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Research Article

Optimising traditional nutri-diets with finger millet, sesame, moringa and bambara groundnuts inclusion for under five children.

Chibandamabwe Lawrence[1*] and **Gadzirayi Christopher[2]**

1. Pamushana High School, P.Bag 514, Nyika, Zimbabwe.
2. Bindura University of Science Education, Faculty of Agriculture and Environmental Sciences, 741 Chimurenga Road, Bindura, Zimbabwe.

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Corresponding Author
Prof. Dr. Chibandamabwe Lawrence
E-mail: lawrechibanda@gmail.com
Tel: +263779689943

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Abstract

Traditional complementary porridges were formulated using millet, Bambara groundnut, sesame and moringa using different ratios. The formulated weaning porridges had energy values which ranged from 329.2 to 371.5 Kcal/100g and protein which ranged from 6.7 to 13.07%. All the porridge had recommended standard protein for weaning foods except Mi. All the porridgeas had recommended vitamins; thiamine which ranged from 0.29 to 0.63mg/100g, riboflavin 0.14 to 2.24mg/100g and niacin 0.90 to 2.39mg/100g. The most abundant mineral was calcium which ranged from 221 to 646.6mg/100g and the least was zinc which ranged from 1.02 to 2.74mg/100g. A formulated porridge $MiSBaMO_5$ (60% Millet, 5% Bambara groundnut, 25% Sesame and 10% Moringa) had the highest minerals. All formulated porridges did not meet the recommended standard zinc weaning requirement of 3.6 mg/100g. A porridge sample $MiSBaMO_1$ with 60% Millet, 25% Bambara groundnut, 5% Sesame and 10% Moringa showed the highest score of overall acceptability by caregivers. In conclusion, the study showed that complementary weaning foods can be produced using locally available plant resources.

1. Introduction

Malnutrition among children is unacceptable in the world with large numbers of affected children in developing countries [1]. It is a significant global issue with irreversible consequences for infants [2]. Protein energy malnutrition (PEM) is a prevalent problem, especially in regions where maize is a staple food [3]. PEM is caused by a deficiency of protein and calories [4], which is often a result of inadequate food supply due to political, socio-economic, and natural factors [5]. This condition leads to physical and cognitive impairments, increased mortality rates, and chronic mental problems. [6].

According to [7, 44], approximately 155 million children under the age of five are affected by PEM globally, with a high concentration in sub-Saharan Africa. Stunting, a consequence of PEM, is estimated to cause 1 million deaths annually. Undernutrition is responsible for 50% of children's deaths, with severe and moderate malnutrition accounting for 8.4% and 4.6% of deaths, respectively [5]. The global stunting rate for children under five in 2017 was 155 million, primarily concentrated in Sub-Saharan Africa and Asia [8]. In developing countries, 65% of children are underweight, 50% of child deaths are attributed to PEM, and 32.5% are stunted [6]. In 2023, Zimbabwe had 23% of children between 6-59 months who were stunted and 6.9% underweight which is above WHO 5% threshold for public health [49]. PEM occurs during the transition from breastfeeding to solid or adult foods [10]. While the number of stunted children is decreasing in most regions, Africa still faces challenges in combating malnutrition [42].

Breast milk is recommended by the World Health Organization for the first four months of a child's life due to its essential nutrient content [11]. However, as breast milk alone cannot meet the nutritional needs of a growing child beyond six months, complementary feeding which involves introducing other foods alongside breast milk, becomes necessary [11]. These complementary foods should be designed to meet the specific nutritional requirements of infants [12]. In developed countries, complementary foods are made of staple cereal and they are of insufficient and low nutrition [1]. Fortified complementary foods from cereal-legume blends can reduce malnutrition since infants require highly nutritious foods with high energy and protein to cater for their high growth velocity [2].

In Zimbabwean households, cereals are commonly used as complementary foods for children, but they have low protein (9.4%) and micronutrient content [13]. Traditional porridges made from finger millet and maize also lack essential amino acids [13]. High food prices often limit the ability of families to provide diverse diets for their children after the weaning stage, leading to a heavy reliance on low-protein porridges [14]. To address malnutrition, it is crucial to utilize locally available small grains and legumes [16]. Blending cereals, legumes, and nutrient-rich ingredients like moringa leaf powder can help reduce malnutrition in children [17, 18]. The formulation of complementary foods should prioritize acceptability, affordability, and nutritional value [10].

Studies have focused on blending cereals with legumes such as beans, groundnuts, cowpeas and soybeans, but the potential of Bambara groundnuts has been overlooked [27]. There is a need for optimizing traditional nutri-diets which refers to the process of adapting and improving traditional dietary practices in order to meet the nutritional needs of a population. This study aims to develop a traditional nutri-pack using finger millet, sesame, moringa, and Bambara groundnuts in different ratios to create a cost-effective traditional complementary porridge. There is one porridge mixed in different ways and the idea is to find out the optimal mixture of ingredients. Nutri-pack is a localized product line that offers packaged food products or dietary supplements. The goal is to combat protein energy malnutrition among children under five, determine the nutritional composition of these nutri-diets and assess consumer acceptability. This initiative aligns with Sustainable Development Goal 3, which aims to ensure healthy lives and promote well-being for all ages and it will also contribute to the advancement of knowledge in the lives of children through better nutrition.

2. Materials and methods

2.1 Sample collection and preparation

Moringa (*Moringa oleifera*) leaves were obtained in Chiremwaremwa and Mashoko areas of Bikita District of Masvingo Province, Zimbabwe and were harvested at about 0900 hours. The trees were 3 months old and about 2.0 m high. The moringa leaves were removed of dust particles and extraneous material through washing on tap water which contains 1% Sodium chlorate 1 (NaCIO) and stored for 7 days at room temperature to allow for drying. The dried moringa leaves were ground into powder with a grinding stone. The powder was sieved through a 0.25 mm sieve to remove the large material. The powder was lastly packaged in well labelled Zip-lock bags as argued by [11] and stored in an air tight plastic container in a dark room [15] ready for formulation of the porridge.

The white Bambara groundnut (*Vigna subterranea*) landrace variety, finger millet (*Eleusine coracana*) and Sesame (*Sesamum indicum L*) were purchased at Mbare Musika in Harare, Zimbabwe. The Bambara groundnuts were sorted by removal of foreign material through winnowing and cleaned with tap water. The Bambara groundnuts were soaked in water for 24 hours as done by [19]. It was dehulled manually by hand to remove the seed coat [17]
as shown in Fig. 1. The dehulled Bambara were dried
water for 24 hours as done by [19]. It was dehulled

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Table 1. Composition of the designed porridge formulations (%)

Product Name	Code	Millet	Bambara groundnut	Sesame	Moringa
1	Mi	[100%]	[0%]	[0%]	[0%]
2	MiBa	[70%]	[30%]	[0%]	[0%]
3	MiSBaMo1	[60%]	[25%]	[5%]	[10%]
4	MiSBaMo2	[60%]	[20%]	[10%]	[10%]
5	MiSBaMo3	[60%]	[15%]	[15%]	[10%]
6	MiSBaMo4	[60%]	[10%]	[20%]	[10%]
7	MiSBaMo5	[60%]	[5%]	[25%]	[10%]

Legend: Mi-Millet, Ba- Bambara groundnut, S-Sesame, Mo- Moringa powder

manually by hand to remove the seed coat [17] as shown in Fig. 1. The dehulled Bambara were dried in the sun for 5 days. The dried Bambara was milled into flour through a 0.50 mm sieve and stored in a polyethylene bag.

Figure 1. The processed sesame, Bambara nuts and finger millet, respectively.

The finger millet was manually cleaned by winnowing to remove foreign material and washed with tap water. It was soaked overnight to enable germination. It was drained by spreading on a clean sack at room temperature and also to enable germination. A process of germination was done to increase the bioavailability of vitamins, proteins, increase digestibility, minerals and also decrease the anti-nutrients [1]. The germinated finger millet was then washed and dried for 2 days as recommended by [38]. The dried finger millet was then ground into flour using a Changfar grinding mill with 0.50 mm sieve to produce flour. The flour was stored in an air tight polyethylene bag at room temperature ready for formulation of porridge.

The sesame seeds were cleaned to remove extraneous material and washed with clean tap water and drained at room temperature. The seeds were boiled in water in a pot for 5 minutes for dehulling [15]. Dehulling of sesame was done according to the previous method [46]. The sesame seeds were roasted in an oven at 160^{o}C for 25 minutes [20] and cooled at room temperature. The roasted sesame seeds were pounded in a mortar and grounded using a grinding stone. The flour was stored in an air tight polyethylene bag and stored at room temperature for formulation.

For organoleptic evaluations, the sample porridges were cooked on a Defy gas stove. Half large Kango pot water was boiled whilst blending cold water with the porridge. To boiling water, the blended porridge was added whilst stirring using a wooden rod to prevent lamps. A half table spoon of pure cooking oil was added to 100 % millet (Mi) and 70% Millet: 30% Bambara groundnuts (MiBa) samples since they had no sesame whilst stirring and is optional when cooking the porridges. The porridges were cooked for 10 minutes and grand fine salt and brown sugar were added to taste and later the porridge was removed to be served to the participants whilst still hot.

2.2 Formulation of composite blends

The blends were formulated using the modified [21, 22] methods and they were blended in % as shown in Table 1 below. Most traditional porridges in the communal areas where this study was done are made of finger millet hence it was found in all formulations. The choice for the flours was because the crops were locally produced. During preparation, millet (Mi) was composite with Bambara groundnuts (Ba), Sesame (S) and Moringa (Mo) in different rations as shown in Table 1. The formulated blends were mixed thoroughly in a mixer for 10 minutes and packaged individually in a clean sealed 1kg polyethylene bags and kept at optimum temperature condition for analysis.

2.3 Determination of the chemical composition of the formulated products

2.3.1 Determination of moisture content

Moisture was determined using the AOAC method

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934.01 [28]. An empty evaporating dish with a lid was oven dried at 105°C for 3 h, cooled on a desiccator and weighed. A sample of 3g was weighed into a dish and uniformly spread. An evaporating dish with a sample was oven dried at 105°C for 3 h, cooled in a desiccator and a dish with a sample was reweighed and the moisture content was calculated.

2.3.2 Crude fibre determination

Crude fibre was determined using the method done by [27]. A sample of 4g was weighed into a 250 mL beaker, 50 mL of 4% H_2SO_4 was added and 200 mL of distilled water was added into the beaker. The contents were heated to a boiling point for 30 minutes whilst constantly stirring using a stirring rod. To ensure a constant volume, distilled water was added and after boiling, the mixture was poured into a funnel with a filter paper connected to a vacuum pump. The beaker was then washed with hot distilled water and transferred with a jet of hot water and washing was also continued on the funnel until the filtrate was free of acid as it was indicated by a litmus paper. The acid-free residue was then transferred quantitatively from the filter paper into the beaker and removing some traces with 5% NaOH and 200 mL by volume of hot water. The mixture was again brought to boil for 30 minutes whilst stirring and keeping the volume constant with hot water. The mixture was later filtered and washed until alkaline free [27].

The resultant residue was finally washed with 2 parts of 2 mL of 95% alcohol and residues on filter paper were transferred to weighed crucible and dried in an oven at 110 °C to a constant weight after it had been cooled in a desiccator. The crucible contents were ignited at 550°C for 8 hours in muffle furnace, cooled and weighed. The crude fibre was later calculated as weight loss after ignition [27].

2.3.3 Determination of crude fat

The fat content was determined using the Soxhlet method [27,23]. A bottle and a lid were placed in an incubator at 105°C overnight to get a constant weight of the bottle. A sample of 5g was weighed, put into extraction thimble and transferred into Soxhlet. A prepared bottle was filled with 250 mL of petroleum ether extract and taken to the heating mantle. The Soxhlet apparatus was connected, water was turned on to cool and the heating mantle was switched on. The sample was heated for 14 h at a heat rate of 150 drops/ min. The solvent was evaporated using a vacuum condenser. The bottle was incubated at 85°C and the solvent had completely evaporated and the bottle was dry. The bottle partially covered with a lid was transferred to a desiccator to be cooled. The bottle was reweighed and its dried content and the fat content were calculated.

2.3.4 Carbohydrate and energy determination

The total carbohydrate analysis of the porridge samples was calculated by method of difference as follows: Total carbohydrate (%) = 100 - [% moisture + % crude fibre + % crude protein + % crude fat] as argued by [13, 25].

According to [34], the maximum amount of energy after a sample has completely burnt in a bomb calorimeter is 4.1 Kcal/g for carbohydrates, 5.65 Kcal/g for protein and 9.45 Kcal for fats. The net heat of combustion in the human body differs from bomb calorimeter because heat energy in the calorimeter comes from oxidation of carbon-to-carbon dioxide, hydrogen to water and nitrogen from the proteins to nitrous oxide but the body is not capable of using the energy from nitrogen and this amounts to 1.3 Kcal, so the body is only capable of using 4.3 Kcal/g of the protein [34]. The factors 4, 9 and 4 approximately represent the amount of energy available to the body per gram of protein, fat and carbohydrate. Therefore, the energy content in the porridge samples was calculated by multiplying the grams of carbohydrates, protein and fats by the factor as indicated by the formula: Energy (kcals)= (protein x 4 + fat x 9 + carbohydrates x 4).

2.3.5 Protein analysis

Porridge sample was passed through a 20-mesh screen for it to be homogenous as argued by [25]. The sample was weighed to 1.0 g and placed into a Kjeldahl flask and 5 g of Kjeldahl catalyst was added together with 200 mL of concentrated H_2SO_4 [23]. A blank solution was prepared in a tube. The flask was placed in inclined position and heated until frothing ceased and boiled bristly until the solution cleared and this was done for digestion to breakdown all organic matter. The sample was cooled and 60 mL of distilled water was added. The flask was immediately

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connected to the digestion bulb on the condenser and with the tip of the condenser immersed in standard acid and 6 drops of mix indicator in receiver. The flask was rotated to mix the contents and later heated until NH_3 was distilled. The receiver was removed, condenser washed and titrate excess standard acid with standard NaOH and the protein content was calculated as

$$Protein\ \% = (A - B) \times N \times 14.007 \times 6.25 \div w$$

Where A = volume (ml) of 0.2 N HCl used in the titration
B= volume (ml) of 0.2 N HCL that was used in blank titration
N= normality of HCL
W= weight of the sample in g
14.007 = atomic weight of nitrogen
6.25= protein- nitrogen conversation factor of the prepared porridge samples

2.3.6 Vitamin analysis

The vitamins analysed were thiamine (Vitamin B_1), riboflavin (Vitamin B_2), and niacin. For Riboflavin (Vitamin B_2) analysis, AOAC Method 970.65 using the Fluorescence approach was used [26]. The AOAC Method 944.13 using the Microbiological approach was used for Niacin [26]. For Thiamine, the method used was according to [27].

To a sample of porridge, 5 g was weighed and 5 mL of 0.02 M HCl was added. The mixture was transferred into a 100 mL volumetric flask and more 0.02 M of HCl was added up to the 70 mL mark and the mixture was warmed at 50°C for 1 hour in a water bath whilst periodically shaking the mixture. The flask was cooled at room temperature and the flask was made up to 100 mL mark by adding distilled water. The flask was shaken vigorously and left for 15 minutes and the suspensions were filtered using a filter paper. For spectrophotometric measurement, 5 mL of the sample was pipetted into the test tubes which were well labelled and 5 mL of potassium ferricyanide: NaOH mixture 1:9 v/v (oxidation solution) was added. The mixture was shaken; left to stand for 2 minutes and 3 drops of H_2O_2 was added into the test tube and shaken. The absorbance of the preparation was determined at 369 nm against the blank prepared in the same manner but instead, 5 mL of water was added instead of the porridge sample extract and the calculations were done as follows:

$$Mg\ Vit.B1 = \frac{\text{Abs.x100} * \text{x110x1000}}{5}$$

Where 100* is the volume to which extract was made up to, 110 is a conversion factor and 5 is weight of sample taken for extraction of Vit. B.

2.3.7 Mineral analysis

The mineral elements that were analyzed were calcium, zinc, magnesium, iron, potassium and phosphorus [24]. A sample of 0.5g each was weighed into 100 mL beakers and labelled. A digestion mixture of concentrated HNO_3 and H_2O_2 (5:3) was added into the beaker with samples and left in a fume chamber overnight [24]. The mixture was digested at 100 °C for 3 hours until a clear solution was obtained. The resultant clear digest was topped up with 50 mL deionized water for the respective different mineral elements. The atomic Absorption Spectrophotometer was then used for the mineral analysis and the results obtained were converted to mg/100g.

2.4 Sensory Evaluation

According to [28], for effective sensory evaluation tests for porridges, the sample size should be 50-100 caregivers. The sampling size was 50 mother-child pairs with 6-59 months old children at and around Mashoko Mission in Bikita District ward 1 of Masvingo Province. Purposive sampling technique with a closed ended structured questionnaire was used for literacy mothers who can understand the details of the 9-point hedonic scale score evaluation form. Structured questionnaires based on the 9-point hedonic scale were used to gauge the sensory acceptance of the formulated porridge as argued by [29]. The 9-point hedonic scale questionnaire consisted of the colour, taste, texture, aroma, appearance and overall acceptability of the porridge which was rated from dislike extremely to like extremely [28].

2.5 Statistical analysis

Proximate and mineral analysis data was done in triplicate and analyzed using an analysis of variance (ANOVA) procedure of the Statistical Package for Social Science statistical software program (IBM SPSS version 20.0). The results were reported as (mean ± SD) and the difference between the treatments was determined by Fisher's Least Significance Difference

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Table 2. Energy, protein and vitamin content of the porridge samples

Code	Energy (Kcal/100g)	Protein (g/100g)	Thiamine (mg/100g)	Riboflavin (mg/100g)	Niacin (mg/100g)
Mi	$329.2^{e}\pm0.20$	$6.7^{e}\pm0.20$	$0.62^{a}\pm0.02$	$0.14^{c}\pm0.02$	$0.90^{d}\pm 0.20$
MiBa	$348^{d}\pm0.10$	$11.21^{d}\pm0.02$	$0.29^{c}\pm0.20$	$0.17^{b}\pm0.02$	$0.96^{d}\pm0.02$
$MiSBaMO_1$	$343.5^{d}\pm0.47$	$13.07^{a}\pm0.02$	$0.55^{b}\pm0.02$	$2.23^{a}\pm0.02$	$1.86^{c}\pm0.02$
$MiSBaMO_2$	$353.3^{c}\pm0.47$	$12.9^{b}\pm 0.02$	$0.57^{b}\pm0.02$	$2.24^{a}\pm0.20$	$1.97^{c}\pm0.02$
$MiSBaMO_3$	$362.4^{b}\pm 0.10$	$12.4^{c}\pm 0.01$	$0.59^{b}\pm0.02$	$2.24^{a}\pm0.00$	$2.17^{b}\pm0.02$
$MiSBaMO_4$	$371.5^{a}\pm0.10$	$12.6^{c}\pm 0.02$	$0.61^{a}\pm0.02$	$2.24^{a}\pm 0.00$	$2.26^{a}\pm0.02$
$MiSBaMO_5$	$355.5^{c}\pm0.10$	$12.4^{c}\pm 0.02$	$0.63^{a}\pm0.02$	$2.24^{a}\pm0.00$	$2.39^{a}\pm0.02$
P Value	0.01	0.00	0.04	0.00	0.00

Means of triplicate determinations ± S.D with different superscript letters on the same column are significantly different ($p\leq0.05$).
Legend: Mi -100% Millet, 0% Bambara groundnut, 0% Sesame, 0% Moringa; MiBa- 70% Millet, 30% Bambara groundnut, 30% Sesame, 0% Moringa; $MiSBaMo_1$-60% Millet, 25% Bambara groundnut, 5% Sesame, 10% Moringa; $MiSBaMo_2$-60% Millet, 20% Bambara groundnut, 10% Sesame, 10% Moringa; $MiSBaMo_3$- 60Millet, 15% Bambara groundnut, 15% Sesame, 10% Moringa; $MiSBaMo_4$-60% Millet, 10% Bambara groundnut, 20% Sesame, 10% Moringa; $MiSBaMo_5$-60% Millet, 5% Bambara groundnut, 25% Sesame, 10% Moringa.

(LSD) at 0.05 significance level. Post Hoc Tests were used to determine which mean treatments are different.

3. Results and discussion

3.1 Nutritional analysis

3.1.1 Energy, proteins and vitamins

There was a significant difference in terms of energy and for all nutrients of the traditional complementary porridges formulated ($P<0.01$) as shown in Table 2. A porridge sample $MiSBaMO_4$ had the highest mean energy value (371.5±0.10 Kcal/100g). According to [30] in developing countries, complementary food provides 200 kcal for 6–8-month-old infants, 300 kcal for 9-11 and 550 kcal for 12–23-month infants with average breast milk intake. According to [11], complementary weaning foods should be of low dietary bulky and have a balanced calorie density. The amount of energy required in infants from complementary foods depends on the quantity of breast milk consumed and the age of the child [31]. All the formulated porridge was within the range of the required energy requirements for 6-8- and 9-11-months old infants. The recommended infant and children's foods should be energy dense since low energy food limits the utilization of other nutrients and also total energy intake as argued by [16]. According to [15, 16], the recommended energy from complementary food for infants should be between 400-425 Kcal to meet the WHO and FAO requirements. However, all the formulated porridge was slightly below the recommended infant's energy needs as argued by [15].

There were significant differences in protein content among all the formulated porridge ($p<0.00$) as shown in Table 2. A porridge sample $MiSBaMO_1$ had the highest protein content with a mean value of 13.07±0.02 g/ 100g whilst the control which had millet only had the least amount of 6.7±0.20 g/ 100g. According to [15] protein plays a significant role in infants' body by being involved in enzyme and hormone synthesis during infants' growth and development. According to [40], there was 53.82% increase in protein from fortified Ogi and 174 % increase in fat after fortifying with Bambara groundnut. The results showed the importance of incorporating Bambara groundnuts in complementary infants' feeds. The recommended protein standard for weaning foods is between 11-21% as argued by [15], so the formulated porridge was within the range of protein requirements for weaning foods. According to [50], protein content increased with increasing Bambara groundnuts from 8.64% in 90% Sorghum: 10% to 13.44% in 50;50 sorghum and Bambara groundnuts respectively and this was in line with the results obtained in this study. The protein requirement for infants should be between 13-15g/100g for complementary weaning foods as argued by [32] and high protein content in the formulated porridge might be a contribution of moringa as argued by [33]. A porridge sample $MiSBaMO_1$ had protein content within the range for the

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Table 3. Mineral content (mg/100g) of the formulated porridge samples

Code	Ca (mg/100g)	P (mg/100g)	Zn (mg/100g)	K (mg/100g)	Fe (mg/100g)	Mg (mg/100g)
Mi	315^{d}±0.06	259.6^{d}±0.07	1.35^{d}±0.07	408.2^{d}±0.28	4.0^{e}± 0.21	63.7^{g}± 0.07
MiBa	221^{e}±0.07	181.7^{g}±0.14	1.02^{e}±0.02	286.8^{e}±0.14	9.6^{c}±0.14	285.5^{f}±0.70
$MiSBaMO_1$	441.2^{c}±0.08	207.5^{f}±0.14	1.25^{d}±0.01	401.7^{d}±0.01	8.6^{d}±0.08	305^{e}±1.41
$MiSBaMO_2$	492.5^{c}±0.05	239.3^{e}± 0.14	1.6^{c}±0.02	425.5^{c}±0.00	11.25^{a}±0.21	328.5^{d}±0.70
$MiSBaMO_3$	591.1^{b}± 0.07	270^{c}± 0.14	1.97^{c}±0.02	449.1^{b}±0.07	10.7^{b}±0.14	352^{c}±0.70
$MiSBaMO_4$	595.1^{b}±0.09	302^{b}± 0.14	2.36^{b}±0.02	472.5^{a}± 0.70	10.3^{b}±0.28	376^{b}±2.12
$MiSBaMO_5$	646.6^{a} ±0.07	334.1^{a}± 0.07	2.74^{a}±0.01	496.5^{a}±0.70	9.6^{c}±0.07	401^{a}±1.41
P Value	0.00	0.02	0.00	0.01	0.00	0.00

Means of triplicate determinations ± S.D with different superscript letters on the same column are significantly different ($p \leq 0.05$).
Legend: Mi -100% Millet, 0% Bambara groundnut, 0% Sesame, 0% Moringa; MiBa- 70% Millet, 30% Bambara groundnut, 30% Sesame, 0% Moringa; $MiSBaMo_1$-60% Millet, 25% Bambara groundnut, 5% Sesame, 10% Moringa; $MiSBaMo_2$-60% Millet, 20% Bambara groundnut, 10% Sesame, 10% Moringa; $MiSBaMo_3$- 60Millet, 15% Bambara groundnut, 15% Sesame, 10% Moringa; $MiSBaMo_4$-60% Millet, 10% Bambara groundnut, 20% Sesame, 10% Moringa; $MiSBaMo_5$-60% Millet, 5% Bambara groundnut, 25% Sesame, 10% Moringa.

Recommended Daily Dietary Intakes for infants as stated by [34].

All the porridges had the recommended thiamine needs for infants as argued by [35] except MiBa with the mean value of 0.29±0.20 mg/100g. The results showed that blending of the flour enriches the porridge in terms of the vitamins. According to [34] the recommended niacin Dietary Reference Intakes is between 2-8mg, 0.2-0.6mg thiamine and 0.3-0.6mg riboflavin for children up to 8 years old. The formulated porridge samples from $MiSBaMO_1$ – $MiSBaMO_5$ were within the recommended range for thiamine and riboflavin. The formulated porridge flours had vitamins that were within the range of the recommended nutrient composition for third world complementary weaning food as argued by [32].

3.1.2 Mineral analysis

There were significant differences ($p<0.05$) in all the porridge for all the minerals (Table 3). The results showed that blending of small grains, legumes and moringa improves the mineral content of the traditional complementary porridge. According to [7] complementary foods should have high nutrient density and should be fed frequently to the infants to ensure physical growth as well as brain development. The formulated porridges showed improved nutritional composition for all the elements as compared to the control porridge which is 100% finger millet.

According to [34], the 2000 Dietary Reference Value (DRV) for calcium ranges from 210-500mg for 6- 36 months old infants and up to 800 mg for less than 8 years old children. This was in agreement with the results obtained from this study with a range of 221 to 646.6mg/ 100g for all the porridge samples formulated. According to [28] iron and zinc deficiency affects the health, growth and development of infants. Zinc is an important element in children's diet for skin integrity, bone formation, tissue and cell growth and also for cell replication and its deficiency leads to retarded mental development and also stunted growth in infants [28]. All formulated porridge samples did not meet the zinc recommended value of 3.6 mg/100g of complementary infant's foods as the range was 1.02 to 2.74mg/100g. However, the formulated porridges were fair and close to FAO/WHO 1991 infant formulas requirements.

Iron is also an important element in infants' body since it is a component of hemoglobin which transports oxygen in the red blood cells and its deficiency causes anemia in infants as argued by [30] and [28]. According to [34], the Recommended Dietary Allowance (RDA) for iron ranges from 6-10mg for infants and the formulated porridges had the recommended iron content. All the formulated porridge flours had iron value that is recommended for complementary foods as argued by [32] whilst the control (Mi) had iron content below the recommended 4.0± 0.21 mg/100g. These results showed the significance of blending cereals with legumes in effort to increase the mineral elements to reduce malnutrition in infants since all the mineral elements

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Table 4. Mean sensory evaluation scores for each porridge

Code	Taste	Colour	Aroma	Texture	Appearance	Overall Acceptability
Mi	$7.44^{a}\pm 1.35$	$6.46^{a}\pm1.87$	$6.50^{a}\pm1.76$	$7.10^{a}\pm2.00$	$6.72^{a}\pm 1.94$	$6.62^{a}\pm1.70$
MiBa	$7.34^{a}\pm1.94$	$7.64^{b}\pm1.46$	$7.28^{b}\pm1.89$	$7.32^{a}\pm1.73$	$7.34^{b}\pm1.72$	$7.86^{b}\pm1.12$
$MiSBaMO_1$	$7.56^{a}\pm 1.45$	$6.98^{a}\pm1.55$	$7.36^{b}\pm1.57$	$7.48^{a}\pm1.81$	$7.42^{b}\pm1.66$	$8.24^{c}\pm1.11$
$MiSBaMO_2$	$6.92^{b}\pm1.62$	$6.54^{a}\pm1.74$	$6.64^{a}\pm 1.97$	$6.88^{b}\pm1.66$	$6.60^{a}\pm 1.81$	$6.76^{a}\pm1.61$
$MiSBaMO_3$	$6.92^{b}\pm2.24$	$7.36^{c}\pm1.62$	$7.16^{b}\pm1.82$	$6.52^{b}\pm2.06$	$6.28^{c}\pm 2.29$	$6.68^{a}\pm1.81$
$MiSBaMO_4$	$7.04^{a}\pm2.02$	$6.84^{a}\pm1.68$	$5.82^{c}\pm2.21$	$6.66^{b}\pm1.83$	$6.08^{c}\pm2.05$	$6.44^{a}\pm1.97$
$MiSBaMO_5$	$6.90^{b}\pm1.89$	$6.90^{a}\pm1.71$	$6.28^{a}\pm 1.81$	$6.84^{b}\pm 2.10$	$6.28^{c}\pm 2.16$	$6.54^{a}\pm1.69$
P Value	0.31	0.05	0.00	0.12	0.02	0.00

Means of triplicate determinations ± S.D with different superscript letters on the same column are significantly different ($p\leq0.05$).

Legend: Mi -100% Millet, 0% Bambara groundnut, 0% Sesame, 0% Moringa; MiBa- 70% Millet, 30% Bambara groundnut, 30% Sesame, 0% Moringa; $MiSBaMo_1$-60% Millet, 25% Bambara groundnut, 5% Sesame, 10% Moringa; $MiSBaMo_2$-60% Millet, 20% Bambara groundnut, 10% Sesame, 10% Moringa; $MiSBaMo_3$- 60Millet, 15% Bambara groundnut, 15% Sesame, 10% Moringa; $MiSBaMo_4$-60% Millet, 10% Bambara groundnut, 20% Sesame, 10% Moringa; $MiSBaMo_5$-60% Millet, 5% Bambara groundnut, 25% Sesame, 10% Moringa.

were increased with blending as compared to the control. Phosphorus ranges from 181.7 to 334.1mg/100g and it increases with increase in the amount of sesame. Magnesium ranges from 63.7 to 401mg/100g and Potassium ranges from 286.8 to 496.5mg/100g in the formulated porridges and both were within the recommended complementary food ranges.

Finger millet is a major complementary weaning food for infants in marginal areas of Africa which are hot and dry as argued by [53]. According to [53], it contains 7-11% proteins, 1.5-5% fat, 60-70% carbohydrates, 130-284 mg/100g phosphorus and 160-358 mg/100g calcium. After optimizing the traditional porridges by blending ingredients using different ratios, MiBa and $MiSBaMO_1$ showed improved nutritional values close to the dietary needs infants as compared to finger millet porridge.

3.2 Sensory evaluation

The organoleptic evaluations of the porridge samples were rated according to taste, colour, aroma, texture, appearance and overall acceptability using a 9-point hedonic scale as argued by [36]. For all the attributes on a 9-point hedonic scale, like moderately to like extremely with an average mean score of 6 and above was considered liked or positive and mean score of 5 with score which ranges from like moderately to like extremely was considered neutral and mean score below 4 which ranges from dislike moderately to dislike extremely was considered disliked or negative as argued by [37,39].

The results showed significant differences in colour, aroma, appearance and overall acceptability ($p<0.05$) whilst there were no significant differences in taste and texture ($p>0.05$) of the porridges as shown in Table 4. A p-value is a measure of the significance of the results. A formulated porridge $MiSBaMo_1$ was overall more accepted with overall acceptable value of mean± S.D 8.24 ± 1.11 and $MiSBaMO_4$ was least accepted with mean ± S.D value of 6.44 ± 1.97. According to [51], complementary foods that incorporate Moringa Leaf Powder (MLP) may be more acceptable when MLP is added as "sprinkles" to infant's usual complementary foods than when used as part of a cereal–legume flour to prepare porridges and other meals. The results showed that $MiSBaMO_1$ and MiBa were highly accepted as compared to other porridges. MiBa had 0% moringa whilst $MiSBaMO_1$ had 10% moringa but 25% Bambara groundnuts which gives it a whitish colour as compared to the dark colours of other porridges. From the study by [50], sensory evaluation showed blend made from 70:30% Sorghum and Bambara groundnuts respectively was most acceptable and the results were in line with the results from this study. An increase in moringa leaf powder reduces overall acceptability of complementary weaning foods [47,51].

The study shows that complementary weaning porridges can be formulated using finger millet, Bambara groundnuts, sesame and moringa with recommended nutritional needs for infants and well accepted. The porridges will have an impact in

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averting PEM in developing nations, in Sub-Saharan Africa where commercial weaning foods like Cerelac are too expensive with price range between USD 6.70-7,50/500g (Zimbabwe) which led to heavy dependency on cereal weaning porridge which is low in nutritive quality. The indigenous unexploited crops if processed and properly blended can provide low-cost weaning food for low socioeconomic classes especially in Zimbabwe where the ingredients are very cheap and locally available all year round.

4. Conclusions

The findings from the study showed that complementary weaning porridges formulated from locally available food products (millet, Bambara groundnuts, sesame and moringa) may avert protein energy malnutrition for under five children. A porridge sample $MiSBaMO_4$ had the highest amount of energy of 371.5±0.10 Kcal/100g whilst Mi had the least energy value of 329.2±0.20 Kcal/100g. The entire porridge samples had energy values below the infants' complementary foods recommendations but within the range of the required energy requirements for 6-8- and 9-11-months old infants. $MiSBaMO_1$ had the highest amount of crude protein of 13.07±0.02 g/100g and was within the recommended infants' dietary needs. The formulated porridge had vitamins that were within the range of the recommended nutrient composition for third world complementary weaning food. All the porridge samples had micronutrients which were within the recommended dietary range. All the porridges were accepted by caregivers and MiBa and $MiSBaMO_1$ were highly accepted as compared to other porridges. The formulated porridges are easily prepared and formulated from less costly and locally available products with high nutrient content. However, they should be thoroughly processed and cooked to reduce the effect of antinutritional factors. Further researches are required to analyze for antinutrients in the formulated porridges. These include phytic acid, tannins, hydrocyanic acid and trypsin inhibitors since they reduce digestion and absorption of nutrients.

Ethical statements

Research authorization was sought from Bindura University of Science Education's Agricultural Economics, Education and Extension Ethics Committee (ethical clearance number: AEE/0183/20206). Written permission to carry out the study in Mashoko Mission was obtained from the district, ward authorities and Mashoko Mission Hospital Administration. The study objectives, procedures, benefits and possible risks were explained to the caregivers of each infant for organoleptic evaluations. Participants signed the informed consent form before taking part and they were written in both Shona (native language) and English. The data was reported as it is without falsification. Confidentiality was assured by the use of code of names through questionnaires for consumer acceptability of the porridge.

Authors' contributions

Carried out the study and wrote the manuscript, C.L.; Supervised, reviewed and approved the manuscript, G.C.

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Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors declare no conflict of interest.

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