introduction of complementary foods, contributing significantly to the high prevalence of malnutrition in children below the age of 5 (Muhimbula and Zacharia, 2010; Mosha *et al*., 2000). According to these studies, a majority of infants are introduced to cereal-based complementary foods well before the recommended age of 6 months or, in some cases; they do not receive these foods until they reach their second year of age.

One of the main causes of death among children and pregnant mothers or nursing mothers is malnutrition, which has permanent impacts on health in underdeveloped nations. Iron, zinc, iodine and vitamin A deficiency-related protein-energy malnutrition disorders have also been a problem to young children (Haidar *et al*., 2003).

According to Mosha *et al*. (2000), Tanzanian traditional supplementary foods are based on starchy staples, typically cereals such as maize, rice, sorghum, and finger millet as well as non-cereals such as cassava, sweet potatoes, yams, bananas, and plantains. Unfortunately however, such diets are typically provided without enough supplementation with high quality protein sources (Kikafunda *et al*. 2006). These foods are widely available, inexpensive, and therefore accessible to most rural residents who are lysine deficient (FAO *et al*., 2015). The primary cause of the widespread protein energy malnutrition that affects babies and young children is an overdependence on these starchy sources of protein.

Children need nutrient-rich diet that is high in vitamins, minerals, proteins, and carbohydrates for a healthy growth. These are essential for newborns and young children's healthy development and for the treatment of disorders brought on by a poor diet, such as malnutrition, which has long been recognized as a significant nutritional issue in developing nations (FAO *et al*., 2015). After six months, it is appropriate to introduce complementary foods, which provide additional nutrition to meet all the growing child’s needs, when breast milk alone is no longer sufficient to provide enough nutrients. In recent years inadequate child feeding procedures, a shortage of complementary foods of sufficient quantity and quality, and high rates of infections, have contributed to health and growth problems among children (FAO *et al.*, 2015).

Food-based strategies greatly improve the nutritional quality of foods while posing little risk in many developing countries (Omar and Michael, 2008; WHO/FAO, 2006), making them effective, acceptable, and sustainable approaches to combating the devastating effects of malnutrition. One potential approach is the creation of affordable, nutrient-dense complementary/supplementary foods employing underutilized local cereal, legume, root, and tuber crops (Forsido *et al*., 2013; Omar and Michael, 2008; WHO/FAO, 2006).

Complementary food refers to any solid foods or nutritious beverages, aside from breast milk, that are introduced to infants to supplement their diet when mother's milk alone is no longer sufficient. These foods are introduced to infants once they reach the age of six months, following a period of exclusive breastfeeding. Inadequate amounts and quality of complementary foods can result in elevated infection rates and other health complications in young children (FAO *et al.*, 2015).Research has indicated that more than 85% of the complementary foods given to infants fail to meet the nutrient density levels recommended by the World Health Organization (WHO), thereby contributing to malnutrition problems(Tenagashaw *et al*., 2017).

The aim of current research was to produce and investigate the potential nutrient-rich and appetizing complementary food products from readily available, wholesome, reasonably priced, and locally grown underutilized crops such as the *Moringa oleifera* mixed with cereals and other non-cereal starchy foods.

Materials and Methods

Samples

Pearl millet and Orange fleshed sweet potato were obtained from Mawenzi market, in Morogoro, Moringa leaves were obtained from Frida homestead, Morogoro. Dry dates were obtained from the Kilombero market, Arusha Tanzania.

Sample preparation

The processing steps for the preparation of Pearl millet, Orange fleshed sweet potato, Dates and Moringa leaf flour are shown in Fig. 5

Preparation of Moringa leaf powder

Fresh Moringa leaves from the farm were sorted and young, fresh leaves were selected (what was the weight of the Moringa leaves?). Damaged and diseased leaves were discarded. Leaves were washed with clean water and soaked in a 1% NaCl solution for 5 minutes to kill microbes. Excess water was drained off and the leaves were spread out on grids for 20 minutes before being shade-dried at room temperature (how much?) for 4 days. A multifunctional high-speed grinder, (brand) model 750A, was used to reduce the leaves to powder. A 500µm sieve was used to obtain a fine powder (Olaitan et al.,2014; Malla et al., 2021).

Preparation of Orange-Fleshed Sweet Potato Flour.

The sweet potatoes were washed, (what was the weight of the sweet potatoes?) peeled and cut into 3 mm thick slices. The slices were oven-dried at 500°C overnight, then ground using a high-speed multifunctional grinder, model 750A. A 500µm sieve (brand?) was used to obtain a fine powder (Falade et al., 2010).

Fig 1. Moringa leaf powder

Fig 2. Orange flesh sweet potato flour

Germination and Preparation of pearl millet

The pearl millet was sorted to remove foreign matter, then washed to remove dust and mud. The sorted (what was the weight of pearl millet?) and cleaned millet was soaked in a 5-liter bucket of cold water for 10 hours at room temperature (how long?). The water was drained from the millet grains and spread individually on a damp muslin cloth where water was sprinkled every 6 hours to stimulate the germination process. The millet grains germinated after 48 hours. The germinated millet was oven-dried at 60˚C for 10 hours, then ground to flour using a (brand-name) hammer mill. A 500µm sieve (brand name) was used to screen the sprouted flour (Nefale et al., 2018). All flour samples were stored in airtight polyethylene bags and kept in a freezer at -10˚C.

Fig 3. Pearl millet flour

Fig 4. Date powder

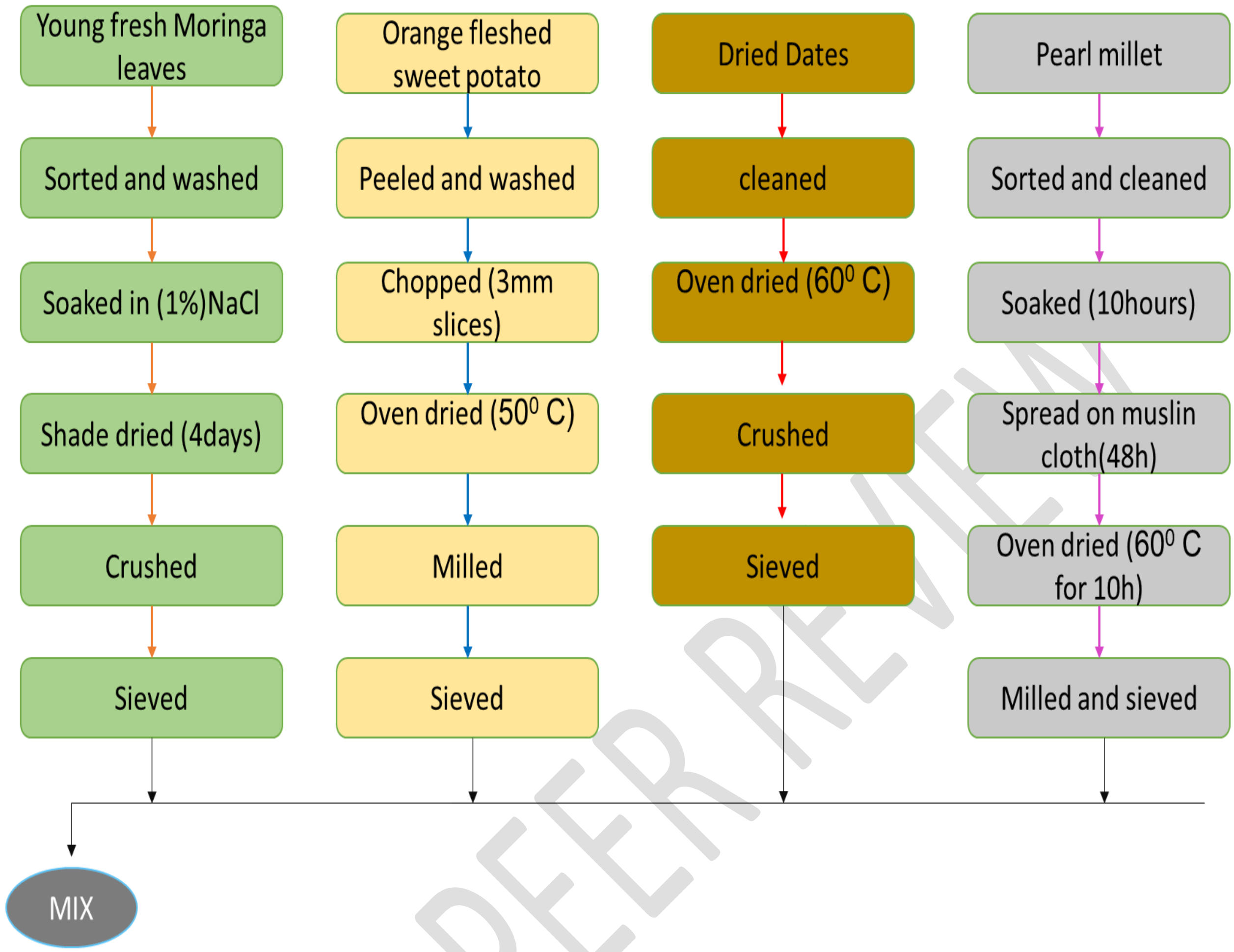

Fig. 5. Flowchart for the preparation of complementary food powder

Preparation of Date Powder

Dried dates (what was the weight of pearl millet?) from the market were washed in clean water to remove dust. The internal seeds were also removed and the dates were put in a (branded) oven for 12 hours at 600°C. They were then left to dry for one hour. They were then left to dry for one hour. A multifunctional high-speed grinder (brand name) model 750A was used to crush the dates to obtain a powder, which was then sieved using a 500 µm sieve (Hasan et al., 2019).

Fig 6. Formulated porridge flour packed in zipper bags.

Formulation of potential complementary food

The linear regression method was used to combine the samples into different formulations to meet the FAO/WHO/UNICEF (1985) requirement for micronutrients for young children and infants. Seven samples (including the control sample) were formulated as indicated in Table 1.

Table 1. Composition of complemented food from pearl millet, orange-fleshed sweet potato, date, and Moringa leaf (g/100 g)

Ingredients	Formulation Name	Ratios
Pearl Millet+ Moringa leaf powder+ Dates	PmMD1	90:2.5:7.5
	PmMD2	95:2.5:2.5
	PmMD3	88:03:09
Pearl Millet+ Moringa leaf powder+ Orange-fleshed sweet potato	PmMP1	95.5:2:2.5
	PmMP2	88:02:10
	PmMP3	95:2.5:2.5
Pearl Millet+ Dates + Orange- fleshed + sweet potato (Control sample)	PmDP	50:15:35

Key: Pm = Pearl Millet, M= Moringa Leaf, D= Dates, P= Orange fleshed sweet potatoes

Proximate and mineral composition

The proximate composition of the product was determined according to official AOAC methods as shown below. Results were presented as means of duplicate determinations.

Crude fat

Total fat content was analyzed using the official Soxhlet method 945.87 (AOAC, 1999). A dry sample weighing 5 g was placed in the extraction die and assembled in the Soxhlet device. Refluxing was carried out with 60 ml of petroleum ether in three distinct phases: a 15-minute boiling phase, a 30-minute fat extraction phase and a 10-minute petroleum ether recovery phase. The recovered petroleum ether was evaporated (using what?) and the fat obtained was collected in pre-weighed cups (using a brand-name balance). To remove the remaining petroleum ether, the cups were dried in a (brand-name) oven at 105°C for 30 minutes. After cooling in a desiccator for 20 minutes, the cups were weighed.

Percentage fat was calculated by using the formula:

$$\%\ Crude\ fat = \frac{weight\ of\ crude\ \ fat\ (g)}{weight\ of\ dry\ sample\ \ (g)} \text{x } 100$$

Ash content

Ash content was determined according to the procedure described in AOAC (1999) method 923.03. First, a dry sample weighing five grams was oven-dried (branded) at 105°C for 24 hours. The weights of the crucible and dried sample were accurately recorded. Next, the dried samples contained in the crucibles were incinerated in a muffle furnace (brand name) at a temperature of 550°C for a period of three hours, resulting in the formation of gray ash. Ash content was calculated as the variance between sample weight before and after the incineration process.

Percentage ash was calculated from the relationship:

$$Ash\ (\%DM) = \frac{weight\ of\ ash\ (g)}{weight\ of\ dry\ sample\ \ (g)} \text{x} 100$$

Crude protein

The determination of crude protein content in the samples was performed using the micro-Kjeldahl method 920.87 as specified in AOAC (1999). Initially, dried samples weighing 0.5 g were accurately weighed and transferred into digestion tubes. To each tube, 0.6 g of a catalyst mixture comprising 10 g of K_2SO_4 and 0.5 g of $CuSO_4$, along with 6 mL of concentrated H2SO4, were added. The samples were then digested using a Tecator digestion system 40 (Model 1016 digester, Sweden) for a duration of 3 hours, resulting in a clear greenish solution. After cooling, the digested solution was transferred to a distillation unit (Foss Tecator, Model 2200 Kjeltec auto distilling unit, Sweden). A total of 70 mL of distilled water was added to the digested solution, followed by 70 mL of 40% NaOH, and the mixture was steam distilled for 4 minutes. The distillate, measuring 50 mL, was collected in a conical Erlenmeyer flask containing 25 mL of

4% boric acid. The collected distillate was then titrated with 0.105 g/100 mL hydrochloric acid. A blank volume was also determined, and a value of 0.04 mL was obtained.

$$\% \; Crude \; Proiten = \frac{14.01 \; x \; (Title - Blank) \; x \; 6.25 \; x \; Concentraton \;\; of \; acid \; (n/mol)}{weig\,ht \; of \; dry \; sample \; (g) \; x \; 10} \text{x}100$$

Where 6.25is the protein-nitrogen conversion factor

Crude fiber

Crude fiber content was determined using the official method 920.86 described in AOAC (1999). The Ankom fiber analyzer (model ANKOM 220, USA) was used for this purpose. A 1.0 g sample was digested in the fiber analyzer with dilute sulfuric acid (0.125 M H2SO4) for 30 minutes. The residues obtained were then washed with hot water. The residues were then digested with dilute alkali (0.125 M KOH) for 30 minutes and washed again with hot water. The digested residues were dried in a (brand-name) oven at 105°C for 5 hours, cooled and weighed(using a brand-name balance). The residues were then subjected to incineration in a muffle furnace (using a branded balance) at 550°C for 2 hours, followed by cooling and weighing. The difference in weight between the residues before and after incineration was taken as the total fiber content.

$$\% \; Crude \; Fiber = \frac{(weig\,ht \; of \; sample \;\; residues \;\; before \;\; incinaration \;\; - weig\,ht \; after) \; (g)}{weig\,ht \; of \; dry \; sample \;\; (g)} \text{x}100$$

Carbohydrate

Carbohydrate was calculated as a percentage difference by the formula:

% Carbohydrate = 100 % – (% protein + % crude fiber + % crude fat + % Ash).

Energy

The energy content was calculated using the Atwater’s conversion factors. Thus energy

Values were obtained by multiplying % fat by factor 9, and % protein and % carbohydrate

by factor 4 each (AOAC, 1999).

Energy content = [(%Carbohydrate x 4) + (%Fat x 9) + (%protein x 4)]

Mineral Composition

Analysis of the mineral composition of the samples was carried out with slight modification following the method described by Jachimowicz et al. (2021). First, the samples were sieved using a 1.18mm sieve (brand name). Next, 0.5g of each sample was accurately weighed (using a branded balance) and placed in vials. For digestion, 2 mL nitric acid (HNO3) and water in a 1:1 ratio were added to each sample. In addition, 5 mL hydrochloric acid (HCl) in a 1:4 ratio with distilled water was also added. The flasks were covered with watch glasses.

The samples in the vials were heated in a hot block (Hot block 150 model: SC-154-240) to 95°C and boiled for 30 minutes until they reached 85°C. After this process, the flasks were removed and allowed to cool to room temperature. Distilled water was then added to each vial, for a total volume of 50 mL. The contents of each vial were transferred to test tubes and analyzed using the inductively coupled plasma optical emission spectrometer (ICP-OES-5900 Agilent) with model number (Agilent 5900 SVDV ICP-OES), serial number MY2215CP04, software version 7.6.0.12121, and firmware version 5590).

Vitamin A

The Vitamin A content in the samples was determined through the UV-VIS Spectrophotometry method by measuring β-carotene, its precursor in plants. To extract β-carotene, a mixture of 50 mL acetone-hexane with 0.1% BHT was added to 5g of the sample. After shaking for 10 minutes, the mixture was centrifuged and the supernatant was separated using a funnel. The resulting solution was saponified with 25 mL of 0.5M methanolic potassium hydroxide, followed by shaking and settling for 30 minutes, with subsequent washing using 100 mL portions of distilled water. The aqueous layer was continuously discarded, and the extract was dried by filtering over anhydrous sodium sulfate.

The filtrate was concentrated at 45°C using a (brand-name) rotary evaporator, then reconstituted in methanol to a final volume of 50 mL. Standard solutions of different concentrations were prepared using 95% UV β-carotene. A stock solution of 100 µg/mL was prepared by dissolving 0.01 g standard β-carotene in 10 mL hexane, then made up to 100 mL. The absorbance (A) of each concentration was measured at a wavelength of 450 nm using UV-VIS spectrophotometry (Malla et al., 2022).

Data analysis

All data was analyzed by Statistical Package for Social Sciences (SPSS) version 25. One way analysis of variance (ANOVA) test was performed following a post-hoc test with significant differences being determined at 5% level ($p<0.05$). All results were expressed as mean ± SD of duplicate values.

Results and Discussion

The chemical composition of complementary food blended with Moringa Leaf Powder (g/100 g dry weight) is summarized in Table 2. The composition was compared to the recommended daily intake for children aged 12-24 months by WHO (2005) and WHO/UNICEF (1998) (Table 3).The composition was also compared to the Tanzania standard for processed cereal based foods for infants and young children (TZS 180:2013) indicated by the Tanzania Bureau of Standards (Table 3).

Table 2.Proximate composition (g/100 g DM), energy (kcal/ 100 g) of Complementary food blended with Moringa Leaf Powder

Sample	Protein	Crude Fat	Fiber	Ash	Energy	Carbohydrates
PmDP	8.34 ± 0.01^{a}	1.10 ± 0.07^{f}	3.33 ± 0.00^{g}	2.13 ± 0.19^{h}	352 ± 0.76^{i}	77 ± 0.04^{j}
PmMD1	10.09 ± 0.05^{bc}	1.05 ± 0.07^{f}	2.82 ± 0.25^{g}	1.99 ± 0.25^{h}	347 ± 2.60^{i}	74 ± 0.87^{k}
PmMD2	10.19 ± 0.00^{cd}	0.66 ± 0.49^{f}	3.23 ± 0.32^{g}	2.00 ± 0.30^{h}	346 ± 0.57^{i}	74 ± 0.96^{jk}
PmMD3	11.07 ± 0.28^{e}	0.98 ± 0.01^{f}	3.01 ± 0.02^{g}	2.23 ± 0.25^{h}	347 ± 1.42^{i}	73 ± 0.60^{k}
PmMP1	9.92 ± 0.06^{c}	1.29 ± 0.04^{f}	2.85 ± 0.34^{g}	2.03 ± 0.09^{h}	348 ± 2.22^{i}	74 ± 0.51^{k}
PmMP2	9.72 ± 0.03^{b}	1.25 ± 0.03^{f}	3.10 ± 0.31^{g}	2.04 ± 0.08^{h}	348 ± 0.28^{i}	74 ± 0.10^{k}
PmMP3	10.58 ± 0.00^{d}	1.38 ± 0.06^{f}	2.69 ± 0.58^{g}	1.99 ± 0.21^{h}	350 ± 0.39^{i}	74 ± 0.24^{k}

Means ± SD, values within the same column with different superscript letters are significantly different from each other ($p<0.05$).

Fat

There was no significance difference ($p>0.05$) in crude fat among the samples. The values ranged from 0.66g/100g DM in PmMD2 to 1.38g/100g DM in PmMP3. Similar observations were made by Gebretsadikan*et al*. (2015) where fat content of OFSP-Soybean-Moringa leaf porridge was not significantly altered. The results were due to inclusion of high levels of OFSP (60%-85%) and low levels of Soybean (10%-30%). A study by Bello *et al.* (2022) reported that the fat content of the Pearl millet-OFSP-bean cookies was mainly from margarine that was added during preparations of the cookies. Pearl millet and OFSP have been reported to have low lipid content of 2.25% and 0.37% respectively (Adebiyi *et al*., 2017; Kolawole *et al*., 2020). This could also be the reason for low fat content observed in this study. A study by Haile *et al*. (2016) on composite flour of OFSP and bulla *(Enset ventricosum)* flours had fat content of 0.2% to 0.8% which is also within the set standard although it was not sufficient for the daily requirements for adults who were the targeted group. Although the values obtained in the current study were much lower than those given in Table 3 (Tanzania standard, TZS180:2013), they all met the set standard, and hence may be incorporated into infants food formulations complied.

Table 3. Recommended daily nutrient requirements for children aged 12-23 months

Nutrient	Requirement/day
Energy	900kcal
Protein	13g
Vitamin A	300µg
Iron	7mg
Zinc	3mg

Sources: WHO, (2005), WHO/UNICEF, (1998)

Ash

Ash refers to any inorganic material present in food or a residue that remains after heating and removing water. In current study, the ash content ranged between 1.99 to 2.13%. There was no significance difference (p>0.05) in ash content among all samples in this study. According to Gebretsadikan*et al*. (2015) total ash content of OFSP-Moringa-Soybean porridge was positively influenced by OFSP and Moringa due to their high mineral content. A Study by Xu *et al*. (2020) support that potatoes have high mineral content. A study by Mohammed *et al*. (2016) on cookies reported that OFSP had higher contribution in mineral content of the cookies. Contrary to the present study, a study by Haile *et al*. (2016) on porridge made from composite flour of OFSP and bulla reported a significant difference in ash among the samples. The study also indicated an increase in crude ash content as the amount of OFSP increased. Another study by Olaitan *et al*. (2014) on quality evaluation of complementary food made from Pearl millet and Moringa leaf powder indicated an increase in the ash content as the amount of Moringa increased. All formulated samples under the current study were within the set levels as per TZS 180: 2013 indicated in Table 4.

Protein

Protein ranged between 8.34g/100g DM (52.1%) to 11.07g/100g DM (68.7%). There was a significant difference in protein content (p<0.05) among studied samples. This was from the samples with no Moringa to the sample that had the highest amount of Moringa of 3%. It was observed in this study that amount of increased protein content was directly proportional to Moringa Leaf Powder added This could be due to considerable amounts of protein that are found in Moringa. A study by Malla *et al*. 2021 reported 20% protein in the Moringa leaf. Other studies by Ntila (2017) and Kayi (2013) reported 20.47% and 30.3% of protein in dried Moringa leaf, respectively. Increased protein level in Moringa supplemented porridge could be due to significant amounts of protein found in Moringa leaves (Abuye *et al*., 2003: Mellese *et al*., 2009). A study by Olaitan *et al*. (2014) reported a significant difference in protein between the porridge samples upon addition of Moringa leaf powder. Increased protein content as the amount of Moringa was added in Moringa supplemented biscuits samples was reported by Hedhili *et al*. (2021).

The protein content in this study is within the acceptable limit set by TZS 180:2013 but was below the limits set by WHO/UNICEF.

Table 4. Requirements for processed cereal-based foods for infants and young children.

Characteristics	**Requirements**
Moisture content, % by mass, max.	Products for further processing 8.0
Total protein (quality at least 70% that of casein) by mass, min	14.0
Fat, % by mass, max.	8.5
Total carbohydrates, %by mass, min	60.0
Total ash, % by mass, max.	5.0
Ash insoluble in HCL, % by mass, max	0.05
Crude fiber (on dry basis), % by mass, max.	5
Vitamin A, IU/100g. min	500
Vitamin C mg/ 100g, min	25
Added Vitamin D, IU/100g.	25
Thiamine (as hydrochloride) mg/100g. min	300 to 800
Nicotine acid, mg/100g.min.	0.5
Calcium, mg/100g.max	1.0
Phosphorus mg/100g. min	25.0
Iron mg/100g, min	10

Source: TZS 180: 2013.

Crude Fiber

There was no significance difference ($p>0.05$) in crude fiber content among the samples in this study. The fiber content in the samples was contributed by Moringa and OFSP. A study by Gebretsadikan *et al*. (2015) reported direct association of crude fiber with Moringa leaf powder and soybean. Moringa leaf powder is reported to have high fiber content than OFSP (Abuye *et al*., 2003: Senanayake *et al*., 2013). A study by Haile et al. (2016) reported an increase in fiber content as OFSP was added to Bulla flour. A study by Olaitan et al. (2014) on Pearl millet and

Moringa leaf powder porridge reported a significant difference in fiber content. There was an increase in fiber content among the porridge samples as Moringa leaf powder was added. As per standards sets by TZS 180:2013 for crude fiber content all samples in this study complied with the specification.

Carbohydrates

Although the carbohydrate content varied from 73 g/100 g DM to 77 g/100 g DM, there was a significant difference ($p<0.05$) in carbohydrate content between the control and all other samples, except PmMD2. The product's carbohydrate content comes from both OFSP and pearl millet. Pearl millet contains 63-78% carbohydrates (Taylor and Kruger, 2016). The amount of carbohydrates increased significantly in the product as quantities of OFSP were added, which was due to its high starch content (Faber et al., 2010).A study by Gebretsadikan et al. (2015) reported limited impact on carbohydrate changes due to a narrow range of OFSP used in the blend. Olaitan et al. (2014) found a decrease in the carbohydrate content of porridge samples as Moringa leaf powder was added to the formulation. This is because Moringa contains fewer carbohydrates than pearl millet, reducing the carbohydrate content of the sample. The Tanzanian Bureau of Standards has set a minimum carbohydrate content of 60%, and all the samples in this study met this standard.

Energy

The energy content of the samples ranged between 346 kcal/100g DM and 352 kcal/100g DM There was no significant difference ($p>0.05$) in energy among the samples in this study. This could have been attributed by limited variation in the amount of ingredients used to develop the products. A study by Haile *et al*. (2016) reported a significant difference in energy among the samples. The energy content was reported to increase as the amount of OFSP increased. A higher energy content of OFSP than that of bulla was reported to be responsible for the increased energy. All the samples in the study were below the energy set limits set by WHO/ UNICEF and Tanzania Bureau of Standards under TZS 180:2013.

Mineral Composition

The mineral and vitamin A composition of the supplementary feed mixed with Moringa leaf powder (g/100 g dry weight) is summarized in Table 5.

Iron

The Iron content of formulated products ranged from 4.5mg/100g to 6.3 mg/100g. There was no significant difference ($p>0.05$) in iron among the samples in this study. The amount of Iron increased as the amount of Moringa increased in the sample. Similar observations were made by Gebretsadikan *et al*. (2015) in porridge samples where iron content increased as the amount of soybean and Moringa increased in the samples. Other studies by Abuye *et al*. (2003) and Mellese *et al*. (2009) had similar observations on the increase of iron content in the products as concentration of Moringa increased. Moringa leaves are a rich source of iron and other essential minerals (Gandji *et al*., 2018). A study by Govender & Siwela (2020) reported an increase in iron content from bread fortified with 5% and 10% Moringa compared to the unfortified bread.

According to WHO/UNICEF the set standard for iron content in complementary food for a 12–24-month child is 7mg/100g. CODEX (2006) has set a minimum of 4.8mg/100g while Tanzania Bureau of Standards under TZS 180:2013 has set a minimum of 10.87 mg/100g. All the samples in this study were below the limits set by WHO/UNICEF and TZS 180:2013. Six out of seven samples in the study reached the set limits made by CODEX (2006).

Zinc

The zinc content ranged from 1.46mg/100g to 1.81mg/100g among the samples. There was no significance difference ($p>0.05$) in zinc among samples in this study. An increase in zinc content in the samples that had more amount of Moringa was observed. This implicates that addition of Moringa leaf powder boost the amount of zinc in food. Similar observations were made by Roni *et al*. (2021) in the Moringa fortified cakes. According to CODEX (1991) amount of zinc in the weaning food should have a minimum of 2.42mg/100g. On the other hand, WHO/ UNICEF have set a standard of 3mg/day of zinc for complementary foods for children of 12-23 months of age. All the samples in this study were below the requirements set by both CODEX and WHO/UNICEF.

Calcium

The calcium content of porridge samples increased with Moringa concentration. There was a significant difference ($p<0.05$) in calcium content between samples. The maximum calcium content of 240g/100g was recorded in the PmMD3 sample and the minimum calcium content of 183g/100g was recorded in the PmDP control sample. The increase in calcium content in the samples was confirmed by the presence of calcium in Moringa leaves (Kasolo et al., 2010). A study by Sengev et al. 2013 reported a significant difference in calcium between Moringa-enriched and non-enriched bread samples. According to FAO/WHO (1991), the minimum calcium content of weaning foods should be 435 mg/100 g.

Table 5.Mineral Composition (mg/100g DM), Vitamin A (µg/100g)of Complementary food blended with Moringa Leaf Powder

Samples	Iron	Zinc	Calcium	Vitamin A
PmDP	4.56 ± 0.22^{a}	1.51 ± 0.01^{b}	183 ± 2.12^{c}	441 ± 380^{ef}
PmMD1	5.77 ± 1.09^{a}	1.73 ± 0.04^{b}	237 ± 2.12^{d}	308 ± 535^{e}
PmMD2	5.85 ± 0.63^{a}	1.81 ± 0.16^{b}	236 ± 2.82^{d}	357 ± 368^{ef}
PmMD3	6.33 ± 0.66^{a}	1.81 ± 0.02^{b}	240 ± 0.70^{d}	434 ± 117^{ef}
PmMP1	5.7 ± 0.14^{a}	1.47 ± 0.67^{b}	202 ± 1.41^{e}	381 ± 680^{ef}
PmMP2	5.40 ± 0.57^{a}	1.46 ± 0.57^{b}	210 ± 0.70^{f}	497 ± 797^{f}
PmMP3	6.19 ± 0.14^{a}	1.54 ± 0.73^{b}	237 ± 2.12^{d}	373 ± 815^{ef}

Means ± SD, values within the same column with different superscript letters are significantly different from each other ($p<0.05$)

Vitamin A

The β- carotene content among the samples ranged from 308µg to 497 µg per 100g. There was a significant difference ($p < 0.05$) in β- carotene content among samples. The increase in β-carotene is due to addition of both Moringa leaf powder and Orange fleshed sweet potato. OFSP contains a significant amount of Pro vitamin A (Bechoff, 2010). A study by Malla *et al*. (2021) reported that Moringa leaf powder contains higher contents of β- carotene than Millet. The study also reported that β- carotene content improved in the Moringa fortified flour compared to the unfortified samples. It was furthermore reported in this study that β- carotene is one of the target nutrient that increased due to addition of Moringa. A study by Boateng *et al*. (2019) supports that Moringa is a good fortificant to obtain enough amounts of Vitamin A. There were significant amounts of β- carotene in all the samples in this study due to addition of OFSP and Moringa, both of which have significant amounts of β- carotene. A study by Bello *et al*. (2022) reported that β- carotene content increased in cookies samples as OFSP increased. According to the Recommended Daily Intake of Vitamin A set by WHO/UNICEF for a 12–23-month-old, all the samples under this study reached the set limits.

Contribution of the nutrient's composition of the formulated porridge to the nutrient

Requirement of children aged 12-23 months.

Based on recommendations from UNICEF and WHO, children aged 12-23 months should be given three-quarter to a full cup (250mls) of complementary food per serving, with additional nutritious snacks offered 1-2 times per day as desired (WHO, 2009). However, according to FAO (2011), UNICEF (2010), and Brown (2003), children in this age group should ideally be given 3-4 servings a day due to their increased rate of growth and energy requirements as they continue to grow. If the porridge formulated in this study is provided to these children, it is assumed that children aged 12-23 months will consume a total of 1000mls per day (250mls per serving, 4 servings in a day).

The formulation labeled as "PmMP2," which was the most acceptable from the sensory evaluation panelists, could provide the following nutrients for children aged 12-23 months: 1,392 Kcal Energy, 38.8g crude protein, 1491 µg vitamin A, 21.6 mg Iron, and 5.6 mg Zinc. These nutrient levels exceed the recommended allowances for some nutrients targeted in this study. This indicates that the formulated porridge has the potential to provide beneficial nutritional contributions beyond the recommended amounts for children in this age group.

Another formulation that can be given to children aged 12-23 months is "PmMP3" which was the second most accepted formulation. If provided in 3 servings, a child will consume a total of 750mls per day. A child will obtain 1,050kcal Energy, 30g crude protein, 1119 µg vitamin A, 18.5mg Iron and 4.6mg Zinc from such diet. This formulation could also provide beneficial nutritional contributions beyond the recommended amounts for children in this age group. The Table 6 indicates amount that can be obtained in each nutrient and from every formulated mix when administered in 3 servings in a day.

Table 6. Distribution summary of nutrients in each sample obtained from 3 servings per day.

Amount of nutrients obtained from 3 servings per day						
Sample	**Energy (Kcal)**	**Iron (mg)**	**Zinc (mg)**	**Calcium(mg)**	**Protein (g)**	**Vitamin A (µg)**
PmDP	1056	13.5	4.5	549	24	1323
PmMD1	1041	17.1	5.1	711	30	924
PmMD2	1038	17.4	5.4	708	30	1071
PmMD3	1041	18.9	5.4	720	33	1302
PmMP1	1044	17.1	4.2	606	30	1143
PmMP2	1044	16.2	4.2	630	29	1491
PmMP3	1050	18.5	4.6	711	30	1119

All the samples in this study have shown to meet the stipulated standard set by WHO/UNICEF. Among all the samples the control sample PmDP provides the highest amount of energy. The sample PmMP2 provides the highest amount of Vitamin A. Iron, zinc, protein and calcium are obtained at a higher concentration in the porridge sample PmMD3. Although the sample PmMD3 has the highest amount of most nutrients it is among the least accepted sample in the sensorial aspect and therefore has the least chance to be taken.

Conclusion and Recommendation

The objective set for this study was achieved, and revealed that incorporating Moringa into the supplementary diet increased nutrient levels. For children aged between 12 and 23 months to receive all the recommended daily nutrients, they would need to be provided with the meal quantities suggested by the FAO and UNICEF. This research showed that Moringa did indeed improve the nutrient content of the complementary food. However, using more than 3% Moringa could further improve nutrient levels. To overcome its bitter taste, leafy aroma and dark green color, other foods can be added to mask these undesirable aspects of Moringa. In this way, children will be able to consume the food without any problems while enjoying the nutritional benefits of Moringa.

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