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FORMULATING FINGER MILLET (*ELEUSINE CORACANA L.*) AND COWPEA (*VIGNA UNGUICULATA*) FOOD BLEND FOR ENHANCED MICRONUTRIENTS FOR CHILDREN BELOW 5 YEARS

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ABSTRACT

Malnutrition of children under 5 years is a public health concern because it is the most vulnerable stage of child's growth where its impact results in long term health conditions such as stunting, wasting, obesity and poor cognitive development. This study aimed at developing a Rapoko-Cowpea porridge blend to enhance dietary micronutrients among children below the age of 5 years and assess its sensory acceptability. A mixed methods research approach was adopted consisting of a quasi- experiment and a cross sectional survey. Vendors from Mbare market were clustered based on the source of their finger millet and cowpea grains (Masvingo, Murewa, Gokwe). A Completely Randomised Design (CRD) was used with three treatments (blends) replicated three times. Proximate analysis was done using standard AOAC methods. Compared to cowpea, finger millet had the highest levels of carbohydrates (78.12g/100g), iron (8.7mg/100g), zinc (3.77mg/100g). Results also show that 75:25. Rapoko-Cowpea blend ratio had the ability to meet WHO daily nutrient requirements for children under the age of 5 years. Blend ratio of Rapoko: cowpeas (75:25) had the highest carbohydrates (69.41g/100g), protein (25.64g/100g), zinc (1.74mg/100g), iron (5.14mg/100g), energy (411.37kcal), and vitamins (0.11 mcg RAE) with RaCoB1 blend having the lowest nutrient composition. Results have showed that finger millet (Rapoko), cowpeas and RaCoB (Rapoko-Cowpea blend) blends have high macro and micronutrients (iron and zinc) to support daily nutritional requirements of children below the age of 5 years and may help in addressing malnutrition. Sensory evaluation was done with 100 panellists from the University of Zimbabwe and of the three blends, a 75:25 ratio was the most preferred (90.88%). Further studies need to analyse the effects of anti-nutritional factors, bioavailability of nutrients, shelf life of the food blend and commercialization potential of RaCoB blends. The government is therefore encouraged to provide agronomic support for increased productivity of small grains and pulses through improved research and extension. There is a need to develop a policy at national level that promotes blending of cereals and pulses as well as innovative small scale food processing initiatives through private-public partnerships.

Key words: Children under 5 years, Cowpea, food blending, Malnutrition, Micronutrients, Rapoko, Sensory evaluation

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INTRODUCTION

Globally, an estimated 700 million people are hungry and almost one billion people are undernourished and experience malnutrition due to limited food diversity with pronounced devastating impact on children under 5 years and pregnant women [1]. As a result, about 13% of children are underweight, 6% suffer from acute malnutrition and 27% suffer from chronic malnutrition [2]. Significant malnutrition burdens particularly among children under the age of 5 years have been widely reported with 5-9% being overweight, 21.9% being stunted and 7.3% wasted [3]. Studies indicate that undernutrition is the underlying cause of 45% of all preventable child deaths world-wide. This has been similarly reported by UNICEF [1] where 200 million children under the age of 5 years are reported to have suffered from stunting or wasting and 340 million suffered from hidden hunger.

In middle- and low-income countries such as Zimbabwe, malnutrition in children under 5 years is reported to be at 26% which is still very high as compared to global acceptable levels [1]. Micronutrient malnutrition is one of the most important health and welfare problems for infants, women of childbearing age and young children in Zimbabwe due to inadequate food intake or illness with only 4% of the children receiving minimum acceptable diets [2]. Consumption of unhealthy diets in Zimbabwe by children under 5 years of age has contributed mainly to high levels of malnutrition. Marume *et al*. [31] argue that, in Zimbabwe, modern dietary pattern for children under 5 years is heavily characterised by 'westernised' fast foods like potato fresh fried chips, red meats, pizza and fried chicken. Traditional dietary patterns on the other hand are characterised by high intake of wild fruits, red meat, insects, worms, and maize meal in the form of porridge as well as thick porridge ('sadza' or pap) made from maize meal. These diets are mainly of high calorific value with very limited micronutrient content. Hence malnutrition at infancy in Zimbabwe is a public health concern because it is the most vulnerable stage of child's growth where its impact will result in long term health conditions such as stunting, wasting and obesity which will be very difficult to correct later in life. Zimbabwe has few children under 5 years who can consume adequate iron and vitamin rich foods respectively due to food insecurity [5]. The outbreak of the COVID-19 pandemic has exacerbated malnutrition crisis particularly among children under 5 years due to limited access to healthy diets [32]. Households cannot afford healthy diets due to reduced disposable income as well as persistent droughts, diseases, and cyclones because of changing climatic conditions [34]. This means that relying on rain-fed agriculture for production of healthy diets is no longer sustainable. Therefore, smallholder farmers in rural areas can rely on drought tolerant crops such as small grains (finger millet, sorghum) and pulses (cowpea and groundnuts) for household food consumption [33]. In this study, finger millet is also referred to as Rapoko (hence,

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the terms will be used interchangeably). Locally produced food initiatives may provide a lasting solution to this nutrition vicious cycle through fortification of cereals with pulses.

A study by FAO [11] indicate that global cowpea production is approximately 5.0 million tons from an estimated area of 10.5 million hectares and this will help support Finger Millet-Cowpea fortification in this study. Over 60% of Zimbabwe's farmland lies in marginal regions best suited for production of cowpeas and finger millet. Kumar *et al.* [12] argue that finger millet can thrive in extreme conditions like drought and some of the varieties have been proved to prevail in flooded areas and even swampy areas. In addition, finger millet has also been proven to be rich in essential micronutrients such as calcium, iron, copper, magnesium, B-vitamins and oxidants (see Table 3) as similarly reported by Kumar *et al.* [12]. Besides, finger millet has been used as staple food and processed into other food products such as flat bread, porridge, and non-alcoholic beverages in Africa and Asia mostly.

There are efforts being done towards fortification of staple foods at industrial scale, nutritional supplementation, and modification of traditional diets to meet specific nutritional requirements, though not sufficient in ending hunger and malnutrition among children [13]. Such initiatives have only targeted commercial food stuffs such as margarine, cooking oil, salt and mealie meal which are mostly beyond the reach of many marginalised households. This has resulted in consumption of high calorific diets, with limited protein and essential micronutrients such as zinc, iron and vitamin A. This study therefore explores the potential of blending finger millet (*Eleusine coracana L*) with cowpeas (*Vigna unguiculata*) to produce a product that has potential to support nutrition of children under the age of 5 years. Blending a cowpea and finger millet may help increase the nutritional value and consumer acceptability of Finger Millet-Cowpea Blend (RaCoB) and availability of low-cost nutritious foods for undernourished children.

In developing countries, the missing link to ending malnutrition lies in provision of improved food from household based value addition initiatives by vulnerable and affected groups such as women, children and the elderly as argued by Kumar *et al.* [12] who postulated that the inclusion of millet-based foods in international, national and state-level feeding programs will help to overcome the existing nutrient deficiencies of protein, calcium and iron in developing countries. Numerous studies have been made to explore the potential of small grains, particularly finger millet and pulses in complementing dietary micronutrients to combat malnutrition in Africa. However, much emphasis is placed on use of commercial micronutrient supplements yet majority of rural and some urban households do not have adequate access due to poverty and limited income. Resultantly, at present, there is limited evidence on cereal-pulse blending, consumer acceptability especially in the case finger millet and cowpea porridge blends in Zimbabwe.

This cereal-pulse food blending initiative is hypothesised to enhance micronutrient content such as Iron, Vitamin A, and Zinc among children under 5 years of age. Hence, the initiative will positively contribute to the Global Nutrition targets focussing on achieving a 40% reduction in the number of children under-5 who are stunted; and reduce and maintain childhood wasting to less than 5% by 2025. To date, there are very few countries that are on track to meet these targets.

MATERIALS AND METHODS

Study sites

This study was carried out at the University of Zimbabwe (UZ) Department of Food, Nutrition and Family Science laboratory with appropriate facilities for proximate and micronutrients analysis of the ingredients and formulated food blends. The new cereal-pulse blended-food product was further subjected to sensory evaluation with the University of Zimbabwe students within the same department to investigate sensory acceptability.

Research design and collection of ingredients

A mixed method research was used in this study. Quantitative research was used to conduct laboratory Proximate analysis of Rapoko and cowpeas that was randomly purchased from three vendors at Mbare Market in Harare. Rapoko, cowpeas and Rapoko-Cowpea (RaCoB) blend formulation (Table 4) were all subjected to proximate and mineral analysis to determine their nutritional composition. Rapoko proximate and mineral results were used as a control in this study. Study results were compared to WHO micronutrients daily intake guidelines (Table1) to check on sufficiency of nutrients to meet daily requirements for children under 5 years. It is important to note that this study was focused on target and market driven Rapoko-Cowpea food to food fortification with the view of getting a highly nutritious blend to address malnutrition.

Sampling procedures

Rapoko and cowpea grains were purchased from a major market where most agricultural produce are sold. A sample of 5 kg of each of the two crops was randomly sourced from Mbare market which is the biggest fruit, cereal, pulses, and vegetable local market in Zimbabwe's capital city, Harare. Clustering of major cowpea and Rapoko supplying locations was done (Masvingo province, Murewa and Gokwe districts). Cluster sampling was used to address the issue of uncontrolled variation in variety and growing conditions of the two grains. One vendor was selected through simple random sampling from each cluster from a population of 5 vendors who were selling both grains. A digital scale was used during purchasing of 1.666kg of Rapoko and cowpea grain respectively from each selected vendor in the cluster. The composite samples were cleaned, graded

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to remove any extraneous material, discoloured and decayed grains before milling them into flour. Proximate and nutritional analysis were done in triplicates on flour from both grains to reduce errors and bias.

Preparation of Finger Millet and Cowpea Flour

Finger millet was cleaned, and malting carried out according to a method detailed by [29]. Finger millet grains (2kg) were washed and steeped in a 2-litre water container for a period of 24 hours. Water was changed after every 6 h during steeping. The finger millet grains were then washed and germinated in ventilated cupboards for 2 days at an ambient temperature of 28 °C with regular sprinkling of water. The malted finger millet grains were removed and dried in an oven at 48 ± 2 °C for 24 hours. The grains were milled using an experimental mill fitted with a 500 µm opening screen to give whole grain flour and stored at 9-10 °C until further analysis. Cowpeas grains (Fig 2) were also screened, cleaned, and milled into flour. Cowpeas were hydrated, germinated, and fermented to increase nutrition quality and reduce antinutritional factors. Cowpeas were soaked for 8 hrs, germinated for about 52 hours at 25^{o}C and fermented for 24 hours at 30^{o}C. However, this did not affect its proximate composition of both finger millet and cowpeas.

Figure 2: Cowpea grains

Figure 3: Finger millet (Rapoko) grains

Formulation of Rapoko-Cowpea blend ratios

A single factor Completely Random Design (CRD) was used to conduct proximate analysis of the ingredients and blends. The crop was used as a factor with Rapoko and cowpeas as factor levels and nutritional composition as dependant variables. The experiment had three treatments that is: Rapoko- Cowpea blend formulation ratios (Table 4) that were replicated three times. The formulations were RaCoB1; RaCoB2 & RaCoB3 as clearly depicted in Table 4 as informed by previous studies [15]. The Rapoko-Cowpea blends were formulated according to the guidelines of previous studies procedure [15].

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A sample of each of the two grains was cleaned, graded, and milled into flour. Three replicate samples for both Rapoko and cowpeas were constituted and tested in triplicates for macro and micronutrients. Further testing was done on composite samples in triplicates to increase data reliability and reduce uncontrolled variation. Blend mixtures (Table 4) were in the ratios 85:15, 75:25 and 60:40. Blending ratios from other studies were reviewed to increase concurrent validity. Blend results were compared to Rapoko nutrient content as a control. The blends were then prepared as porridge after heating and adding water to produce thick porridge. Additives such as sugar and salt were added to taste.

Sensory evaluation

The cross-sectional study design was adopted for sensory acceptability evaluation of the formulated blends. A total of 100 panellists were used for sensory acceptability evaluation with 30 trained and 70 untrained. Simple random sampling was done from a total of 150 students in the Department of Food science at UZ (Department of Food, Nutrition, and Family Sciences). A total of 150 pieces of paper were cut to equal sizes and put in a hat with 100 papers coded yes and 50 coded no. The coded pieces of paper were thoroughly shaken, and all the students were asked to draw a piece of paper without replacement. A total of 100 students who picked papers written yes constituted the sensory evaluation panellists. The University of Zimbabwe students were recruited primarily because it was convenient to access them since the COVID-19 imposed regulations resulted in restricted movements hence it was convenient and easy to access students within the institution without risking spreading the COVID-19 virus to other distant communities. The participants were requested to sign consent forms after adequate debriefing. A sensory evaluation tool was designed, and pilot tested with 10 randomly selected students from a total of 150 students using the same method as that of selecting panellists.

Pilot testing was done to check the validity and reliability of the questionnaire and also to determine the required time in administering the questionnaire. The questionnaire was used to evaluate acceptability of thin porridge from three RaCoB blends using blends; (85:15, 75:25, 60:40) as informed by literature from other studies [15]. The formulated food blends were evaluated using a 5-point hedonic scale which employs the following scale factors; Liked extremely (Score 5), Liked moderately, (Score 4) Neither liked nor disliked (Score 3), Disliked moderately, (Score 2), Disliked Extremely (Score 1). The flour was prepared for sensory evaluation by weighing, adding water, heating for 10 minutes in a stainless pot to avoid contamination, and adding salt/sugar when porridge was ready for eating. From a total of 100 panellists, 30 panellists were trained on the evaluation process and objective of the study and 70 were not trained. Panellists were provided with an evaluation sheet to score the three RacoB blends for the following Sensory quality attributes; Colour and Appearance, Taste/Aroma, Body and Texture and overall acceptability of the new product. This sensory evaluation method allows panellists to conclude whether there is difference or not in sensory attributes. COVID-19 pandemic regulations of social distancing, sanitisation and use of sterilised equipment without sharing among panellists were upheld. Panellists were screened for any symptoms related to COVID-19 by means of temperature checks and self-reported visits and contact tracing.

Nutrient Analysis of Ingredients

Proximate analysis

Nutrient composition of cowpea, Rapoko and the blends of Rapoko and cowpea were determined using Standard methods by Association of Analytical Chemists (AOAC) method [18]. Moisture content, carbohydrates, crude fat, protein, and energy were determined using the AOAC method. Energy in (Kcal) = 4 x protein value+ 4x carbohydrate value + 9 x fat value. Crude protein (CP) content of the finger millet, cowpea and the three RaCoB blend ratios was determined by micro-Kjeldahl procedure [30] using a conversion factor of 6.25. The moisture content of the finger millet samples was determined using oven-drying to a constant weight at 103 °C. About 10 grams (10 g) of each of the sample was exposed to a single stage air for 3 h. The ash content of the finger millet, cowpea and RaCoB blend ratio compositing flours was determined by oven-drying at 550 °C for 8 hours, subsequently followed by decomposition in a muffle furnace. Zinc and Fe in cowpea, Rapoko and RacoB blends were measured by inductively coupled plasma atomic emission spectrophotometry (ICP-OES) (Model ICAP 6000, Thermo-Fischer Scientific).

Mineral composition analysis

The metals in cowpea, Rapoko and RacoB blend ratios were measured by inductively coupled plasma atomic emission spectrophotometry (ICP-OES) (Model ICAP 6000, Thermo-Fischer Scientific). The samples were milled to fine powder and transferred to 100ml beakers. About 2g of homogenized samples were weighed into a 200ml beaker and 10ml concentration and HNO_3 was added. The beakers were covered with watch glasses and left to digest overnight. The samples were then heated on a sand bath with boiling until a clear solution was obtained. Then solution was left to cool, then filtered, and transferred into a 50ml volumetric flask and then diluted to the mark with deionised water. The standard stock solutions with concentration of 1000mg/L of all the minerals were used. Working standards for the metals were prepared by serial dilution of the standard solutions. Certified Standard Reference Material provided by Institute for Reference Materials and Measurements of the European Joint Research Centre (Geel, Belgium) were used for method and results validation.

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Determination of Vitamin A in Cowpea, Finger millet and formulated blends

Vitamin A was determined using a chemical procedure. A standard method using HPLC for the quantitative determination of vitamin A in food samples was adopted as similarly used by [28]. Samples of Rapoko, cowpeas and the different blend ratios were saponified with aqueous ethanolic potassium hydroxide, and the vitamin A alcohol liberated was extracted with n-hexane. After concentration of the extract, the residue was dissolved in methanol and the vitamin A content determined, after HPLC separation on a RP-C-18 column, by means of an UV or fluorescence detector [28].

Statistical data analysis

Controlled experiment

Data collection sheets from laboratory proximate analysis of Rapoko, cowpeas and food formulations (RaCoB) were processed in SPSS. The data was analysed using One-way Analysis of Variance (ANOVA) and Fisher's Least Significance Difference (LSD) was used for mean comparison (Post-hoc tests). This analysis was done at 5% significance level.

Sensory evaluation

Data on acceptability and sensory evaluation of formulated blends were collected using a survey with structured questionnaires which were administered to panellists and was processed in Statistical Package for Social Sciences (SPSS). Data were analysed using non-parametric tests since the data could not meet the assumptions of parametric ANOVA. Hence, Kruskall-Wallis test was used for confirmative analysis, and mean separation was done using LSD at 5 % significance level. Exploratory data analysis was done using clustered graphs (Fig. 4) for sensory acceptability analysis.

RESULTS AND DISCUSSION

Nutritional composition of Rapoko and Cowpeas

Moisture (g/100g)

Moisture content is a very important attribute in the storage of Rapoko and cowpea grains because it affects shelf life of products and availability between seasons. Cowpea has the highest moisture content (9.11%) than Rapoko (6,02%) as shown in Table 5. Farmers should be capacitated to dry their produce to recommended moisture storage levels especially in high rainfall areas like Murewa. Farm produce that is stared at high moisture levels is most likely going to be affected by fungal disease. Similar studies recommended that good post-harvest handling of grains is key to longer shelf life for food products [17]. Rapoko, cowpeas moisture levels are lower than a range of 7.8-13% which was reported in other studies [18]. Rapoko and cowpeas are normally stored at moisture below 12.5%. Lower moisture levels are highly recommended because they will

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allow small holder farmers to formulate blends and feed their children during lean seasons there by reducing malnutrition.

Ash (g/100g)

There is more ash content in cowpeas (3.67%) than in Rapoko (1.84%) and cowpeas from Murewa has more ash may be because of the soil amendment and agronomic practices given to the crop in that region [19]. Rapoko grains are reported to have higher levels of minerals like calcium, potassium, and magnesium (Table 5) that are necessary in enhancing nutrition [18]. Ash content is key for the health of children and the content is within the range of 3.6-4.1%, which was reported by Asif *et al.* [18].

Crude Fat (g/100g)

Rapoko has the highest crude fat content at (3.88%) with cowpeas having the least (3.73%) although there is no significant difference between the two substrates. Fat contributes to fat acids for optimum neurological, immunological, and functional development in children below the age of 5 years. The results of this study concur with those done from other studies in terms of fat composition which ranges from 3.38 - 4.47% [19]. Fats are important as they improve the palatability of food, thereby increasing their intake particularly for children. Blending of cereals and pulses help increase fat composition. Fat also plays an important role in diets as it contributes to flavour and mouth feel of the product. Fats contribute substantially to the energy value of foods as well as provide essential fatty acids for optimal neurological, immunological, and functional developments in children [20].

Crude Fibre (g/100g)

Crude fibre plays a crucial role in enhancing gastrointestinal movement of food. There is a statistically significant difference ($p<0.05$) in crude fibre content between cowpea and Rapoko (Table 5). Rapoko has the highest crude fibre at (5.61%) than cowpeas (1.37%). Cereals have more fibre than pulses as reported by Asif *et al.* [18].

Carbohydrate (g/100g)

There is a statistically significant difference ($p<0.05$) in CHO content between cowpeas and Rapoko. Carbohydrates levels in Rapoko (78.12%) are more than those in cowpeas (69.41%) thereby confirming results from other studies that cereals have more carbohydrates than pulses and blending the two increases the targeted carbohydrates for children below the age of 5 years.

Crude Protein (g/100g)

The results confirm that cowpea is a good source of protein than Rapoko and this element is necessary for structural components of all body cells, tissue repair, cellular integrity, and other body functions for children below 5 years [21]. Cowpeas sourced

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from Murewa has the highest crude protein whilst those sourced from Gokwe having the lowest because proteins may be easily denatured in hot regions. Crude protein in blend 75:25 falls within the range of (20.3%-27.7%) of other results as reported in [18]. Crude protein plays an important role in cellular integrity, supporting body maintenance and growth especially among children below the age of 5 years.

Zinc (mg/100g)

Results depict that there is more Zinc content in Rapoko than cowpeas and blending the two food crops is hypothesised to increase zinc content in the food blend. Zinc is one of the essential micronutrients that lacks during early childhood development. This is similarly reported by Chandel *et al*. [22] who argued that finger millet contains highest content of zinc (4.1 mg/100 g) among all small grains. Zinc and iron, play an important role in enhancing the immunity particularly for vulnerable children under the age of 5 years.

Iron (mg/100g)

There is more iron in Rapoko than cowpeas (Table 5). Iron content is statistically significantly different ($p<0.05$) between Rapoko and cowpea. This result supports the assertion that finger millet can be used for improving iron (Fe) content in pulses. This finding corroborates with Platel [23] who proposed the use of millet flour in food blending in India to alleviate micronutrient deficiency. Chandel *et al.* [22] similarly argued that millets are a good source of iron (2.7 mg/100 g).

Energy (kcal)

Rapoko has high energy than cowpea since cereals are the prime source of energy in semi-arid tropics and drought prone regions of Africa and Asia. Inclusion of Rapoko in these blends will provide the much-needed energy for the growth of children [10]. High Carbohydrates levels will combat protein -energy malnutrition in children below 5 years since there will be enough carbohydrates to provide energy and spare proteins for its primary functions of body building.

Vitamin A mcg RAE

Rapoko and cowpeas do not have many vitamins since better amounts of vitamins are obtained from green vegetables. Findings from this study are in sharp contrast to what Kumar et al [12] reported that millets are also good source of β-carotene and B-vitamins especially riboflavin, niacin and folic acid. This discrepancy could be attributed to the differences in varieties and origin of finger millet that were used in this study. Vitamin A deficiency is a serious threat to the wellbeing of children and pregnant women and needs to be supplemented.

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Proximate composition of Rapoko-Cow pea (RaCoB) blends
Blending of Rapoko with cowpeas in the stated proportions produce a highly nutritious product that provides the required macronutrients, micronutrients, as well as sensory acceptability. The macro and micronutrients nutrient in the formulated blends are higher than those in sole Rapoko and cowpea (Table 6). RaCoB2 blend has the highest crude fibre, carbohydrates, protein, zinc, iron, energy, and vitamins with RaCoB1 blend having the lowest nutritional content (Table 6).

Crude Protein
There is more crude protein content in cowpeas than Rapoko and the available zinc and iron levels from finger millet may help address malnutrition challenges in children under 5 years. Proximate result shows that these two ingredients have high levels of nutrients to support daily nutrient intake by children under the age of 5 years in line with WHO recommended intake Garrow *et al.* [7]. Fortifying Rapoko with cowpea gives high levels of key micronutrients elements (zinc, iron, calcium and magnesium) that are necessary in addressing micronutrient malnutrition in children under the age of 5 years. RaCoB1 blend ratio has the highest ash (3.32%) with least in RaCoB3 blend (3.03%).

Crude fat and Crude fibre
Blend ratio RaCoB2 has the highest crude fat at (3.46%) and RaCoB3 blend ratio having the least (3.21%) crude fat content. Higher crude fat levels in RaCoB2 blend may be attributed to mixing proportions. Crude fat in RaCoB2 blends is higher than the range of 1.2-3.4% that were reported by Asif *et al.* [18]. The results of crude fibre from RaCoB2 are relatively within the range of other studies at 2.6%-24% as reported by Asif *et al.* [18].

Zinc (Zn)
Zinc levels in formulated blends is lower than other studies that ranged from 3.3-6.9% probably because of the genotype of the varieties and agronomic practises given to the crops [18]. The lower values for zinc content in the formulated food product could also have been due to some loss of the minerals during processing of the flours and the presence of ant nutritional factors such as phytate as similarly reported by Gibbs *et al.* [24].

Iron (Fe) and Vitamin A
There is statistical significance difference in iron content across blends, with RaCoB2 blend yielding the highest iron content. The levels of iron in RaCoB2 blend ratio (5.14%) falls with the range from other studies (5.3-15.9%) and concurs with results from previous studies by Asif *et al.* [18]. The recommended blend RaCoB2 has more Vitamin A (0.11mcg RAE) than results from previous studies by Asif *et al.* [18].

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Table 8 also depicts the correlation coefficients (r) of nutrients between the different formulation blends. The strength of the relationship of moisture, ash, crude fat and crude fibre were all positive signifying that both Rapoko and cowpea grains constitute these nutrients in good amounts despite the different formulation levels. Crude protein's relationship was negative across all the different blends or ratios. The results show that Zinc was positive and relatively stronger with high ratios of Rapoko whilst Iron and Vitamin A were very strong and positive when high levels and low levels of Rapoko and cowpea were compared. From previous studies [25, 26, 27] similar positive correlation findings were reported for Zinc and Iron.

Sensory evaluation of Rapoko-Cowpea (RaCoB) Blends

Figure 4 depicts overall percentages of sensory acceptability evaluation of the different porridge food blends. Sensory acceptability evaluation of Rapoko-Cowpea (RaCoB) blends developed porridge blend was done and showed that RaCoB2 blend was the most accepted by the panellists with an overall mean score of 13.69±1.034b and RaCoB3 blend ratio had the least mean acceptability score. RaCoB2 blend had the highest score for all sensory attributes that include colour and appearance (4.69±0.47b) taste and aroma (4.53±0.59b), body and texture (4.47±0.50b) (see Table 7). Kumar *et al.* [12] argued that millet flour is generally unpalatable, a result which is contrary to the finding in this study. The improve taste and aroma in the RaCoB blends particularly RaCoB2 is attributable to the blending of finger millet with cowpea. This is an important food attribute since children under the age of 5 years prefer tasty and appealing food stuffs. Hence the blending of finger millet with cowpea yield the desired sensory attributes in the fortified food product by way of improving taste, aroma and texture.

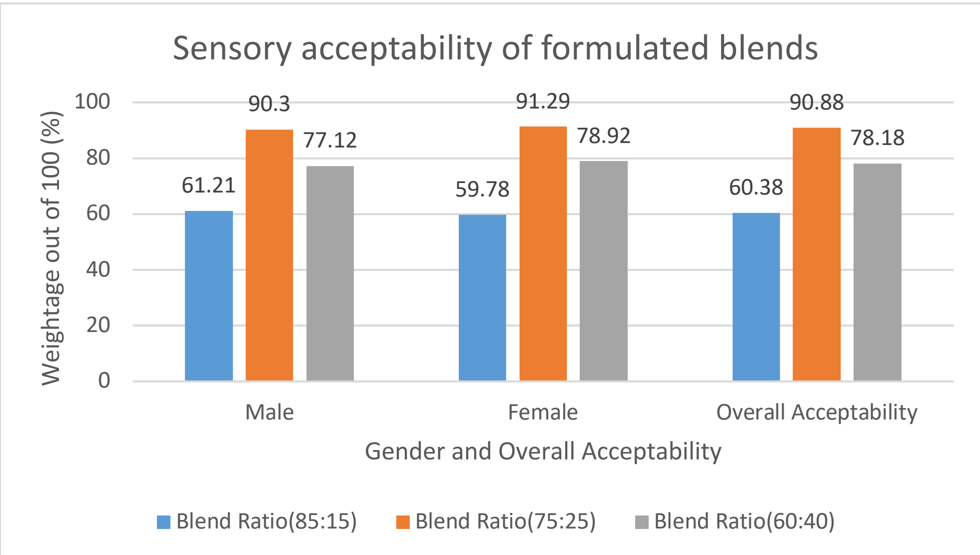

Figure 4: Percentages of sensory acceptability of formulated blends disaggregated by sex

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CONCLUSION

Major findings from the study show that Rapoko and cowpeas are a nutritious grain and pulse, respectively, with high macro and micronutrients content necessary in supporting optimal health, growth, and development in children under the age of 5 years. The study results show that blending Rapoko with cowpea at the ratio of 75:25 makes an acceptable amount of key elements like Zinc, Iron, Vitamin A and also proteins which play a key role in addressing micronutrient deficiency among children below the age of 5 years. Most importantly is to note that different blends have different acceptability and the 75: ratio had the best acceptability according to the sensory evaluations. The nutrient composition is within the WHO recommended range of daily macro and micronutrient intake by children under 5 years [7]. The results support the underlying hypothesis that blending Rapoko with cowpea enhances micronutrient content with target for children under the age of 5 years. All the study hypothesis was met since Rapoko, cowpeas and RaCoB blends proved to have high nutrient levels necessary to support nutrition in children below 5 years.

The research recommends further detailed studies on the nutritional gains by children who are fed on RaCoB blend. A detailed study on anti-nutritional inhibitors like protease, lipase, phytic, oxalic acids and oxalates) that may affect intake of the porridge must be done. Furthermore, it is important to have an in-depth study of the shelf life of the developed new product. It is also imperative to investigate the bio availability of micronutrients in Rapoko and cowpea blends among children and other vulnerable groups such as pregnant women. Notable implications for policy pertain to the promotion of production of small grains and pulses since they are generally regarded as ‘women crops’ and are thus grown on small marginal infertile land. Agronomists need to improve crop production extension support and inputs to smallholder farmers for increased productivity. The government and private sector need to partner and support smallholder farmers in value addition and localised food fortification initiatives which are cheap and sustainable. Hence there is need for increased support for small scale agriculture enterprises with possibilities for commercialisation through improved market access.

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Declaration of conflict of interest
Authors have not provided the full description and formulations of the fortified food cereal to the public domain since the work is not yet patented.

Ethical statement
The ethical clearance for this study was granted by the Bindura University of Science Education ethical committee. It involved the development of a fortified food product that does not pose any harm to individuals instead it enhances beneficence through improved food security and nutrition. Individual consent was sought through signing of consent forms after debriefing of respondents engaged during sensory attributes evaluation of the prepared fortified food cereal. COVID-19 regulations and restrictions were adhered to throughout the study period especially during the sensory evaluation study. Social distancing, sanitisation and use of sterilised equipment without sharing among panellists were upheld. Panellists were screened for any symptoms related to COVID-19 by means of temperature checks and self-reported visits and contact tracing.

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Table 1: Recommended WHO daily nutrient intake for children under 5 years

Nutrient	Daily intake
Carbohydrates	25g/day
Energy in MJ (Kaca)/day	7.2 (1715)Kcal/day
Crude Fibre	35g/day
Protein	19,7g/day
Crude Fat	1200 cal/day
Iron	5.5mg/day
Zinc	6.5mg/day
Vitamin in RE	350 RE/day

Table 2: Macro and micro nutrient composition of cowpea according to various authors (mg/100g)

Data source	Akinyele and akin-losatu (1991)	Boukar, Massane& Muranaka (2011)	Belane and Dakara (2012)	Carvalho et al (2012)	Heuze and Tran (2015) [a]	USDA-ARS (2016) [a]
Micronutrient	Mean	Mean	Mean	Mean	Mean	Mean
Calcium	0.446	0.826	0.6	0.37	11	0.95
Phosphorus		5.06	4.7		4.2	4.92
Iron	16.9	5.3	6.1	6.9	42.2	11.2
Zinc	4.5	3.6	4.3	3.3	3.8	6.9

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Table 3: Micro nutrient composition (mg/100g) of Finger millet (Rapoko) Kumar *et al.* [12]

Nutrient	Ca	Fe	P	Zn	Thamine	Niacin	Riboflavin
Pearl millet	35±8.9	10.3±7.0	339	--	0.3±0.1	1.11±1.3	1.48±1.9
Sorghum	35.2±7.24	5.29±1.28	266.3±32.3	3.01±0.89	0.28	5.19	0.05
Finger millet	348±3.5	4.227±0.6	250	36.6±3.7	0.4±0.1	0.8±0.9	0.6±0.7

Table 4: Ratios of Rapoko-Cowpea (RaCoB) blends formulated

Main ingredients	Formulation name	Mixing Ratios
(Rapoko: Cowpea)	RaCoB 1	85:15
(Rapoko: Cowpea)	RaCoB 2	75:25
(Rapoko: Cowpea)	RaCoB 3	60:40

Source: (Ch, M. (2013)

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Table 5: Macro and Micronutrient content of Rapoko and Cowpeas / Dry matter basis

Nutrient	Cowpeas_Murehwa	Cowpeas_Masvingo	Cowpeas_Gokwe	Rapoko_Murehwa	Rapoko_Masvingo	Rapoko_Gokwe	P-value	F-value
Moisture (g/100g)	9.30±0.34[a]	9.10±0.048[b]	9.11±0.022[b]	6.02±0.027[c]	6.43±0.019[c]	6.21±0.020[c]	<0.001	3142.18
Ash (g/100g)	3.67±0.047[a]	3.61±0.025[b]	3.64±0.018[c]	1.84±0.024[d]	1.88±0.027[e]	1.83±0.021[d]	<0.001	494.03410
Crude Fat (g/100g)	3.78±0.018[a]	3.78±0.016[a]	3.73±0.020[b]	3.83±0.023[c]	3.88±0.022[d]	3.81±0.026[e]	<0.001	50.63
Crude Fibre (g/100g)	1.43±0.12[a]	1.37±0.025[a]	1.56±0.68[a]	5.57±0.030[b]	5.61±0.022[b]	5.34±0.34[b]	<0.001	455.46
Carbohydrate(g/100g)	59.77±0.36[a]	60.063±0.054[a]	60.031±0.024[a]	78.080±0.019[b]	77.99±1.12[b]	78.12±0.016[b]	<0.001	3 809.23
Crude Protein(g/100g)	22.33±0.29[a]	22.12±0.068[b]	22.08±0.042[b]	7.61±0.020[c]	7.62±0.025[c]	7.61±0.022[c]	<0.001	38 191.88
Zinc (mg/100g)	0.62±0.082[a]	0.72±0.045[b]	0.60±0.014[a]	3.47±0.18[c]	3.77±0.021[d]	3.68±0.097[e]	<0.001	2835.77
Iron (mg/100g)	0.59±0.040[a]	0.71±0.051[b]	0.55±0.024[a]	8.40±0.17[c]	8.70±0.13[d]	8.69±0.15[d]	<0.001	13 586.71
Energy(kcal)	362.40±0.20[a]	362.76±0.34[b]	362.033±0.31[c]	377.25±0.29[d]	377.33±4.66[e]	377.24±0.20[f]	<0.001	162.45
Vitamin A mcg RAE	0.080±0.0087[a]	0.088±0.0031[a]	0.16±0.24[a]	0.13±0.0023[a]	0.11±0.0045[a]	0.11±0.0024[a]	0.532	0.83

*The mean difference in elements is significant at the 0.05 level

*±SD- it simply means that, the sample result mean figure can deviate from the true value by ±SD observed value

*Average element content with different superscript(s) along the row are statistically significant whilst those with the same or common superscript(s) are statistically insignificant at 5% level

*Note: blend ratio (a: b)- means a% of Rapoko content as to b% content of cowpea, for instance blend (85:15)- means 85% of Rapoko content as to 15% of cowpea content

* Generally, if the p-value is less than 0.05, the element content in Blend Ratio is statistically significant and the F-values indicate which element is more significant than the other (the bigger the F-value the better)

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Table 6: Nutritional content of Rapoko and Cowpea (RaCoB) blends

Macro and Micronutrient content of RaCoB/ Dry matter basis (DMB) n=36					
Element	Blended (85:15)	Blended (75:25)	Blended (60:40)	P-value	F-value
Moisture (g/100g)	8.91±0.012^{a}	7.32±0.021^{b}	6.91±0.012^{c}	<0.001	14349
Ash (g/100g)	3.32±0.020^{a}	3.20±0.020^{b}	3.03±0.058^{c}	<0.001	45.13
Crude Fat (g/100g)	3.57±0.015^{a}	3.46±0.015^{b}	3.21±0.0058^{c}	<0.001	637.27
Crude Fibre (g/100g)	2.42±0.021^{a}	3.02±0.021^{b}	2.60±0.015^{b}	<0.001	780.12
Carbohydrate (g/100g)	59.30±0.015^{a}	69.41±0.010^{b}	61.43±0.067^{c}	<0.001	53593.69
Crude Protein (g/100g)	22.39±0.010^{a}	25.64±0.020^{b}	22.82±0.015^{c}	<0.001	38282.23
Zinc (mg/100g)	0.90±0.015^{a}	1.74±0.015^{b}	1.41±0.010^{c}	<0.001	2841.41
Iron (mg/100g)	2.90±0.10^{a}	5.14±0.012^{b}	4.03±0.15^{c}	<0.001	335.35
Energy (kcal)	358.93±0.095^{a}	411.37±0.20^{b}	365.86±0.30^{c}	<0.001	54406.12
Vitamin A mcg RAE	0.084±0.0015^{a}	0.11±0.0020^{a}	0.092±0.0021^{a}	<0.001	173.34

*The mean difference in elements is significant at the 0.05 level

*±SD- it simply means that, the sample result mean figure can deviate from the true value by ±SD observed value

*Average element content with different superscript(s) along the row are statistically significant whilst those with the same or common superscript(s) are statistically insignificant for (p-value<0.05)

*Note: blend ratio (a: b)- means a% of Rapoko content as to b% content of cowpea, for instance blend (85:15)- means 85% of Rapoko content as to 15% of cowpea content

* Generally, if the p-value is less than 0.05, the element content in Blend Ratio is statistically significant and the F-values indicate which element is more significant than the other (the bigger the F-value the better)

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Table 7: Determine the acceptability of different RaCoB blends through sensory evaluation attributes (Texture, Colour, Aroma, and overall acceptability)

Samples	Colour and Appearance	Taste and Aroma	Body and Texture	Overall Acceptability
Blended (85:15)	3.76±0.74[a]	3.90±0.59[a]	4.18±0.86[a]	11.84±1.71[a]
Blended (75:25)	4.69±0.47[b]	4.53±0.59[b]	4.47±0.50[b]	13.69±1.034[b]
Blended (60:40)	3.02±0.97[c]	3.18±0.97[c]	2.77±0.91[c]	8.97±2.23[c]
p-value	<0.001	<0.001	<0.001	<0.001
F-value	77.43	52.21	83.6	117.92

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Table 8: Correlation coefficients of nutrients between the three different formulation blends (RaCoB1, RaCoB2 and RaCoB3)

	Pearson Correlation Coefficient (r)		
Nutrient	RacOB1*RaCoB2	RaCoB1*RaCoB3	RaCoB2 *RaCoB3
Moisture	0.9707253	0.9707	1
Ash	0.5	0.8660254	0
Crude Fat	0.7857143	0.1889822	0.7559289
Crude Fibre	0.9819805	0.9285714	0.9819805
Carbohydrate	0.98198805	-0.1147079	-0.3003757
Crude Protein	-0.5	-0.3273265	-0.6546537
Zinc	0.1428571	0.6546537	-0.6546537
Iron	-0.3273268	-0.6546537	0.9285714
Energy	0.48782287	0.09803916	0.9165631
Vitamin A	-0.3273268	0.05241424	-0.9607689

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