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Nutritional Evaluation of Complementary Food Blends from Sprouted Red Maize and Roasted Sesame Seed

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Abstract

Breast milk provides complete nutrition for infants during the first six months of life. As growth advances, however, breast milk alone becomes insufficient, making the introduction of semi-solid foods alongside breastfeeding known as weaning essential. This study developed and evaluated complementary food blends from sprouted red maize (RM) and roasted sesame seed (SS), using Frisocream (FC) as the standard control. Sprouted RM flour was combined with varying proportions of dehulled and roasted SS to improve protein quality for managing protein-energy malnutrition (PEM). Four blends were formulated: Blend A (80% RM, 20% SS), Blend B (70% RM, 30% SS), Blend C (60% RM, 40% SS), and Blend D (50% RM, 50% SS). Proximate composition, mineral content, and *in vitro* protein digestibility were analyzed using standard methods. Protein levels in Blends A (36.71%), B (30.32%), C (26.75%), and D (15.97%) were significantly ($p < 0.05$) higher than the control (16.31%), with Blend A showing the highest protein content. Moisture, fiber, and fat contents of all blends were also significantly ($p < 0.05$) higher than FC, though moisture remained within WHO's recommended limit (< 10%). Potassium (K) and iron (Fe) were significantly ($p < 0.05$) higher in Blend A compared to other blends and the control. Zinc (Zn) levels varied significantly ($p < 0.05$), except between Blends A, B, and FC. *In vitro* protein digestibility increased significantly ($p < 0.05$), reaching 89.75% at one hour and 91.30% at six hours. These findings demonstrate that sprouted red maize-sesame blends, particularly Blend A, provide nutritionally superior complementary foods with potential to combat PEM in infants and young children.

Keywords: *Red Maize (RM); Sesame Seed (SS); Frisocream (FC); Protein-Energy Malnutrition (PEM)*

Introduction

Breast milk is the perfect food for infants during the first six months of life. It contains all essential nutrients as well as immunological components that safeguard the child's health while supporting growth and development [1]. At this stage, infants require higher energy and protein intake to meet their rapidly increasing nutritional demands. Breastfeeding alone can no longer provide sufficient nutrition, making complementary feeding practices essential alongside breastfeeding to ensure optimal health and development [2].

Complementary foods play a critical role in preventing malnutrition, mortality, morbidity, hypovitaminosis, and mineral deficiencies in infants [3]. In Nigeria, weaning is a gradual process of introducing semi-solid foods alongside breastfeeding until the infant's gastrointestinal tract matures enough to accept the family diet [4]. Protein-energy malnutrition (PEM) remains one of the most severe nutritional problems affecting infants and young children in developing countries. It manifests in conditions such as kwashiorkor and marasmus, characterized by muscle wasting, loss of subcutaneous fat, stunted growth, impaired immunity, chronic diarrhea, and intellectual disability [5]. These conditions are often linked to poverty and limited nutritional knowledge among parents in rural areas [6].

Commercial weaning foods are often expensive and unaffordable for many families, particularly in rural Nigeria, where approximately 87 million people live in extreme poverty [7]. Locally available weaning foods in Nigeria and other developing countries are typically based on monocereal grains such as maize, millet, sorghum, wheat, or rice, commonly prepared as "Ogi" or "Akamu". However, these foods are nutritionally inadequate, lacking essential amino acids such as lysine and tryptophan. While cereals are rich in sulfur-containing amino acids (cysteine and methionine), legumes provide lysine and tryptophan, making cereal-legume combinations nutritionally superior [22].

Processing techniques and complementary formulations that combine cereals with legumes or animal protein sources such as crayfish are crucial for enhancing nutritional quality, palatability, digestibility, and acceptability of weaning foods [8]. In West Africa, complementary foods are often prepared from cereals and legumes such as soybeans, groundnuts, cowpea, sweet potatoes, and peanuts to alleviate protein deficiency [9]. In addition to protein, vitamins and minerals are significantly improved through processing techniques recommended by the Food and Agricultural Organization [10].

Traditional food processing methods such as sprouting, fermentation, and germination where seeds, nuts, legumes, and grains are soaked in water for several hours greatly enhance nutrient composition [11]. Germination induces biochemical and physiological changes that improve nutrient bioavailability. Both fermentation and germination are widely used in traditional and modern food systems to improve the nutritional quality of foods and beverages [19].

Sesame (*Sesamum indicum*) is an annual edible oilseed crop belonging to the family Pedaliaceae. It is often referred to as the "queen of oilseeds" due to its high antioxidant activity and rich content of polyunsaturated fatty acids (PUFA) [12]. Sesame seeds are nutritionally valuable, being rich in protein, vitamin B1, dietary fiber, calcium, copper, magnesium, manganese, zinc, and phosphorus. They also contain bioactive compounds such as sesamin and sesamolin, which are lignans known to lower cholesterol, reduce hypertension risk, and enhance vitamin E levels in animals [12]. Therefore, this study was undertaken to formulate and evaluate complementary food blends from sprouted red maize and roasted sesame seed, with the aim of improving protein quality, mineral composition, and digestibility. By utilizing locally available crops and traditional processing methods, the research seeks to provide affordable, nutrient-dense alternatives to commercial weaning foods for combating protein-energy malnutrition in infants and young children.

Materials and Methods

Sample collection

Red maize (*Zea mays*) and sesame (*Sesamum indicum*) were purchased from Yunusari Local Government Area of Yobe State, Nigeria.

Sample identification

The samples were identified and authenticated at the Faculty of Agriculture, University of Maiduguri, Borno State, Nigeria.

Sample preparation

Preparation of sprouted maize

Sprouting was carried out following the method described by [13], with slight modifications. Approximately 1 kg of red maize grains was soaked in 1L of tap water in a plastic bucket and steeped for 12 hours at room temperature (36- 37°C). The steep water was discarded by decantation, and the grains were transferred into a container covered with a jute bag for 48 hours to allow sprouting.

The sprouted grains were spread on a clean tray and sun-dried for two days. The dried grains were milled using an attrition mill (Hunt No. 2A Premier Mill, Hunt & Co., UK) to an average particle size of < 0.3 mm. The flour was sieved through a fine mesh (0.5 mm) to obtain sprouted red maize flour.

Preparation of sesame

Sesame seeds were processed according to [14], with slight modifications. Exactly 500g of sesame seeds were sorted to remove dirt and contaminants, steeped in water for 20 minutes, washed, and dried. The seeds were then roasted for 10 - 15 minutes, ground into fine powder, and sieved to obtain sesame flour.

Preparation of food blends

Sprouted red maize flour and roasted sesame flour were thoroughly mixed in different ratios to produce four blends: Blend A: 80% red maize, 20% sesame Blend B**:** 70% red maize, 30% sesame Blend C: 60% red maize, 40% sesame and Blend D: 50% red maize, 50% sesame

The blending was carried out using a rotary mixer (Model HR 2000/A, Holland), following the method described by [13].

Determination of ash content (Gravimetric method)

A silica dish was cleaned, ignited, cooled in a desiccator, and weighed (W_1). Five grams of sample (W_2) were placed in the dish and incinerated in a muffle furnace at 500°C until a grey ash was obtained. The dish was cooled in a desiccator and weighed (W_3).

$$\% \text{ Ash} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100$$

Determination of crude fibre [15]

Two grams of sample were transferred into a 250 mL conical flask. 100 mL of digestion mixture was added and refluxed for 45 minutes with occasional shaking. The mixture was filtered, washed with boiling water, alcohol, and petroleum ether, and then dried at 100°C to constant weight. The residue was weighed with filter paper (b), and the weight of the paper alone (a) was subtracted to obtain residue weight (C = b-a). The residue was then ashed at 600°C for 4 hours. The crucible weight with ash (e) minus crucible weight alone (d) gave ash weight (f).

$$\% \text{ of crude fibre} = \frac{c-f}{2g} \times 100$$

Where: b= Weight of paper +residue. a= Weight of paper alone. C=b-a = Weight of residue. e= Weight of dish + ash. d= Weight of dish alone. f= e-d = Weight of ash and C-f = Weight of crude fibre.

Determination of fat content (Soxhlet extraction method)

Five grams of sample (W) were weighed into a thimble. A flat-bottom flask was weighed (W_1) and attached to the extractor. Petroleum ether (40 - 60°C) was used for continuous extraction for 5 hours. The solvent was evaporated, and the flask with residue was dried, cooled, and weighed (W_2).

$$\% \text{ Extractable fat} = \frac{W_3 - W_2}{W_1}$$

Determination of protein content (Kjeldahl method)

Protein content was determined using the Kjeldahl method, which excluded nitrogen from nitrites and nitrates but included nitrogen from proteins, alkaloids, and nucleic acids. Organic matter was oxidized with concentrated sulfuric acid and a catalyst, converting nitrogen to ammonium sulfate. The procedure involved digestion, distillation, and titration. In digestion, 2g of sample were treated with 20 mls sulfuric acid and digested for 3 hours, then neutralized with 50 ml of 40% NaOH and diluted to 100 ml. During distillation, 5 ml of digested sample and 20 ml NaOH were distilled, and 75 ml of distillate were collected in borate solution with mixed indicators, then titrated with 1M HCl. Standardization was performed by distilling ammonium solution with NaOH, absorbing liberated ammonia in boric acid, and titrating with 0.1 M HCl to obtain the acid factor. Crude protein percentage was calculated using the standard formula.

$$\%Protein = \frac{A \times N \times F \times 14.007}{Weight\ of\ sample \times aliquot\ taken} \times 100$$

Where: A=Volume of the acid used. N=Molarity of the acid. F=Factor 6.25.

Determination of carbohydrate content (By difference)

The carbohydrate content was determined by differences obtained after the subtraction of total crude protein, fat, ash and crude fibre from the total dry matter [15].

% of carbohydrate = 100 - (% Moisture + % protein + % fat + % ash + % crude fibre).

Determination total energy content (Formular method)

The total energy value was determined according to the method [15] using the formula:

Total energy (Kcal/100g) = (% available carbohydrate x 4) (% protein x 4) + (% fat x 9).

Determination of mineral elements

Mineral elements (Ca, Na, K, Fe, Mg, and Zn) were determined using an Atomic Absorption Spectrophotometer (AAS, AA 6800 series, Shimadzu Corp). Two grams of sample were incinerated at 600°C for 3 hours. The ash was digested with 10 mL of 6N HCl, boiled for 10 minutes, filtered, and diluted to 100 mL with deionized water. The solution was aspirated into the AAS, and readings were recorded in ppm.

Wavelengths used: Fe = 248.3 nm, K = 766.5 nm, Zn = 213.9 nm Na = 589.0 nm, Ca = 422.7 nm and Mg = 285.23 nm.

Parameters (%)	Blend A	Blend B	Blend C	Blend D	Frisocream (F®)
Protein	36.71 ± 0.03^{a}	30.32 ± 0.01^{b}	26.75 ± 0.03^{c}	15.97 ± 0.01^{c}	16.31 ± 0.01^{c}
Ash	9.16 ± 0.03^{a}	7.40 ± 0.01^{b}	6.96 ± 0.01^{c}	3.48 ± 0.01^{d}	4.73 ± 0.02^{d}
Moisture	9.01 ± 0.01^{a}	9.62 ± 0.02^{a}	9.97 ± 0.02^{a}	8.02 ± 0.01^{b}	3.21 ± 0.01^{c}
Fiber	5.92 ± 0.01^{d}	7.28 ± 0.02^{c}	9.15 ± 0.01^{a}	8.22 ± 0.01^{b}	1.21 ± 0.01^{e}
Fat	5.50 ± 0.04^{c}	11.00 ± 0.01^{b}	4.50 ± 0.01^{d}	12.50 ± 0.01^{a}	2.81 ± 0.03^{e}
CHO	35.70 ± 0.01^{d}	34.36 ± 0.01^{e}	42.66 ± 0.01^{c}	51.81 ± 0.01^{b}	71.73 ± 0.02^{a}
Energy (Kcal/100g)	321.14 ± 0.01^{d}	357.72 ± 0.01^{c}	318.64 ± 0.02^{e}	383.62 ± 0.0^{a}	377.45 ± 0.03^{b}

Table 1: *Proximate composition of complementary food blend.*

Value are mean ± SEM, n = 3. Values with different superscript along the row are significantly different (P < 0.05).

Mineral elements (mg/100g)	Blend A	Blend B	Blend C	Blend D	Frisocream (F®)
Potassium	301.09 ± 0.55^{a}	225.95 ± 0.12^{d}	252.79 ± 0.06^{c}	140.55 ± 0.22^{e}	290.57 ± 0.16^{b}
Calcium	200.56 ± 0.05^{e}	298.26 ± 0.15^{b}	138.43 ± 0.27^{d}	104.31 ± 0.18^{e}	309.85 ± 0.37^{a}
Magnesium	15.66 ± 0.05^{e}	20.75 ± 0.09^{d}	49.32 ± 0.02^{a}	34.74 ± 0.02^{c}	46.10 ± 0.01^{b}
Sodium	59.72 ± 0.17^{b}	46.32 ± 0.26^{d}	61.43 ± 0.06^{a}	40.73 ± 0.01^{e}	49.46 ± 0.31^{c}
Phosphorus	132.58 ± 0.21^{e}	150.48 ± 0.11^{d}	190.66 ± 0.30^{a}	150.49 ± 0.01^{c}	151.96 ± 0.35^{b}
Iron	1.19 ± 0.01^{d}	2.07 ± 0.02^{c}	3.16 ± 0.13^{a}	2.80 ± 0.03^{b}	2.90 ± 0.06^{b}
Zinc	1.16 ± 0.02^{c}	1.82 ± 0.00^{a}	1.12 ± 0.01^{c}	1.27 ± 0.01^{b}	1.18 ± 0.04^{c}

Table 2: *Mineral element composition of complementary food blend.*

Value are mean ± SEM, n = 3. Values with different superscript along the row are significantly different (P < 0.05).

Percent (%)	Blend A	Blend B	Blend C	Blend D	Frisocream (F®)
Digestibility at 1 hour	89.72 ± 0.00^{b}	89.75 ± 0.00^{b}	89.62 ± 0.01^{b}	73.11 ± 0.01^{b}	90.12 ± 0.01^{b}
Digestibility at 6 hours	90.81 ± 0.01^{a}	91.30 ± 0.01^{a}	91.22 ± 0.01	88.21 ± 0.01^{a}	91.15 ± 0.14^{a}

Table 3: *In-vitro protein digestibility of complementary food blends.*

Value are mean ± SEM, n = 3. Values with different superscript along the column under are significantly different (P<0.05).

Discussion

The crude protein content of the complementary food blends ranged between 26.75% and 36.71%. Notably, Blend A and Blend B exhibited higher protein levels compared to the commercial weaning product Frisocream and the daily recommended protein intake for infants (16%) [17]. This enhancement is largely attributable to sprouting, a processing technique known to improve protein concentration by reducing anti-nutritional factors and increasing bioavailability [27]. The findings underscore the nutritional advantage of sprouted formulations in infant feeding.

The fat content of the blends ranged from 4.50% to 12.49%, significantly higher ($p < 0.05$) than Frisocream. This increase may be explained by the inclusion of legumes such as sesame, which are rich in lipids and serve as energy reservoirs [26]. Despite this improvement, both the complementary blends and Frisocream fell short of the recommended dietary allowance (RDA) of 20 - 25% fat for infants aged 1 - 3 years, as specified by the Institute of Medicine. Interestingly, Blend D (12.50%) was closest to meeting the RDA, suggesting potential for further optimization.

The moisture content of all blends was below 10%, aligning with acceptable standards [18]. Moisture levels are influenced by food type and storage conditions [28]. Low moisture enhances storage stability by reducing mold growth and biochemical reactions [16,23]. Consequently, these complementary blends are expected to exhibit extended shelf life [29].

Ash content, an indicator of mineral composition, ranged from 6.96% to 9.16%, higher than Frisocream (4.73%). Blend A (9.16%) emerged as the richest mineral source. Similarly, crude fibre levels were elevated in the blends compared to Frisocream, suggesting potential health benefits such as reduced risk of cardiovascular disease, diabetes, and colon cancer [20]. Fiber also promotes gastrointestinal health by producing larger, softer stools [21].

The complementary blends demonstrated higher concentrations of K, Mg, Na, P, Fe, and Zn compared to Frisocream, likely due to the inclusion of sesame, which are mineral-rich [25]. However, calcium levels were lower than in Frisocream, reflecting the fortification practices common in commercial weaning foods to meet FAO/WHO infant formula standards [24].

The improvement *in vitro* protein digestibility was observed, likely due to the reduction of anti-nutritional factors during processing [26]. This highlights the importance of processing techniques in enhancing nutrient utilization and overall dietary quality for infants.

Conclusion

The complementary food blends developed in this study demonstrated superior nutritional qualities compared to the commercial weaning product Frisocream, particularly in terms of protein, ash, fiber, and mineral content. While fat and calcium levels remain below recommended thresholds, the blends show promise as nutrient-dense alternatives for infant feeding.

Recommendations

1. The food blends should be administered to human subject especially on children with severe acute malnutrition (SAM) with an establishing the effectiveness of the blends since they posse appreciable levels of protein content.
2. Research into the shelf-life studies should be carried out to determine the span of the finished products.

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