Research Paper

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# Evaluating essential micronutrient content, sensory acceptability & economic viability of formulated sesame (*Sesamum indicum*), pearl millet (*Pennisetum glaucum*) & groundnut (*Arachis hypogea*) food blend

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Food blending involving legumes and cereals that has been widely explored, however, there is a paucity of evidence of the use of 'neglected crops' such as sesame oil seed in complementing cereals and legumes to alleviate micronutrient deficiency. A completely randomised design involving food blends as treatments and a cross-sectional survey for sensory acceptability of food blends evaluation was done. Proximate macro- and micro-nutrient composition of substrates and food blend mixes was done using the Association of Analytical Chemists (AOAC) method. Calcium, iron, and zinc were determined by a flame Atomic Absorption Spectrophotometer while potassium (K) was determined using a flame photometer. Sesame had significantly higher Ca (221.1mg/100g), K (149.1mg/100g), Fe (8.1mg/100g) and Zn (4.34mg/100g) compared to groundnuts. Food blends were formulated from sorghum, millet, sesame, and groundnuts. The food blend product had a significantly higher protein, fats, fibre, and micronutrient content compared to the control sample (Sorghum). Blend 5 yielded the best results in terms of K (83.56mg/100g), Ca (10.85mg/100g), Fe (8.79mg/100g) and Zn (0.79mg/100g) content as well as taste, flavour, and appearance although Zn content was relatively low. Sensory evaluation of the food blends showed that the taste, flavour, appearance, and texture were significantly different from the control sample. The blending of small grains with sesame significantly improves essential micronutrients especially Fe which met the WHO/FAO recommended dietary intake. Partial budget analysis shows that the rate of return was maximised by changing from Blend 4 to Blend 5 by 1164.7%. This study recommends the use of cheap, locally available sesame and millet to formulate food blends that can be used as complementary foods with high levels of micronutrients for children and adults.

## 1. Introduction

Undernourishment affects 11% of the global population, with a prevalence of 13% in low and middle-income regions (FAO, 2015). Deficiencies in micronutrients such as iron, zinc and vitamin A rank highest among the leading causes of death in developing countries (WFP, 2006). The Global Burden of Disease estimates show that among the 26 major risk factors of the global burden of disease, iron deficiency ranks ninth overall, zinc deficiency is eleventh, and vitamin A deficiency, is thirteenth (Grimm *et al.,* 2012).

There are about 1 billion people globally with iron deficiency anaemia and a further 1 billion with iron deficiency without anaemia (WHO and FAO, 2006). Undernutrition resulting from inadequate intake of nutrients and supplements is a prominent nutritional problem in Africa (Omoba et al, 2015) and is the major cause of Non-Communicable Diseases (NCDs). The prevalence of micronutrient deficiencies is high across all age groups but is much more pronounced among infants(MoHCC, 2014). Iron deficiency among children in rural areas stands at 37% and 27% for women (ZIMSTAT and ICF International, 2012). Nutritional deficiencies result in negative health outcomes for example stunting, wasting, obesity and increased incidence of infectious diseases).

Iron deficiency has a negative impact on the health and productivity of women (and of adult men) and in impairing the cognitive development in infants and young children (Darton-hill et al 2005). Zinc has recently been established as important for the treatment of diarrhoea but is likely to have a role, along with other micronutrients, in the prevention of both diarrhoea and respiratory diseases (Darton-hill *et al.,* 2005).

A positive calcium balance is also important throughout life, especially among children less than 2 years old, during puberty and adolescence, pregnant, lactating, and postmenopausal women, as well as elderly men.

In Zimbabwe, malnutrition in children is reported to be at 26% which is still very high compared to globally acceptable levels (UNICEF, 2020). In addition, only 4% of the children receive minimum acceptable diets (Global Nutrition Report, 2020). 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. Common dietary patterns for children under 5 years are heavily characterized by 'Westernized' fast foods like potato fresh fried chips, red meats, pizza, and fried chicken Marume et al. (2022). Traditional dietary patterns, on the other hand, are characterized by a 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, resultantly consumption of these diets has made children more vulnerable to long-term conditions of stunting and wasting due to micronutrient deficiency.

In most developing countries, micronutrient malnutrition is common among children mainly because they are weaned abruptly into starchy foods that are bulky and deficient in essential macro and micronutrients (Charles, 2017). The formulation and development of nutritious complementary foods from locally and readily available cereals, oil seeds and legumes has received limited attention in many developing countries. This is despite the availability of drought tolerant and nutritious legumes such as sesame and groundnuts which can be used as food fortification vehicles to combat undernutrition. Sorghum, pearl millet, groundnuts and sesame are mostly grown in semi-arid regions of Zimbabwe and are regarded as cheap and readily available sources of food for many smallholder farmers (Rohrbach & Mutiro, 1997). Sesame is one crop that is rich in essential macro and micronutrients and is widely grown in Zimbabwe.

Despite legumes and small grains being highly nutritious, most rural communities are unaware of their potential in addressing undernutrition among poor resourced and vulnerable groups. There is potential for local communities to fully utilize these crops through value addition and food blending to enhance food security and nutrition. Due to the changing climatic conditions where rainfall patterns have become highly unreliable, the growing of sesame and groundnuts among resource-constrained communities has become common since these crops are stress-tolerant and do not require commercial inputs such as fertilizers and fertile soils. This is because over 60% of Zimbabwe's agricultural land lies in marginal regions where these crops are widely grown. Sesame is widely grown


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for commercial purposes mostly in the South-Eastern parts (Mwenezi district, Masvingo province) and North-Western parts (Mt Darwin and Muzarambani districts in Mashonaland Central Province) because of its high nutritional value whilst groundnuts are also widely grown by women for processing especially into peanut butter and oil for household consumption whilst surplus is also commonly sold.

There is also a pronounced paucity of literature and empirical evidence regarding the blending of native cereals, legumes, and oil seeds. These small grains have been primarily consumed as sole starchy diets with limited essential micronutrient content resulting in undernutrition. Food blending studies have not exhaustively targeted specific micronutrients such as zinc, iron, and calcium. It has primarily focused on proteins and other macronutrients such as energy and fats. Food blending has been widely reported and done using cereals and legumes, for example, pearl millet, maize, and sorghum (Muhimbula *et al.,* 2011); maize, roasted pea, and barley (Fikuri *et al.,* 2017) and maize, Bambara nuts, and groundnuts (Mbata *et al.,*2009). To the best of our knowledge studies that have considered 'neglected high-value crops such as sesame (oil seed) which is rich in micronutrients, especially zinc, calcium, and iron are non-existent.

This is because conventional complementary foods in Zimbabwe are costly and unaffordable to most consumers particularly those in rural communities hence the need for use of localised food blending initiatives using readily available food crops such as sesame and groundnuts. It is hypothesised that the nutritional composition of the formulated food cereal product is rich in micronutrients (iron, calcium, and zinc) and that it meets the FAO/WHO recommended nutrition guidelines as compared to sole cereal, oil seed and legume grains. The main objectives of this study were to: develop blended food cereal from sorghum, pearl millet, groundnuts, and sesame as well as to determine the proximate, mineral contents of each product, and to; evaluate the sensory attributes of the food blends.

## 2. Materials and Methods

### 2.1 Research design

The study used a mixed method approach whereby a quantitative research technique involving a controlled experiment and a qualitative strand involving a survey were combined in a single study. A simple Complete Randomized Design (CRD) was used during the allocation of six treatment combinations that were formulated. A cross-sectional survey consisting of a 100-member panel of consumers was employed to conduct a sensory evaluation of the food blends. The Organoleptic evaluation scored the taste, flavour, appearance, and texture of the formulated cereal blends.

### 2.2 Sampling and collection of raw materials

Simple random sampling was used to select farmers from which substrates were purchased from Mbare Agriculture Market in Harare. A total sample of 10 traders selling the selected raw materials were randomly selected. Three samples of each (sorghum, pearl millet, groundnuts, and sesame) (10kg) were bought and made into respective composite samples of sorghum, pearl millet, groundnuts, and sesame.

### 2.3 Statistical data analysis

The data on micro and macronutrient content were subjected to parametric analysis of variance (ANOVA) whilst the scores on organoleptic tests were analysed using the non-parametric test of Kruskal Wallis test using IBM SPSS version 26. The Least Significance Difference (LSD) at 5% was used for the post hoc test.

### 2.4 Formulation of the fortified food cereal

#### 2.4.1 Roasting and Milling of Food Substrates

After cleaning the samples, a 5kg sample of sorghum and pearl millet was roasted/pre-heated at 70oC for 10 min and left to cool at room temperature. as similarly done by Muhimbula *et al.,* (2011. The cereals and legumes were then milled using a Deluxe Blender AE-099 and sieved through screen No. 1 for fine and uniform particles. Cereal grains and legumes instantized by roasting were coarse ground using a Deluxe Blender AE-099 and sieved through ISI Mesh No.1 (1 mm) to obtain a paste of uniform particle size.

#### 2.4.2 Cereal-legume blends mixes

The mixing ratios were adopted with some modification as similarly used by Muhimbula et al (2011) in which the inclusion of cereals was from 50% to 90%

and that of legumes ranged from 10% to 30%. Six food blends were formulated by mixing different ratios of millet, sorghum, sesame and groundnuts and labelled as B1- B6. These treatments were replicated three times. These were compared to a traditional straight sorghum cereal used as a control. The treatments were supplemented with sugar as energy supplements to improve the sensory attribute of the formulated foods and some salt.

### 2.4.3 Preparation of fortified food cereal

The cereal formulation blends were prepared from composite flours using the standard recipe of flour -100g, water -300ml, and sugar -20g. About 250ml was boiled and 100g of each flour blend was added. The mixture was stirred to avoid lumping and cooked for 30-35mins until it thickens. The cereal was left to simmer for 5min before being served after adding 10g of sugar and 2g of salt to taste. Muhimbula et al (2011) used sugar and oil as additives to enhance the taste of the food blend in line with WHO dietary guidelines.

### 2.5 Proximate Analysis

Standard methods by the Association of Analytical Chemists (AOAC, 2000) were adopted to conduct proximate analysis. Standard methods by the Association of Analytical Chemists (AOAC) were adopted in the analysis of sesame, groundnuts, sorghum and pearl millet as similarly used in another study by Horwitz & Latimer (2005). Energy, moisture, ash and crude protein content were calculated as follows:

Energy in (Kcal) = 4 x protein value+ 4x carbohydrate value + 9 x fat value. The crude protein (CP) content of sesame, groundnuts, sorghum, pearl millet and the six food blend ratios were determined by the micro-Kjeldahl procedure (AOAC, 2000) using a conversion factor of 6.25. The moisture content of the finger millet samples was determined using oven-drying. The ash content of the sesame, groundnuts, sorghum, pearl millet and food blends was determined by oven drying at 550 °C for 8 hours, subsequently followed by decomposition in a muffle furnace.

### 2.6 Micronutrient analysis

The analytical method described by Bamigboye *et al.,* (2010) was adopted for the analysis of minerals in the samples. Potassium (K), Calcium (Ca), Iron (Fe), and Zinc (Zn) analysis was carried out using Atomic Absorption Flame Emission Spectrophotometry (AA-6701F). Certified Standard Reference Material Number BCR- 191 provided by the Institute of Reference Materials and Measurements of the European Joint Research Centre was used for the method and results validation (AOAC, 2005).

### 2.7 Sensory acceptability evaluation

Simple random sampling was done from a population

**Table 1.** Cereal-legume blend formulations for the fortified food product

| Main Ingredients | Formulation name | Mixing ratios (in grams) |
|---|---|---|
| Sorghum, groundnut, Sesame | B1 | 60g Sorghum + 20g Groundnut + 20g Sesame |
| Pearl Millet, groundnut, Sesame | B2 | 65g Pearl millet + 25g Groundnut + 10g Sesame |
| Sorghum, Pearl Millet, groundnut, Sesame | B3 | 60g Sorghum + 20g Pearl millet + 5g Groundnut + 15g Sesame |
| Sorghum, Sesame | B4 | 80g Sorghum + 20g Sesame |
| Pearl Millet, Sesame | B5 | 70g Pearl millet + 30g Sesame |
| Pearl Millet, Sorghum, groundnut, Sesame | B6 | 60g Pearl millet + 10g Sorghum + 15g Groundnut + 15g Sesame |
| Sorghum | Control | 100g |


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of 180 students in the Faculty of Science, Department of Food, Nutrition, and Family Sciences, University of Zimbabwe. A sample of 100 students was selected as panellists' using the hat method. Generally, these panellists were students in the age category of 24 – 35 years. In terms of gender, 33 students were females whilst 67 were males in their second and third year of university undergraduate degree studies. Half of the panellists were trained to conduct sensory evaluation whilst the other half were not trained as similarly done by Muhimbula et al (2011)

## 3. Results

### 3.1 Macro and micronutrient content in substrates used.

#### 3.1.1 Carbohydrate content

Significant differences ($p<0.05$) were observed in the carbohydrate content of the oil seed and the legumes. There was no statistically significant difference ($p<0.05$) between the cereals (sorghum and pearl millet).

#### 3.1.2 Protein content

There were significant differences in the level of protein ($p<0.05$) between the groundnuts, sorghum, pearl millet and sesame. However, there was also a significant difference between the protein content of groundnut (16.6g/100g) and sesame (18.8g/100gthere was no significant difference ($p>0.05$) in protein content between the cereals (see Table 2).

#### 3.1.2 Crude fibre content

There was no significant difference ($p<0.05$) in crude fibre levels of all the samples tested. Pearl millet had the highest fibre content (Table 3) among the cereals while the legumes had groundnut with the highest fibre content (see Table 2).

#### 3.1.3 Fat content

There were significant differences in fat content between cereals and legumes ($p<0.05$). A significant difference ($p<0.05$) was also recorded between groundnuts and sesame, with the highest amount of fat recorded in sesame (see Table 2).

#### 3.1.4 Moisture content

All the samples had a low moisture content of less than 12g/100g (see Table 2). However, there were significant differences in moisture ($p<0.05$) across all samples of cereals and legumes analysed.

#### 3.1.5 Ash content

Cereals had higher amounts of ash as compared to groundnuts and sesame samples.

### 3.2 Mineral composition of substrates used in food blend formulation.

#### 3.2.1 Potassium content

There were significant differences ($p<0.05$) across all the samples in terms of potassium content (Table 3). The potassium content in sesame was high (149.69mg/100g).

#### 3.2.2 Zinc content

There were no significant differences in zinc content among the three samples of groundnut, pearl millet and sesame ($p>0.05$). However, the only significant difference ($p<0.05$) in the amount of zinc among the samples was noted in the sorghum sample which recorded (2.35mg/100g). The raw samples showed substantial zinc content which is an essential micronutrient that could be complemented in the blended cereal food product developed.

#### 3.2.3 Iron content

There was a significant difference ($p<0.05$) in iron content between the samples of raw materials analysed. Sesame had the highest amount of iron (8.05mg/100g). This meant that the inclusion of sesame in the food blend would contribute more in terms of iron content.

**Table 2.** Macronutrients and essential micronutrients proximate composition of raw materials used in product formulation.

| Sample | Ash (g/100g) | Moisture (g/100g) | Fat (g/100g) | Protein (g/100g) | Fibre (g/100g) | Carbohydrates (g/100g) | Potassium (mg/100g) | Zinc (mg/100g) | Iron (mg/100g) | Calcium (mg/100g) |
|---|---|---|---|---|---|---|---|---|---|---|
| Groundnut | $4.6^{a} \pm 1.53$ | $6.50^{a} \pm 0.05$ | $40.50^{a} \pm 14.5$ | $25.5^{a} \pm 0.99$ | $9.95^{a} \pm 3.98$ | $12.96^{a} \pm 0.85$ | $174.1^{a} \pm 24.6$ | $3.24^{a} \pm 0.8$ | $4.47^{a} \pm 0.5$ | $7.84^{a} \pm 0.04$ |
| Pearl millet | $38.89^{b} \pm 34.13$ | $4.65^{b} \pm 0.50$ | $12.00^{b} \pm 1.41$ | $9.00^{b} \pm 0.14$ | $5.65^{b} \pm 3.93$ | $41.83^{b} \pm 1.12$ | $159.8^{b} \pm 5.2$ | $4.34^{b} \pm 0.1$ | $6.38^{b} \pm 2.3$ | $4.81^{b} \pm 0.6$ |
| Sesame | $4.44^{a} \pm 1.39$ | $3.57^{c} \pm 0.16$ | $53.50^{c} \pm 2.12$ | $18.8^{c} \pm 0.14$ | $4.34^{c} \pm 1.71$ | $4.64^{c} \pm 0.75$ | $149.7^{c} \pm 19.7$ | $4.34^{b} \pm 0.8$ | $8.1^{c} \pm 1.1$ | $221.1^{c} \pm 27.8$ |
| Sorghum | $29.78^{c} \pm 22.99$ | $7.53^{d} \pm 0.76$ | $10.50^{b} \pm 1.41$ | $8.55^{b} \pm 0.07$ | $3.07^{c} \pm 0.44$ | $40.57^{b} \pm 1.27$ | $153.6^{d} \pm 6.5$ | $2.35^{c} \pm 0.9$ | $5.19^{d} \pm 0.1$ | $4.48^{b} \pm 0.02$ |
| *P-value* | 0.31 | ≤0.001 | 0.01 | ≤0.001 | 0.24 | 0.01 | 0.013 | 0.029 | 0.168 | <0.001 |
| *F-value* | 1.40 | 134.84 | 15.88 | 524.06 | 2.07 | 16.23 | 13.98 | 5.12 | 169.7 | |

*Means having different superscripts within the same column are significantly different at p≤0.05 +- =Standard deviation of the sample mean.*



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**Table 3.** Macro and micronutrient content of the different cereal blends formulated.

| Cereal Blend | Moisture (g/100g) | Ash (g/100g) | Fat (g/100g) | Protein (g/100g) | Fibre (g/100g) | Carbohydrates (g/100g) | Potassium (mg/100g) | Zinc (mg/100g) | Iron (mg/100g) | Calcium (mg/100g) |
|---|---|---|---|---|---|---|---|---|---|---|
| B1 | $4.90^{a}$ ±0.14 | $3.28^{a}$ ±0.39 | $45.5^{a}$ ±2.12 | $19.69^{a}$±0.08 | $2.13^{a}$ ±0.14 | $24.53^{a}$±0.01 | $13.06^{a}$±0.00 | $0.65^{a}$±0.1 | $6.3^{a}$±0.1 | $11.79^{a}$±0.02 |
| B2 | $3.95^{b}$ ±0.71 | $2.71^{b}$ ±0.04 | $41.0^{b}$ ±1.41 | $19.34^{a}$±0.04 | $1.58^{a}$ ±0.02 | $31.42^{b}$±0.01 | $11.5^{b}$±0.01 | $0.62^{a}$±0.01 | $7.43^{b}$±0.01 | $6.9^{b}$±0.02 |
| B3 | $5.70^{c}$ ±0.14 | $5.37^{c}$ ±3.00 | $35.0^{c}$ ±1.41 | $14.72^{b}$±0.05 | $2.73^{a}$ ±0.01 | $36.84^{c}$±0.00 | $12.74^{a}$±0.02 | $0.59^{a}$±0.07 | $5.48^{a}$±0.01 | $8.98^{b}$±0.01 |
| B4 | $6.15^{d}$ ±0.35 | $3.13^{a}$ ±0.17 | $36.0^{c}$ ±1.41 | $15.47^{b}$±0.13 | $3.62^{b}$ ±0.02 | $35.63^{c}$±0.01 | $14.17^{c}$±0.00 | $0.40^{b}$±0.11 | $4.72^{c}$±0.04 | $8.47^{b}$±0.07 |
| B5 | $4.10^{e}$ ±0.14 | $3.47^{a}$ ±0.03 | $49.5^{d}$ ±2.12 | $20.12^{a}$±0.08 | $2.10^{a}$ ±0.01 | $20.71^{d}$±0.01 | $83.56^{d}$±0.25 | $0.79^{a}$±0.11 | $8.79^{b}$±0.04 | $10.85^{a}$±0.05 |
| B6 | $4.40^{e}$ ±0.21 | $3.12^{a}$ ±0.17 | $49.5^{d}$±10.61 | $18.69^{a}$±0.08 | $2.34^{a}$ ±0.07 | $21.95^{d}$±0.01 | $12.31^{a}$±0.0 | $0.89^{c}$±0.04 | $7.02^{b}$±0.03 | $7.69^{b}$±0.04 |
| Control | $7.15^{f}$ ±0.21 | $2.37^{b}$ ±0.17 | $34.0^{c}$ ±2.83 | $8.55^{c}$± 0.07 | $6.24^{c}$ ±0.01 | $41.69^{e}$±0.01 | $82.00^{d}$±0.32 | $0.63^{a}$±0.001 | $6.45^{a}$±0.03 | $2.78^{c}$±0.01 |
| *P value* | ≤0.001 | 0.33 | 0.03 | ≤0.001 | ≤0.001 | ≤0.001 | ≤0.001 | ≤0.004 | ≤0.001 | ≤0.001 |

*Means with different superscripts within the column are significantly different at $p<0.05$.*
*+- =Standard deviation of the sample mean is an estimate of how far the sample mean deviate the from population mean.*


**Fig 1.** Picture of the samples of the six food blends (B1-B6)

### 3.2.4 Calcium content

Sesame had the highest amount of calcium from the analysis (221mg/100g). However, the analysis showed that there was a significant difference (p<0.05) between the calcium levels of cereals versus the oil seeds with sesame recording the highest.

### 3.3 Proximate macro- and micro-nutrient analysis of the food blends

### 3.3.1 Moisture content

Significant differences in moisture (p<0.05) content across all the cereal blends were observed (Table 3). All the formulated blend samples had lower moisture content as compared to the control (100% sorghum flour).

### 3.3.2 Ash content

There was a significant difference (p<0.05) between the ash content of the food formulation blends except for B4, B5 and B6. The highest ash content was found in blend B3 (5.37g/100g) and the least ash content was in the control diet which had 2.37g/100g.

### 3.3.3 Fat content

There is relatively a high level of fat) in the cereal blends compared to raw samples (Table 3). In addition, statistically significant differences (p<0.05) in fat content between the different cereal blends were recorded. However, cereal blends B3, B4 and the control showed no significant differences (p>0.05). The food blends had significantly higher levels of fat across all formulations compared to the raw samples and were within the range of FAO/WHO recommended nutrition intake guidelines of 29-70g.

### 3.3.4 Fibre content

There was a significant difference (p<0.05) in content between the formulated cereal blends and the control (100% sorghum flour). However, the control flour (sorghum only) had the highest fibre (6.24 g/100g), while among the cereal flours; blend B2 had the lowest fibre content. Blend B4 had a relatively high fibre percentage (3.62 g/100g) as compared to the other formulated blends.

### 3.3.5 Protein content

Formulated food blend B5 had the highest protein content followed by B6 (Table 3). Of the formulated cereal blends, B3 had the lowest protein content among the samples analysed. The control (Sorghum only) sample


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had the lowest protein content of 8.55g/100g (Table 3) and the finding was significantly different ($p<0.05$) from the rest of the formulated blends.

**3.3.6 Carbohydrate content**

The formulated blended food cereal contained carbohydrates in the range of 20.71g/100g -36.84g/100g (Table 3). Values obtained in this study for carbohydrates (Table 3) suggest that carbohydrates may not be sufficient to meet requirements but the high level of fat in the product can supplement the low carbohydrate in the product.

**3.4 Essential micronutrient composition of the fortified food cereal product**

Results from Table 3 show that there was a significant contribution of essential micronutrients from sesame particularly Fe in the blended cereal food product. The level of Fe in the fortified cereal was within the FAO/WHO average recommended nutrient intakes of 3.9mg to 19.2mg for both children and adults. Sesame and pearl millet are assumed to be the significant Fe contributors based on their nutrient composition (Table 3). Relatively high quantities of potassium, iron and calcium were found in the formulated food cereal product samples compared to the control (100% sorghum flour). Results show that significant amounts of potassium of up to 83.56 mg/100g in cereal blend B5 were harnessed in the food blend product while the other blends ranged between 11 mg/100g and 13 mg/100g. However, Zinc content was low (0.4 mg/100g - 0.89 mg/100g) (Table 3) in the formulated cereal food product as compared to the raw materials (Table 3). Zinc, Calcium, and Potassium levels in the food blend were significantly lower than the recommended FAO/WHO nutrition guidelines.

Iron and calcium were found in relatively high quantities (4.72 mg/100g – 8.79mg/100g) in the blend food product than in substrates used during formulation whilst K was very low. The B5 and B6 cereal blends yielded the best results in terms of Fe, K, Ca, and Zn content. The two blends (B5 and B6) had high acceptability through taste; flavour and appearance although Zn content was relatively low (0.4 mg/100g – 0.89 mg/100g). Sesame had high concentrations of Ca and Fe in the raw materials and was the major source of the minerals in the food blend.

**3.5 Sensory evaluation of the food cereal blends.**

Blends B3, B1 and B5 were highly acceptable upon ranking by the panellists with percentage acceptance levels of 94%, 87% and 81% for semi-trained panellists, respectively) Sensory evaluation analysis was done on all the food cereal blends using the Kruskal-Wallis H test which showed that there was a statistically significant difference in taste, flavour, appearance, and texture between the different food cereal formulations. The Chi-square and p-values for appearance; taste, flavour and texture were $\chi2$ (6) = 86.271, p = 0.001 for appearance, $\chi2$ (6) = 146.86, p = 0.001 for taste, $\chi2$ (6) = 221.06, p = 0.001 for flavour, and $\chi2$ (6) = 101.76, p = 0.001 for texture (Table 4). The mean ranks for the different formulations are shown in Table 7. The highest mean rank for taste was noted on Blend 4 followed by B3 with the least in terms of taste being the control.

A post hoc LSD test for the mean scores between the formulations revealed that appearance blends B2, B4 and the control were significantly different ($p<0.05$) from the other blends. In terms of taste, B2 was significantly different ($p<0.05$) from all other blends. Blend B5 is recommended in terms of all the organoleptic tests (texture, appearance, taste and flavour).

**3.6 Economic profitability of cereal-pulse food blending**

A partial budget analysis shows the costs and benefits associated with a specific change in each food blending formulation. Results from Table 5 show that a change from formulation Blend 4 (B4) to Blend 5 (B5) gave a marginal rate of return of 1164.7% which was the highest amongst all the blends with Blend 3 (B3) being second best with 428% marginal rate of return. Therefore, the B5 blend is recommended since it is more profitable. This means that an additional unit increase in Pearl millet and Sesame in the blend (B5) recouped 1US$ and resulted in 11.647 more units of micronutrients (Fe, Zn, Ca and K) complimented.

**Table 4.** Non-parametric test results of sensory evaluation of formulated food blends

| Blend name | Taste | Flavour | Appearance | Texture |
|---|---|---|---|---|
| **B1** | 319.14 | 325.56 | 339.11 | 294.14 |
| **B2** | 350.00 | 355.83 | 346.31 | 296.31 |
| **B3** | 402.07 | 530.45 | 458.82 | 306.19 |
| **B4** | 466.89 | 390.22 | 261.94 | 270.69 |
| **B5** | 377.89 | 385.04 | 394.36 | 435.88 |
| **B6** | 384.45 | 339.64 | 402.39 | 366.14 |
| **Control** | 153.04 | 123.02 | 250.56 | 484.13 |
| **P value** | <0.001 | <0.001 | <0.001 | <0.001 |

*mean ranks for Kruskal-Wallis non-parametric one-way analysis of variance.

**Table 5.** Partial budget analysis results for the profitability of the different food blends

| Variables | Control | B1 Blend | B2 Blend | B3 Blend | B4 Blend | B5 Blend | B6 |
|---|---|---|---|---|---|---|---|
| Sorghum (20 kg) | $8.00 | $4.80 | ------ | $4.80 | $6.40 | ----- | $0.80 |
| Pearl millet (20 kg) | ----- | ------ | $5.20 | $1.60 | ------ | $5.60 | $4.80 |
| Groundnuts (20 kg) | ----- | $3.20 | $4.00 | $0.80 | ------ | ------ | $2.40 |
| Sesame (20 kg) | ----- | $5.00 | $2.50 | $3.75 | $5.00 | $7.50 | $3.75 |
| Labour | $50.00 | $50.00 | $50.00 | $50.00 | $50.00 | $50.00 | $50.00 |
| Milling | $5.00 | $8.00 | $8.00 | $10.00 | $6.00 | $6.00 | $10.00 |
| Packaging | $20.00 | $20.00 | $20.00 | $20.00 | $20.00 | $20.00 | $20.00 |
| Total Variable Costs (TVC) | $83.00 | $91.00 | $89.70 | $90.95 | $87.40 | $89.10 | $91.75 |
| Total Revenue | $120.00 | $160.00 | $160.00 | $170.00 | $140.00 | $180.00 | $170 |
| Net Income (NI) | $37.00 | $69.00 | $70.30 | $79.05 | $52.60 | $90.90 | $78.25 |
| Δ VC | ----- | $8.00 | -$1.30 | $1.25 | -$3.55 | $1.70 | $2.65 |
| Δ Revenue | ----- | $40.00 | $0.00 | $10.00 | $30.00 | $40.00 | -$10.00 |
| Δ NI | ----- | $32.00 | $1.30 | $8.75 | -$26.48 | $38.30 | -$12,65 |
| Marginal Rate of Return (MRR) | ----- | 0.352 | 0 | 4.28 | -5.276 | 11.647 | -2.0367 |

*NB: The figures were calculated in US$ terms.


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## 4. Discussion

### 4.1 Macro and micronutrient content of substrates

There were no significant differences (p<0.05) in carbohydrate content between groundnut and sesame. This could be because sesame and groundnuts have high oil content that is easily converted into energy. These results were however lower than those reported by Durojaiye *et al.,* (2016), of 65 – 75g/100g carbohydrate in sorghum mainly because cereals are prime energy sources compared to legumes and oil seeds.

Carbohydrate content was lower than values reported by Bamigboye *et al.,* (2010), that is 21.4g/100g ± 0.12 and those reported by Oyerinde, (2017) of 15.2 g/100g. The carbohydrate content of groundnuts was lower than that of those reported by Temba *et al.,* (2016) of 19g/100g. Rehman *et al.,* (2016), postulated that cereals are rich in carbohydrates and low in protein, a result that is similar to that of Muhimbula *et al.,* (2011) recorded. Temba *et al.,* (2016) concluded that cereals have significant amounts of fibre and other minerals as compared to other crops as similarly reported in this study hence the need to include cereals in the complementary food blend. These results are in line with other findings by Ogungbenle & Onoge, (2014) where sesame had fat content ranging over 40%. Moisture content was reported to be generally high in substrates hence the need for heat treatment of substrates to improve palatability and shelf life. The lower the moisture content, the longer is storage stability (Kindiki*et al.,* 2015). The value for ash content obtained in sesame is comparable to those reported by Bamigboye *et al.,* (2010), while the values for ash in groundnuts were higher than findings by Temba *et al.,* (2016). The level of ash constitutes the component where minerals are harnessed.

These results were comparable to findings by Bamigboye *et al.,* (2010). Potassium levels in cereals were lower than those reported by Omoniyi & Abdulrahman(2018) which ranged between 366.67% for pearl millet and 400.00% for sorghum. With regards to sesame, the amount of zinc found in the sample analysed was not significantly different from those obtained by (Bamigboye *et al.,* 2010) who recorded 4.46mg/100g in raw sesame while this study recorded 4.34mg/100g (Table 4). Pearl millet had a significantly high amount of iron (6.38mg/100g) among the cereals (Table 4).

The findings however were slightly different from Bamigboye *et al.,* (2010) who recorded 3.83 ± 0.75 mg/100g of iron in a sample of raw sesame. This result could be attributed to the different varieties of cereals, legumes and oil seeds used. Sesame contributed the highest level of micronutrients (Fe, Ca & Zn), this justifies the inclusion of sesame in the formulation of complementary diets for both children and adults. The findings in this study were similar to findings reported by Bamigboye *et al.,* (2010) who recorded (281.1 ± 0.68mg/100g) calcium level in raw sesame. The raw materials proved to contain significant amounts of calcium and if used in the formulation of food cereal there is potential to harness Ca into the final product. Nedumaran *et al.,* (2015) also concluded that legumes play a vital role as sources of micronutrients such as, calcium, iron, phosphorus, and other minerals necessary to combat undernutrition.

### 4.2 Macro and micronutrient content of food blends

The food blend formulation substrates had higher moisture which was slightly higher than that of the formulated cereal food blends. The roasting of cereal ingredients done during product formulation could have resulted in the lower moisture content of the cereal food product (Muhimbula *et al.,* (2011); Fikuru et al. (2017)). The low moisture content of food samples is a desirable phenomenon since microbial activity is reduced at low moisture levels. Similar results were obtained by Sampath, (2015) who concluded that roasting improves colour, extends shelf life, enhances flavour and reduces the anti-nutrient factors of cereals and legumes. The highest ash content was found in blend B3 (5.37g/100g) and the least ash content was in the control diet which had 2.37g/100g. This was is at variance from findings by Sampath, (2015) who reported that the ash content of raw and roasted maize flours was 1.23g/100g and 1.51g/100g respectively.

The food blends had significantly higher levels of fat across all formulations compared to the raw samples and were within the range of FAO/WHO recommended nutrition intake guidelines of 29-70g. High fat content is attributable to the inclusion of oil seed (sesame) and groundnuts in this study as similarly reported by Fikuri et al (2017) where fats were increased in the food blend as the proportion of roasted pea to maize and malted barley was increased. Fats contribute substantially to the energy value of foods as well as provide essential fatty acids (Chukwuma *et al.,* 2016). The formulated fortified cereals showed an overall low fibre content ranging from 1.58 g/100g to 6.24 g/100g as similarly reported by Solomon, (2005) who concluded that compounded diets of cereal and legumes had fibre content of less than 10g/100g. Similarly, Ezeokeke & Onuoha, (2016) recorded similar quantities of fibre in a cereal and legume flour blend. However, Solomon (2005) reported findings which are at variance from this study probably due to the differences in varieties and geographical location of the sources of substrates.

### 4.3 Macro and micronutrient content of formulated food product

The lower values for zinc content in the product could have been due to some loss of the minerals during the processing of the flours and the presence of anti-nutritional factors such as phytate and tannins as similarly reported by Gibbs et. al., (2011). There is a need therefore to complement the zinc content in the food blend using commercially available zinc fortification vehicles and supplements. Consumption of nuts, seeds, beef, and milk products can augment zinc levels in the diets of infants and adults.

Iron and calcium were found in relatively high quantities (4.72 mg/100g – 8.79mg/100g) in the blend food product than in substrates used during formulation whilst K was very low. This is mainly attributed to the high levels of Fe and Ca identified in sesame. This result could also be because of heat treatment and further processing which reduced the anti-nutritional factors such as phytates and tannins (Ezeokeke & Onuoha 2016) thereby releasing more minerals in the food blend. The low levels of zinc in the food blend product could be because of the heat treatment that denatures the essential mineral.

### 4.4 Sensory acceptability of food blend

Blends B3, B1 and B5 were highly acceptable upon ranking by the panellist with percentage acceptance levels of 94%, 87% and 81% for semi-trained panellists, respectively). The highest mean rank for taste was noted on Blend 4 followed by B3 with the least in terms of taste being the control (sorghum). This is mainly because B3 and B4 blends constitute both groundnuts and sesame which improves the taste of food as similarly reported by Ezeokeke & Onuoha (2016) in a study involving feeding older infants with maize-soya bean and banana complementary food in Nigeria. Oil seeds (sesame) and legumes (groundnuts) improve the smoothness of the food blend and delay the swelling of the starch granules thus restricting too much binding of water to the starch (Muhimbula *et al.,* 2011). In addition, oils and fats from sesame and groundnuts improve the flavour/taste of food (Fikuri *et al.,* 2017) as similarly observed in blends B3, B4 and B5. Unlike the other blends, the control (Sorghum) alone yielded the least score in terms of taste as expected because generally sorghum alone is not palatable, but it improves with an increase in concentration of legumes and oil seeds. Blend B5 is recommended in terms of all organoleptic tests (texture, appearance, taste, and flavour). These results are consistent with Mbata et al. (2009) who reported high overall acceptability of complementary processed food formulated from maize–Bambara and ground nut.

### 4.5 Economic viability of formulated food blend

The higher marginal rate of return associated with food blend B5 makes economic sense in that it had the highest ratio (30g) of sesame which has high nutritional value. Likewise, Pearl millet which is rich in minerals had the highest concentration (70g) compared to other blends. These findings are similarly echoed by Ezeokeke and Onuoha (2016) in which the cost of producing the maize-soya bean and banana complementary feed formulated is about N50-N100 (US$0.50 cents) per gram cheaper than commercially available cereal (Nestle Cerelac) in a study involving feeding older infants in Nigeria. Hence complementary food blends can be fed to infants at a much cheaper rate compared to commercially available cereals and mineral supplements.

## 5. Conclusions

Empirical evidence from the study proves that legumes such as sesame and groundnuts contain high levels of proteins, fats and micronutrients as compared to sole cereals (pearl millet and sorghum). Similarly,


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cereals dominated in carbohydrate levels. The analysis of essential micronutrients in legumes also supported the underlying hypothesis that legumes are rich in micronutrients as compared to cereals. The food blend product has a higher content of micronutrients as compared to sole cereals as previously hypothesised that cereals fortified with sesame and groundnuts have significantly high micronutrients relative to sole legume and cereal food crops. However, potassium was low in the formulations as compared to the control while calcium, iron and zinc were higher in the food blend than in the substrates. The amounts of micronutrients recorded in the blended food product were found to be within the recommended WHO daily consumption levels. The B5 formulation consisting of millet and sesame only emerged as the best blend for optimising essential micronutrients (K, Fe, Ca) in cereal-based diets. Sensory evaluation of the food blends shows that blends B3, B5 and B6 scored high on taste, flavour and appearance and were preferred more by consumers. Sesame is a rich crop in both macro and micronutrients hence a good source of complementing low micronutrient cereal-based diets. A partial budget analysis showed that a change from formulation Blend 4 (B4) to Blend 5 (B5) gave a marginal rate of return of 1164.7%% which was the highest amongst all the blends with Blend 3 (B3) being second best with 428% marginal rate of return.

This study recommends the use of cheap, locally available sesame and millet to formulate food blends that can be used as complementary foods with high levels of micronutrients for children. There is also an urgent need for policymakers to support and scale up household-level value addition and food blending initiatives to address the challenges of undernutrition. Promotion of the use of small grains and legume food crops in household food blending should be prioritised targeting rural communities. Further studies can explore the bioavailability of the blended food product, analysis of anti-nutritional factors and evaluation of the shelf life of the blended food product.

**Declaration of conflict of interest**

Authors have no conflicts to declare.

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