

Nutritional and Mineral Composition of Weaning Food Produced from Malted Sorghum, Yellow Maize, and Tiger nut Flours

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Abstract

This study evaluated the nutritional and mineral composition of complementary foods produced from processed flours of malted sorghum, yellow maize, and tigernut at varying proportion (CWF1–CWF5). A standard AOAC method was used in proximate and mineral analyses. Results showed significant ($P \leq 0.05$) differences among formulations. Moisture contents of the samples were relatively low (8.03–8.25%), indicating low water activity (a_w) and storage stability. Protein decreased from 10.89% to 8.98% with increasing tigernut inclusion, while crude fat (5.44–10.36%), crude fibre (2.87–3.89%), ash (1.70–1.85%), and energy value (375.88–396.72 kcal/100 g) increased. Carbohydrate content declined from 70.84% in CWF1 to 66.89% in CWF5. Mineral analysis revealed significant increases in calcium (34.45–61.60 mg/100 g) and potassium (361.00–405.50 mg/100 g) from CWF1 to CWF5, while magnesium (115.50–121.00 mg/100 g) remained relatively stable. Iron content decreased (3.79–3.07 mg/100 g) with reduced malted sorghum, whereas zinc (1.57–1.99 mg/100 g) showed no significant variation. Among all formulations, CWF4 (40% malted sorghum, 30% yellow maize, and 30% tigernut) exhibited the most balanced nutritional profile, combining adequate protein, high energy density, and superior mineral composition. The study concludes that tigernut inclusion significantly improve the energy composition and micronutrient concentrations of cereal-based complementary foods, demonstrating its potential as a functional ingredient to improve infant nutrition.

Key Words: *Infant nutrition, complementary foods, malted sorghum, micronutrients.*

Introduction

Weaning, which usually starts at six months of age, is a crucial period in an infant's development and is defined as the gradual introduction of complementary foods alongside breast milk (WHO,

2023). Infants have higher nutritional needs during this time, including those for energy, protein, and micronutrients that breast milk can no longer adequately supply (Abeshu et al., 2016). In many poor nations, especially in sub-Saharan Africa, inadequate supplemental feeding practices continue to be a significant cause of stunting, micronutrient deficiencies, and protein-energy malnutrition (PEM) (Dewey and Adu-Afarwah, 2008). Therefore, it is a public health priority to develop weaning foods that are reasonably priced, readily available, and nutritionally sufficient. Cereal-based complementary foods such as maize and sorghum are widely used in traditional infant feeding systems due to their availability and affordability. However, when utilized as the only weaning meal, these staples frequently have low protein quality, few essential amino acids, and poor micronutrient density, which can impair infant growth and development (Michaelsen et al., 2009). By boosting enzymatic activity, increasing digestibility, and lowering anti-nutritional components, processing methods like malting have been demonstrated to increase the nutritional quality of cereals, improving nutrient bioavailability in complementary foods (Fasoyiro et al., 2010). Tigernut (*Cyperus esculentus*), an underutilized tuber commonly consumed in parts of Africa and Europe, has gained increasing attention as a functional ingredient in food formulation due to its rich composition of dietary fiber, healthy lipids, essential minerals like calcium, magnesium, and potassium, as well as bioactive compounds with potential health-promoting properties (Yu et al., 2022; Sánchez-Zapata et al., 2012). By adding it to cereal-based blends, weaning foods' calorie density and mineral profile can be improved, filling in the micronutrient gaps that are frequently seen in newborn diets. Using locally accessible raw resources, the combination of malted sorghum, yellow maize, and tigernut flours offers a promising method for creating nutrient-dense complementary foods. In addition to increasing food security and lowering dependency on imported baby formulae, such composite formulations may enhance protein-energy balance, mineral content, and overall nutritional quality (Alaka et al., 2020). Few studies have thoroughly assessed the nutritional and mineral makeup of blends that explicitly include malted sorghum, yellow maize, and tigernut, despite the growing interest in composite weaning diets (Anukam et al., 2022; Fatukasi et al., 2025). Therefore, this study aims to determine the nutritional and mineral composition of weaning food produced from malted sorghum, yellow maize, and tigernut flours, with the goal of formulating supplemental foods for weaning nutrition that are reasonably priced, locally sourced, and nutritionally enhanced.

Materials and Methods

Materials

Tigernut (*Cyperus esculentus*) was purchased from Hausa market in Aviele, while yellow maize (*Zea mays*), and sorghum (*Sorghum bicolor*), were purchased from Uchi market, all within Auchi metropolis, Edo State, Nigeria. Raw materials were validated at the department of crop science, Auchi Polytechnic Auchi. Analytical grade reagents were used for all laboratory analyses.

Preparation of Raw Materials

Malting of Sorghum

This was done according to procedure described by Adeleye et al., (2025). Seeds of sorghum, steeped in water for eighteen hours. After draining the steep water, the grains were placed in sterile woven baskets to germinate under carefully monitored conditions. In order to maintain the jute sack's moisture content and promote the best possible seed germination, the grains were watered twice a day. After germination for 24, 48, and 72 hours, the grains were dried for five days at an average of eight hours each day in an air oven (40–50°C). The vegetative portion of

the seed was carefully removed by physically rubbing the dry grains between the palms. The de-vegetated seeds were milled using sterile laboratory attrition mill and sieved through a 250–500 µm mesh screen into a fine flour and stored at 4°C (Adegbusi et al., 2023; Idowu et al., 2024).

Preparation of Tigernut Flour

Tigernut tubers (*Cyperus esculentus*) were thoroughly cleaned in a series of clean water to remove adherent soils after being sorted to eliminate stones, pebbles, dirt, broken tubers, and other superfluous elements. After cleaning, the tubers were drained, dried, and baked for 24 hours at 85°C. After removing the burned tubers, the remaining bulk was dry ground into flour and sieved to produce fine flour (Wakil and Ola, 2018).

Preparation of yellow maize

Yellow maize grains were winnowed, manually sorted to remove extraneous materials and washed before steaming for ten minutes to pre-gelatinize the starch content. The grains were dried in a cabinet dryer for 20 hours at 60°C. Dried grains were then hammer milled (Perten, UK), sieved through 500 µm, sieve and packaged in airtight container (Alaka et al., 2020).

Formulation of Composite Weaning Foods

Composite flour blends were prepared by mixing malted sorghum, yellow maize, and tigernut flours in different proportions based on weight/weight ratios as shown in Table 1. The blends were homogenized thoroughly using a mechanical mixer to ensure uniform distribution. The formulated samples were stored in airtight polyethylene containers prior to analysis.

Table 1: Formulation ratio of weaning food (%)

Samples	Malted Sorghum	Yellow Maize	Tigernut
CWF1	60	30	10
CWF 2	50	30	20
CWF 3	40	40	20
CWF 4	40	30	30
CWF 5	30	40	30

Proximate Composition Analysis

The proximate composition of each flour sample was determined using standard analytical methods described by AOAC (2016). Crude protein content was determined by the micro-Kjeldahl method ($N \times 6.25$), while crude fat was extracted with *n*-hexane using a Soxhlet extraction apparatus and quantified gravimetrically. Ash content was determined by incinerating the samples in a muffle furnace at 550 °C for 8 h. Crude fibre was determined following sequential acid and alkali digestion of defatted samples using 1.25% sulfuric acid and 1.25% sodium hydroxide, respectively. Moisture content was determined by oven drying to constant weight, and total carbohydrate was calculated by difference. The gross energy value of each composite flour blend was estimated using the Atwater conversion factors;

Energy value Kcal/100g = 100 - (carbohydrate% X 4 + fat% X 9 + protein% X 4)

Mineral Analysis

Five grams of the sample were ashed into white ash for two hours at 550°C in a muffle furnace in order to perform mineral analysis. This was followed by an acid wash and filtration. Potassium levels were measured using a flame photometer. After sample ash was wet digested with a mixture of nitric and perchloric acids (1:1 v/v), other mineral contents were determined using an atomic absorption spectrophotometer (AAS, Buck Model 20A, Buck Scientific, East Norwalk, CT06855, USA). Each computation was carried out in triplicate (AOAC, 2016).

Statistical Analysis

The results were presented as mean $\pm$ standard deviation, and all analyses were performed in triplicate. SPSS version 21.0 was used to do a one-way analysis of variance (ANOVA) on the collected data. Duncan's Multiple Range Test (DMRT) was used to identify significant variations between means at $p < 0.05$.

Result and Discussion

Proximate Composition

The results of the proximate composition of formulated weaning food from malted sorghum, yellow maize, and tigernut is displayed in Table 2. Significant differences ($P \leq 0.05$) among the samples indicate the influence of malted sorghum, yellow maize, and tigernut proportion influence on nutritional quality. Moisture content ranged from 8.03% to 8.25%, with CWF4 recording the lowest value (8.03%) and CWF3 the highest (8.25%). All values were below 10%, which is considered desirable for complementary foods since low water activity (a_w) improve stability by limiting microbial growth and enzymatic deterioration. This similar observation was reported by Adegbusi *et al.*, (2023) and Alaka *et al.* (2020) for cereal-based complementary foods formulated from local ingredients. Significant decrease in protein content (10.89% in CWF1 to 8.98% in CWF5) was observed. Since sorghum contains significant levels of protein and malting has been shown to promote protein digestibility by enzymatic alteration of grain components, the highest protein level seen in CWF1 may be explained by its greater percentage of malted sorghum (60%). The relatively lower protein content of tigernut flour could be the cause of the steady decrease in protein content with increasing tigernut inclusion and decreasing sorghum proportion. Similar findings were reported by Alaka *et al.* (2020) and Adegbusi *et al.* (2023). A significant increase in crude fat from 5.44% in CWF1 to 10.36% in CWF5 which correspond directly with increase tigernut was observed. Tigernut is naturally high in oil, especially monounsaturated fatty acids like oleic acid (Zhang *et al.*, 2023; Yu *et al.*, 2022). The higher fat content is nutritionally advantageous because fat act as a concentrated source of dietary energy, improve the absorption of fat-soluble vitamins (A, D, E, and K), enhance palatability, and support proper growth and neurological development in infancy (Delplanque *et al.*, 2015; Uauy & Castillo, 2003; Koletzko, 2000). The results agree with that of Yu *et al.* (2022), who described tigernut as an oil-rich tuber containing appreciable amounts of healthy lipids suitable for food fortification. Ash content, an indicator of total mineral content of food ranged from 1.70% to 1.85%, with CWF2 and CWF4 recording significantly higher values than the other formulations. Although relatively small, the differences indicate that composite formulation positively influenced the mineral content of the developed complementary foods. Tigernut has been reported to contain appreciable levels of calcium, magnesium, potassium, phosphorus, and other essential minerals that contribute to the ash fraction (Abdullahi *et al.*, 2022). These findings are consistent with Yu *et al.* (2022) and Abdullahi *et al.* (2022), who reported that tigernut contributes significantly to the mineral composition of composite food products. Significant increase from 2.87% in CWF1 to 3.89% in CWF5 was observed in crude fibre. The level of crude fibre observed remain within moderate level and consistent with Alaka *et al.*, (2020) observation. Carbohydrate content though, decreased significantly ($P \leq 0.05$) from 70.84% in CWF1 to 66.89% in CWF5 remained the predominant macronutrient in all formulations. This trend is expected because increasing substitution with tigernut flour, which contains relatively fatter and fibre but less carbohydrate than cereals, reduced the overall carbohydrate proportion of the composite blends. The reduction in carbohydrate accompanied by

increased fat content is nutritionally beneficial as it enhances the energy density without substantially increasing feeding volume of the weaning food. Yu et al. (2022) and Adegbusi et al. (2023) reported similar findings. The gross energy value significantly increases ($P \leq 0.05$) from 375.88 kcal/100 g in CWF1 to 396.72 kcal/100 g in CWF5 could be attributed to tigernut higher fat contribution, since lipid provide 9 kcal/g, compared with 4 kcal/g for protein and carbohydrate. The energy levels found are within the ideal range for complementary foods meant for young children and infants, who need foods high in energy due to their small stomach capacity and quick growth. According to the results, adding more tigernuts to cereal-based supplemental foods can significantly increase their caloric density. High energy potential of tigernut due to its lipid rich was reported by Alaka et al., (2020)

Table 2: Result of proximate analysis of developed weaning food samples (%)

	CWF1	CWF 2	CWF 3	CWF 4	CWF 5
Moisture (%)	8.23 ^{ab} ±0.04	8.11 ^{bc} ±0.01	8.25 ^a ±0.07	8.03 ^c ±0.04	8.15 ^{abc} ±0.06
Protein (%)	10.89 ^a ±0.05	10.40 ^b ±0.07	9.98 ^c ±0.04	9.47 ^d ±0.02	8.98 ^e ±0.04
Crude Fat (%)	5.44 ^c ±0.01	7.68 ^d ±0.03	8.05 ^c ±0.08	10.03 ^b ±0.03	10.36 ^a ±0.01
Ash(%)	1.73 ^b ±0.02	1.82 ^a ±0.01	1.70 ^b ±0.01	1.85 ^a ±0.01	1.73 ^b ±0.1
Fibre (%)	2.87 ^c ±0.01	3.46 ^{ab} ±0.00	3.38 ^b ±0.01	3.69 ^{ab} ±0.40	3.89 ^a ±0.01
Carbohydrate (%)	70.84 ^a ±0.01	68.53 ^{bc} ±0.01	68.64 ^{bc} ±0.01	66.93 ^c ±0.01	66.89 ^d ±0.00
Energy (kcal/100g)	375.88 ^c ±0.01	384.84 ^d ±0.02	386.93 ^c ±0.01	395.87 ^b ±0.00	396.72 ^a ±0.01

Mean ± standard deviation based on three replicates. Means within the same row with different superscript are significantly different at $P \leq 0.05$. Key: CWF1- 60% malted sorghum, 30% yellow maize, 10% tigernut; CWF2 – 50% malted sorghum, 30% yellow maize, 20% tigernut; CWF3 – 40% malted sorghum, 40% yellow maize, 20% tigernut; CWF4 – 40% malted sorghum, 30% yellow maize, 30% tigernut; CWF5 – 30% malted sorghum, 40% yellow maize, 30% tigernut flour.

Mineral Analysis

Mineral composition of developed weaning food developed from malted sorghum, yellow maize and tigernut as determined is displayed in Table 3. Significant ($P \leq 0.05$) differences were observed among the samples for calcium, magnesium, potassium, and iron, whereas zinc content did not differ significantly ($P > 0.05$).

Table 3: Mineral contents (mg/100 g) of the malted sorghum, yellow maize, and tigernut formulated weaning food samples

Samples	Calcium	Magnesium	Potassium	Iron	Zinc
CWF1	34.45 ^e ±0.07	118.00 ^{bc} ±1.41	361.00 ^e ±1.41	3.79 ^a ±0.01	1.57 ^a ±0.76
CWF 2	51.10 ^c ±0.14	121.00 ^a ±1.41	386.00 ^c ±1.41	3.71 ^b ±0.01	1.99 ^a ±0.01
CWF 3	45.10 ^d ±0.14	116.50 ^c ±0.71	380.50 ^d ±0.71	3.43 ^c ±0.00	1.93 ^a ±0.01
CWF 4	61.60 ^a ±0.14	119.50 ^{ab} ±0.71	405.50 ^a ±0.70	3.34 ^d ±0.01	1.90 ^a ±0.00
CWF 5	55.50 ^b ±0.07	115.50 ^c ±0.71	400.50 ^b ±0.71	3.07 ^e ±0.00	1.84 ^a ±0.01

Mean ± standard deviation based on three replicates. Means within the same column with different superscript are significantly different at $P \leq 0.05$. Key: CWF1- 60% malted sorghum, 30% yellow maize, 10% tigernut; CWF2 – 50% malted sorghum, 30% yellow maize, 20% tigernut; CWF3 – 40% malted sorghum, 40% yellow maize, 20% tigernut; CWF4 – 40% malted sorghum,

30% yellow maize, 30% tigernut; CWF5 – 30% malted sorghum, 40% yellow maize, 30% tigernut flour Calcium content increased significantly ($P \leq 0.05$) from 34.45 mg/100 g in CWF1 to 61.60 mg/100 g in CWF4, before slightly declining to 55.50 mg/100 g in CWF5. The progressive increase in calcium which is important for mineralization of bones, teeth, blood clotting and numerous cellular metabolic processes during infancy (Abrams, 2021)), with increasing tigernut suggest tigernut contributed substantially to its content. This finding is in agreement with those of Yu et al. (2022); and Abdullahi et al. (2022), who identified tigernut as a good dietary source of calcium suitable for food fortification. Magnesium, an essential cofactor for more than 300 enzymatic reactions involved in carbohydrate metabolism, protein synthesis, energy production, neuromuscular function, and bone development (Dzupina et al., 2024) content ranged from 115.50 to 121.00 mg/100 g, with CWF2 recording the highest value. Zhang et al. (2023) and Yu et al. (2022) reported comparable magnesium concentrations for tigernut-based food products. Potassium content increased significantly ($P \leq 0.05$) from 361.00 mg/100 g in CWF1 to 405.50 mg/100 g in CWF4, followed by a slight reduction to 400.50 mg/100 g in CWF5. Potassium is the principal intracellular cation and plays a critical role in maintaining fluid and electrolyte balance, acid–base homeostasis, nerve impulse transmission, muscle contraction, and normal cardiovascular function. Adequate potassium intake during infancy is essential for normal cellular growth, enzyme activity, and metabolic processes (National Academies of Sciences, Engineering, and Medicine, 2019; Weaver, 2013). The observed trend corroborates the findings of Yu et al. (2022) and Mane et al. (2022). These results also align with the findings of Alaka et al. (2020), who observed higher iron content in cereal-based complementary foods with higher amounts of cereal flours, and Taylor and Duodu (2015), who emphasized sorghum as a significant source of dietary iron. The concentration of zinc in the formulated weaning food ranged from 1.57 to 1.99 mg/100 g, with no significant ($P > 0.05$) differences. Zinc is an essential micro-mineral required for DNA replication, immunological response, cognitive development and protein synthesis (Chasapis et al., 2020; King et al., 2016). The observed zinc concentrations are comparable to values reported for cereal-based complementary foods by Alaka et al. (2020).

Conclusion

The results of this study showed that increasing tigernut flour in the composite formulations significantly increased the levels of crude fat, crude fibre, ash content, and energy density, while simultaneously reducing protein and carbohydrate levels. Similar trend was observed in the mineral composition, where increment in tigernut composition improved calcium and potassium contents and slightly enhanced magnesium levels, while lowering iron concentration with reduced malted sorghum, underscoring the contribution of sorghum as a key iron source in the blends. All formulations showed equivalent contributions from the three constituents, as seen by the generally steady zinc levels. With comparatively high protein (9.47%), appreciable fat (10.03%), adequate fiber (3.69%), and high energy value (395.87 kcal/100 g), as well as superior mineral composition with the highest calcium (61.60 mg/100 g) and potassium (405.50 mg/100 g) contents and appreciable magnesium (119.50 mg/100 g), iron (3.34 mg/100 g), and zinc (1.90 mg/100 g). These characteristics imply that CWF4 provides the most balanced nutrient profile and, as a result, has great promise as a nutrient-dense supplemental food that can promote the best possible growth, development, and general nutritional well-being for infants.

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Conflict of Interest

Authors declare no conflicts of interest.

Ethics Statement

Not applicable.

Data Availability

The data supporting the findings of this study are available upon request.

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