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Original Research Article

Evaluation of Locally Produced Ready to Use Therapeutic Food (RUTF) for Prevention of Childhood Malnutrition

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ABSTRACT

Ready to use therapeutic food (RUTF) is a macronutrient paste that is vital to treating severe acute malnutrition in children in Nigeria and other developing countries. The study aims to evaluate locally produced RUTF for the prevention of childhood malnutrition in Nigeria. In this study, maize, soybeans, groundnut and dates were processed, then their proximate and mineral composition was determined. Two RUTFs were produced by two different formulas, F1 and F2. The F1 comprised of soya beans, groundnut and dates, while F2 was composed of maize, soya beans, groundnut, and sugar. The sensory properties of the formulated RUTF were tested by a panel of 20 persons. The analysis of the formulated RUTFs showed the percentages of carbohydrate, crude protein and crude lipid of F1 as 44.18, 10.70, 30.30, while that of F2 as 47.46, 14.50 and 21.78 respectively. The standard RUTF showed the percentage of carbohydrate, crude protein and crude lipid as 52.93, 10.73, and 19.90 respectively. The metabolizable energy content in F1 (464.70 kcal) was significantly higher than F2 (404.95 kcal) and standard RUTF (433.70 kcal). The calcium content of F1 (2.58g) and F2 (2.83g) was significantly higher than the standard RUTF (0.63g). There was no significant difference in the taste, texture and overall acceptability between the standard RUTF and F2, however, their overall acceptability was significantly better than F1. In conclusion, RUTF was produced using locally available food materials and the F2 formula was more preferred than the F1 in terms of overall acceptability.

Keywords: Malnutrition, Ready to use therapeutic food, proximate analysis, mineral composition, sensory evaluation

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Introduction

Malnutrition refers to the body's deficiency of minerals, vitamins and other essential macronutrients needed for healthy living.[1] Some forms of malnutrition include overweight, obesity, wasting, stunting, underweight, and inadequate vitamins or minerals. Malnutrition could either be protein-energy malnutrition or micronutrient deficiencies. Protein-energy malnutrition is the deficiency of protein (kwashiorkor) and/or a lack of protein and calories (marasmus) intake. Common micronutrient deficiencies include a lack of vitamin A, vitamin B9, iron, iodine, etc.[2] In 2018, 10.8% of the total population of the world representing 821 million individuals were undernourished.[3] Protein-energy malnutrition (PEM) was estimated to have led to 187,345 deaths in 2021.[4] In 2019, the global prevalence of protein–energy malnutrition increased to 14,767,275 cases.[5]

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Most children that are affected by PEM also have other co-morbid conditions like diarrhea, anemia, malaria, sepsis, bronchopneumonia, tuberculosis, keratomalacia and rickets.[2] In underdeveloped economies, the accessibility and utilization of proteinaceous foodstuff are insufficient because of an explosion in population and urbanization. This can lead to protein energy malnutrition (PEM), which can be eased by looking for cheaper sources of protein.[6] Ready-to-use therapeutic foods (RUTF) are high caloric, ready-to-eat foods fortified with vitamins and minerals suitable for the treatment and management of severe acute malnutrition (SAM) in children and other vulnerable groups. RUTF is usually crushable or soft, and easy to consume without any preparation for children. RUTF is capable of meeting the energy and nutritional requirements of children (0 to 5 years old) for growth and development, and also for speedy recovery from SAM. The nutrients lack as a result of SAM has negative influence on all body functions leading to pathological conditions, such as edema, wasting and even death.[7] RUTF is an essential lifesaving supply item that treats severe wasting in under 5 years children.[8] UNICEF views RUTF as a medical commodity that is usually part of the community-based management of acute malnutrition in children in line with international best practices. Despite the importance of RUTF, it is not readily available and it is expensive thus its supply is unsustainable for government intervention in developing countries. Therefore, the aim of the study is the evaluation of the proximate composition, mineral content, and sensory properties of locally produced RUTF for the prevention of childhood malnutrition in Nigeria.

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Materials and Methods

Collection and Identification of Plant Material

Maize, soya beans, groundnut and date were all purchased from Masaka local market, Masaka, Karu, Nasarawa State. All the plants were collected on the 5th of January 2024. The maize (*Zea mays*), soya beans (*Glycine max*), groundnut (*Arachis hypogaea*) and date (*Phoenix dactylifera*) were taken to National Institute for Pharmaceutical Research and Development (NIPRD), Abuja for plant identification, and voucher numbers were allocated as NIPRD/H/7410, NIPRD/H/7412, NIPRD/H/7413 and NIPRD/H/7414 respectively.

Preparation of food items

Exactly, 1 kg each of maize, soybeans and groundnut was winnowed using a tray, and foreign materials and stones were removed, steeped in water overnight for 12 hours, oven-dried on low heat for 20 mins at temperature of 100 °C, roasted on medium heat for 30 mins with the temperature of 150 °C using an electric oven, and milled into powder using an electric blender individually. While 1 kg of dates was placed in a tray and sorted out (foreign materials and stones removed). It was deseeded, broken into pieces using a mortar and pestle, dried using an electric oven and then milled into powder.

Composition of Locally Formulated RUTF

Two RUTFs, F1 and F2 were formulated. F1 comprises 47.8g of soya beans, 6.7g of dates, 51.2g of groundnut and 3g of vegetable oil (*Power oil* which is from palm olein). While F2 is composed of 47.8g of soya beans, 12.7g of yellow maize, 38.5g of groundnut, 3g of vegetable oil and 3g of table sugar (Dangote Refined Granulated White Sugar). All the roasted and ground ingredients were weighed and mixed using an electric mixer.

Determination of moisture and ash content

Drying samples in the oven at 105 ± 2ºC for 18 hours was the method used to determine moisture content.[9] Results are calculated and reported in percentage (gram per 100g of sample). Decomposition of organic matter from a sample by incineration in the muffle furnace to 600ºC held for 2hrs and weighing of the ash obtained.[9] Results are calculated and reported as percentages (g/100g of sample).

Determination of crude fat

The ether extract method based on the principle that nonpolar components of the sample are easily extracted into petroleum ether was used to determine the crude lipid according to AOAC.[9] This direct extraction gives the proportion of "free" lipid constituents in the dried sample and the results are expressed in percentages.

Determination of crude fibre

The crude fibre was determined by the method where samples were digested in dilute acids in specific concentrations for the exact length of time to dissolve that part of food which will probably be digested by an animal's digestive system.[9] Then the residue is washed and dried containing the crude fibre and the materials which make up the ash. Results are calculated and expressed in percentage (gram/100g of sample).

Determination of crude protein

The crude protein was determined by the Kjedahl method where the sample is digested in H_2SO_4 using catalyst, which converts Nitrogen to Ammonia which is distilled and titrated.[9] The percentage of crude protein is ascertained by percentage of Nitrogen multiplied by a factor of 6.25. Results are calculated and expressed in a percentage (gram/100g of sample).

Determination of phosphorus and calcium content

The determination of phosphorus content in the samples was done by colorimetric method.[9] Acid solutions containing orthophosphates when treated with molybdic acid forms a stable orange-yellow coloured complex of Vana dimolybdiphosphoric acid (H_3Po_4, $VO_311M_0O_{33n}H_2O$). The colour intensity is proportional to the concentration of phosphate in the sample. Results are calculated and expressed (reported) in percentage (gram/100g of sample). The calcium in the sample was determined by the dry ash titrimetric method,[9] where calcium is converted to calcium oxalate by the addition of ammonium oxalate which is easily precipitated out and titrated against standard potassium permanganate solution. Results are calculated and expressed in percentage (gram/100g of sample).

Sensory Evaluation

The sensory evaluation of the formulated RUTF by a panelist of 20 people made up of males and females in the ratio of 1:1 with an average age bracket of 20-50 years in the study was done to evaluate notable differences in sensory attributes such as appearance, aroma, taste, texture, and overall acceptability.[10] A 5-point hedonic scale (Scale: 5-like extremely; 4-like slightly; 3-neither like nor dislike; 2-dislike slightly; 1-dislike extremely) was used to rate the sensory attributes.

Statistical Analysis

Data analysis was done using SPSS version 21.0 (SPSS Inc., Chicago, IL) and expressed as mean ± standard deviation. The significant differences between the mean values were compared using One-way ANOVA, and the Duncan Multiple Range test at the significance level of 5% ($P < 0.05$).

Results and Discussion

Proximate composition of plants

The proximate analysis in percentages for carbohydrate, crude fiber, crude lipid and crude protein of roasted soya beans are 41.78, 5.70, 16.40 and 26.92 respectively, while that of roasted yellow maize is 78.66, 0.80, 4.10 and 8.84 respectively (Table 1). The proximate analysis in percentages of carbohydrate, crude fiber, crude lipid and crude protein of roasted groundnut is 25.97, 11.96, 29.30 and 29.30 respectively, while that of dried dates is 74.74, 9.10, 0.33 and 4.53 respectively. The mineral composition of these food items is displayed in Table 2.

Table 1: Proximate analysis of plant materials

Parameters	Roasted soya beans	Roasted yellow maize	Roasted groundnut	Dried dates
MC (%)	1.95 ± 0.30	6.44 ± 0.78	1.90 ± 0.30	10.11 ± 0.49
CP (%)	26.92 ± 2.00	8.84 ± 0.80	29.30 ± 2.00	4.53 ± 0.90
CF (%)	5.70 ± 0.88	0.80 ± 0.15	11.96 ± 1.50	9.10 ± 1.00
CL (%)	16.40 ± 1.60	4.10 ± 1.00	29.30 ± 1.50	0.33 ± 0.10
AC (%)	7.15 ± 0.75	1.15 ± 0.20	1.57 ± 0.23	0.95 ± 0.20
N.F.E (%)	41.78 ± 3.00	78.66 ± 4.00	25.97 ± 1.80	74.74 ± 5.00
M.E (kcal)	422.40 ± 4.00	386.90 ± 7.00	414.42 ± 6.00	320.05 ± 5.00

Data presented as mean ± standard deviation (n = 3). M.E = Metabolisable Energy, N.F.E = Nitrogen Free Extract, A= Ash Content, CL= Crude Lipid, CF= Crude Fiber, CP= Crude Protein, MC= Moisture Content.

The roasted soya bean flour had a low moisture content which might be due to the processing method, the low moisture content of 1.95% implies that it can be stored for a very long time since the less the moisture the less the microbial growth. The crude lipid of 16.40% for roasted soya bean powder is similar to the value reported by Eshun.[11]

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Table 2: Mineral composition of plant materials

Food items	Calcium (%)	Phosphorus (%)
Roasted soya beans	0.60 ± 0.07	0.20 ± 0.03
Roasted yellow maize	0.43 ± 0.03	0.60 ± 0.03
Roasted groundnut	0.50 ± 0.05	0.70 ± 0.01
Dried dates	0.35 ± 0.04	0.62 ± 0.05

Data presented as mean ± standard deviation (n = 3).

The high carbohydrate content in soya beans suggests its importance in managing protein energy malnutrition as there is a sufficient quantity of carbohydrates to derive energy from thereby sparing protein for its primary function of building the body and repairing worn-out tissues.

The moisture content (6.44%), fibre content (0.80%), and carbohydrate (78.66%) of roasted yellow maize were similar to those of Alex.[12] The results also show crude protein in roasted groundnuts is 29.30% which is slightly lower than the result of Regina et al,[13] which recorded 31.45-33.17% for roasted groundnuts. The fibre content of 11.96% in roasted groundnuts was higher than that of 3.09% in roasted peanuts reported by Kumar et al,[14] in a different study. Shokunbi et al.[15] reported higher crude lipid content (33.6-54.95%) in roasted groundnuts than 29.30% found in this study. Carbohydrate content in this study is 25.97% indicating that peanuts are also a good source of carbohydrates and can complement high-calorie diets.[16]

The moisture content of the dates was similar to that reported by Ogungbenle,[17] but the ash content was lower in value. The crude fibre content was 9.10% which was similar to Gamel et al,[18] also for dates in another study. Fibre content of food helps in the digestion process and prevention of cancer.[19] The crude protein content of date was 4.53% which was higher than the 2.1% reported by Cust et al.[20] It a well known fact that proteins serves as enzymatic catalyst, mediates cell responses, and control growth and development.[21]

Crude fat content of 9.10% was recorded from the analysis. The relevance of lipids in diets cannot be over emphasized as it contributes significantly to the energy value of food. The result shows that the date palm is a good source of carbohydrate (simple sugar) as it has 77.74% carbohydrates in form of N.F.E, which may give rise to a source of energy. The value is slightly lower than the 80.67% obtained by Ogungbenle,[17] and 320.05kj/100g metabolic Energy value was also recorded.

Proximate Composition of Formulated RUTF

In Table 3, the moisture content of F1 (8.85%) and F2 (8.50%) was significantly increased ($p<0.05$) compared to standard RUTF (2.65%). Low moisture levels in RUTFs are crucial for shelf stability. The low moisture content in standard RUTF compared to the formulated F1 and F2 suggests longer shelf life, as high moisture promotes microbial growth. Manary et al.[22] have also emphasized low moisture content (<10%) for effective storage stability. Moisture content below 10% is desirable to ensure shelf stability and prevent microbial contamination during storage, and this criterion was met by both the standard RUTF and formulated RUTFs (F1 and F2). Diop et al.[23] reported RUTF moisture content of 2–3% in peanut-based RUTF, reinforcing standard RUTF superior shelf stability compared to formulated RUTFs (F1 and F2).

The ash content of F1 was significantly decreased ($P<0.05$) when compared to the standard RUTF but F2 was not statistically different ($P>0.05$) when compared with standard RUTF. There was no significant difference between F1 and F2. Ash content reflects the mineral composition of food items. Standard RUTF had the highest ash content, indicating richer mineral content than F1 and F2. The high mineral content in RUTF is a result of fortification with various vitamins and minerals. Studies on mineral content in RUTF, such as those by Ahmed et al.,[24] emphasize the importance of calcium, zinc, and iron for child growth and immune function.

The crude fibre content of the F1 and F2 were significantly decreased ($P<0.05$) when compared to the standard RUTF. Also, F2 had significantly elevated ($P<0.05$) crude fibre compared to F1. The crude fibre content was higher in the standard RUTF. Crude fiber represents the indigestible portion of plant materials, primarily cellulose, hemicellulose and lignin. While not a direct energy source, fiber aids in digestion and prevent gastrointestinal issues. However, excessive fiber in RUTF can reduce nutrient bioavailability and energy density. The crude fiber content of F1 and F2 is within the acceptable limit (<5%) for RUTFs.[25] WHO guidelines for therapeutic foods recommend low fiber content to ensure high energy density and digestibility.[25] Manary et al.[22] noted that RUTF should have minimal crude fiber to avoid bulkiness and improve digestibility for malnourished children. Ahmed et al.[24] reported crude fiber content <5% in peanut- and cereal-based RUTFs to ensure better nutrient absorption and energy delivery.

The crude protein content of standard RUTF (10.73 %) was not significantly different ($p>0.05$) when compared to F1 (10.70%) but F2 (14.50%) significantly increased ($p>0.05$) compared to standard RUTF. Protein is essential for addressing muscle wasting in malnourished children. The higher protein content of F2 aligns with FAO/WHO recommendations for therapeutic food formulations with protein levels of 10–15% for RUTF.[26] Similar studies, such as by Diop et al.,[23] report comparable protein levels (10–15%) in peanut-based RUTFs. Diop et al.[23] reported protein levels around 10–12% in peanut-based RUTF, similar to standard RUTF and F1. Ahmed et al.[24] highlighted protein enrichment using soy flour and milk powder to improve amino acid profiles, consistent with F2 formulation.

The NFE contents indicate carbohydrate availability excluding fiber, correlating with energy provision. The Standard RUTF has the highest, suggesting higher energy density. The carbohydrate content of F2 was not significantly different ($P<0.05$) from F1 and standard RUTF, but the carbohydrate content of the standard RUTF was significantly increased from F1. The metabolizable energy of F1 was significantly increased ($P<0.05$) when compared to the standard RUTF, while sample F2 was statistically decreased when compared to F1 and standard RUTF.

Table 3: Proximate Composition of Formulated RUTF (F1 & F2 RUTF)

Parameters	Standard RUTF	F1	F2
MC (%)	2.65 ± 0. 10[b]	8.85 ± 0.80[a]	8.60 ± 0.80[a]
CP (%)	10.73 ± 0.97[b]	10.70 ± 0.60[b]	14.50 ± 1.10[a]
CF (%)	9.60 ± 0.20[a]	3.82 ± 0.13[c]	4.84 ± 0.10[b]
CL (%)	19.90 ± 2.00[b]	30.30 ± 2.00[a]	21.75 ± 1.50[b]
AC (%)	4.20 ± 1.00[a]	2.15 ± 0.10[b]	2.85 ± 0.80[ab]
NFE (%)	52.93 ± 3.00[a]	44.18 ± 3.00[b]	47.46 ± 4.00[ab]
ME (kcal)	433.70 ± 6.00[b]	464.70 ± 6.00[a]	404.95 ± 5.00[c]
Ca (%)	0.63± 0.02[b]	2.58 ± 0.10[a]	2.83 ± 0.30[a]
P (%)	0.14 ± 0.60[a]	0.10 ± 0.20[a]	0.16 ± 0.10[a]

Data presented as mean ± standard deviation (n = 3). Means having different alphabets in the same column are significantly different at $P<0.05$. M.E = Metabolisable Energy, N.F.E = Nitrogen Free Extract, A= Ash Content, CL= Crude Lipid, CF= Crude Fiber, CP= Crude Protein, MC= Moisture Content, Ca= Calcium, P= Phosphorus

Crude lipid (fat) is a primary energy source in RUTF, contributing to high caloric density and palatability. Fat also plays a critical role in the absorption of fat-soluble vitamins (A, D, E and K). The crude lipid content of the F1 and F2 were significantly increased ($P<0.05$) when compared to the standard RUTF. Also, F1 had significantly elevated ($P<0.05$) crude lipid compared to F2. Therapeutic food formulations generally target lipid levels between 30% and 45% of total energy.[27] F1

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had the highest lipid content (30.30%), closer to WHO recommended levels, whereas standard RUTF (19.90%) and F2 (21.75%) fell short. Insufficient lipid content can lower the overall energy density, potentially affecting the efficacy of RUTF in addressing severe malnutrition. Briend et al.[28] emphasized lipid-rich formulations (30-35%) using peanut butter and vegetable oil to achieve energy levels>500kcal/100g, which is essential for treating severe acute malnutrition. Diop et al.[23] also reported crude lipid content of 30-35% in peanut-based RUTFs, aligning with F1's lipid composition.

Mineral Composition of Food Items
Calcium and phosphorus are vital for bone health in children. Combining calcium-rich samples with phosphorus-rich ones can optimize the formulation for producing RUTF. Samples with low contributions may require supplementation or fortification. The calcium content of both F1 and F2 was significantly increased (P>0.05) when compared to standard RUTF (Table 3). However, there was no significant difference in the phosphorus content between standard RUTF and formulated RUTF. The formulated RUTFs, F1 and F2, had higher calcium values, which align with the needs of malnourished children, supporting findings from studies such as Golden.[29]

Sensory Properties of Formulated RUTF
The sensory properties of the formulated RUTF assessed by 20 panelists in the study demonstrate notable differences in sensory attributes such as appearance, aroma, taste, texture, and overall acceptability. The appearance and aroma of F1 and F2 were not significantly different (P<0.05) from Standard RUTF (Table 4). The similarity in appearance scores across the samples (F1, F2, and standard RUTF) reflects the importance of visual appeal in food products. Studies have shown that consumers often associate consistent appearance with food quality and acceptability, making it a critical factor in sensory evaluation for nutritional products like RUTF. The study found no significant difference in appearance among the samples (F1, F2, and standard RUTF). Research by Bahwere et al.[30] noted that appearance is generally rated highly in RUTF, as a consistent color and visual appeal are crucial for acceptance among children and caregivers.

The significantly lower aroma scores for F1 compared to standard RUTF and F2 align with findings that aroma heavily influences food acceptability. Research highlights aromas, especially those perceived retro-nasally during mastication, enhance the sensory perception of food. A weaker aroma can negatively affect a product's overall palatability, particularly in therapeutic foods designed for children. In the results, F1 scored significantly lower in aroma compared to standard RUTF, while F2 showed no significant difference from standard RUTF. Ali et al.[31] reported similar findings, where formulations with higher roasted peanut content had better aroma scores. This emphasizes that raw ingredient processing significantly impacts aroma.

Table 4: Sensory properties of formulated RUTF

Sensory properties	Standard RUTF	F1	F2
Appearance	4.50 ± 0.70[a]	4.00 ±1.15[a]	4.20 ± 1.03[a]
Aroma	4.20 ± 0.91[a]	3.50 ± 0.97[a]	3.90 ± 1.19[a]
Taste	4.50 ± 0.70[a]	3.50 ± 1.08[b]	4.10 ± 0.87[ab]
Texture	4.50 ± 0.70[a]	3.20 ± 1.22[b]	4.00 ± 1.15[ab]
Overall Acceptability	4.70 ± 0.48[a]	3.70 ± 1.15[b]	4.50 ± 0.70[a]

Data presented as mean ± standard deviation (n = 3). Means having different alphabets in the same column are significantly different at P<0.05.*

The taste of F1 was significantly (P<0.05) less appealing compared to Standard RUTF but F2 was not significantly different (P<0.05) compared to F1 and Standard RUTF (Table 4). The lower scores for taste for F1 compared to standard RUTF and the intermediate score for F2 are consistent with the critical role taste plays in acceptability. Sweetness and savory flavors are often associated with higher consumer acceptance, especially in child-targeted products. Small changes in taste profiles, as seen in RUTF formulations, can significantly impact their acceptability and consumption rates. Taste scores in the study were significantly lower for F1 but closer to standard RUTF for F2. Taste is a critical factor influencing the acceptability of RUTF. Kamwendo et al.[32] also identified taste as a determinant of acceptability, with formulations having balanced sweetness (from sugar or milk powder) performing better. They noted that bitterness or off-flavors due to certain fortifications (e.g., iron) could reduce scores, which could explain F1's lower score

Texture differences highlight its influence on the eating experience. While standard RUTF and F2 maintained similar scores, F1's significantly lower score could stem from less appealing textural properties such as grittiness or lack of smoothness, which are common issues in RUTF formulations. Research supports the importance of achieving a uniform texture in therapeutic foods to ensure ease of consumption. The study revealed a significant difference in texture, where F1 scored lower than standard RUTF, while F2 was comparable. Studies by Manary et al.[33] found that smoother textures (without grittiness) are preferred, especially for malnourished children who may have difficulty chewing. This aligns with the findings, where F2 likely had a more refined texture compared to F1.

In the overall acceptability, F2 was not significantly different (P<0.05) compared to Standard RUTF but F1 was significantly different to Standard RUTF (Table 4). The study showed that F1 had significantly lower overall acceptability compared to standard RUTF, whereas F2 was similar to standard RUTF. This suggests that minor adjustments in formulation can make alternative RUTF formulations competitive. This agrees with the literature emphasizing that improving sensory attributes directly correlates with higher acceptability and compliance with therapeutic nutrition products. Similarly, Briend et al.[34] found that formulations with balanced sensory attributes (taste, texture, and aroma) had higher overall acceptability scores. They emphasized the importance of aligning formulations with local preferences to improve compliance. Formulations with a balanced taste, appealing aroma, and appropriate texture can significantly enhance the effectiveness of RUTF in addressing childhood malnutrition.

Conclusion

The RUTFs, F1 and F2, were produced using locally available foodstuffs and had similar compositions with the Standard RUTF in terms of carbohydrates, protein, and lipids. Also, F1 and F2 were similar to the Standard RUTF in appearance, aroma, and taste; however, the F2 formula was preferable to F1 in terms of overall acceptability.

Conflict of Interest

The authors declare no conflict of interest.

Author's Declaration

The authors hereby declare that the work presented in this article is original. Any liability for claims relating to this article will be borne by us.

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