



# Nutritional Quality and Vitamin Composition of Complementary Foods Formulated from Traditionally Processed Food Ingredients

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## ABSTRACT

Malnutrition continues to be a serious public health concern in Nigeria, particularly among newborns and children, emphasizing the need for affordable, nutrient-dense diets made from locally available ingredients. This study evaluated the nutritional quality and vitamin composition of complementary foods formulated from traditionally processed maize, millet and sorghum. The grains were subjected to roasting, fermentation or left unprocessed (control), then blended with soybean, groundnut, pumpkin seed, watermelon seed and tomato in a fixed ratio (35:21:11:10:2:3:2:3:13), producing nine formulations: roasted maize (RMZ), roasted millet (RM), roasted guinea corn (RGC), fermented maize (FMZ), fermented millet (FM), fermented guinea corn (FGC), unprocessed maize (UMZ), unprocessed millet (UM) and unprocessed guinea corn (UGC). Proximate composition was determined using standard AOAC methods, while vitamins A, E and C were quantified spectrophotometrically. Protein content ranged from 0.15% (UGC) to 10.76% (FM), while crude fat ranged from 2.48% (FMZ) to 6.24% (RGC). Carbohydrate content ranged from 70.07% (UM) to 86.68% (RMZ), with RMZ also recording the highest energy value (406.72 kcal). Vitamin A ranged from 0.72 mg/100 g (RMZ) to 1.77 mg/100 g (RM); vitamin E from 14.27 mg/100 g (RMZ) to 31.71 mg/100 g (UM); and vitamin C from 16.24 mg/100 g (RGC) to 52.87 mg/100 g (RM). Overall, roasted millet (RM) emerged as the most nutritionally balanced formulation, reaching or exceeding baby Recommended Dietary Allowances (RDAs). The findings demonstrate the potential of affordable, locally sourced and traditionally processed cereal-legume complementary foods as practical interventions for reducing infant undernutrition and improving child nutritional outcomes in resource-limited settings.

**Keywords:** weaning foods, malnutrition, traditional processing, maize, millet, sorghum, proximate composition, functional properties, infant nutrition, Nigeria

## 1.0 INTRODUCTION

In Nigeria, malnutrition is a major health issue that is more severe in infants and children and has resulted in high rates of morbidity and mortality in these susceptible populations (Kuh & Davey, 2023). In developing countries like Nigeria, where most children are weaned on pap, a gruel made from fermented grains like maize, millet, and guinea corn, mortality rates are higher. The situation is even more critical now that the prices of commercial weaning food are too expensive for many mothers. Adequate nutrition and health care in the first few years of life are critical to meeting the Millennium Development Goals (MDGs) for child survival and malnutrition prevention (Lutter, 2019).

Recent scoping assessments confirm that traditional complementary meals in Sub-Saharan Africa are mostly made up of starchy foods like maize, sorghum, and millet, which are low in energy and nutrients (Tura *et al.*, 2025). Tura *et al.*; (2025) identified why comparing maize, millet and sorghum under identical formulation condition and different processing methods is necessary. Enrichment of sorghum with amaranth, spinach and pigeon pea has been shown to enhance protein, energy, fats, calcium, iron, potassium and zinc content. Similarly, Ikujeunlola and Iwayemi (2025) demonstrated that malting and fermentation significantly improved the amino acid profile of sorghum, particularly enhancing methionine levels,

highlighting the advantages of cereal-legume blends in complementary food formulations.

Weaning practices vary greatly by location, tribe, language, and nation. In most situations, weaning techniques are only affected by some characteristics such as the environment, maternal age, marital status, exposure, literacy, and the socioeconomic position of most mothers. (Oladiran & Emmambux, 2020). These characteristics are associated with breastfeeding initiation and duration. In urban areas, most mothers may wean their babies using commercial products such as Nutrends, Cerelac, Friso, and so on, whereas in traditional or rural settings, mothers may use cheap available food/grains to prepare a supplementary food for the baby, which, unfortunately, will often lack the essential nutrients needed for the child's proper growth and development.

Breast milk provides the recommended nutrition for most infants during the first six months after which complementary foods are introduced while breast feeding continues. Stunting and growth failure occur between the ages of 6 and 24 months in infants, thus the quality of food utilized in supplemental feeding is critical. To prevent malnutrition, complementary foods/weaning foods, whether produced or cooked locally, must meet newborn nutritional requirements.

Although the causes of malnutrition are numerous and diverse, insufficient consumption of foods and key nutrients is a major culprit, few researches register the fact that processing methods also affects the nutrient dense nature of weaning foods and this topic is understudied in many developing countries, including Nigeria (Kikafunda, 2023). According to Njongmeta *et al.* (1999), one of the most significant challenges in combatting and preventing infant malnutrition and diarrhea in Africa is a lack of trustworthy data on supplemental feeding habits that may influence the development of intervention strategies. Any program aimed at improving supplemental feeding must first do a nutritional assessment of local food sources (George *et al.*, 2024).

The objectives of this research are to first of all process grains in three major ways, the roasting, soaking and unprocessed dry form, then formulate a complementary weaning food from the processed grains and determine the nutritional composition of each differently processed grain formulation.

## 2.0 MATERIALS AND METHODS

## 2.1 Study Area

This research was conducted at the Department of Usmanu Danfodiyo University Sokoto, which is located on Latitude 13.0909N Latitude and 5.2407E Longitude. Sokoto State falls within the Sudan Savana and is found in the North West geopolitical zone of Nigeria.

## 2.2 Materials and Reagents

Maize seeds (*Zea mays*), Guinea corn seeds (*Sorghum bicolor*), millet seeds (*Pennisetum glaucum*), groundnut seeds (*Arachis hypogaea*), Soybean seeds (*Glycine max*), pumpkin seed, tomatoes, watermelon seed, Cerelac, Crucibles, thimbles, Analytical balance, Muffle furnace, Oven, Desiccator, Goldfish Fat Extraction Apparatus, Ankom Fiber Analyzer, Weighing papers, Glasswares, Stirring apparatus,

Hotplate, Centrifuge, Sulfuric acid ( $\text{H}_2\text{SO}_4$ ), Cupric Sulphate ( $\text{CuSO}_4$ ), Sodium Sulphate ( $\text{Na}_2\text{SO}_4$ ), Sodium Hydroxide ( $\text{NaOH}$ ), Hydrochloric acid ( $\text{HCl}$ ), Conway indicator, Ethyl alcohol, Petroleum ether, Antifoam, Distilled water. Kjeldahl digestion and distillation apparatus, 500 ml Kjeldahl flasks, 250 ml Erlenmeyer flasks, Glass beads.

### 2.3 Sample Collection and Selection

A total of eight (8) different samples were purchased. The different types of grains selected for the research are: Maize seeds (*Zea mays*), Guinea corn seeds (*Sorghum bicolor*), millet seeds (*Pennisetum glaucum*). Other legumes like soybeans and groundnuts seeds were also used. Watermelon and pumpkin seeds and tomatoes were bought from the central market Sokoto, Nigeria in August, 2025.

## 2.6 Weaning Food Formulation

The formulation followed the standard UNICEF/WHO guidelines for weaning formulas (WHO, 2007; UNICEF, 2004). Flours were formulated in accordance with Codex Guidelines for preparing weaning food based on the F100 nutrient profile in order to provide a similar nutrient profile in a form that requires further processing (Codex Alimentarius, 2019). Each ingredient was weighed into a bowl and combined with an electric mixer (Kenwood Chef, KMC200, Kenwood Co. Ltd., and UK) for 2 minutes. The samples were then transferred to sealed plastic containers and stored at room temperature until needed for proximate assays.

Each of the differently processed (unprocessed, fermented and roasted) grains (Maize, millet and guinea corn) were measured in the same proportion (35:21:11:10:2:3:2:3:13). The nutritional compositions of the commercial weaning food (Cerelac) was used as positive control which prompted the selection of the legumes, seeds and vegetables used to give nine (9) different weaning formulations as presented in Table 1.

**Table 1: Composition of Formulated Weaning Foods (Grams)**

[illegible]

[illegible]

**Where: UMZ = Unprocessed Maize, UM = Unprocessed Millet, UGC = Unprocessed Guinea Corn, RMZ = Roasted Maize, RM = Roasted Millet, RGC = Roasted Guinea Corn, FMZ = Fermented Maize, FM = Fermented Millet, FGC = Fermented Guinea Corn. The values represent grams of each ingredient per 100g of formulated weaning food. Formulation proportions were based on the UNICEF/WHO guideline for weaning formulations (WHO, 2007; UNICEF, 2004).**

## 2.7 Determination of Some Functional Properties

### 2.7.1 Determination of the Water Swelling Capacity

**2.4.1 Determination of the Water Swelling Capacity**  
The swelling capacity was determined by the method described by Okaka and Potter (1977).

### 2.7.2 Determination of the Water Absorption Capacity

Water absorption was expressed as grams of water absorbed by 1 g of the flour sample (Sosulski et al., 1976).

### 2.7.3 Determination of the Bulk Density

This was determined using the method described by Onwuka (2005).

## 2.8 Determination of Proximate Composition of the Formulated Weaning Foods

The nine prepared weaning diets were analyzed for proximate composition, such as moisture, ash, crude protein, lipids, crude fiber, and nitrogen free extract/soluble carbohydrate, using standard protocols established by the Association of Official Analytical Chemists (AOAC, 1990). The protein content of the samples was measured using the micro-Kjeldahl method (Kjeldahl 1973). In addition, the fat content of the samples was determined using the Soxhlet method (AOAC, 1990). The crude fiber, ash, and moisture content of the samples were determined as follows. Each nutrient was determined in triplicate (AOAC, 1990).

### 2.8.1 Moisture Content Determination

**2.1.1 Moisture Content Determination**  
Moisture content was determined using the method described by Bakare (1985).

### 2.8.2 Ash Content Determination

Ash content was determined using the method described by Bakare (1985).

### 2.8.3 Crude Lipid Estimation

The crude lipid content of the formulated weaning foods was estimated using the Soxhlet extraction method (AOAC, 1990).

#### 2.8.4 Estimation of Crude Protein

Crude protein was estimated using the Kjeldahl method (Kjeldahl, 1973).

### 2.8.5 Estimation of Carbohydrate by Difference

The nitrogen-free extractive (N.F.E.), also known as soluble carbohydrate, was calculated as the difference between 100 and the sum of percentage ash, moisture, crude fat, and protein (Oyeleke, 1984).

### 2.8.6 Determination of Crude Fibre

Crude fibre was determined using the method described by AOAC (1990).

### 2.8.7 Energy Content

The energy content was calculated in accordance with Atwater and Woods (1896). The technique is based on the thermal combustion of protein, fat, and carbohydrates, which is adjusted for urea losses during digestion, absorption, and urine excretion. It applies a single factor to each of the energy-yielding substrates (protein, lipids, and carbs), regardless of the meal in which they are located. Here's the formula:

Energy (kcal) = (4 × carbohydrates in grams) + (4 × protein in grams) + (9 × fat in grams) (Atwater & Woods, 1896).

## 2.9 Estimation of Vitamin-A Content

The concentration of vitamin A was estimated by the method of Rutkowski et al. (2006).

## 2.10 Estimation of Vitamin-C Content

The concentration of vitamin C (ascorbic acid) was estimated by the method of Omaye et al. (1979).

## 2.11 Estimation of Vitamin-E Content

Vitamin E (tocopherol) was estimated by the method of Desai and Lewis (1984).

## 2.12 Data Analysis

Microsoft Excel 2010 was utilized to handle and analyze data. Values were reported as mean  $\pm$  standard deviation and presented in tables. Proportions were represented by charts and graphs. Steel and Torrie (1980) performed one-way analysis of variance

(ANOVA) to compare sample means and found significant differences at  $p < 0.05$ .

## 3.0 RESULTS

### 3.1 Functional Properties of the Processed Grains

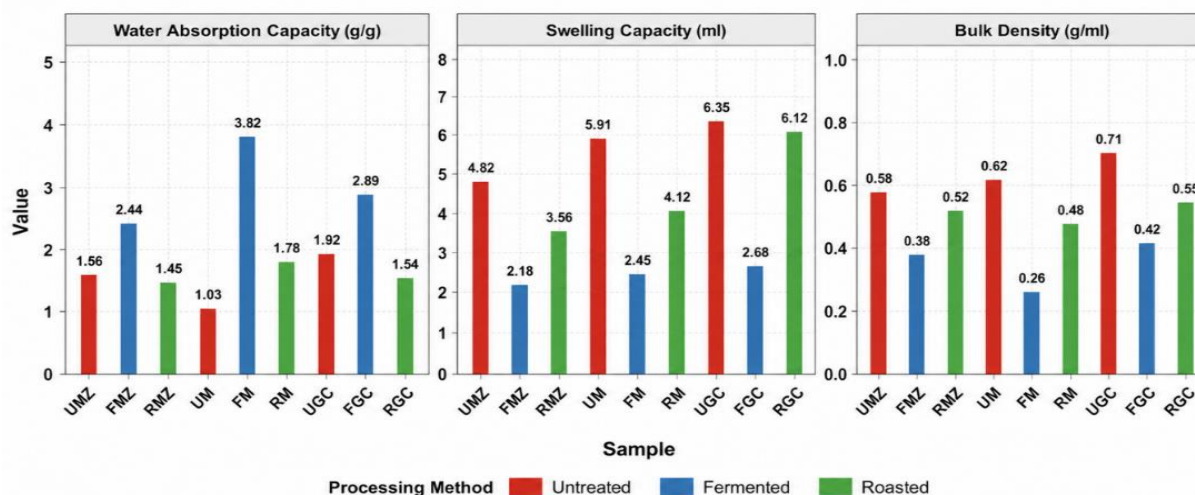


Figure 1: Functional Properties of Processed Grains (Maize, Millet, Guinea corn)

Where: UMZ = Unprocessed Maize, FMZ = Fermented Maize, RMZ = Roasted Maize, UM = Unprocessed Millet, FM = Fermented Millet, RM = Roasted Millet, UGC = Unprocessed Guinea Corn, FGC = Fermented Guinea Corn, RGC = Roasted Guinea Corn

### 3.2 Proximate Composition of the Different Processed Grain Formulations

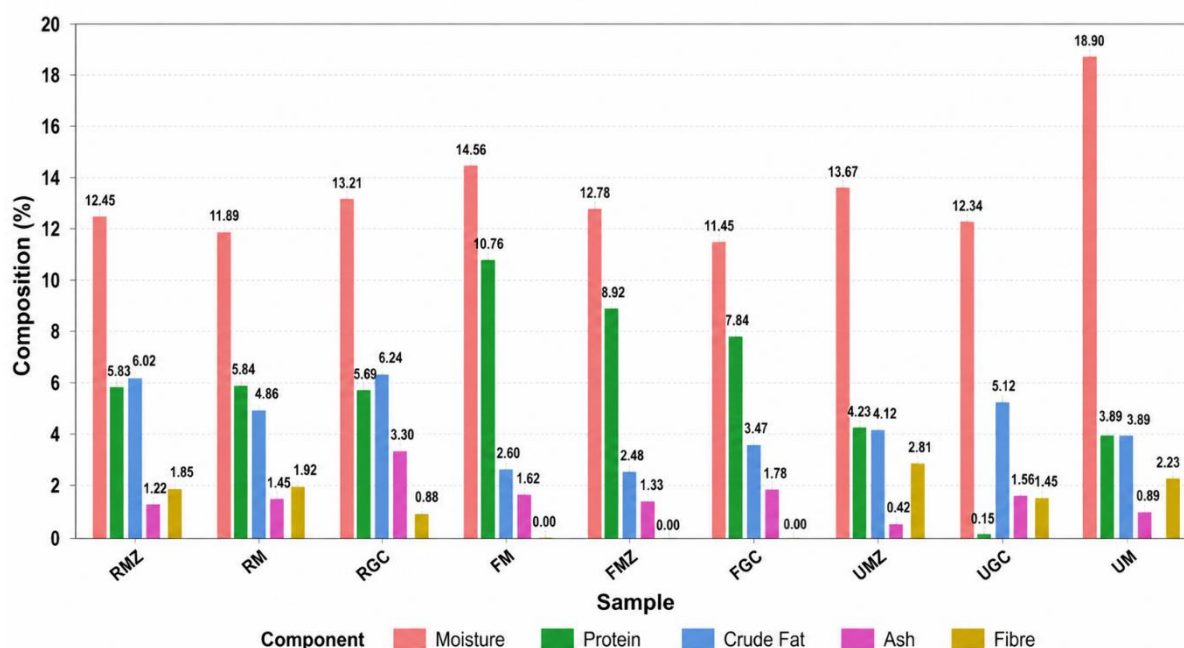


Figure 2A: Proximate Composition of the Different Processed Grain Formulations

Where: UMZ = Unprocessed Maize, FMZ = Fermented Maize, RMZ = Roasted Maize, UM = Unprocessed Millet, FM = Fermented Millet, RM = Roasted Millet, UGC = Unprocessed Guinea Corn, FGC = Fermented Guinea Corn, RGC = Roasted Guinea Corn

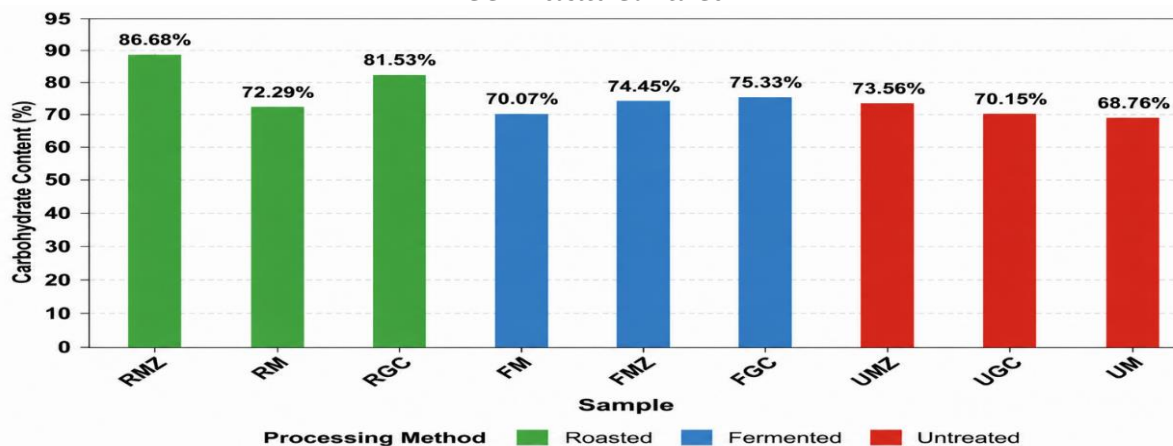


Figure 2B: Carbohydrate Composition of the Different Processed Grain Formulation

UMZ = Unprocessed Maize, FMZ = Fermented Maize, RMZ = Roasted Maize, UM = Unprocessed Millet, FM = Fermented Millet, RM = Roasted Millet, UGC = Unprocessed Guinea Corn, FGC = Fermented Guinea Corn, RGC = Roasted Guinea Corn

### 3.3 Vitamin Content of Processed Grain Formulations

The results of the vitamin content of the processed grain formulations are presented in Table 2.

Table 2: Vitamin Content of Processed Grain Formulations

| Sample | Vitamin A (mg/100g)       | Vitamin E (mg/100g)        | Vitamin C (mg/100g)        |
|--------|---------------------------|----------------------------|----------------------------|
| RMZ    | 0.72 ± 0.10 <sup>f</sup>  | 14.27 ± 2.00 <sup>c</sup>  | 31.00 ± 5.00 <sup>c</sup>  |
| RM     | 1.77 ± 0.50 <sup>a</sup>  | 31.18 ± 4.30 <sup>a</sup>  | 52.87 ± 3.10 <sup>a</sup>  |
| RGC    | 1.21 ± 0.30 <sup>d</sup>  | 18.43 ± 3.70 <sup>bc</sup> | 16.24 ± 5.10 <sup>c</sup>  |
| FM     | 1.47 ± 0.15 <sup>c</sup>  | 17.62 ± 2.70 <sup>c</sup>  | 30.41 ± 4.80 <sup>c</sup>  |
| FMZ    | 1.67 ± 0.40 <sup>ab</sup> | 15.11 ± 3.90 <sup>c</sup>  | 32.51 ± 1.60 <sup>bc</sup> |
| FGC    | 1.44 ± 0.40 <sup>c</sup>  | 21.41 ± 6.10 <sup>b</sup>  | 33.51 ± 2.90 <sup>b</sup>  |
| UMZ    | 1.59 ± 0.46 <sup>b</sup>  | 16.00 ± 7.20 <sup>c</sup>  | 41.34 ± 7.13 <sup>ab</sup> |
| UGC    | 0.91 ± 0.11 <sup>c</sup>  | 22.39 ± 8.12 <sup>b</sup>  | 26.47 ± 9.23 <sup>d</sup>  |
| UM     | 1.65 ± 0.24 <sup>a</sup>  | 31.71 ± 6.67 <sup>a</sup>  | 33.81 ± 7.15 <sup>b</sup>  |

Data are presented as Mean ± SD. Data with different superscripts are significantly different ( $p < 0.05$ ). RMZ = Roasted Maize, RM = Roasted Millet, RGC = Roasted Guinea Corn, FM = Fermented Millet, FMZ = Fermented Maize, FGC = Fermented Guinea Corn, UM = Unprocessed Millet, UMZ = Unprocessed Maize, UGC = Unprocessed Guinea Corn. Superscripts (a, b, c, d, e, f, bc, ab, abc) indicate significant differences at  $p < 0.05$ . The Recommended Dietary Allowance (RDA) for infants aged 7-12 months is approximately 1.67 mg/100g for vitamin A, 5 mg/day for vitamin E, and 50 mg/day for vitamin C.

**Table 3: Energy Content of Formulated Weaning Foods**

| Sample | Energy (kcal/100g) |
|--------|--------------------|
| RMZ    | 406.72             |
| RM     | 398.45             |
| RGC    | 385.21             |
| FM     | 372.68             |
| FMZ    | 365.14             |
| FGC    | 358.92             |
| UMZ    | 351.47             |
| UGC    | 348.23             |
| UM     | 340.56             |

**Where:** RMZ = Roasted Maize; RM = Roasted Millet; RGC = Roasted Guinea Corn; FM = Fermented Millet; FMZ = Fermented Maize; FGC = Fermented Guinea Corn; UM = Unprocessed Millet; UMZ = Unprocessed Maize; UGC = Unprocessed Guinea Corn. Energy values were calculated from the proximate composition data using Atwater factors (4 kcal/g for protein and carbohydrate; 9 kcal/g for fat). The recommended energy requirement for infants aged 6-12 months is approximately 80-100 kcal/kg body weight per day (WHO, 2007).

#### 4.0 DISCUSSION

##### 4.1 Functional Properties of the Processed Grains

The functional features of several formulated weaning diets were assessed (Figure 1). All processed grains had a water absorption capacity ranging from 1.03 to 3.82 g, a swelling capacity of 2.18 to 6.35 ml, and a bulk density of 0.26 to 0.71 g/ml. The WAC values for FM were quickly followed by those for FGC. While their WAC values were not substantially different ( $p > 0.05$ ), they were significantly higher ( $p < 0.05$ ) compared to other processing methods. Fermentation enhances WAC by breaking down complex carbs (starches) and protein structures via enzymes and microorganisms, which could explain the observed considerable variances. This exposes additional hydrophilic regions, which can bind water. Roasting, on the other hand, may lower WAC by denaturing proteins and partially gelatinizing starch, resulting in grains that are slightly less hydrophilic. Higher WAC has been shown to improve the softness and palatability of weaning foods, making them simpler for infants to swallow and digest (Sosulski et al., 1976; Okaka & Potter, 1977).

The treated grains were also tested for swelling capacity. The effect for the processed grain's swelling capacity is that decreased swelling means less viscous porridges at greater solid concentrations, allowing for more nutrients per volume, which is especially beneficial for infants with small stomachs. The results

also showed that all unprocessed grains (UMZ, UM, and UGC) had considerably higher swelling capacity values ( $p > 0.05$ ) than fermented or roasted grains. High swelling capacity of the fermented supplemental food is not ideal since this may diminish the nutrient density of the meal, and limit the absorption of nutrients by the infant (Afam-Anene & Ahirakwem, 2023). The study found that fermented grains have significantly ( $p < 0.05$ ) lower swelling capability. FM and RMZ exhibited the lowest swelling capacity values, with no significant difference ( $p > 0.05$ ) between them. Fermentation may swell slightly because enzyme activity partially hydrolyzes starch, limiting its potential to absorb water and expand (Mahanta et al., 2020). The functional qualities, with some modifications, are comparable to previous results by Ogunka-Nnoka and Mepha (2022) and Afam-Anene and Ahirakwem (2023) for designed complementary foods and Nutrend, a commercial supplemental food.

The bulk density of uncooked grains was substantially higher ( $p < 0.05$ ) than processed grains. This led to the conclusion that fermentation may reduce bulk density because microbial activity loosens the grain matrix, resulting in more porous particles. Similarly, roasting reduces bulk density by expanding and puffing the grain due to heat, resulting in lighter, airier particles. Overall, the FM had the lowest bulk density. Lower bulk density is beneficial in weaning foods because it

results in lighter porridge with higher nutritional density per spoon, allowing infants to take more energy and nutrients (Onwuka, 2005; Mahanta et al., 2020).

#### 4.2 Proximate Composition

The proximate composition data showed that fermentation greatly increased the protein content of the designed weaning foods. FM's higher protein content ( $10.76 \pm 0.57\%$ ) is likely due to fermentation by microbes, which break down complex proteins into simpler peptides and amino acids. Ikujenlola and Iwayemi (2025) also found that malting and fermentation considerably increased sorghum's amino acid profile, notably methionine levels, underlining the benefits of cereal-legume blends in supplemental food formulations.

The decrease in fat content of fermented millet (FM) could be attributed to increased activity of lipolytic enzymes, which hydrolyze fat into fatty acid and glycerol. Adebo et al. (2022) made similar observations. Banwo et al. (2024) also found that food synergy with sesame seeds and natural fermentation improved the crude protein, lipid, and vitamin C content of traditional fermented foods made from maize and sorghum. The low moisture content (10-15%) indicates that they have the potential for a longer shelf life. This is consistent with the findings of Adebayo-Oyetoro et al. (2012). The low moisture content of food products inhibits biochemical activities of invading microorganisms and therefore prevents food spoilage during storage (Ijarotimi & Keshinro, 2013).

An increase in carbohydrate content was seen during grain fermentation and roasting, which is consistent with Akande and Fabiyi's (2010) findings. Fermentation can partially hydrolyze complex carbs into simple sugars, making them easier to digest, and it decreases oligosaccharides (such as raffinose), which produce flatulence. Roasting, on the other hand, causes the Maillard reaction to occur between reducing sugars and amino acids, which might improve flavor while decreasing lysine bioavailability. It also leads to partial gelatinisation of starch, boosting digestibility.

#### 4.3 Vitamin Composition

The vitamin content of weaning food is vital to promoting normal infant growth, immunological function, and cognitive development throughout the critical supplemental feeding phase (usually 6 months to 2 years). Based on the examination of vitamin A concentration across the various formulations, it is clear that some processed weaning foods outperform others in terms of nutritional demands.

The Recommended Dietary Allowance (RDA) for vitamin A in infants aged 7-12 months is approximately 500 micrograms retinol activity equivalents (RAE) per day, equivalent to about 1.67 mg of vitamin A per 100g. In this study, RM recorded

the highest vitamin A content at  $1.77 \pm 0.5$  mg/100g, closely followed by FMZ at  $1.67 \pm 0.4$  mg/100g and UM at  $1.65 \pm 0.24$  mg/100g. min

Vitamin E's antioxidant activity is critical for maintaining cellular integrity, aiding brain development, and improving immunological function. The recommended daily allowance of vitamin E for infants aged 7 to 12 months is around 5 mg. RM ( $31.18 \pm 4.3$  mg/100g) and UM ( $31.71 \pm 6.67$  mg/100g) exceed the requirement by over six times, providing a significant nutritional reserve. Vitamin C is essential in early childhood nutrition because it helps with iron absorption, collagen formation, and immune system function. The RDA for vitamin C in infants aged 7-12 months is 50 mg/day. RM again leads in this category with  $52.87 \pm 3.1$  mg/100g, just surpassing the RDA and providing a complete daily dose in a 100g serving.

#### 5.0 CONCLUSION

The nutritional assessment of processed grains indicates their variable compatibility for various dietary demands, particularly for newborns and those with special nutritional needs. Fermented millet (FM) has the greatest protein content (10.76%), making it an ideal choice for protein-rich meals, particularly during important growth phases. Roasted maize (RMZ) and roasted guinea corn (RGC), with high carbohydrate (86.68% and 81.53%, respectively) and fat levels (6.02% and 6.24%, respectively), are energy-dense options suited for active adults or growing children. Unprocessed guinea corn recorded the highest ash content among the formulation indicating a relatively greater total mineral residue, however, specific mineral determination were not determined in this study.

From a vitamin standpoint, roasted millet (RM) emerges as the best formulation, providing the highest quantities of vitamin A (1.77 mg/100g), vitamin E (31.18 mg/100g), and vitamin C (52.87 mg/100g), reaching or exceeding the RDA for all three. Its high vitamin A, E, and C levels make it the best single formulation tested in this study.

The presence of antinutritional substances such as oxalates, phytates, tannins, and saponins emphasizes the importance of careful preparation methods. While unprocessed samples such as guinea corn and millet may contain larger quantities of these chemicals, they can impede nutrient absorption or digestion if not properly processed. However, procedures like as roasting and soaking greatly lower antinutrient levels, increasing the bioavailability of important minerals and proteins.

#### 6.0 RECOMMENDATIONS

Based on the analysis of processed grains, it is recommended that tailored processing methods be adopted to enhance the nutritional quality of grains while mitigating potential risks associated with anti-nutritional factors. For energy-rich diets, roasted grains



such as maize and guinea corn are excellent options, particularly for growing children and individuals with higher energy demands.

Fermenting grains such as millet is an excellent way to meet protein-focused and balanced nutritional goals. This approach not only increases protein content but also lowers antinutrients, increasing the bioavailability of important minerals and lowering the glycemic level. Fermentation is especially beneficial for infants and children throughout supplementary feeding stages, since it promotes prolonged energy release and improved digestion. Ikujeunlola and Iwayemi (2025) found that a combination of malted-fermented sorghum and full-fat soybeans had a higher Protein Efficiency Ratio (PER), underlining the benefits of cereal-legume combinations.

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