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Insect and Pulse-Based Ready-to-Use Therapeutic Food as an Alternative to Standard Milk-and Peanut Paste-Based Formulation for Treating Childhood Malnutrition

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Abstract

Background: Severe acute malnutrition (SAM) remains a critical challenge affecting over 13 million children globally, particularly in low- and middle-income countries. Ready-to-use therapeutic foods (RUTFs) have revolutionized the treatment of SAM; however, conventional peanut-based formulations are limited by high cost, allergenic potential, and dependency on imported raw materials. This study investigated developing and evaluating two novel RUTFs formulated from locally available and nutrient-rich ingredients, African palm weevil larvae and pulses (Bambara nut and Nigerian brown beans). **Methods**: Two lipid-based RUTF formulations were prepared: Sample A (Grub–Brown Beans-Based) and Sample B (Grub–Bambara Nut-Based), following WHO guidelines for local RUTF production, while standard peanut-based RUTF (Sample C) served as control. Proximate, mineral and vitamin A content were determined using standard analytical methods. Sensory evaluation was conducted with 30 semi-trained panellists using discriminatory, descriptive, and 9-point hedonic scale tests. Data was analysed using SPSS version 27, applying one-way ANOVA and independent t-tests with significance set at $P < 0.05$. **Results**: The control (Sample C) had significantly higher protein (13.91±0.09 g), fat (33.38±0.55 g), and energy (536.22±6.06 kcal) compared to the test formulations ($P<0.05$). However, Samples A and B showed higher carbohydrate and vitamin A content. Sample B also recorded higher magnesium (231.83±5.53 mg) and appreciable ash and fibre content. There was no significant difference in taste and overall acceptability across samples. Sample B was rated highly for texture, appearance, and residual effects. **Conclusion:** Grub- and pulse-based RUTFs offer nutritionally adequate and culturally acceptable alternatives to standard peanut-based formulations. The use of affordable, locally sourced ingredients makes them suitable for scalable implementation in resource-constrained settings. This innovation supports Sustainable Development Goal 2: Zero Hunger, by contributing to locally driven, sustainable solutions for managing severe acute malnutrition.

Keywords: ready-to-use therapeutic food; African palm weevil; Bambara nut; severe acute malnutrition; SDG 2

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1. Introduction

Severe acute malnutrition (SAM) continues to be a pressing global health concern, affecting an estimated 45 million children under the age of five years, with over 13 million requiring urgent

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therapeutic nutritional interventions (WHO, 2023). Ready-to-Use Therapeutic Foods (RUTFs) have emerged as a cornerstone in the community-based management of SAM, offering high-energy, micronutrient-dense, shelf-stable formulations that do not require cooking or refrigeration (Sani et al., 2024; Sadler et al., 2022).

Despite the proven efficacy of RUTFs, the conventional peanut-based formulation is associated with limitations. These include high production and importation costs, potential allergenicity, and limited ingredient adaptability to local food systems, particularly in resource-limited settings (Fetriyuna et al., 2023; Adu-Afarwuah et al., 2021). These drawbacks have driven interest in exploring alternatives, locally sourced, and culturally appropriate ingredients that meet the nutritional and functional requirements of RUTF (Manida, 2022).

Edible insects, such as the African palm weevil larvae (*Rhynchophorus phoenicis*) and winged termites (*Macrotermes bellicosus*) and Westwood (*Cirina forda*) (Adepoju and Ayenitaju, 2021; Adepoju and Ajayi,2020; Adepoju and Daboh, 2020) offer promising, protein-rich, sustainable alternative. These insects are traditionally consumed in various African communities and are known for their high protein, fat, iron, and zinc content (Egonyu et al., 2021). Similarly, underutilised pulses like Bambara groundnut (*Vigna subterranea*) and Nigeria brown beans (*Vigna unguiculata*) are nutrient-dense legumes, rich in protein, fibre, and essential micronutrients, and widely accepted in local diets (Kayode et al., 2021).

The combination of insect-based and plant-based proteins in RUTF formulations could address the nutritional demands of malnourished children and the need for locally adaptable, cost-effective solutions. Previous studies have highlighted the functional and nutritional advantages of incorporating edible insects and legumes into food systems, yet limited evidence exists on their combined use in RUTF formulations (Joshi et al., 2025).

The current reliance on a small number of global producers for Ready-to-Use Therapeutic Foods (RUTFs), with the largest being based in France, has led to high importation costs that limit local access and compromise the effectiveness of community-based management of acute malnutrition (CMAM) (United Nations Children's Fund, 2016). Most RUTFs are peanut- and milk-based, which makes them expensive and less adaptable to local dietary contexts (Rogers et al., 2015). This study aimed to develop two alternative RUTF formulations using locally available animal and plant protein sources, African palm weevil larvae, Bambara nut, and Nigerian brown beans, and to evaluate their nutritional composition and sensory acceptability relative to a standard peanut-based RUTF. By leveraging locally available ingredients, this work seeks to inform the development of culturally acceptable, nutritionally adequate, and scalable alternatives for treating SAM in sub-Saharan Africa and similar settings.

2. Materials and Methods

Study Design and Setting

This experimental study evaluated the nutritional composition and sensory attributes of two formulated lipid-based Ready-to-Use Therapeutic Foods (RUTFs) developed from grub (African palm weevil larvae) and pulses. The study was conducted at the Dietetics Kitchen of the University College Hospital (UCH), Ibadan, where RUTF samples were formulated and prepared. Nutritional analyses were conducted at the Institute of Agricultural Research and Training (IAR&T) and the National Horticultural Research Institute (NIHORT), Ibadan.

Materials

Ingredients

- **Animal protein:** African palm weevil larvae (*Rhynchophorus phoenicis*)
- **Plant proteins/pulses:** Nigeria brown beans (*Vigna unguiculata*), Bambara nut (*Vigna subterranea*)

Other ingredients: Soymilk powder, Banga red palm oil, soya oil, crystallised white sugar, and a standard vitamin-mineral premix

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All plant-based ingredients and oils were randomly purchased from Bodija Market, Ibadan. The vitamin and mineral premix was obtained from the Dietetics Department of UCH. Palm weevil larvae were sourced from Epe and Itokin Local Government of Lagos State.

Equipment and Tools

Regulated electric oven, blender (22,700 RPM), miller, kitchen scale, aluminium strainer, muslin cloth, jute bags, $NaHCO_3$ (0.5 g/100 mL), food processor, planetary mixer, sensory evaluation questionnaires, and sterile packaging materials.

Sample Preparation

African Palm Weevil Larvae

Larvae were degutted and rinsed, steamed over boiling water, oven-dried at 25°C until crispy, cooled, and milled into powder using a regulated blender.

Nigeria Brown Beans

Beans were sorted, rinsed, boiled until soft, cooled, blended into a paste, microwave-dried at 25 °C to prevent denaturation, and re-blended into powder.

Bambara Groundnut Flour

Seeds were soaked for 12 h at 28±2 °C, germinated for 48 h, dehulled, boiled for 15 min in 0.5 g/100 mL $NaHCO_3$, oven-dried at 60 °C for 12 h, roasted at 140 °C for 40 min, and milled using a disc attrition mill to <0.3 mm particle size.

Soy Milk

Soymilk powder was spread in trays, covered with mesh cloth, and sun-dried in a controlled environment to prevent contamination for 2–3 days.

Product Formulation and Composition

The RUTF formulations were designed to meet WHO standards for local production. All ingredients were milled to a particle size <200 microns and mixed without water to prevent microbial growth. The protein and carbohydrate sources were embedded into a lipid matrix. Mixing was done using a Qaza QCB-2L Stainless steel food processor. Final products were cooled and packaged in sterile nylon bags (net weight: 100 g).

Composition by weight (%):

Ingredient	% Weight
African palm weevil larvae	15.4
Nigeria brown beans *or* Bambara nut flour	15
Soymilk powder	25
Banga red palm oil	10
Soya oil	5
Crystallised white sugar	28
Vitamin and mineral mix	1.6

Study Population for Sensory Evaluation

Thirty semi-trained panellists were selected from within the hospital community for sensory testing.

Sensory Evaluation

The perceptible differences between samples were determined using the standard RUTF as a reference. Descriptive Test, and 9-point Hedonic Scale were used to measure consumer acceptability of appearance, taste, aroma, texture, viscosity, residual effect, and aftertaste. Evaluations were conducted while the products were fresh. Panellists observed, tasted, and rated each sample based on the provided questionnaire. The hedonic scale ranged from 1 ("Dislike extremely") to 9 ("Like extremely").

Data Collection and Analysis

Nutrient composition was determined using standard proximate and mineral analysis methods. Sensory data were analysed using descriptive statistics and one-way ANOVA with Duncan or

Games-Howell post hoc tests. Comparative analysis between samples was performed using independent t-tests. Statistical significance was set at $p < 0.05$.

Ethical Consideration

Ethical approval was obtained from the UI/UCH Ethics Review Committee (Approval No. UI/EC/21/0060). Informed consent was obtained from all sensory evaluation participants.

3. Results

From Table 1, Sample C (standard peanut-based RUTF) had the highest protein, fat, and energy; while Sample A recorded the highest carbohydrate and moisture content. All parameters showed significant differences ($p < 0.001$).

Table 1. Proximate and Energy Composition of formulated and Standard Ready-To-Use. Therapeutic Foods (g/100 g)

Nutrient	Sample A	Sample B	Sample C	*p*-Value
Protein	6.51 ± 0.20c	11.10 ± 0.47b	13.91 ± 0.09a	.000
Fat	9.90 ± 0.04c	14.10 ± 0.21b	33.38 ± 0.55a	.000
Fibre	0.24 ± 0.02	0.39 ± 0.03	—	.000
Ash	1.58 ± 0.04	2.46 ± 0.06	—	.000
Moisture	13.41 ± 0.07a	7.01 ± 1.45b	1.78 ± 0.22c	.000
Dry Matter	86.59 ± 0.08c	93.49 ± 0.41b	98.22 ± 0.22a	.000
Carbohydrate	68.35 ± 0.21a	65.44 ± 0.35b	45.04 ± 3.35c	.000
Energy (kcal/)	388.61 ± 0.32c	433.04 ± 2.36b	536.22 ± 6.06a	.000

Sample A—Grub–Brown Beans-Based RUTF (N = 6). Sample B—Grub. Bambara Nut-Based RUTF (N = 6). Sample C—Standard (peanut-based) RUTF (eeZeePaste™) (N = 3). One-Way ANOVA, P<0.05; Independent t-test, P<0.05. a, b, c Levels of significant difference; Duncan (Games-Howell for Moisture content).

Table 2 shows that Sample C had significantly higher potassium, calcium, and phosphorus than the formulated samples. Magnesium and vitamin A contents of the formulated samples were significantly higher than that of Sample C, with Sample B having the highest value of each ($p < 0.05$).

Table 2. Mineral and Vitamin A Contents of formulated and Standard Ready-To-Use. Therapeutic Foods (mg/100 g)*.

Nutrient	Sample A	Sample B	Sample C	*p*-Value
Sodium	220.00 ± 3.16b	260.83 ± 4.83a	260.00 ± 27.22a	.000
Potassium	532.00 ± 5.76c	702.33 ± 11.84b	1157.67 ± 50.74a	.000
Calcium	171.83 ± 5.19b	202.50 ± 9.48b	424.00 ± 121.31a	.000
Magnesium	189.83 ± 4.79b	231.83 ± 5.53a	129.00 ± 14.11c	.000
Phosphorus	310.33 ± 5.95b	341.83 ± 6.91b	543.67 ± 52.00a	.000
Iron	8.68 ± 0.05b	10.85 ± 0.42a	11.65 ± 1.20a	.000
Zinc	3.20 ± 0.05c	5.13 ± 0.90b	12.33 ± 1.28a	.000
Vitamin A (µg/)	1968.47 ± 1.05a	2004.49 ± 12.77a	998.00 ± 106.78b	.000

Sample A—Grub–Brown Beans-Based RUTF (N = 6). Sample B—Grub. Bambara Nut-Based RUTF (N = 6). Sample C—Standard (peanut-based) RUTF (eeZeePaste™) (N = 3). One-Way ANOVA, P<0.05. a, b, c Levels of significant difference; Duncan (Games-Howell for Magnesium).

Table 3 reveals that 93.3% of participants identified differences between the standard RUTF and both test samples. Differences were primarily in taste and texture, whereas fewer participants could distinguish between Samples A and B.

Table 3. Discriminatory Test Between Standard RUTF and Two Test Samples (N = 30).

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Comparison	Different—Sure	Different—Not Sure	Guess Different	Guess Same	Same—Not Sure	Same—Sure
A vs. B	14 (46.7%)	6 (20.0%)	1 (3.0%)	1 (3.0%)	2 (6.7%)	6 (20.0%)
A vs. C	26 (86.7%)	2 (6.7%)	—	—	—	2 (6.7%)
B vs. C	28 (93.3%)	—	—	—	—	2 (6.7%)

Comment on Differences (A vs. B); Texture: 4 (36.4%); Taste: 1 (9.1%); Consistency: 3 (27.3%); Aroma: 1 (9.1%); Combination: 2 (18.2%).; Comment on Differences (A vs. C); Texture: 2 (20.0%); Taste: 7 (70.0%); Combination: 1 (10.0%); Comment on Differences (B vs. C); Texture: 2 (22.2%); Taste: 2 (22.2%); Taste & Texture: 5 (55.6%).

Table 4 shows that Sample B received more favourable ratings than Sample A in appearance, texture, residual effect, and aftertaste. Both samples were equally rated for taste and aroma, while Sample A was slightly preferred for sweetness, flavour, and viscosity.

Table 4. Descriptive Rating Test for Test Samples Against the Standard RUTF (N = 30).

Property	Sample A Unappealing	Sample A Appealing	Sample B Unappealing	Sample B Appealing
Appearance	6 (20.0%)	24 (80.0%)	10 (33.3%)	20 (66.7%)
Aroma	12 (40.0%)	18 (60.0%)	12 (40.0%)	18 (60.0%)
Texture	8 (26.7%)	22 (73.3%)	5 (16.7%)	25 (83.3%)
Taste	5 (16.7%)	25 (83.3%)	5 (16.7%)	25 (83.3%)
Sweetness	3 (10.0%)	27 (90.0%)	4 (13.3%)	26 (86.7%)
Flavour	9 (30.0%)	21 (70.0%)	10 (33.3%)	20 (66.7%)
Viscosity	6 (20.0%)	24 (80.0%)	11 (36.7%)	19 (63.3%)
Residual Effect	9 (30.0%)	21 (70.0%)	7 (23.3%)	23 (76.7%)
Aftertaste	10 (33.3%)	20 (66.7%)	9 (30.0%)	21 (70.0%)

Table 5 shows significant differences in appearance, aroma, and viscosity across samples. Sample C scored highest in appearance and aroma, while Samples A and C were more acceptable than Sample B in viscosity ($p < 0.05$).

Table 5. Sensory Analysis of Standard RUTF and Two Test Samples (N = 30).

Property	Sample A	Sample B	Sample C	*p*-Value
Appearance	6.17 ± 1.91ab	5.70 ± 1.91b	7.10 ± 1.67a	.014
Taste	6.23 ± 1.57	6.53 ± 1.94	7.03 ± 1.57	.192
Aroma	5.83 ± 1.68b	5.80 ± 1.92b	7.30 ± 1.51a	.001
Texture	6.50 ± 1.54	6.03 ± 2.19	6.60 ± 1.45	.416
Viscosity	6.47 ± 1.28a	5.50 ± 2.25b	7.10 ± 1.03a	.001
Acceptability	6.40 ± 1.99	5.87 ± 2.21	7.00 ± 1.89	.104
Residual Effect	5.60 ± 1.67	5.57 ± 2.08	6.53 ± 1.76	.076
Aftertaste	5.60 ± 1.67	5.63 ± 1.94	6.57 ± 1.73	.064

* Mean ± SD of ratings. ANOVA, $p< 0.05$ a, b Levels of significant difference, Games-Howell.

4. Discussion

The formulated RUTFs Grub–Brown Beans-Based (GBB) and Grub–Bambara Nut-Based (GBN) had significantly lower energy and fat contents than the standard peanut-based RUTF (P-RUTF). This was expected due to the high fat content of groundnuts (45.8 g/100 g) compared to Bambara nut (6.5 g/100 g) and Nigerian brown beans (1.47 g/100 g) (Nigerian Food Composition Table, 2017). Since fat contributes the most energy per gram, its concentration directly influences the energy density of the final products, hence the higher energy content of P-RUTF. Despite lower energy values, both GBB and GBN meet the criteria for high-energy density foods (≥2.25 kcal/g), as classified by the World Cancer Research Fund and American Institute for Cancer Research, 2007 (Clinton, et al., 2020).

Insect–Brown Beans-Based and GBN RUTFs had energy densities of 3.89 kcal/g and 4.33 kcal/g, respectively, making them suitable for managing tissue-building conditions such as SAM. A slight increase in serving size, for example, a 25% increase for GBN, could compensate for the energy gap, ensuring each sachet delivers 500 kcal of energy without overburdening the child's appetite.

Although the protein content of P-RUTF was higher, the protein–energy ratio of GBN matched that of P-RUTF (26 g/1000 kcal), exceeding the minimum required for effective weight gain in SAM treatment (24 g/1000 kcal) (Golden, 2008). This ratio also falls within WHO's recommended range of 10–12% energy from protein (WHO et al., 2007), further supporting GBN's nutritional adequacy. Using insect and soy protein may also enhance the protein quality, offering a composition closer to reference proteins used in therapeutic feeding.

The potassium content of all RUTFs exceeded the 1600 mg/1000 kcal recommendation (Golden, 2008), although still below F-100's 2400 mg/1000 kcal. Rapid restoration of potassium is essential in severely malnourished children, particularly those with kwashiorkor, and its inclusion at adequate levels supports reduced mortality (Alleyne, 1970).

Magnesium levels were higher in the formulated RUTFs than in the standard P-RUTF. This is attributed to the naturally high magnesium content of brown beans and Bambara nut, compared to groundnut (NFCT, 2017). Interestingly, the formulated RUTFs also showed acceptable levels of ash and fibre.

However, calcium content was a limiting factor. Both GBB and GBN fell below the recommended calcium density (840 mg/1000 kcal), which is difficult to achieve through food-based formulations that exclude milk (Golden, 2008). Consequently, the Ca:P ratio of both GBB (0.55) and GBN (0.59) was also lower than the recommended range of 0.7–1.3 for children above six months of age.

The sensory evaluation revealed comparable acceptability across all samples. Although P-RUTF scored higher for aroma, GBB and GBN were rated similarly in terms of texture, appearance, taste, and overall acceptability. The GBB was rated slightly closer to the standard in terms of viscosity and appearance, possibly due to a closer resemblance to conventional peanut butter, which may have influenced panellist perception. These findings align with those of Nga et al. (2013), who reported high acceptability of locally produced RUTFs, even when the standard RUTF scored higher in specific sensory attributes. Panellists' familiarity with peanut-based products could have influenced subjective preferences; nonetheless, the comparable scores suggest that the insect- and pulse-based RUTFs are palatable and culturally acceptable.

5. Conclusions

This study demonstrated the feasibility of formulating locally produced RUTFs using African palm weevil larvae combined with either Nigerian brown beans or Bambara nut. While the standard peanut-based RUTF exhibited superior energy and fat content, the insect- and pulse-based alternatives met key nutritional requirements and were well accepted in sensory evaluations. Notably, the Insect–Bambara Nut-based RUTF showed promising nutritional and organoleptic properties, making it a viable, culturally adaptable, and substitute in treating severe acute malnutrition. These findings support the localisation of therapeutic food production and contribute meaningfully to achieving Sustainable Development Goal 2: Zero Hunger in resource-limited settings.

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