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Effect of Vitamin-Mineral Fortification on the Nutritional Composition and Sensory Acceptability of a Locally Formulated Maize-Based Ready-To-Use Therapeutic Food for Children with Severe Acute Malnutrition

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ABSTRACT

Ready-to-use therapeutic food (RUTF) plays an important role in the community-based management of severe acute malnutrition (SAM). However, reliance on commercially produced and imported RUTF can limit its affordability and availability in low-resource settings. This study developed and evaluated maize-based RUTFs (MB-RUTFs) from locally available ingredients and examined the effect of vitamin-mineral fortification on their nutritional composition and sensory acceptability. Two formulations were produced: an unfortified formulation (MB-U-RUTF) and a vitamin-mineral premix-fortified formulation (MB-F-RUTF). Proximate composition, mineral and vitamin contents, amino acid profile, and sensory acceptability were determined using standard analytical procedures. Data were analyzed using an independent-samples t-test, with significance set at $P < 0.05$. Energy content ranged from 581.17 to 586.03 kcal/100g, while moisture content ranged from 2.12 to 2.24%. Protein and lipid contents ranged from 10.12 to 11.55 and 45.02 to 47.17 g/100g, respectively. Fortification significantly increased most mineral and vitamin concentrations, including potassium (35.98-1,373.68 mg/100g), calcium (3.98-344.73 mg/100g), iron (3.10-4.86 mg/100g), zinc (0.19-12.75 mg/100g), vitamin A (0.052-0.607 mg/100g), vitamin E (0.34-2.91 mg/100g), and folic acid (1.62-141.67 µg/100g) ($P < 0.05$). Most amino acids were also higher in the fortified formulation. Both formulations received high sensory acceptability scores, with no significant differences in the sensory attributes assessed ($P > 0.05$). The findings show that locally available ingredients can be used to produce acceptable maize-based RUTF. Vitamin-mineral fortification improved the micronutrient composition without compromising sensory acceptability. However, further formulation optimization is needed to meet all recommended RUTF nutrient specifications.

Keywords: Ready-to-Use Therapeutic Food, Maize-Based, Acute Malnutrition, Vitamin-mineral Fortification, Nutritional Composition

INTRODUCTION

Acute malnutrition in young children remains a major public health concern, particularly in settings where household food insecurity, infectious diseases, limited access to health services, and disruptions in food supply interact (Dipasquale et al., 2020; Clark et al., 2020; Drammeh et al., 2019). Worldwide, malnutrition contributes to nearly half (45%) of all deaths among children under five years of age (UNICEF *et al*., 2020), affecting millions of children each year. Beyond its immediate health consequences, malnutrition can impair children's growth, development, and future productivity, with broader implications for national economic development (Sa'eedu *et al*., 2025). Nigeria continues to bear a high burden of malnutrition, with approximately 8% of children under five years classified as wasted, 27% underweight, and 40% stunted (FMHSW *et al*., 2024; UNICEF, 2026). The Northwest and Northeast regions have particularly high proportions of children affected by severe acute malnutrition (SAM), underscoring the need for concerted efforts to reduce the morbidity, mortality, and long-term consequences associated with acute malnutrition.

Addressing this menace of malnutrition in all its forms remains a major national and global health priority, reflected in the national policies, the Sustainable Development Goals (SDGs) and other international policies and commitments. Effective management of acute malnutrition requires an integrated approach that combines treatment of affected children with interventions targeting the immediate and underlying causes of undernutrition. These include behaviour change communication (BCC), promotion of appropriate Maternal, Infant and Young Child Nutrition (MIYCN) practices, improved care practices and health-service utilization, and measures to strengthen household food security and livelihoods. The management of acute malnutrition encompasses inpatient therapeutic care,

outpatient treatment, supplementary feeding, and community-based interventions (WVI, 2018; WHO, 2013).

Ready-to-use therapeutic food (RUTF) is a key component of outpatient treatment for children with uncomplicated SAM. RUTF is an energy-dense, ready-to-consume food designed to provide essential nutrients required for nutritional rehabilitation without the need for cooking or refrigeration. The Codex Guidelines for Ready-to-Use Therapeutic Foods describe RUTF for children aged 6–59 months with SAM as a product that should be safe, palatable, energy-dense, and nutritionally adequate (FAO and WHO, 2022). Its characteristics make it particularly suitable for community-based treatment programmes, especially in settings where access to cooking facilities, electricity, or safe food preparation may be limited.

The continued reliance on commercially produced and imported RUTF presents challenges related to procurement costs, foreign exchange requirements, supply-chain disruptions, and the adaptability of products to local food systems. Evidence from Bangladesh demonstrated that RUTF can be developed using locally available ingredients and accepted by children with SAM, while research in Malawi has investigated milk-free RUTF formulations based on locally available ingredients such as soya, maize, and sorghum for use within community-based management programmes (Choudhury *et al*., 2018; Banda *et al*., 2021). These studies demonstrate the potential for locally formulated RUTF; however, locally developed products require rigorous evaluation to establish their nutritional adequacy, safety, and sensory acceptability before wider application.

Vitamin-mineral fortification is particularly important in the development of locally formulated RUTF because cereals, legumes, seeds, and other locally sourced ingredients may not independently provide sufficient amounts of all essential micronutrients required during the treatment of acute malnutrition. Fortification with an appropriate vitamin-mineral premix may therefore improve the micronutrient adequacy of locally formulated therapeutic foods while maintaining their desired nutritional and sensory characteristics.

Thus, the present study was aimed to compare two maize-based RUTF formulations developed from locally available ingredients: MB-U-RUTF, formulated without a vitamin-mineral premix, and MB-F-RUTF, formulated with a vitamin-mineral premix. The study assessed whether vitamin-mineral fortification influenced the nutritional composition and sensory acceptability of the formulations. It was hypothesized that the vitamin-mineral fortification of locally formulated maize-based RUTF would significantly improve the concentrations of selected vitamins and minerals than the unfortified formulation, while maintaining its acceptable sensory characteristics.

MATERIALS AND METHODS

Study Design, Collection and Authentication of Plant Materials

An experimental laboratory-based design was used to formulate Maize-Based Ready-to-Use-Therapeutic Food (RUTF) for Acute Malnutrition in children (6-59months). The maize (*Zea mays* L.), groundnut (*Arachis hypogaea* L.), soybean (*Glycine max* (L.) Merr.), sesame (*Sesamum indicum* L.), moringa leaf (*Moringa oleifera* Lam.), tilapia fish (*Oreochromis niloticus*), vegetable oil, and granulated sugar were purchased from Rimi Market, Kano State, Nigeria, while the commercial RUTF micronutrient premix (Batch No. 3574) was procured from BNSL Limited, KM 26, Lagos–Ibadan Expressway, Ibafo, Ogun State, Nigeria. All food ingredients were carefully selected based on freshness, wholesomeness, and suitability for the study. The plant materials were authenticated at the Herbarium Unit, Department of Plant Biology, Bayero University, Kano, and voucher numbers were assigned to the authenticated specimens as follows: maize (BUKHAN 0277), groundnut (BUKHAN 0405), soybeans (BUKHAN 0088), sesame (BUKHAN 0288) and moringa leaves (BUKHAN 0011).

Processing of Ingredients for the Formulation of RUTFs

All ingredients used in the formulation of the ready-to-use therapeutic foods (RUTFs) were processed separately before blending. The processing methods were selected to improve the quality, palatability, and nutritional characteristics of the final products. The preparation procedures for each ingredient are described below.

Maize flour was prepared following the method described by Life *et al*. (2020), with modifications. The grains were cleaned, washed, steeped in potable water at a 1:3 (w/v) ratio for 24 h, drained, and roasted until brown before milling and sieving through a 200 µm mesh. Soybean flour was prepared according to Ijarotimi and Keshinro (2012). The grains were cleaned, steeped in water at a 1:3 (w/v) ratio for 24 h, drained, roasted, milled, and sieved through a 200 µm mesh. Sesame and groundnut pastes were prepared following the methods of Oner and Tan (2026) and de Freitas Floriano *et al*. (2020), respectively. The seeds were cleaned, washed, roasted, and milled into smooth pastes. Moringa leaf powder was prepared according to Gopalakrishnan *et al*. (2016) and Saini *et al*. (2016) with slight modification. The leaves were sorted, washed, oven-dried, milled, and sieved through a 200 µm mesh. Tilapia fish powder was prepared following Kabir *et al*. (2022). The dried fish was cleaned, sorted, washed with hot potable water, dried at 105°C for 2 h, milled, and sieved through a 200 µm mesh. All processed ingredients were packaged in labelled, airtight containers and stored at room temperature until formulation.

Formulation of RUTF Using Concept4-S Software

Two maize-based ready-to-use therapeutic food (MB-RUTF) formulations were developed using the Concept4-S Formulation System (Version 8.01.01; Creative Formulation Concepts, LLC, Annapolis, Maryland, USA). The software uses linear programming to optimize ingredient proportions based on predefined nutritional targets (Agriculture XPRT CFC, 2022). The proximate composition, energy, vitamin and mineral contents, moisture, crude fibre, and other relevant nutritional data of the individual ingredients were entered into the software, while UNICEF and Codex RUTF specifications were used as formulation targets.

Two formulations were selected based on their ability to meet the specified nutritional requirements. MB-U-RUTF was formulated without vitamin-mineral premix, whereas MB-F-RUTF was fortified with a commercial vitamin-mineral premix (Table 1).

Mixing and Preparation of RUTFs

The RUTF was prepared following the methods described by Jibril (2017) and Sosanya *et al*. (2018), with slight modifications. The processed ingredients were mixed using a precision electric mixer (Russell Hobbs, Model 18553, 220–240 V, 800 W). Dry ingredients were first blended thoroughly, followed by gradual incorporation of vegetable oil and subsequent addition of the powdered and paste ingredients. The mixture was homogenized for approximately 5 min until a smooth and uniform paste was obtained.

Table 1: Formulation of Unfortified and Vitamin–Mineral Fortified Maize-Based Ready-to-Use Therapeutic Foods (MB-RUTFs)

S/N	Ingredient	MB-U-RUTF (Unfortified) (g/100g)	MB-F-RUTF (Fortified)
1	Maize flour	15.0	15.0
2	Groundnut paste	10.0	11.0
3	Soybean flour	10.0	11.5
4	Sesame seed paste	1.0	1.0
5	Moringa leaf powder	4.0	-
6	Tilapia fish powder	1.0	-
7	Granulated Sugar	24.0	25.0
8	Vegetable oil	35.0	35.0
9	Vitamin-mineral premix	-	1.5
Total		100.0	100.0

MB-U-RUTF, formulated without a vitamin-mineral premix, and MB-F-RUTF, formulated with a vitamin-mineral premix

Nutrients Analysis and Energy Determination of the Formulated RUTFs

The nutritional composition of the formulated RUTF was determined using standard analytical methods. Moisture, crude fat, total ash, crude fibre, and crude protein were analyzed using gravimetric, Soxhlet extraction, enzymatic-gravimetric, and Kjeldahl methods, respectively (AOAC, 2019). Total carbohydrate was calculated by difference, while energy content was estimated using Atwater conversion factors (FAO, 2003). Vitamins were determined according to AOAC (2000), as modified by Heudi *et al*. (2005) for water-soluble vitamins and Kienen *et al*. (2008) for fat-soluble vitamins. Mineral concentrations were determined by atomic absorption spectrometry (AAS) using a Hitachi Z-8200 spectrometer equipped with a graphite furnace, following AOAC (2010) procedures. The amino acid profile was determined by high-performance liquid chromatography (HPLC) following acid hydrolysis of the samples, with individual amino acids quantified using appropriate standards (Ibarra-Herrera *et al*., 2020).

Sensory Acceptability of Formulated RUTFs

Sensory acceptability of the RUTF formulations was evaluated following the method described by Sosanya *et al*. (2018), with slight modifications, using a 9-point hedonic scale with 9 as like extremely to 1 as dislike extremely, with 5 as neither like nor dislike. Approximately 2 g of each sample (MB-U-RUTF and MB-F-RUTF) was served in identical disposable plates labelled with randomly assigned three-digit codes. The coded samples were presented to the panelists along with the sensory evaluation questionnaire. Caregivers were used in the sensory evaluation because of their familiarity with children's feeding preferences and behaviours. The panelists evaluated the samples for taste, texture, flavour, appearance, mouthfeel, colour, aroma, aftertaste, and overall acceptability. Drinking water was provided for mouth rinsing between samples to minimize carry-over effects. Written informed consent was obtained from all panelists before participation. The study objectives and procedures were explained to the participants in simple and understandable language, and participation was voluntary.

Statistical Analysis

Data was analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Data were summarized as mean ± standard deviation (SD). Differences in the nutrient composition, energy values, and sensory attributes between MB-U-RUTF and MB-F-RUTF were compared using an independent-samples t-test. Statistical significance was set at $P < 0.05$.

RESULTS AND DISCUSSION

Results

Table 2 presents the proximate composition of the maize-based ready-to-use therapeutic foods (MB-U-RUTF and MB-F-RUTF). Energy content was significantly higher in MB-U-RUTF (586.03 ± 1.89 kcal/100g) than in MB-F-RUTF (581.17 ± 0.31 kcal/100g) ($P = 0.012$). Protein and carbohydrate contents were significantly higher in MB-F-RUTF, increasing from 10.12 ± 0.20% to 11.55 ± 0.15% ($P = 0.001$) and from 37.36 ± 0.25% to 37.83 ± 0.30% ($P < 0.001$), respectively. Conversely, lipid and crude fibre contents were significantly higher in MB-U-RUTF, decreasing from 47.17 ± 0.35% to 45.02 ± 0.23% ($P = 0.001$) and from 2.85 ± 0.15% to 1.25 ± 0.10% ($P < 0.001$), respectively, following fortification. Ash content increased from 0.26 ± 0.02% in MB-U-RUTF to 2.23 ± 0.20% in MB-F-RUTF, the difference was statistically significant ($P < 0.001$). However, moisture content showed no significant difference between MB-U-RUTF (2.12 ± 0.08%) and MB-F-RUTF (2.24 ± 0.06%) ($P = 0.103$).

Table 2: Proximate Composition and Energy Content of MB-RUTFs

Parameter	MB-U-RUTF	MB-F-RUTF
Energy (kcal/100g)	586.03 ± 1.89^{a}	581.17 ± 0.31^{b}
Protein (%)	10.12 ± 0.20^{b}	11.55 ± 0.15^{a}
Lipid (%)	47.17 ± 0.35^{a}	45.02 ± 0.23^{b}
Moisture (%)	2.24 ± 0.06^{a}	2.12 ± 0.08^{a}
Total Ash (%)	0.26 ± 0.02^{b}	2.23 ± 0.20^{a}
Crude Fibre (%)	2.85 ± 0.15^{a}	1.25 ± 0.10^{b}
Carbohydrate (%)	37.36 ± 0.25^{b}	37.83 ± 0.30^{a}

Values are mean ± SD (n = 3). Means within the same row bearing different superscript letters ($^{a, b}$) differ significantly ($p < 0.05$).

Table 3 presents the mineral composition of MB-U-RUTF and MB-F-RUTF. Significant differences ($P < 0.05$) were observed between the formulations for all minerals analyzed. Among the macro minerals, MB-F-RUTF had higher concentrations of sodium (224.87 ± 0.40 mg/100g), potassium (1373.68 ± 0.18 mg/100g), calcium (344.73 ± 0.006 mg/100g), and magnesium (35.64 ± 0.000 mg/100g) than MB-U-RUTF (206.21 ± 0.02, 35.98 ± 0.70, 3.98 ± 0.003, and 0.36 ± 0.000 mg/100g, respectively). In contrast, phosphorus and chloride concentrations were higher in MB-U-RUTF (263.94 ± 0.80 and 156.18 ± 2.48 mg/100g, respectively) than in MB-F-RUTF (219.97 ± 0.32 and 149.57 ± 1.43 mg/100g, respectively).

Among the trace minerals, Table 3 shows that MB-F-RUTF contained higher concentrations of iron (4.86 ± 0.000 mg/100g), zinc (12.75 ± 0.08 mg/100g), copper (1.003 ± 0.001 mg/100g), and iodine (60.53 ± 0.00 µg/100g) compared with MB-U-RUTF (0.31 ± 0.001, 0.19 ± 0.000, 0.056 ± 0.002 mg/100g, and 53.46 ± 0.06 µg/100g, respectively). Conversely, manganese concentration was higher in MB-U-RUTF (0.151 ± 0.001 mg/100g) than in MB-F-RUTF (0.114 ± 0.000 mg/100g).

Table 3: Mineral Composition of MB-RUTFs

Mineral	Unit	MB-U-RUTF	MB-F-RUTF
Sodium	mg/100g	206.21 ± 0.020^{b}	224.87 ± 0.40
Potassium	mg/100g	35.98 ± 0.700^{b}	1373.68 ± 0.180
Calcium	mg/100g	3.98 ± 0.003^{b}	344.73 ± 0.006
Phosphorus	mg/100g	263.94 ± 0.800^{b}	219.97 ± 0.320
Magnesium	mg/100g	0.36 ± 0.000^{b}	35.64 ± 0.000
Iron	mg/100g	0.31 ± 0.001^{b}	4.86 ± 0.000
Zinc	mg/100g	0.19 ± 0.000^{b}	12.75 ± 0.08
Copper	mg/100g	0.056 ± 0.002	1.003 ± 0.001
Iodine	µg/100g	53.46 ± 0.06	60.53 ± 0.00
Manganese	mg/100g	0.151 ± 0.001	0.114 ± 0.000
Chloride	mg/100g	156.18 ± 2.48	149.57 ± 1.43

Values are mean ± SD (n = 3). Means within the same row bearing different superscript letters ($^{a, b}$) differ significantly ($p < 0.05$).

Table 4 presents the vitamin composition of the locally formulated maize-based ready-to-use therapeutic foods (MB-RUTFs). Vitamin A content increased significantly from 0.052 ± 0.003 mg/100g in MB-U-RUTF to 0.607 ± 0.015 mg/100g in MB-F-RUTF ($P < 0.001$). Similarly, vitamin D increased from 0.00009 ± 0.00000 µg/100g to 10.02 ± 0.27 µg/100g, while vitamin E increased from 0.34 ± 0.02 mg/100g to 2.91 ± 0.14 mg/100g and vitamin K from 0.81 ± 0.08 µg/100g to 8.44 ± 0.21 µg/100g ($P < 0.001$ for all).

Also, findings presented in Table 4 shows that, thiamine (vitamin B1) increased from 0.018 ± 0.001 mg/100g in MB-U-RUTF to 3.25 ± 0.35 mg/100g in MB-F-RUTF, while riboflavin (vitamin B2) increased from 0.297 ± 0.006 mg/100g to 1.54 ± 0.01 mg/100g. Vitamin B6 increased from 0.020 ± 0.000 mg/100g to 0.27 ± 0.01 mg/100g, and niacin (vitamin B3) increased from 0.20 ± 0.01 mg/100g to 3.33 ± 0.01 mg/100g ($P < 0.001$ for all). Vitamin C content also increased significantly from 10.64 ± 0.07 mg/100g to 38.87 ± 2.77 mg/100g ($P < 0.001$). Folic acid showed a marked increase from 1.62 ± 0.04 µg/100g in MB-U-RUTF to 141.67 ± 6.51 µg/100g in MB-F-RUTF ($P < 0.001$).

Table 4: Vitamin Composition of MB-RUTFs

Vitamin	Unit	MB-U-RUTF	MB-F-RUTF
Vitamin A	mg/100g	0.052 ± 0.003^{b}	0.607 ± 0.015^{a}
Vitamin B_1	mg/100g	0.018 ± 0.001^{b}	3.25 ± 0.35^{a}
Vitamin B_2	mg/100g	0.297 ± 0.006^{b}	1.54 ± 0.01^{a}
Vitamin B_3	mg/100g	0.20 ± 0.01^{b}	3.33 ± 0.01^{a}
Vitamin B_6	mg/100g	0.020 ± 0.000^{b}	0.27 ± 0.01^{a}
Folic Acid	µg/100g	1.62 ± 0.04^{b}	141.67 ± 6.51^{a}
Vitamin C	mg/100g	10.64 ± 0.07^{b}	38.87 ± 2.77^{a}
Vitamin D	µg/100g	0.00009 ± 0.000^{b}	10.02 ± 0.27^{a}
Vitamin E	mg/100g	0.34 ± 0.02^{b}	2.91 ± 0.14^{a}
Vitamin K	µg/100g	0.81 ± 0.08^{b}	8.44 ± 0.21^{a}

Values are mean ± SD (n = 3). Means within the same row bearing different superscript letters ($^{a, b}$) differ significantly ($p < 0.05$).

Table 5 presents the amino acid composition of the locally formulated maize-based ready-to-use therapeutic foods (MB-RUTFs). Glutamic acid, serine, and glycine contents increased significantly from 31.17 ± 0.03, 3.64 ± 0.05, and 14.37 ± 0.01 mg/100g, respectively, in MB-U-RUTF to 91.75 ± 0.10, 18.31 ± 0.02, and 49.47 ± 0.04 mg/100g, respectively, in MB-F-RUTF ($P < 0.001$).

Similarly, alanine, arginine, tyrosine, valine, methionine, and phenylalanine contents increased significantly from 3.67 ± 0.01, 63.38 ± 0.02, 8.88 ± 0.01, 14.19 ± 0.02, 3.15 ± 0.03, and 66.63 ± 0.03 mg/100g, respectively, in MB-U-RUTF to 22.61

± 0.02, 179.20 ± 0.02, 21.54 ± 0.01, 49.20 ± 0.10, 33.30 ± 0.02, and 83.41 ± 0.02 mg/100g, respectively, in MB-F-RUTF ($P < 0.001$).

Leucine and proline contents also increased significantly, from 19.81 ± 0.02 to 65.10 ± 0.01 mg/100g and from 8.92 ± 0.01 to 58.96 ± 0.02 mg/100g, respectively ($P < 0.001$). Conversely, isoleucine and lysine contents decreased significantly from 14.38 ± 0.01 to 0.79 ± 0.02 mg/100g and from 290.27 ± 0.04 to 73.31 ± 0.02 mg/100g, respectively ($P < 0.001$).

Table 5: Amino Acid Profile of MB-RUTFs

Amino Acid	Unit	MB-U-RUTF	MB-F-RUTF
Glutamic acid	mg/100g	31.16 ± 0.03^{b}	91.75 ± 0.10^{a}
Serine	mg/100g	3.64 ± 0.05^{b}	18.31 ± 0.02^{a}
Glycine	mg/100g	14.37 ± 0.01^{b}	49.47 ± 0.04^{a}
Alanine	mg/100g	3.67 ± 0.01^{b}	22.61 ± 0.02^{a}
Arginine	mg/100g	63.38 ± 0.02^{b}	179.20 ± 0.02^{a}
Tyrosine	mg/100g	8.88 ± 0.01^{b}	21.54 ± 0.01^{a}
Valine	mg/100g	14.19 ± 0.02^{b}	49.20 ± 0.10^{a}
Methionine	mg/100g	3.15 ± 0.03^{b}	33.30 ± 0.02^{a}
Phenylalanine	mg/100g	66.63 ± 0.03^{b}	83.41 ± 0.02^{a}
Isoleucine	mg/100g	14.38 ± 0.00^{a}	0.79 ± 0.02^{b}
Leucine	mg/100g	19.81 ± 0.02^{b}	65.10 ± 0.01^{a}
Lysine	mg/100g	290.27 ± 0.04^{a}	73.31 ± 0.02^{b}
Proline	mg/100g	8.92 ± 0.01^{b}	58.96 ± 0.02^{a}

Values are mean ± SD (n = 3). Means within the same row bearing different superscript letters ($^{a, b}$) differ significantly ($p < 0.05$).

Figure 1 presents the sensory evaluation scores of MB-U-RUTF and MB-F-RUTF. The mean taste scores were 8.60 ± 0.97 and 8.80 ± 0.63, respectively. Similarly, the mean scores for texture, flavour, appearance, colour, aroma, aftertaste, and overall acceptability were 8.60 ± 0.97 for MB-U-RUTF and 8.80 ± 0.63 for MB-F-RUTF. No significant differences were observed between the formulations for these sensory attributes ($P > 0.05$).

For mouthfeel, MB-U-RUTF and MB-F-RUTF recorded mean scores of 7.00 ± 3.06 and 8.40 ± 1.58, respectively. Although MB-F-RUTF had a higher mean score and lower variability, the difference was not statistically significant ($P > 0.05$).

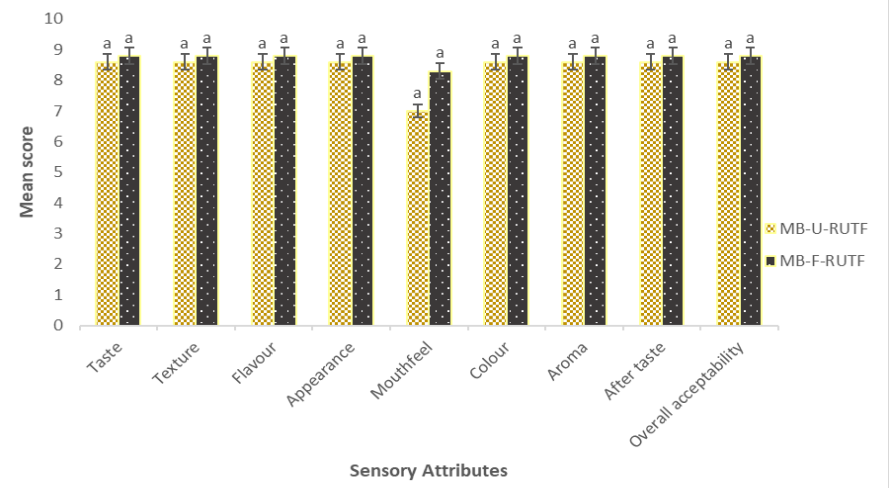


Figure 1: Sensory Evaluation of MB-RUTFs

Values are mean ± SD (n = 20). Error bars represent the standard deviation. Means for the same sensory attribute bearing the same superscript letter (^{a}) are not significantly different ($p > 0.05$).

Discussion

Ready-to-use therapeutic food (RUTF) is an important component of the management of uncomplicated severe acute malnutrition (SAM), particularly in community-based treatment settings. Its nutrient density, safety, palatability, and ease of use make it suitable for nutritional rehabilitation. Locally formulated RUTFs may reduce dependence on imported products, lower costs, improve availability and cultural acceptability, and promote the use of locally available food ingredients. This may also support local agricultural production and food systems in developing countries. However, their nutritional adequacy, safety, and acceptability require rigorous evaluation before wider application (Manary, 2006; Schoonees *et al*., 2019).

Proximate Composition and Energy Values of the Formulated RUTFs

The energy content of MB-U-RUTF and MB-F-RUTF ranged from 581.17 to 586.03 kcal/100g, exceeding the Codex recommended range of 520-550 kcal/100g (FAO and WHO,

2022). The values were also higher than those reported for NutriFEEDO® RUTF (540 kcal/100g) and several locally formulated RUTFs (Sosanya *et al*., 2018; Sa'eedu *et al*., 2025; Edafioghor *et al*., 2025; Ishaq *et al*., 2025). The relatively high energy density may be related to the inclusion of energy-dense ingredients, particularly vegetable oil, groundnut paste, and sesame paste. Such energy density is important in therapeutic feeding because it allows adequate energy to be provided in relatively small quantities.

Protein contents of 10.12 and 11.55 g/100g for MB-U-RUTF and MB-F-RUTF, respectively, were below the Codex recommended range of 13-17 g/100g (FAO and WHO, 2022) and the 14.0 g/100g reported for NutriFEEDO® RUTF (Bharaniidharan and Reshmi, 2019). However, the values were higher than those reported in some previous locally formulated RUTFs (Sandeep and Mona, 2014; Edafioghor *et al*., 2025). The relatively low protein content indicates that further adjustment of the ingredient proportions may be required to achieve the desired protein level while maintaining adequate energy density.

The lipid contents of 47.17 and 45.02 g/100g were relatively high compared with previously reported RUTF formulations (Sandeep and Mona, 2014; Ashish *et al*., 2022). The high lipid content contributes substantially to the energy density of the formulations and facilitates the absorption of fat-soluble vitamins.

Crude fibre contents of 2.85% and 1.25% were within the recommended maximum of 5% for complementary foods. The reported low fibre content may be associated with processing steps such as milling and sieving, which remove portions of the fibrous fractions. Sa'eedu *et al* (2025) reported slightly higher (4.85 and 3.93%) fiber contents, however, similar values have been reported in other locally formulated RUTFs (Amegovu *et al*., 2018; Edafioghor *et al*., 2025). Dietary fibre supports bowel function, promotes beneficial gut microbiota, and helps prevent constipation (O'Keefe, 2019), however, maintaining moderate fibre levels is desirable because excessive fibre may reduce energy and nutrient availability (Yangilar, 2013).

Moisture contents of 2.12% and 2.24% were within the Codex recommended maximum of 2.5% (FAO and WHO, 2022). The low moisture levels are favourable for product stability because reduced water availability limits microbial growth and may enhance shelf stability during storage (Sa'eedu *et al*., 2025).

Mineral Composition of the Formulated RUTFs

Significant differences were observed between the two formulations for all minerals analyzed. MB-F-RUTF had higher concentrations of sodium, potassium, calcium, magnesium, iron, zinc, copper, and iodine, whereas phosphorus was higher in MB-U-RUTF. The higher concentrations of several minerals in MB-F-RUTF are consistent with the inclusion of the vitamin-mineral premix.

Sodium concentrations in both formulations were within the recommended maximum of 290 mg/100g. Potassium and calcium were substantially higher in MB-F-RUTF, with calcium reaching the recommended range (FAO and WHO, 2022). These minerals are important for electrolyte balance, skeletal development, muscle function, and other physiological processes during nutritional rehabilitation.

In contrast, phosphorus and magnesium concentrations were below the recommended levels in the formulations. Iron concentration increased from 3.10 to 4.86 mg/100g in the fortified formulation but remained below the recommended 10-14 mg/100g. Similarly, although zinc increased to 12.75 mg/100g and met the recommended range, copper and iodine remained below their respective recommended levels. These findings indicate that, despite the improvement associated with fortification, some micronutrient requirements were not fully achieved and may require further optimization using micronutrients premix.

Vitamin Composition of the Formulated RUTFs

MB-F-RUTF contained significantly higher concentrations of all vitamins analyzed than MB-U-RUTF ($P < 0.05$), indicating a substantial improvement in vitamin content in the fortified formulation demonstrating the impacts of vitamin-mineral premix. Vitamin A increased from 0.052 to 0.607 mg/100g but remained below the reported Codex and the values reported in most imported RUTFs. Vitamins D, E, and K also increased in MB-F-RUTF but remained below their respective recommended levels. These vitamins play vital physiological roles, including maintaining vision, supporting immune function, and regulating blood coagulation.

Among the B-complex vitamins, thiamine exceeded the reported minimal codex recommended level (> 0.5 mg/100g), whereas riboflavin, niacin, and vitamin B6 remained below the corresponding recommendations despite significant increases in MB-F-RUTF. Collectively, these vitamins are essential for energy metabolism, nervous system function, haemoglobin synthesis, immune response, and maintenance of healthy skin and mucosal tissues (IOM, 1998). Folic acid and vitamin C also increased markedly following fortification but remained below the recommended levels. In general, the findings suggest that vitamin-mineral fortification substantially improved the vitamin profile of the formulation, although additional adjustment of the premix or formulation may be necessary to meet all target micronutrient levels.

Amino Acid Composition of the Formulated RUTFs

Amino acids are the building blocks of proteins and are indispensable for tissue growth, repair, immune function, enzyme and hormone synthesis, energy metabolism, collagen formation, neurotransmission, nitrogen metabolism, and overall recovery from acute malnutrition (Walker and van der Donk, 2016; Holeček, 2022; Abdul-kader, 2025). Significant differences were observed in the amino acid concentrations between MB-U-RUTF and MB-F-RUTF. Most amino acids were present at higher concentrations in MB-F-RUTF, including glutamic acid, serine, glycine, alanine, arginine, tyrosine, proline, valine, methionine, phenylalanine, and leucine. These differences may reflect differences in the proportions of protein-contributing ingredients used in the formulations, particularly soybean and groundnut.

However, lysine, and isoleucine were lower in MB-F-RUTF, may be as a result of absence of fish and moringa in the formulation. The marked reductions in lysine and isoleucine are particularly noteworthy because these are essential amino acids required for normal growth and protein synthesis (Church *et al*., 2020). Thus, although MB-F-RUTF showed an overall increase in several amino acids, the lower concentrations of some essential amino acids indicate that the formulation may require further optimization to achieve a more balanced amino acid profile.

Sensory Evaluation of the Formulated RUTFs

Sensory acceptability is essential to the success of Ready-to-Use Therapeutic Food (RUTF) programmes, as products that are not palatable are less likely to be consumed consistently by children undergoing nutritional rehabilitation. Although sensory evaluation of RUTF has been conducted using children (Nga *et al*., 2013), the present study employed healthy adult panelists who are also caregivers of the target

beneficiaries because they are better able to objectively assess sensory attributes and are familiar with children feeding behaviours.

Fortification with the vitamin-mineral premix did not adversely affect the sensory characteristics of the products. Although MB-F-RUTF consistently recorded slightly higher mean scores than MB-U-RUTF for taste, mouthfeel, and other sensory attributes, the differences were not statistically significant ($p > 0.05$).

The high acceptability of both formulations may be attributed to the processing methods, particularly roasting, which enhances flavour and aroma, as well as the use of familiar local ingredients such as maize, peanut paste, sesame paste, vegetable oil, and sugar. The absence of significant differences between the formulations indicates that fortification improved the nutritional quality of the maize-based RUTF without compromising its organoleptic properties or consumer acceptability.

CONCLUSION

According to the findings of this experimental study, acceptable maize-based RUTFs with improved nutritional composition can be formulated using locally available food ingredients. Both formulations demonstrated high energy density, low moisture content, and high sensory acceptability, indicating their potential suitability for therapeutic feeding. Vitamin–mineral fortification substantially improved the micronutrient composition of MB-F-RUTF, resulting in higher concentrations of most vitamins and minerals compared with the unfortified MB-U-RUTF. These findings suggest that the locally formulated RUTFs have potential for supporting the nutritional rehabilitation of children under five years of age. However, although several nutrients met or approached international RUTF specifications, some micronutrients remained below the recommended levels, highlighting the need for further formulation optimization to achieve the desired nutrient and energy specifications.

AUTHORS' DECLARATION

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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