J. Food. Stab (2023) 6 (4): 20-33 Journal homepage: www.foodstability.com

Received: 02/09/2023/ Revised: 04/10/2023/ Accepted: 06/10/2023 / Available online: 23/10/2023

DOI: 10.36400/J.Food.Stab.6.4.2023-048

Journal of Food Stability

https://www.ajol.info/index.php/jfs

ORIGINAL ARTICLE

Formulation and Characterization of a Novel Finger Millet-Based Instant Complementary Premix Powder for Infants Aged between 6-59 Months in Zimbabwe

Tafadzwa Dhliwayo[1] / Prosper Chopera[1]/ Tonderayi M Matsungo[1] / Catherine Chidewe[2] / Stanley Mukanganyama[2] / Elijah Nyakudya[3] / Florence Mtambanengwe[3]/ Paul Mapfumo[3] / Loveness K Nyanga[1]*/

Authors' Affiliation

[1]Department of Nutrition Dietetics and Food Science, Faculty of Science, University of Zimbabwe.

[2]Department of Biotechnology and Biochemistry, Faculty of Science, University of Zimbabwe

[3]Faculty of Agriculture Environment and Food Systems, University of Zimbabwe

Corresponding author

Prosper Chopera

Email:
pchopera@gmail.com

Funding

The Ministry of Higher and Tertiary Education Innovation Science and Technology Development through the University of Zimbabwe's Vice Chancellor's Research Fund funded this work.

Abstract

When an infant is older than six months, human milk is no longer enough as sole dietary source for optimal growth, and thus, a greater reliance is placed on complementary foods for children aged 6-24 months. These foods are often not nutritious in developing countries. This study focused on the development and evaluation of an instant complementary porridge made using Finger millet (*Eleucine coracana)* as the main ingredient, cowpea (*Vigna unguiculata*), and bio-fortified vitamin A "orange" maize (*Zea mays).* All the raw materials were pre-processed by germination, roasting and milling before the instant complementary premix powder formulation. Standards methods were used to evaluate the nutritional values of the formulated complementary food. The resultant instant complementary premix powder had the following levels of nutrients; 68.64% carbohydrates, 13.14% protein, 9.04% fat, 4.27% moisture, 2.84% ash and 2.06 % fiber. The mineral content was as follows; zinc levels were 1.36±0.01 mg $100g^{-1}$. The iron content was 7.52±0.18 mg 100 g^{-1}, sodium 563±0.01mg $100g^{-1}$, calcium 517±0.01 mg $100g^{-1}$, magnesium 516.7±0.05 mg $100g^{-1}$ and phosphorus 366.7±0.01 mg $100g^{-1}$. Tannins were not detected; oxalates were 0.22±0.01 $g100g^{-1}$ and phytates 2.46±0.01 g $100g^{-1}$. A complementary instant porridge for children under 5 years was successfully developed from finger millet, cowpeas and biofortified Vitamin A "orange" maize. The instant complementary premix powder developed was well accepted and met at least 50% of the nutritional needs of children aged between 6 and 59months.

Practical application

Young children require nutrients dense foods in order to realise their full potential in growth and development. Porridge is a common food given to all children regardless of race, background or socio-economic status. It is therefore important in product development of novel instant porridges that they are made from nutrient rich ingredients thus producing a nutritious product.

Key words: *Extrusion, germination, complementary premix powder, finger millet and traditional grains*

1. Introduction

World Health Organization (WHO) states that, the change from breastfeeding alone with or without formula feeding to complementary food occurring after 6 months age is a really sensitive time (Abeshu *et al.,* 2016). When a baby is older than six months, human milk is no longer enough as a sole dietary source for optimal development, and so, a greater reliance is positioned on the

diet's complementary food component (Abeshu *et al.,* 2016). Malnutrition during complementary feeding is primarily ascribed to low-nutrient dense meals that are offered to children as weaning foods in under-developed nations like Zimbabwe (Zimbabwe National Nutrition Survey, 2018).

Complementary foods, produced in sub-Saharan Africa are typically of poor nutritional quality. This is because of the starchy staples that are commonly used and have predominated. Accessibility and affordability determines the type of complementary food eaten in Africa, especially the rural communities. Widespread childhood undernutrition in sub-Saharan Africa is caused by the poor nutritional quality of these complementary foods in comparison to nutritional requirements (Oladiran & Emmambux, 2020). In infant health and nutrition, the complementary food quality, is a very important consideration when producing infant diets. Growing infants especially between the ages of 6-24 months, should not be given complementary foods of low quality, as adverse health effects could result. Stakeholders, particularly in resource-poor nations, have recommended using traditionally sourced food components for supplemental foods (Ekong *et al.,* 2022).

Zimbabwe relies on the following complementary foods, cereal and non -cereal from sorghum, rice, maize, millet and potatoes. The food crops used are a function of local availability and affordability. Some of these staple crops have a high energy density however they often lack other macronutrients such as protein as well as micronutrients (vitamins and minerals) (Rao & Annadana, 2017). Phytate, a compound found in dried legumes, lowers the bioavailability of protein and energy in complementary foods as well as iron, calcium, and zinc (Owino *et al.,* 2008).

Several strategies have been used to formulate complementary foods such as fermentation and soaking (Parvin *et al.,* 2014). Precooked or instant products ease preparation for end-users and reduce the caregivers' time and fuel required for preparation (Gain, 2003). Therefore, according to both the Food and Agriculture Organization (FAO) and the Integrated Child Development Scheme (ICDS), production of complementary food, using locally available foods can combat maternal and child malnutrition among low-income groups and improve care practices (Gain, 2003). The goal of this study was therefore, to produce a nourishing instant complementary premix powder using locally available nutrient-rich foods, such as finger millet (*Eleucine coracana)* as the main ingredient, cowpea (*Vigna unguiculata*), and bio-fortified vitamin A "orange" maize (*Zea mays),* to evaluate nutrient and anti-nutrient content as well as sensory acceptability of the resultant porridge.

2. Materials and Methods

2.1. Materials

The finger millet grain was obtained from Mashonaland West province, Karoi town (16°48′36″S 29°42′00″E), orange maize from Manicaland province, Mutasa district (18°35′S 32°45′E) and the cowpeas were obtained from Manicaland, Buhera district (19°19' 57.00"S, 31° 26' 6.00"E), Zimbabwe. Analytical grade chemicals and reagents were used.

2.2. Methods

2.2.1. Sample preparation and processing

The grains were taken for analysis and product development to the Department of Nutrition Dietetics and Food Science laboratory, Faculty of

Science, University of Zimbabwe, Zimbabwe. Stones and unwanted materials were handpicked. The samples were washed, soaked for 3hrs and germinated for 48hrs (finger millet) and 24hrs (orange maize and cowpeas) according to household standard practice, at room temperature (20-23°C). Germination was done in sacks at room temperature, and water was sprinkled regularly at 3hr intervals. The grains and legume were germinated in order to reduce the anti-nutrients value thus improving availability of minerals like zinc and iron. The germinated grains were then roasted in an oven at a temperature of 60°C for 10-15minutes. The samples were then ground using a grinding mill and sieved using a 2 mm mesh into a fine powder.

2.2.2. Formulation of the instant complementary premix powder

The ingredients and formulation were adopted from CODEX guidelines for complementary foods (WHO, 2009). The composite flour underwent preliminary testing, mostly through sessions of immediate sensory evaluation, to consider the product's sensory and nutritional properties. Other ratios resulted in undercooked and burnt product. Then, a final three composite flour sets were developed by combining the flours from finger millet, orange maize and cowpeas in different ratios; 60:30:10, 65:20:15 and 70:15:15 respectively. Sugar (hulett white refined) (5%), oil (zimgold vegetable oil) (0.5%) and skim milk powder (four seasons low heat) (5%) of the total flour compositions were added. The flour samples were blended, labelled and stored in airtight bags at 25°C for further analysis.

2.2.3. Extrusion processing of the instant complementary premix powder

Extrusion process of the produced flour samples, using a small laboratory single-screw extruder equipped with a die nozzle was done. Finger millet flour was used to run the extruder until the output stabilized by creating a puffed-clean result. The composite flours were then fed into the barrel as it was being moved by the screw. The feed was turned into a semi-solid, plasticized mass by the extrusion screw while it was still moving down the barrel. At the end of the barrel that discharged, the extrudates were forced through the die. After that, milling using a grinding mill was then used to produce the instant complementary premix powder.

2.2.4. Sensory evaluation and consumer acceptability

A final three composite flour sets were developed by combining the flours from finger millet, orange maize and cowpeas in the following different ratios; A, B and C. Sample A consisted of 60% finger millet flour, 30% orange maize flour and 10% cowpeas flour. Sample B consisted of 65% finger millet flour, 20% orange maize flour and 15% cowpeas flour. Sample C consisted of 70% finger millet flour, 15% orange maize flour and 15% cowpeas flour. This instant complementary premix powder was compared with a commercial product already on the market as the control. Porridge was prepared for consumption by mixing the instant complementary premix powder with water to the required consistency. The product was assessed for its orthonasally perceived aroma sensations (during sniffing), visually perceived appearance attributes and attributes perceived in-mouth during oral manipulation of samples.

2.2.5. Proximate composition of the instant complementary premix powder

The proximate content of the instant complementary premix powder for crude protein, moisture, crude fibre, carbohydrate, ash and fat was conducted in accordance with the method of

Association of Official Analytical Chemists (AOAC, 1990) (Rybak-Chmielewska, 2003). The micro Kjeldahl method was used as described by the AOAC procedures 984.13, to determine the nitrogen content of the samples. The percentage nitrogen was converted to crude protein by the factor 6.25. Moisture content was established by the AOAC procedures 925.40; by drying the sample at 103°C in an electric oven. The AOAC procedure 942.05 was used to determine the ash content. The ash was obtained by incinerating the samples at 550°C. Soxhlet apparatus using hexane was used to evaluate the fat content of the samples, using the AOAC 963.15 procedures. The difference method was used to determine the carbohydrate content. The total carbohydrate was the residual weight after subtracting moisture, total protein, total ash, fiber and fat.

2.2.6. Minerals composition of the instant complementary premix powder

The sample was ashed at 550°C for mineral analysis determination. The sample was digested by nitric acid and filtered using a Whatmann filter paper (47mm). Zinc, iron, calcium, magnesium, potassium, sodium and iron were determined using computer controlled Atomic Absorption Spectrometer (AAS Model AA-6701F), Shimadzu, Japan. The mineral content was reported in mg/100 g sample.

2.2.7 Anti-nutrient analysis

2.2.7.1 Phytates

Phytates were determined by the method by (Marolt & Kolar, 2021). Powdered samples of finger millet, cowpeas and orange maize were prepared separately for a 3 hour extraction in 2.4% HCl. The extract (0.5ml) was combined with acidified 0.2 ml $FeCl_3$ (0.00145 gFe/ml 1N HCl) and heated for 15 minutes before cooling and filtered. To 1 ml of supernatant, we added 0.25 ml N/2 HCl, followed by 0.5 ml 10% KCNS and 2.5 ml N/6 HCl. A crimson red hue emerged whose absorbance was read at 540 nm using a spectrophotometer (Biobase BK-D560, China). The content of phytate was expressed as mg/100g.

2.2.7.2 Tannins

Tannins were determined by the method described by Rybak-Chmielewska (2003) in this way: One gram of each, finger millet, orange maize and cowpeas sample were weighed individually and put in a beaker. To extract tannins, each sample was immersed in a solvent solution made up of 80 ml of acetone and 20 ml of glacial acetic acid for five hours. A double layer of filter paper was used to filter the samples to obtain the filtrates. Tannic acid (30 ppm) was used as a standard. The readings were done at 500 nm on a computer controlled Atomic Absorption Spectrometer (AAS Model AA-6701F), Shimadzu, Japan.

2.2.7.3 Oxalates determination

Oxalate determination was as previously described by Adeniyi *et al.* (2009). Each sample (2g) was digested for one hour in a 250 ml volumetric flask filled to the mark with 10 ml of 6 M HCl. The pH of the filtrate was adjusted with concentrated NH_4OH solution, until the solution's colour became faintly yellow from salmon pink colour. Thereafter 5% $CaCl_2$ solution (10ml) was added in order to precipitate the oxalate. The suspension was centrifuged at 2500 rpm, followed by fully dissolving in 10 ml of 20% (v/v) H_2SO_4. Afterwards the supernatant was decanted. All of the filtrate resulting from the H_2SO_4-induced dissolution was made up to 300 ml. The filtrate was heated to near boiling point and an aliquot (125 ml) was used to titrate against a 0.05 M standardized $KMnO_4$ solution. From the titre

value, the evaluation of the oxalate content was done.

2.2.8 Statistical analysis

Data was entered into excel and analysed using Genstat Version 18. ANOVA was used to test for significant differences between means. Mean separation was done at 5% significance level; using least significance difference (LSD).

3. Results and discussion

A multi-grain based instant complementary premix powder was developed in order to promote the utilisation of locally available traditional grains towards reduction of malnutrition in children aged 6-59 months. The formulations were done to produce the most preferred instant complementary premix powder as shown in Table 1. Instant complementary premix powder A consisted of 60% finger millet flour, 30% orange maize flour and 10% cowpeas flour. Instant complementary premix powder B consisted of 65% finger millet flour, 20% orange maize flour and 15% cowpeas flour. Instant complementary premix powder C consisted of 70% finger millet flour, 15% orange maize flour and 15% cowpeas flour.

3.1. Sensory evaluation

The results of the sensory evaluation are shown in Figure 1. Instant complementary premix powder C (70% finger millet flour, 15% orange maize flour and 15% cowpeas flour) had the highest score on branny (a light, dusty grainy aroma associated with cereal bran) and cardboardy (aroma associated with damp cardboard) aroma. Instant complementary premix powder A (60% finger millet flour, 30% orange maize flour and 10% cowpeas flour) had a lower score of branny and cardboardy aroma perceived. On visual appearance after adding water, instant complementary premix powder A (60% finger millet flour, 30% orange maize flour and 10% cowpeas flour) had the highest score of smoothness (degree to which porridge appears homogenous and smooth when stirred with a spoon) and gloss (degree to which porridge has a reflective shine). Instant complementary premix powder C (70% finger millet flour, 15% orange maize flour and 15% cowpeas flour) had the highest score of visible lumps, followed by instant complementary premix powder B (65% finger millet flour, 20% orange maize flour and 15% cowpeas flour). Lastly, instant complementary premix powder A (60% finger millet flour, 30% orange maize flour and 10% cowpeas flour) had the least visible lumps. All the samples showed that they were smooth and glossy on visual appearance. After tasting, the complementary food sample, instant complementary premix powder A (60% finger millet flour, 30% orange maize flour and 10% cowpeas flour) had the highest score on overall flavour (92%) followed by instant complementary premix powder B (65% finger millet flour, 20% orange maize flour and 15% cowpeas flour). Lastly instant complementary premix powder C (70% finger millet flour, 15% orange maize flour and 15% cowpeas flour) had the lowest score on flavour. Instant complementary premix powder C (70% finger millet flour, 15% orange maize flour and 15% cowpeas flour) had the highest scores on coarseness (degree to which the mass feels rough/coarse on oral surfaces), graininess (degree to which the sample contains small grainy particles), stickiness (degree of force required to remove material adhering to teeth and palate during normal eating) and lumps. The premix powder C and B had high legume content. This affected the flavor and taste of the product. Legumes have very low expansion ratio, as such

they affect the overall texture of extruded products. This was also evidenced by Devi *et al.* (2013) whereby expansion of resultant extrudates decreased with the addition of a mixed legume flour. According to Pelembe *et al.* (2002) the inclusion of more cowpeas reduced the firmness of the porridges. The lower firmness can be explained by the differences in amylose–amylopectin ratio in the two grains (finger millet and cowpeas). The amylopectin molecule is more susceptible to shear forces during extrusion, its branched chains allow the water to penetrate the structure more easily and gelatinise more readily than amylose (Huang *et al.,* 2022).

3.2. Nutritional composition

The proximate composition of the instant complementary premix powder A which was chosen as the final product based on sensory evaluation results is shown in Table 2. The moisture level of the instant complementary porridge was less than 10% of the cut-off by FAO/WHO (2009) which is recommended for complementary foods (Owino *et al.,* 2008). This is because higher moisture content may affect the storage quality of the instant complementary porridge. The consistency, texture, and microbiological quality of food are affected by moisture (WHO and UNICEF, 2003).

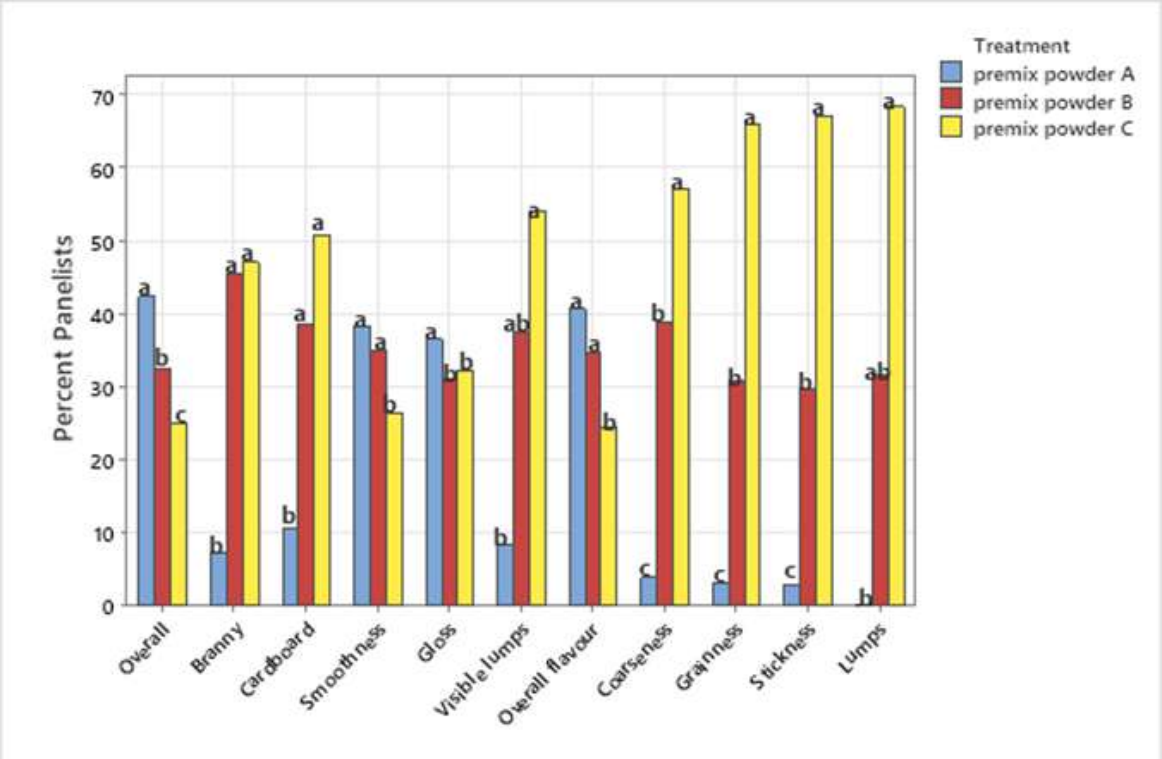

Figure 1: Perceived attributes of the instant complementary premix powder. Bars sharing the same letter within each attribute were not significantly different from each other (ANOVA $p<0.05$). Premix powder A: 60% finger millet flour, 30% orange maize four and 10% cowpeas flour Premix powder B: 65% finger millet flour, 20% orange maize flour and 15% cowpeas flour Premix powder C: 70% finger millet flour, 15% orange maize flour and 15% cowpeas flour.

Olaoye *et al.* (2006) reported that lower moisture content in food have an implication on keeping quality and is useful to prevent microbial contaminations.

Table 1: Formulations done to produce the instant complementary premix powder

Instant complementary premix powder	Flour compositions %				Other ingredients (% of total flour compositions)		
	Finger millet flour	Orange maize flour	Cowpeas flour	Sugar	Oil	Skim milk powder
A	60	30	10	5	0.5	5
B	65	20	15	5	0.5	5
C	70	15	15	5	0.5	5

The fat content of the instant complementary premix powder was 9.04%**.** The value meets the FAO/WHO-recommended daily allowance for food for children between 6-59 months (>6%) (Gemede, 2020). The CODEX standard advises that processed diets based on cereal should not contain more than 3.3 g/kCal of fat (Tizazu *et al.,* 2010). Dietary fats provide energy, essential fatty acids, transports fat soluble vitamins (A, D, E and K) and promotes palatability of food (WHO and UNICEF, 2003) and Suri *et al.* (2014).

A high protein content of 13.14% present in the developed instant complementary premix powder is in agreement with results of other authors (Tumwine *et al.,* 2019) and (Nassanga *et al.,* 2016) whereby they also formulated cereals that were fortified with legumes. The presence of cowpeas in the formulation of the complementary food may have considerably contributed to the protein levels of 13.14% (Dhliwayo *et al.,* 2023). Extrusion cooking may also have significantly increased the protein content as well. Obatolu *et al.* (2000) reported that such an increase in protein content could be because of denaturation of protein molecules as a result of the high extrusion temperature and that this makes the protein molecules more susceptible to proteolysis and therefore improves protein utilization. Degradation of tannins by processes such as soaking and fermentation also increases protein content (Ojo, 2022).

Ash content is a quality indicator for minerals residue left after ignition and complete oxidation of organic matter in a particular food sample since it shows the amount of minerals present (Syeunda et al., 2021). The complementary food met the recommended ash content (<5 g/100 g) as recommended by WHO/FAO (2004). The daily recommended allowance of crude fiber in a complementary food should be <5% *(Okoth et al.,* 2017). Thus, the formulated complementary food processed in this study met this requirement. This could have been attributed to the main ingredient finger millet, which in literature has been shown to have a high level of crude fibre of up to 20 g $100g^{-1}$, among the other ingredients. At least 65 g $100g^{-1}$ of accessible carbohydrates are

advised for complementary dietary products (Affonfere *et al.,* 2021).

The instant complementary premix powder, carbohydrate content is in the recommended range. From prior analysis of ingredients it is evident that orange maize is the ingredient which had the highest carbohydrate content of 73.77 g $100g^{-1}$ (Dhliwayo *et al.,* 2023).

Table 2. Proximate, minerals and anti-nutrient results of the instant complementary premix powder

Proximate	g/100g	Mineral	mg $100g^{-1}$	antinutrient	g $100g^{-1}$
Carbohydrates	68.64±0.02	Fe	7.52±0.18	Phytates	2.46±0.01
Crude protein	13.14±0.02	Zn	1.36±0.01	Oxalates	0.22±0.01
Fat	9.04±0.03	Na	563±0.01	Tannins	ND
Moisture	4.27±0.02	Ca	517±0.01		
Ash	2.84±0.01	Mg	516.7±0.05		
Crude fibre	2.06±0.03	P	366.7±0.01		

This contributed to the required amount of carbohydrates in the instant complementary premix powder.

The mineral content of the finger millet-based complementary porridge in mg $100g^{-1}$ is shown in Table 2. The iron content of the instant complementary premix powder was 7.52±0.18, zinc content was 1.36±0.01, sodium was 563±0.01, calcium was 517±0.01, magnesium was 516.7±0.05 and phosphorus was 366.7±0.01. According to Codex Alimentarius (Codex Alimentarius Commission, 2017) the iron content should range from 3.9 to 11.6 mg depending on the age of the child. The formulated instant complementary premix powder had an iron content which was in the range of the recommended limits. In children, to ensure the body's cells get enough oxygen, iron is required. Without enough iron, children develop anaemia since they cannot produce enough red blood cells (Bayside-Medical, 2010). Cowpeas, which have an iron content of approximately 4.86 mg (Dhliwayo *et al.,* 2023), may have contributed the most iron. The extrusion process may also have led to the increased iron levels. The zinc requirements for children between 6-59 months ranges from 2.4 to 8.3 mg depending on the age of the child (Codex Alimentarius Commission, 2017).

The formulated instant complementary premix powder had zinc content which was below the required levels. This means there is need to fortify with zinc in order to meet the required levels. Zinc is an important nutrient with many functions such boosting the immune system. There is evidence that it reduces the incidence of diarrhoea and probably mortality in young children (Young *et al.,* 2014). The recommended calcium intake from complementary foods is around 500 mg (Codex Alimentarius Commission, 2017). The formulated instant

complementary premix powder had a calcium level which was in the required range. This may be attributed to the main ingredient which is finger millet which is known to have a high calcium content among all the cereals (Anitha *et al.,* 2021).

The selected anti-nutrient results of the finger millet-based complementary food in g $100g^{-1}$ is shown in Table 2. The phytate, oxalate and tannin contents were found to be 2.46, 0.22, and 0.00 g/100g respectively. The porridge was very low in anti-nutrients. Phytates and oxalates were present at trace levels in the instant complementary premix powder. The levels of antinutrients might have decreased due to the processing of the raw ingredients as well as the process of extrusion. Tannins are reduced by soaking in water (Omosebi *et al.,* 2018). Tannins are well known for their capacity to combine with proteins to form insoluble complexes, which decrease the food proteins' ability to be digested (Ogunlade *et al.,* 2011). Therefore, the reduction of these tannin levels may have made other nutrients eg proteins to be more available in the complementary food. This highlights that the porridge will make a significant contribution to diet quality of the children (Omosebi *et al.,* 2018).

The nutritional content of the commercial product which was being used as the control in g $100g^{-1}$ vs the instant complementary premix powder is shown in Table 3. The protein content was 15.0 g $100g^{-1}$ and carbohydrates content was 68.0 g $100g^{-1}$. For the mineral content in mg $100g^{-1}$, sodium was 200 mg $100g^{-1}$, potassium was 550 mg $100g^{-1}$, calcium content was 480 mg $100g^{-1}$, iron was 12 mg $100g^{-1}$ and zinc content was 4 mg $100g^{-1}$. In comparison with the control, the instant complementary premix powder had a higher carbohydrate, calcium and sodium content. Early and excessive exposure to sodium can prime the children's palate for salty foods, increase the risk of obesity, and place a child at greater risk of developing hypertension, which can lead to heart disease and stroke later in life. The protein content of the instant complementary premix powder was in line with the recommended levels. Although orange maize was added to boost the Vitamin A content, it is assumed that the instant complementary premix powder had Vitamin A though this was not assessed. Though the zinc content was lower than the control, the instant complementary premix powder is a potential competitor of the commercial product which is already on the market. There is need to boost the zinc content though in the developed complementary food. Fortification can be considered during the product development process.

Table 3 : Commercial product (control) nutrient content vs the instant complementary premix powder

Nutrients	Commercial product/100g	Instant complementary premix powder/100g
Protein	15.0 g	13.14 g
Carbohydrates	68.0 g	68.64 g
Sodium	200 mg	563 mg
Fat	9.6 g	9.04 g
Iron	12.0 mg	7.52 mg
Zinc	4.0 mg	1.36 mg
Calcium	480 mg	517 mg
Phosphorus	400 mg	366.7 mg

3.3. Comparison with recommended daily allowances (RDAs)

The RDA values of children aged 6-12months in comparison with the formulated instant complementary premix powder was done and is as shown in Table 4. A comparison of the Recommended Daily Allowance against the developed complementary food was done. The carbohydrate content for the instant complementary premix powder contributes 114.4% and 72.3% to the RDA if the child is 6-8months and 7-12months respectively and consumes the entire 100g portion. The porridge contributes 144.4% and 119.5% protein to the RDA if the child is 6-8 months and 7-12months respectively and consumes the entire 100g portion. The fat content required for the infant is 30-31g/day. The developed complementary food would need to be supplied at 3 servings per day to meet the daily recommended fat content for the infants. The fiber content of the developed complementary food was low, which means it would need about 3 servings per day of the complementary food to meet the required fiber content of 6.9g/day or the infant can obtain this from other dietary sources. Concerning calcium requirements, in children aged 6-8 months and 7-12 months, the instant complementary premix powder contributes 143.6% and 95.7% respectively if the child consumes the whole 100g portion. For iron, the instant complementary premix powder contributes 75.2% and 50.1% RDA for children aged 6-8months and 7-12months respectively if the 100g portion is consumed. With regards to zinc, the porridge contributes 68.0% and 45.3% to the RDA of children aged 6-8months and 7-12months respectively if the entire 100g portion is consumed.

Table 4: Comparison of the RDA of selected nutrients for children aged 6-12months vs levels in the formulated instant complementary premix powder

Life stage group	Carbohydrates g	Protein (g)	Fat (g)	Fiber (g)	Calcium (mg/d)	Phosphorus (mg/d)	Magnesium (mg/d)	Iron (mg/d)	Sodium (mg/d)	Zinc (mg/d)
Infants										
6-8-months	60	9.1	31	6.9	360	100	60	10	110	2
7-12 months	95	11.0	30	6.9	540	275	70	15	370	3
Instant complementary premix powder	68.64	13.14	9.04	2.06	517	366.7	516.7	7.52	563	1.36
RDA-Recommended Daily Allowance										

Iron and zinc levels were low, meaning there is need for about 1 and half servings per day to meet the daily iron requirements. The nutrients which did not meet the daily requirements may also need supplementation or consumption of other foods rich in these nutrients in order to achieve a balanced diet for the infants.

4. Conclusion

A complementary instant porridge for children under 5 years was successfully developed from finger millet, cowpeas and orange maize. The most preferred formulation of the instant complementary instant premix powder was the blend with 60% finger millet flour, 30% orange maize flour and 10% cowpeas flour. The porridge from this formulation was in overall well accepted by consumers. This porridge had a high nutrient content, except for zinc levels which were low. Further, the anti-nutrient levels were acceptably low. Though the porridge had high levels of protein, specific aspects like the bioavailability and digestibility of the nutrients in the developed porridge need further investigations. This study provides significant data that can encourage local industries to start considering the use of traditional multi-grains in food.

Acknowledgments

The authors would like to thank all staff and Future Grains for Africa Management from The University of Zimbabwe.

Conflict of interest

The authors declare that they have no competing interests.

Ethics

Informed consent was obtained from all participants after they voluntarily agreed to participate in the sensory evaluation.

Funding source

The Ministry of Higher and Tertiary Education Innovation Science and Technology Development through the University of Zimbabwe's Vice Chancellor's Research Fund funded this work.

References

Abeshu, M. A., Lelisa, A., & Geleta, B. (2016). Complementary Feeding: Review of Recommendations, Feeding Practices, and Adequacy of Homemade Complementary Food Preparations in Developing Countries – Lessons from Ethiopia. *Frontiers in Nutrition*, *3*(41), 1-9. https://doi.org/10.3389/fnut.2016.00041

Affonfere, M., Chadare, F. J., Fassinou, F. T. K., Talsma, E. F., Linnemann, A. R., & Azokpota, P. (2021). A complementary food supplement from local food ingredients to enhance iron intake among children aged 6–59 months in Benin. *Food Science and Nutrition*, *9*(7), 3824–3835. https://doi.org/10.1002/fsn3.2358

Anitha, S., Givens, D. I., Botha, R., Kane-Potaka, J., Sulaiman, N. L. B., Tsusaka, T. W., Subramaniam, K., Rajendran, A., Parasannanavar, D. J., & Bhandari, R. K. (2021). Calcium from finger millet—a systematic review and meta-analysis on calcium retention, bone resorption, and in vitro bioavailability. *Sustainability (Switzerland)*, *13*(16). https://doi.org/10.3390/su13168677

Bayside-Medical. (2010). Iron in Your Child ' s Diet. *Why Is Iron Important*, 1–2.

Codex Alimentarius Commission. (2017). *Guidelines on Formulated Complementary Foods for Older Infants and Young*.

Devi, N. L., Shobha, S., Tang, X., Shaur, S. A., Dogan, H., & Alavi, S. (2013). Development of

protein-rich sorghum-based expanded snacks using extrusion technology. *International Journal of Food Properties*, *16*(2), 263–276. https://doi.org/10.1080/10942912.2011.551865

Dhliwayo, T. C., Chopera, P., Matsungo, T. M., Chidewe, C., Mukanganyama, S., Nyakudya, E., Mtambanengwe, F., Mapfumo, P., & Nyanga, L. K. (2023). *Effect of germination and roasting on the proximate, mineral and anti-nutritional factors in finger millet*. *23*(8), 24346–24362.

Gain. (2003). Nutritional Guidelines for Complementary Foods and Complementary Food Supplements Supported by GAIN. *Global Alliance Fro Improved Nutrition*, *1*, 1–23.

Gemede, H. F. (2020). Nutritional and antinutritional evaluation of complementary foods formulated from maize, pea, and anchote flours. *Food Science and Nutrition*, *8*(4), 2156–2164. https://doi.org/10.1002/fsn3.1516

Huang, X., Liu, H., Ma, Y., Mai, S., & Li, C. (2022). Effects of Extrusion on Starch Molecular Degradation, Order–Disorder Structural Transition and Digestibility—A Review. *Foods*, *11*(16). https://doi.org/10.3390/foods11162538

Idongesit Ekong, A., Eka Bassey, E., Benjamin Achor, A., & Francis, A. (2022). Nutritional composition of traditional complementary foods in Nigeria and health/developmental outcomes: A systematic review. *Scientific African*, *16*, e01203. https://doi.org/10.1016/j.sciaf.2022.e01203

Marolt, G., & Kolar, M. (2021). Analytical methods for determination of phytic acid and other inositol phosphates: A review. *Molecules*, *26*(1). https://doi.org/10.3390/MOLECULES26010174

Nassanga, P., Okello-Uma, I., & Ongeng, D. (2016). Development of a Millet-Sesame-Soy complementary food composite for rural communities. *RUFORUM Working Document Series*, *14*(2), 1051–1057. https://doi.org/http://repository.ruforum.org/

Ogunlade, I., Ilugbiyin, A., & Osasona, A. I. (2011). A comparative study of proximate composition, anti-nutrient composition and functional properties of Pachira glabra and Afzelia africana seed flours. *African Journal of Food Science*, *5*(1), 32–35. http://www.academicjournals.org/ajfs

Ojo, M. A. (2022). Tannins in Foods: Nutritional Implications and Processing Effects of Hydrothermal Techniques on Underutilized Hard-to-Cook Legume Seeds—A Review. *Nutrition and Food Science*, *27*(1), 14–19.

Okoth, J. K., Ochola, S. A., Gikonyo, N. K., & Makokha, A. (2017). Development of a nutrient-dense complementary food using amaranth-sorghum grains. *Food Science and Nutrition*, *5*(1), 86–93. https://doi.org/10.1002/fsn3.367

Oladiran, D. A., & Emmambux, N. M. (2020). Locally Available African Complementary Foods: Nutritional Limitations and Processing Technologies to Improve Nutritional Quality—A Review. *Food Reviews International*, *00*(00), 1–31. https://doi.org/10.1080/87559129.2020.1762640

Omosebi, M. O., Osundahunsi, O. F., & Fagbemi, T. N. (2018). Effect of extrusion on protein quality, antinutritional factors, and digestibility of complementary diet from quality protein maize and soybean protein concentrate. *Journal of Food Biochemistry*, *42*(4), 1–10. https://doi.org/10.1111/jfbc.12508

Owino, V., Amadi, B., Sinkala, M., Filteau, S., & Tomkins, A. (2008). Complementary Feeding

Practices And Nutrient Intake From Habitual Complementary Foods Of Infants And Children Aged 6-18 Months Old In Lusaka, Zambia. *African Journal of Food, Agriculture, Nutrition and Development*, *8*(1). https://doi.org/10.4314/ajfand.v8i1.19176

Parvin, R., Abdus Satter Miah, M., Absha Jabin, S., Abedin, N., Author, C., Kumar Paul, D., Satter, M. A., Islam, F., & Kamruzzaman, M. (2014). Studies on the Development and Evaluation of Cereal Based Highly Nutritive Supplementary Food for Young Children. *International Journal of Innovation and Applied Studies*, *9*(2), 974–984. http://www.ijias.issr-journals.org/

Pelembe, L. A. M., Erasmus, C., & Taylor, J. R. N. (2002). Development of a protein-rich composite sorghum - Cowpea instant porridge by extrusion cooking process. *Lwt*, *35*(2), 120–127. https://doi.org/10.1006/fstl.2001.0812

Rao, C. K., & Annadana, S. (2017). Nutrient Biofortification of Staple Food Crops: Technologies, Products and Prospects. *Phytonutritional Improvement of Crops*, 113–183. https://doi.org/10.1002/9781119079972.ch3

Rybak-Chmielewska, H. (2003). Honey. *Chemical and Functional Properties of Food Saccharides*, *1*(Volume 1), 73–80. https://doi.org/10.7312/seir17116-004

Suri, D. J., Tano-Debrah, K., & Ghosh, S. A. (2014). Optimization of the nutrient content and protein quality of cereal-legume blends for use as complementary foods in Ghana. *Food and Nutrition Bulletin*, *35*(3), 372–381. https://doi.org/10.1177/156482651403500309

Syeunda, C. O., Anyango, J. O., Faraj, A. K., & Kimurto, P. K. (2021). In vitro protein digestibility of finger millet complementary porridge as affected by compositing precooked cowpea with improved malted finger millet. *Journal of Food Science and Technology*, *58*(2), 571–580. https://doi.org/10.1007/s13197-020-04569-1

Tizazu, S., Urga, K., & Ababa, A. (2010). Improvement of energy and nutrient density of sorghum-based complementary foods using germination. *African Journal of Food, Agriculture, Nutrition and Development*, *10*(8). https://doi.org/10.4314/ajfand.v10i8.60875

Tumwine, G., Atukwase, A., Tumuhimbise, G. A., Tucungwirwe, F., & Linnemann, A. (2019). Production of nutrient-enhanced millet-based composite flour using skimmed milk powder and vegetables. *Food Science and Nutrition*, *7*(1), 22–34. https://doi.org/10.1002/fsn3.777

WHO . (2009).Guidelines for an Integrated Approach to the Nutritional Care of HIV-Infected Children (6 Months-14 Years). Geneva: World Health Organization. Appendix V, Guiding Principles for Complementary Feeding of the Breastfed Child (2003) https://www.ncbi.nlm.nih.gov/books/NBK143680/

WHO and UNICEF. (2003). Global strategy for infant and young child feeding. *Fifthy-Fourth World Health Assembly*, *1*, 1–30. https://www.who.int/nutrition/publications/infantfeeding/9241562218/en/

Young, G. P., Mortimer, E. K., Gopalsamy, G. L., Alpers, D. H., Binder, H. J., Manary, M. J., Ramakrishna, B. S., Brown, I. L., & Brewer, T. G. (2014). Zinc deficiency in children with environmental enteropathy - Development of new strategies: Report from an expert workshop. *American Journal of Clinical Nutrition*, *100*(4), 1198–1207. https://doi.org/10.3945/ajcn.113.075036

Zimbabwe National Nutrition Survey. (2018). Zimbabwe National Nutrition Survey 2018. *Nutrition*.

Cite this paper as: Tafadzwa, D., Chopera, P., Matsungo, M.T., Chidewe, C., Mukanganyama, S., Nyakudya, E., Mtambanengwe, F., Mapfumo, P. & Nyanga, K.L. (2023). Formulation and characterisation of a novel finger millet-based instant complementary premix powder for infants aged between 6-59 months in Zimbabwe. *Journal of Food Stability*, 6 (4), 20-33
DOI: 10.36400/J.Food.Stab.6.4.2023-048