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Evaluation of Physicochemical and Nutritional Properties of a Breakfast Meal for School-Aged Children from Bambara Groundnut and Grain Grits Fortified with Fruits and Eggshell Powder

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Abstract

Breakfast is considered the most important meal of the day. It is commonly derived from grain cereals that are processed through toasting, roasting, extrusion, cooking, baking, or puffing, and is often served with milk and sweeteners. This study aimed to develop enriched breakfast meal for school age children fortified with powdered fruits, Eggshell and to evaluate its Particle size distribution, nutritional, and anti-nutritional factors. The grains were clean, dehull, steam, dry and milled. The fruits were wash clean chopped dry and milled into powder and the eggshell was washed dry toasted milled to powder. The meal was prepared by adding the formulations into hot water stirrer to porridge cold to lower temperature sweeten and serve and Golden morn sample is use as control**.** Particle size distribution was determine using Ukpabi and Ndimele (1990), phytochemicals, anti-nutritional factors and Amino acid using AOAC (2006), AOAC (2023) respectively. Mineral content was determined following Adedeye and Adewo (1992). Results showed that enriched breakfast meal particle size distribution 1mm (45.56-72.94), 2mm (0.02-0.46), 850µm (5.03-8.68), 710 µm (3.75-8.34), 500 µm (6.54-16.83), 450 µm (2.79-4.45), 300 µm (1.83-4.40), 250 µm (2.31-4.45), 150 µm (2.59-6.34), 62 µm (0.13-3.52) Base (0.01-0.20). Anti-nutritional factors remained within acceptable limits, with Tanin (7.19–0.06 mg/100g) and Oxalate (9.56–0.12 mg/100g) being the most prevalent. The mineral content, including Fe (4.09–1.99 mg/100g), Zn (4.41-2.81mg/100g), Cu (1.23–0.02 mg/100g), and Mn (12.47–6.75 mg/100g). The Amino acid include Proline (8.02-4.27mg/100g), Serine (5.00-4.18 mg/100g), Arginine (7.15-4.31mg/100g), Tyrosine (3.97-3.27 mg/100g), Cystine (1.46-1.16 mg/100g), Alanine (7.08-5.17 mg/100g), Glutamic acid (18.65-16.36 mg/100g), Glycine (4.76-3.42) and Aspartic acid (9.59-6.14 mg/100g). The study concludes that Eggshell and fruit-fortified breakfast meal for school age children can serve as a nutrient-rich and potentially enhancing mineral intake and addressing nutritional deficiencies.

Keywords: *Breakfast meal, Particle size distribution, Phytochemicals Anti-nutritional, Mineral, Amino acid.*

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1. Introduction

Breakfast is considered the most important meal of the day and is typically derived from cereals processed through flaking, swelling, toasting, roasting, or grinding, often served with milk and a sweetener (Encyclopedia Britannica, 2008). Breakfast is widely recognized as the most important meal of the day, especially for school-aged children, as it significantly contributes to improved cognitive performance, physical growth, and overall well-being (Onabanjo *et al*., 2023). In many developing countries, including Nigeria, children often consume energy-dense but nutrient-poor breakfasts, leading to micronutrient deficiencies that affect academic performance and health outcomes (Akinyele & Bello, 2021). To address this challenge, there is a growing interest in formulating affordable, locally sourced, and nutrient-rich breakfast meals. It is normally pre-cooked or ready-to-consume, and in the United States and elsewhere, it is frequently eaten with sugar, syrup, or fruit. Evidence indicates that people who consume breakfast, particularly ready-to-eat (RTE) cereals, generally have better overall nutrient profiles, improved cognitive functioning, and are less likely to be overweight (Rampersaud *et al*., 2005). Eating breakfast is crucial because, after 8–12 hours without food, the body's muscles and brain need calories to function effectively (Penuela, 2010). As consumers become more conscious of their dietary choices, there is a growing interest in exploring nutritious and functional options for breakfast. A healthy breakfast should provide ample carbohydrates as an energy source, with minimal sodium, sugar, and salt, accompanied by essential nutrients such as protein, calcium, zinc, vitamin B6, vitamin A, and iron (Jegtvig, 2008). Including milk, fruits, and cereals can further enhance its nutritional value.

Recent research highlights the potential of compositing breakfast meals using Bambara groundnut, cereal grains (such as maize, rice, and sorghum), eggshell powder, and fruit varieties, all of which have gained attention due to their health benefits and culinary versatility. Bambara groundnut (*Vigna subterranea*) is an underutilized legume with a high nutritional profile, including good levels of protein, essential amino acids, and minerals such as iron, zinc, and calcium. It is also drought-resistant and adaptable to various agro-ecological zones, making it a sustainable crop option for food security (Murevanhema & Jideani, 2020). Similarly, grain grits such as maize and rice are common staples in many Nigerian households, serving as a source of carbohydrates and dietary fiber. However, when consumed alone, these cereals may lack adequate levels of key micronutrients and protein. To enhance the nutritional density of cereal-based meals, the incorporation of locally available fruits (rich in vitamins and antioxidants) and eggshell powder (a sustainable source of bioavailable calcium) has been explored. Eggshells, often considered waste, contain over 90% calcium carbonate and have shown potential in food fortification strategies when properly processed (Adebayo *et al*., 2022). What we eat for breakfast can significantly impact both our mental well-being and physical health. A well-balanced breakfast that digests slowly and delivers sustained energy is advised to start the day, while poor-quality breakfasts can negatively affect cognitive performance, especially in school-aged children (Murphy *et al*., 1998; Wesnes *et al*., 2003). Additionally, the types of foods consumed at different times of the day are often shaped by cultural factors (Cloake *et al*., 2017).

In Nigeria, common breakfast foods include "*ogi*" also known as pap, "akamu", or "*koko*", made from maize, millet, or sorghum. Mothers typically introduce thin *ogi* as a weaning food to babies between 3 and 6 months, feeding it with a spoon or cup (Onofiok & Nnayelugo, 1992). Other traditional Nigerian breakfast items include "*eko*" (Yoruba), "*komu*" (Hausa), and "*agidi*" (Igbo) (Ogichor *et al*., 2005; Dike & Sanni, 2010). In northeastern Nigeria, "*ndaleyi*", made from sorghum or pearl millet, is a popular indigenous food (Nkama & Malleshi, 1998).

Maize (Zea mays L.) is a key cereal grown in Nigeria, particularly in the derived savanna and rainforest zones, with high-yield, disease-resistant varieties developed through landraces. Maize can be ground, pounded, fried, roasted, or boiled to make diverse dishes like pap and tuwo (Iken & Amusa, 2004). Globally, maize ranks as the third most important cereal after wheat and rice (Osagie & Eka, 1998; Purseglove, 1992). In Nigeria, rice, millet, sorghum, and maize are the most significant grains, and local processing techniques, such as fermentation for *ogi*, are widely used.
Sorghum is a crucial cereal consumed widely across Africa and Asia, particularly among lower-income populations. It provides a significant source of protein, energy, vitamins, minerals, and nutraceutical compounds such as antioxidants and cholesterol-lowering waxes (FAO, 2006; Mauder, 2006; Taylor *et al*., 2007). Sorghum's nutritional profile includes protein (6–25%), ash (1.2–1.8%), oil (3.4–3.5%), fiber (2.3–2.7%), and carbohydrates (71.4–80.7%), with dry matter ranging from 89.2% to 95.3%, depending on cultivar (Lasztity, 1996; Samia *et al*., 2005). It is also a good source of calcium, phosphorus, iron, and over 20 essential minerals (BSTIDNRC, 1996; Dicko *et al*., 2006; Glew *et al*., 1997).

Rice (*Oryza sativa* L.) is the leading food crop in Nigeria, cultivated across all agro-ecological zones, from the Sahel in the north to the mangrove swamps of the south (Danbaba *et al*., 2004; Maji *et al*., 2017). As a global staple, rice consumption has increased significantly (Seck *et al*., 2012), with local Nigerian dishes including *masa*, *waina*, *tuwo*, and *alkakki* (Oludare, 2014). Rice is rich in energy, vitamin B6, vitamin E, thiamine, niacin, potassium, sodium, calcium, and zinc (USDA, 2004). Many populations in developing countries suffer from protein-energy malnutrition (PEM) and micronutrient deficiencies, including iron, iodine, vitamin A, and zinc, which are major contributors to morbidity and mortality, particularly among pregnant women and young children (Ekekezie *et al*., 2012; Müller & Krawinkel, 2005).
This study aims to evaluate the physicochemical and nutritional properties of school-age children's breakfast meals formulated from Bambara groundnut and grain grits (maize, rice, and sorghum), fortified with fruit (mango, banana, and carrot) and eggshell powder. Parameters to be determined include particle size distribution, phytochemicals (flavonoids and phenolics), antinutrients (phytates, tannins, and oxalates), and amino acids (proline, serine, arginine, tyrosine, cysteine, alanine, glutamic acid, glycine, and aspartic acid). The aim of this study is to develop and evaluate a breakfast meal formulated from Bambara nut and grain grits, fortified with powdered fruits and eggshell, focusing on its physicochemical properties, proximate composition, mineral and amino acid content, and potential for school-aged nutrition enhancement. This aligns with current nutritional interventions aimed at combating malnutrition and promoting functional foods in school feeding programs (Okoroafor *et al*., 2024).

2. Materials and Methods

Materials procurement

Grains of yellow maize (*Zea mays* L), Bambara groundnut (*Vigna subterranea*), rice (*Oryza sativa*), sorghum (*Sorghum bicolor (L)* Moench), mango (*Mangifera indica*), banana (*Musa spp*) and carrot (*Daucus carota L*) were purchased from Custom market, Maiduguri, Borno State, Nigeria.

Preparation of sample

Preparation of Maize and Sorghum Grit

The maize and sorghum grit were sorted from plant debris, rocks and other foreign material, temper with water, dehull with machine, the Grains were washed with clean water, maize and sorghum pre-boiled for 30 min and dried under the sun, milled, sieved and packed in an air tie container.

Bambara ground nut and Rice Processing

Bambara ground nut and Rice was processed by modifying the method of (Iwe *et al*, 2016). Bambara ground Paddy rice were cleaned, hulled with milling machine, washed with water and preboiled for 30 minutes, dried on the sun at 40ºC milled, sieve(500µm) and packaged in air tie container

Carrot Powder Processing

The carrot flour was prepared as describe by Nwachukwu *et al***.** (2020). Fresh carrots were washed thoroughly drained, the carrots were grated using a manual grater, dried on sun at 50^0C, blended and sieved (300µm) with sieve to obtain carrot powder

Processing of Mango and Banana into Powder

Partially ripe mango and banana fruits undergo the following processes adopted from Siddiq *et al.* (2017) and Ovando-martinez *et al.* (2009) respectively.

Eggshell Powder Processing

Chicken eggshells were washed, the eggshells were boiled in water for 30 min air dried and toasted in hot sand picked cold and milled with electric blender to powder sieved (300µm) with manual sieve and packaged in an air tie container.

Breakfast Meals Blend Formulation

Composite flours were prepared by mixing RBm, RBb, RBc, MBm, MBb, MBc, SBm, SBb and SBc with eggshell powder at a constant level (2.91%). Nine breakfast cereal samples were prepared by mixing a combination of meals (67.96, 19.42, 9.71, 2.91) cereal and Bambara groundnut grits (70, 20) were fortified separately by10g each of the four-fruit powder mango(m), carrot(c), banana(b) and finally 3g of eggshell powder was added to each of the cereal, Bambara groundnut blends the cereals were rice (R), sorghum(S) and maize(M) grits. The formulated meals were prepared by boiling water, and then the breakfast meal was, poured on the boiling water and continued stirring until cooked and served on cup.

Particle Size Distribution

Particle size distribution were determine using Ukpabi and Ndimele (1990)

Minerals, phytochemicals and antinutrients contents of *Masa*

Mineral contents (Fe, Zn, Cu, and Mn,) were determined using method described by Adedeye and Adewo (1992). Phytochemicals (Phenol and flavonoid) antinutrients (phytate, oxalate and tannins) and Amino acid were determined using the AOAC (2006), AOAC (2023) respectively.

Data Analysis

A one-way analysis of variance (ANOVA) was conducted based on the sensory scores obtained. Duncan's multiple range tests were applied using SPSS software version 17.0 to identify significant differences between means at the $P \leq 0.05$ level.

3. Results

The particle size distribution results of breakfast meal made from grains cereals Eggshell and fruit powder-fortified and the control samples are presented in **Table 1**. Sieves have dimensions of 1 mm, 2 mm, 850 µm, 710 µm, 500 µm, 450 µm, 300 µm, 250 µm, 150 µm, and 62 µm were used to filter all of the samples. the grits were about (45-72%) mainly of the size of 1mm and another small fraction (6.54-16.83mm) with size of about 0.5mm MBcE 45.56% and 72.94% and SBmE respectively had the least and higher proportion of the grits about the size of 1mm, other were within the range, the observation had implication in hydration of the meal, sensory properties and packaging.

Table 1: Particle Size Distribution of Breakfast Meal

Sample retention	1mm	2mm	850(µm)	710(µm)	500(µm)	450(µm)	300(µm)	250(µm)	150(µm)	62(µm)	Base Pan
RBcE	51.63	0.02	7.38	8.00	11.15	3.42	3.26	4.39	6.34	3.52	0.16
RBbE	62.40	0.05	6.58	6.29	8.06	3.66	2.82	3.00	5.00	1.41	0.14
RBmE	64.42	0.15	6.38	6.59	9.14	2.79	3.23	2.68	2.59	1.15	0.20
MBmE	51.81	0.46	6.09	6.89	14.67	4.52	3.94	4.23	5.39	1.36	0.01
MBbE	60.01	0.06	5.22	5.77	11.81	3.25	3.16	4.07	4.54	1.13	0.04
MBcE	45.56	0.32	8.68	8.34	16.83	4.01	4.40	3.50	5.44	1.90	0.08
SBbE	60.36	0.26	6.21	5.30	10.17	4.45	3.19	4.45	3.97	0.13	0.04
SBmE	72.94	0.03	4.00	3.75	8.42	3.98	1.83	2.31	3.83	0.98	0.11
SBcE	66.76	0.03	5.03	4.16	6.54	3.85	1.99	4.37	4.72	1.83	0.07
Mean	59.54	0.15	6.17	6.12	18.77	3.77	3.09	4.09	4.65	1.36	0.09

R= Rice, B=Bambara groundnut, M=Maize, S=Sorghum E= Eggshell powder, c= Carrot powder, m=Mango powder, b= Banana powder

The results of the antinutrients composition of the samples are presented in **Table 2**. The phytate level of the Fruit and Eggshell powders ranged from 0.01 to 1.84 mg/100g, Eggshell powder, which contained the least quantity, and mango powder had the highest value. Significant differences were observed among all the samples. The tannin concentrations ranged from 0.06 to 7.19 mg/100g, Eggshells had the lowest value and the powder made from mango had the highest value. The products' oxalate contents ranged from 0.12 to 9.56 mg/100g. As seen in **Table 2** oxalate is found in greater quantities in mango (79.56) than in Eggshell (0.12). The table also revealed that the oxalate content varied significantly among the samples.

Table 2: Anti-nutrient Content of the Fruit and Eggshell powders

Sample code	Phytates (mg/100g)	Tannins (mg/100g)	Oxalates (mg/100g)
M	1.84[a]±0.14	7.19[a]±0.24	9.56[a]±0.08
E	0.01[c]±0.00	0.06[d]±0.00	0.12[d]±0.00
C	0.62[b]±0.05	2.07[b]±0.04	6.68[b]±0.29
B	0.21[c]±0.02	0.83[c]±0.02	1.73[c]±0.07
Mean	0.67	2.54	4.52

Value is mean standard deviation of 3 replicate determination. In any column, means bearing the same superscripts are not significantly different (P>0.05).M=mango powder, E=Eggshell powder, C= Carrot powder, B=banana powder

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Table 3 shows the results of the phytochemicals analysis of the fruit and Eggshell powders. The flavonoid content ranges 0.02 to 3.01mg/100g. Eggshell had the lowest flavonoid concentration whereas mango powder had the highest, this indicates a significant difference among the samples. The phenolic content of the samples varied between 0.01 and 1.04 mg/100g, with the highest phenolic content in mango powder while the lowest was observed in Eggshell.

Table 3: Phytochemical composition of the Fruit and Eggshell Powders

Sample code	Flavonoids(mg/100g)	Phenolics(mg/100g)
M	3.01[a] ±0.13	1.04[a] ±0.01
E	0.02[d] ±0.00	0.01[d] ±0.00
C	2.67[b] ±0.12	0.80[b] ±0.01
B	0.34[c] ±0.01	0.16[c] ±0.00
Mean	1.51	1.89

Value is mean standard deviation of 3 replicate determination. In any column, means bearing the same superscripts are not significantly different (P>0.05).m=mango powder, E=Eggshell powder, c= Carrot powder, b=banana powder.

The mineral composition results of the formulated breakfast meal made from Eggshell, fruit powder-fortified cereals and the control samples are presented in **Table 4**. The iron content of breakfast meals varied between 1.99 and 4.09mg/100g, SBmE with the least and SBcE with highest respectively. In general, the iron content of breakfast is low, which may be due to the fact that no animal protein has been added to cereals and legumes.

The zinc content range 2.81 and 4.41mg/100g. These results exceeded the 4.28mg/100g control. The meals contained low amount of copper with values ranges between 0.02 and 1.23mg/100g. The results were less compared to the US RDA of 1.5–3.0 mg/100 g, however the control had 1.15 mg/100g. The manganese concentration of the breakfast meals ranged from 6.75 to 12.47 mg/100g with sample RBmE and RBcE with lowest and highest respectively. The US RDA records 2.5 mg/100 g, whereas the control reported 6.49±0.0mg/100g. 11 mg/100 g was the maximum amount that was permitted.

Table 4: Minerals Composition of formulated Breakfast Meals

Formulation	Fe (mg/100g)	Zn (mg/100g)	Cu (mg/100g)	Mn (mg/100g)
RBcE	2.51[c]±0.01	3.88[bc]±0.04	0.06[hi]±0.01	12.47[a]±0.04
RBbE	2.00[e]±0.01	2.81[e]±0.05	0.02[i]±0.01	8.88[c]±0.04
RBmE	3.91[b]±0.01	4.00[b]±0.01	1.02[d]±0.01	6.75[g]±0.00
MBmE	2.27[d]±0.04	3.14[d]±0.01	0.08[h]±0.01	9.11[b]±0.01
MBbE	2.52[c]±0.04	3.84[c]±0.01	1.23[a]±0.02	6.98[ef]±0.02
MBcE	2.06[e]±0.05	3.88[bc]±0.04	0.90[e]±0.01	7.47[d]±0.04
SBbE	2.09[e]±0.02	3.95[bc]±0.07	0.64[d]±0.01	6.95[f]±0.07
SBmE	1.99[e]±0.01	4.28[a]±0.04	0.69[h]±0.01	7.43[d]±0.04
SBcE	4.09[a]±0.01	4.41[a]±0.01a	1.10[c]±0.01	6.90[f]±0.00
Golden Morn	3.98[b]±0.04	4.28[a]±0.04	1.15[b]±0.01	7.09[e]±0.01
Mean	2.74	3.85	0.68	8.00
Cv	0.98	0.93	1.59	0.41

Value are means ± standard deviation of 3 replication determination. In any column, means bearing the same superscripts are not significantly different (P>0.05). R= Rice, B=Bambara groundnut, M=Maize, S=Sorghum E= Eggshell powder, c= Carrot powder, m=Mango powder, b= Banana powder Cv= coefficient of variance.

The Amino acid content as presented in **Table 5**. In general, all meals had a good amino acid content. Glutamic acid was the highest with a range of 18.65 - 16.38 mg/100g, follow by Aspartic acid with 9.59-6.14 mg/100g, Proline 8.02-4.27 mg/100g, Arginine 7.15-4.31, and Alanine with value range 7.08-5.17 mg/100g among the amino acid. While Serine, Glycine, Tyrosine and Cystine on the other hand had a lower value of the amino acid. The findings indicate that different proportions of amino acids were present in the samples. The high amino acid content of the product can be attributed to Bambara nut inclusion. The meals are rich in rice and sorghum, corn evenly distributed in the mixes. It is important to note that the consumption of these products replaces all the necessary amino acids.

4. Discussion

Eating breakfast is essential, especially for school-aged children, because after an overnight fast of about 10–12 hours, the brain and muscles are low on energy, which can impair cognitive performance, memory, and physical activity (Rampersaud *et al*., 2005; Adolphus *et al*., 2016). Breakfast cereal is described as any meal of the swelling, roasting, grinding, rolling, or flaking of any cereal. It is a grain meal, normally pre-cooked or ready-to-consume, typically eaten with milk or cream for breakfast with inside the United States or elsewhere, and regularly eaten with sugar, syrup, or fruit (Encyclopedia Britannica, 2008).

Hence elements like cultural attachments, fitness and dietary benefits suggest a sturdy ability marketplace for a properly packaged fortified multi-cereal wholegrain meal. However, the processing of those conventional African grains for meals is getting too little innovation and funding at an industrial degree, mainly withinside the place of convenience-kind ingredients geared toward the hastily developing center-magnificence city population (SCHITECH Africa, 2019).

The excessive degree of meals insecurity, a large occurrence of malnutrition, and monetary meltdown all integrate to make faculty feeding relevant (Education Cluster, 2009). There is enormous proof that people who devour breakfast, along with ready-to-consume (RTE) cereals, have higher usual vitamins profiles, display enhancements in cognitive functioning, and is probably much less probable to be overweight (Ramersaud *et al.*, 2005).

The findings shows that the particle size distribution of flour is an important quality parameter of flour that greatly affect the processing techniques and end product quality (Sullivan *et al.*, 1960). Also, it was reported that flour particle size distribution is highly related to grain hardness and are therefore used in the classification of seed into hard and soft texture Delcourn and Hoseney, (2010). In hard seed, usually have starch granules that are deeply embedded within the protein matrix of the cotyledons while in soft grain, there are voids in the cotyledon's protein matrix (Tumbull and Rahma, 2002).

The anti-nutrient content of rice-masa and enriched rice-masa samples is shown in Table 2. The table shows that phytates, tannins, and oxalate, contents in the samples ranged from 0.01to 1.84, mg/100g, 7.19 to 0.06 and 9.56 to 0.12 mg/100g respectively. Omosaiye and Cheryan (1979) also observed that phytate established a bridge between the negatively charged protein carboxyl groups by complexing with protein under the action of cations, typically calcium, zinc, or magnesium. It appears that different mango species have varied quantities of these nutrients and phytochemicals Rocha *et al.,* (2007). Tannins are phenolic group-containing chemicals. They alter the tissue's astringent flavor by interacting with glycoproteins and salivary proteins in the mouth Howes, 1953). oxalate is found in greater quantities in mango peel (7.24%) than in pulp (4.31%), regardless of the variety (Deepa *et al.*, 2017).

Phytochemicals are naturally occurring compounds produced by plants that have a variety of beneficial effects on human health, including antioxidant, anti-inflammatory, and anticarcinogenic properties. They are found in fruits, vegetables, grains, and other plant foods, and are considered to be an important part of a healthy diet Nigar (2025). The result also reviles that phenol compound ranges between 0.01-1.04mg/100g.The type and concentrations of phenolic acid vary depending on the mango variety, location and stage of maturity Thangsiri *et al.,* (2024). In Table 3 the flavonoid content ranges 0.03-3.01mg/100g. Flavonoids represent a broad class of polyphenolic compounds abundant in fruits, vegetables, and beverages, including tea and wine. Common dietary sources include citrus fruits, berries, apples, onions, and tea Xu, (2024).

The enriched breakfast meal containing a mixture of cereal grain eggshell and mango powder exhibited significantly higher magnesium, Zinc, Iron and cupper compositions, attributed due to the fortification of breakfast meal with fruits eggshell cereal grain which enhances the micronutrients composition of breakfast meal. This indicated that breakfast meal fortification can be essential strategies to combat micronutrients deficiency. The result revels the ranges values of Iron, Zinc, Copper and Manganese 1.99-4.09, 2.81-4.41, 0.02-1.23 and 6.75-12.47 mg/100g respectively. Magnesium deficiency can lead to conditions such as preeclampsia, arrhythmias, arteriosclerosis, diabetes mellitus, and metabolic syndrome Oyarekua (2011). Zinc is an essential component of all living cells and is involved in numerous bodily processes, including blood coagulation, taste, vision, and wound healing Ryan, (2009). RDA of iron for the recommended daily allowance (RDA) for children aged 4 to 8 is 10 mg, and the RDA for boys and girls aged 9 to 13 is 8 mg. Girls in this age range who are menstruating require an extra 2.5 mg of iron daily. Breakfast cereals produced from maize, sorghum, soybean, and African yam were found to contain (13.46mg/100g) iron (Agunbiade and Ojezele, 2010). Globally, iron deficiency anemia is quite prevalent, particularly in developing nations among women and children. It can take years for iron deficiency symptoms to manifest, such as weakness, exhaustion, and dyspnea (Ryan *et al* 2009). According to the Food and Nutrition Board of the Institute of Medicine FNBIM, (2001), the recommended daily allowance (RDA) for children aged 4 to 8 years is 5 mg, and for boys and girls aged 9 to 13 years is 8 mg. The zinc level was found to be lower than RDA. Also as reported by Agunbiade and Ojezele (2010) lower values of 1.54mg/kg and 1.64mg/kg was obtain compared to this study. Zinc is a necessary component of all living cells and is involved in hundreds of bodily processes, including blood coagulation, taste, eyesight, and wound healing (Ryan *et al.,* 2009). The enzyme 72-cytochrome oxidase, which is involved in energy metabolism, contains copper and iron. Since copper is abundant in other foods, a copper shortage is not a health risk (Adeyeye and Agesin, 2007). There is around 0.9 g of copper in the body. Certain enzymes are crucial for iron metabolism and oxygen reactions contain it. In addition, it contributes to the color of skin and hair and forms a protective sheath around nerve fibre Ryan, (2009). Manganese is a vital component of the enzyme system and plays a role in bone formation, reproduction, and the healthy operation of the nervous system. Higher quantities of manganese were identified in all preparations. Manganese is easily obtained in nuts, whole grains, green vegetables, and tea (Adeyeye and Agesin, 2007; Ryan, 2009).

The result of the essential Amino acid revels glutamic and aspartic acid has a higher while cystine is the list. Essential amino acid plays a role in protein synthesis, muscle growth and repair, immune function and neurotransmitter production. Although vegetable proteins usually have a relatively low biological value compared to egg or milk protein, they are still complete because they contain all the amino acids necessary for human nutrition in varying amounts. (Ogungbenle *et al.*, (2009) who found, that Quinoa has a balanced level of essential amino acids that is better than most grains such as corn, millet and sorghum. Eating a variety of plant foods together can produce higher biological protein (Okafor and Usman, 2016). It is important to note that consuming these products with milk replaces all the necessary amino acids that are missing in the composition.

4. Conclusion

Breakfast is essential for school-aged children, helping to restore energy after an overnight fast and support their mental and physical development. Fortified ready-to-eat cereal meals, especially those made with whole grains, fruit powders, and natural micronutrient sources like eggshell, can help reduce malnutrition and micronutrient deficiencies, especially in low-income areas. The fortified meals in this study showed increased levels of important nutrients such as iron, zinc, copper, manganese, essential amino acids, and beneficial plant compounds. These results highlight the value of using local grains and plant-based ingredients to improve food quality and fight hunger. Investing in local food processing and fortification can play a key role in improving child nutrition and public health in a sustainable way.

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Table 5: Amino acid Content of the Breakfast Meals

	Parameters (mg/100g)								
Formulation	Proline	Serine	Arginine	Tyrosine	Cystine	Alanine	Glutamic. Acid	Glycine	Aspartic. Acid
RBcE	4.27^{i}±0.01	4.33^{ef}±0.01	7.15^{a}±0.01	3.63^{c}±0.02	1.34^{b}±0.01	5.36^{cd}±0.01	16.38^{f}±0.03	4.53^{b}±0.02	9.33^{a}±0.00
RBbE	4.78^{g}±0.00	5.00^{a}±0.00	6.71^{d}±0.00	3.97^{a}±0.01	1.21^{c}±0.00	5.70^{c}±0.01	17.66^{c}±0.02	4.33^{c}±0.00	9.59^{a}±0.02
RBmE	4.88^{f}±0.00	4.85^{b}±0.01	6.88^{c}±0.00	3.45^{d}±0.01	1.16^{c}±0.02	5.17^{d}±0.01	17.20^{d}±0.00	4.76^{a}±0.01	9.19^{a}±0.01
MBmE	8.02^{a}±0.00	4.70^{c}±0.00	4.57^{e}±0.01	3.63^{c}±0.02	1.46^{a}±0.00	6.84^{ab}±0.19	18.23^{b}±0.01	3.85^{e}±0.07	7.08^{bc}±0.00
MBbE	8.02^{a}±0.00	4.41^{d}±0.00	4.39^{f}±0.00	3.27^{e}±0.00	1.40^{b}±0.00	6.41^{b}±0.00	17.65^{c}±0.01	3.42^{g}±0.00	6.80^{bcd}±0.01
MBcE	7.91^{b}±0.01	4.30^{fg}±0.01	4.31^{g}±0.01	3.46^{d}±0.03	1.34^{b}±0.01	6.79^{ab}±0.00	17.35^{d}±0.02	3.52^{fg}±0.01f	6.14^{e}±0.07
SBbE	7.42^{e}±0.01	4.36^{de}±0.00	4.56^{e}±0.00	3.44^{d}±0.00	1.17^{c}±0.02	6.92^{a}±0.01	18.19^{b}±0.01	3.85^{e}±0.07	6.52^{cde}±0.00
SBmE	7.83^{c}±0.01	4.70^{c}±0.00	4.36^{f}±0.00	3.79^{b}±0.00	1.38^{b}±0.00	7.08^{a}±0.01	18.65^{a}±0.21	4.04^{d}±0.03	6.77^{bcd}±0.01
SBcE	7.53^{d}±0.00	4.18^{h}±0.02	4.39^{f}±0.00	3.45^{d}±0.00	1.22^{c}±0.01	6.79^{ab}±0.00	18.15^{b}±0.07	3.52^{fg}±0.01f	6.48^{de}±0.44
Golden Morn	4.59^{h}±0.00	4.25^{g}±0.02	7.07^{b}±0.01	3.79^{b}±0.00	1.34^{b}±0.01	5.30^{cd}±0.28	16.75^{e}±0.02	3.66^{f}±0.00	7.18^{b}±0.01
Mean	2.99	3.76	3.25	3.45	10.22	1.47	4.94	0.91	4.64
Cv	1.12	6.08	4.70	0.45	0.23	1.83	2.14	20.15	0.53

Value are means ± standard deviation of 3 replication determination. In any column, means bearing the same superscripts are not significantly different (P>0.05). R= Rice, B=Bambara groundnut, M=Maize, S=Sorghum E= Eggshell powder, c= Carrot powder, m=Mango powder, b= Banana powder

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