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Edafioghor L.O., Ibeanu V.N., Onodugo N.G., Okorie I. 2025. "Formulation and nutritional evaluation of ready-to-use therapeutic food using locally available food ingredients." *World Nutrition*, *16*(1), March, 21–26. https://doi.org/10.26596/wn.202516121-26

Research

Formulation and nutritional evaluation of ready-to-use therapeutic food using locally available food ingredients

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Keywords: ready-to-use therapeutic food, food formulation, locally available foods, severe acute malnutrition, nutrition

https://doi.org/10.26596/wn.202516121-26

World Nutrition 2025;16(1):21-26

Background
Ready-to-use therapeutic food (RUTF) is a specially formulated high protein and nutrient dense meal used to treat children over 6 months of age who are severely malnourished.

Objective
The aim of this study was to formulate and evaluate 3 RUTF products with graded ratios of the base ingredients - rice, soybean, groundnut, carrot and date palm.

Methods
The products which were coded as RSG-RUTF-1, RSG-RUTF-2, RSG-RUTF–3 (rice, soy bean, and groundnut) were evaluated for nutrient/energy composition and sensory attributes using standard methods. Data obtained were statistically analyzed using IBM-SPSS version 23.

Results
The moisture content of the products ranged from 9.26 - 11.11%, crude fiber 2.39 - 2.79%, and ash 0.99 - 1.07%. The proportions of energy from the macronutrients were protein 6.85 - 9.75%, fat 6.81 - 26.49%, and carbohydrate 50.22 - 71.01%. While the vitamins A (1.14 -1.33mg), and E (20.20 – 20.27mg) and sodium (5.55 – 6.02mg) were within the recommended levels for RUTF, iron (0.68 – 0.85mg), potassium (16.22 – 24.24mg), copper (0.00 – 0.01mg), magnesium (4.27 – 5.22mg) and zinc (0.01 – 0.06mg) were slightly low. However, the energy content of the products which ranged from 374Kcal in RSG-RUTF-2 to 478Kcal in RSG-RUTF-3 was adequate. There were significant ($p<0.05$) differences among the products for taste, texture and general acceptability. The RSG-RUTF-3 had the highest general acceptability score (7.17± 0.25).

Conclusions
All the formulated RSG-RUTFs have potentials of serving as alternatives to the imported RUTF. However, the content of protein, and a few other nutrients would need to be increased slightly.

INTRODUCTION

Malnutrition still is a major global public health concern, remaining one of the most common causes of morbidity and mortality among young children worldwide (WHO, 2020) and in Nigeria. In Nigeria, according to NDHS (2018), report shows that 37% of children under age 5 are stunted (too short for their age) and 17% are severely stunted. Seven percent are wasted (too thin for their height), with 2% being severely wasted. Twenty-two percent of children are underweight (too thin for their age), and 7% are severely underweight. Only 2% of children are overweight. The NDHS 2023 - 24 reported 40% of children under age 5 are stunted, 8% are wasted, 1% are overweight, and 27% are underweight. Ready-to-use therapeutic foods (RUTF) are a high protein/calorie, and micronutrient-supplemented meal in paste form used in the treatment of severe acute malnutrition (SAM) in children. Their advantages include

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resistance to degradation or growth of bacteria, even when refrigeration is unavailable. The widely used brands by UNICEF have been shown to increase the recovery rate of SAM children in sub-Saharan Africa (Manary et al., 2004; UNICEF, 2013), but are expensive to import and often out of stock in Nigerian hospitals. To cut costs and reduce malnutrition in children in poor resource settings, the use of readily available local ingredients in the production of RUTF has been suggested (Kinyuru et al., 2012). Local RUTF could be designed to suit regional tastes (Wieringa et al., 2013). The present study therefore sought to produce an alternative to imported RUTF that would be lower in cost and meet local preferences in the community treatment of MAM/SAM in children.

MATERIALS AND METHODS

The ingredients of the locally formulated RUTF (rice, soybean, groundnut, date palm, carrot vegetable oil, and snail) were purchased from a local market in Abakaliki, Ebonyi State. Foreign matter and dirt were removed and the items processed as follows:

RICE

A modified method of Eke-Ejiofor & Nwiganale (2016) was used to process rice into flour. Five kg of local rice grains were washed with clean water, drained and soaked in 3000 ml water for 16 hours, parboiled at 100^{0}C for 45 minutes and dried at 60^{0}C for 6hours in an air oven. It was ground into flour with a laboratory hammer mill grinder (70 mesh screens). The rice flour was packaged in an airtight container.

SOYBEAN

Soybean was processed using a modified method of Opara, et al. (2012). Five kg of soybean were washed with clean water, drained, soaked in 3000ml of clean water for 24 hours, and then boiled for 45 minutes at 100^{0}C. It was allowed to cool to ambient temperature, dehulled manually and sun dried. The sample was then toasted in a hot air oven at for 1hour, milled into fine powder using laboratory hammer mill operating at 1800 rpm, and packaged in an air-tight container.

GROUNDNUT

Groundnut seeds (2kg) were washed with water, sun dried for 5 hours and then roasted on a local stove for 10 minutes. Thereafter, lab personnel rubbed the seeds between their palms, winnowed them to remove the skin, blended with a kitchen blender (Silver Crest SC-1589), and packaged.

SNAIL

The Antwi (2009) technique was adopted in the processing of the snails. 100 were put in a wooden box containing sawdust for five days for purging (to ensure that no food was left in their intestinal tract). They were then washed with distilled water + 5% w/v sodium chloride (NaCl) 8 times. The snails were then heated in a 5% w/v NaCl solution for 45 minutes at 60^{0}C to aid evisceration, and allowed to cool to room temperature. The meat was then separated from the intestinal tract, cut into 5 cm x 4 cm pieces, dried using gas-oven at 100^{o}C for 2hr, milled in a laboratory hammer mill (FML-0100) AISI-304 stainless steel, operating at 3000 rpm, into fine powder, and packaged.

DATE PALM

The date palm was prepared using the technique described by Babarinde et al. (2016) with modification. Three kg of date palm fruits were washed with clean water and dried with a kitchen towel. Each fruit was cut transversely with a knife to remove the hard seed. The pericarp was dehydrated using an LFD-3801 dehydrator at 70^{0}C for 120 minutes, milled into a fine powder with a laboratory hammer mill at 1800 rpm, and packaged.

CARROT

Carrot roots (3kg) were washed with clean water, grated into approximately 1mm size, oven dried at 125^{0}F for 5hr, allowed to cool, and ground into fine powder using a high-speed blender (Vitamix 5200). The carrot powder was packaged in an air-tight container for use.

FORMULATION OF THE EXPERIMENTAL RUTF

The crude protein contents of rice, soybeans, groundnut, snail, carrot and date palm were determined using the AOAC (2010) method. The Pearson Square method (Egan, et al., 1981) was then used in the formulation of the 3 RUTF products, each of which was expected to furnish 16g of protein. The snail, date palm, carrot and vegetable oil were the fixed ingredients in each formulation. The ingredient composition of the experimental RUTFs is shown in Table 1. After being formulated, each was packaged in an air-tight container at ambient temperature and sent for analysis.

Table 1. Composition of the experimental RUTF products per 100g

Ingredient	Quantity (g)		
	RSG-RUTF-1	RSG-RUTF-2	RSG-RUTF- 3
Rice flour	43.2	53.9	42.1
Soybean flour	17.86	6.37	8.64
Groundnut	8.9	12.8	17.3
Snail	5	10	7
Date palm	10	15	8
Carrot	2	2	2
Vegetable oil	13	0	15

RSG-RUTF – Rice, soybean, groundnut, ready-to-use therapeutic food

CHEMICAL ANALYSIS OF THE EXPERIMENTAL RUTF PRODUCTS

The moisture, crude fibre, ash and fat contents were determined using the official methods of analysis of the Association of Official Analytical Chemists (AOAC, 2010). The micro Kjeldhal method as described by Onwuka (2005) was used to determine the protein content. Carbohydrate was estimated by difference. The calcium, iron, zinc and vitamins (A, E and C) contents of the RUTFs were determined using atomic absorption spectroscopy.as described by AOAC (2010). Tannin was determined using a modified version of Swain's (1979), as adopted by Abdul-Jalil (2016) while oxalate and phytate were determined by the methods described by Umeh & Ogbuagu (2010) and Nwosu (2011), respectively. The Afla Test fluorometer (VICAM VI #4, Watertown, MA, USA) was used to measure the aflatoxin content of the samples (AOAC, 2001).

SENSORY EVALUATION

The three formulated RUTFs were prepared into gruels and the sensory attributes were assessed based on a 9-point Hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike lightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely) using 50 panellists selected purposively from caregivers/mothers attending paediatrics outpatient clinic/immunization clinic at the AE-FUTHA (Alex Ekwueme Federal University Teaching Hospital, Abakaliki). The coded samples were presented on plates and the modalities of the evaluation were explained to the participants: these included rinsing of the mouth with water before tasting each sample and filling in a questionnaire bearing the sample codes after the tasting.

RESULTS

Table 2 shows the proximate composition of the three RUTF products. The micronutrient content of the three RUTFs is shown in Table 3. Table 4 delineates the sensory properties and acceptability evaluation of the gruels made with the experimental RUTF products. There were significant ($p<0.05$) differences in the taste, texture and general acceptability of the products. The RGS-RUTF-3 was rated highest in all the sensory attributes (7.41±0.20 for colour; taste 7.42±0.23; texture 6.53±0.28; appearance 6.72±0.25 and 6.71±0.32 for general acceptability). Tannins, oxalate and phytate were found present in all three samples in low quantities, as shown in Table 5.

Table 2. Proximate composition of the formulated RUTF per 100g of composite flour

	RGS-RUTF-1	RGS-RUTF-2	RGS-RUTF-3
Protein	6.85 ± 0.02	9.41 ± 0.01	9.75 ± 0.03
Ash	0.99 ± 0.01	1.07 ± 0.01	1.06 ± 0.01
Fat	9.50 ± 0.01	6.81 ± 0.03	26.5 ± 0.06
Moisture	9.26 ± 0.08	11.11 ± 0.07	9.89 ± 0.04
Fiber	2.39 ± 0.01	2.79 ± 0.01	2.59 ± 0.01
Carbohydrate	71.00 ± 0.09	68.80 ± 0.04	50.20 ± 0.03
Energy (Kcal)	397.00 ± 0.37	374.00 ± 0.35	478.00 ± 0.44

RSG-RUTF – rice, soybean, groundnut, ready-to-use therapeutic food

Table 3. Micronutrient profile of the formulated RUTFs per 100g/mg

Micronutrient (mg)	RGS-RUTF-1	RGS-RUTF-2	RGS-RUTF-3	Recommended levels
Vitamin A	1.14 ± 0.20	1.33 ± 0.12	1.25 ± 0.20	0.8-1.6mg
Vitamin E	20.2 ± 0.00	20.7 ± 0.12	21.3 ± 0.12	>20 mg
Vitamin C	30.6 ± 0.20	32.2 ± 0.20	38.5 ± 0.12	> 50 mg
Sodium	5.15 ± 0.15	6.02 ± 0.02	5.24 ± 0.06	<290mg
Magnesium	4.27 ± 0.03	4.97 ± 0.03	5.22 ± 0.06	80-235 mg
Potassium	21.1 ± 0.63	24.2 ± 0.51	16.2 ± 0.35	1100-1600 mg
Zinc	0.01 ± 0.00	0.01 ± 0.01	0.06 ± 0.01	11-14 mg
Copper	0.01 ± 0.02	0.00 ± 0.00	0.01 ± 0.02	1.4-1.8 mg
Iron	0.81 ± 0.12	0.68 ± 0.01	0.85 ± 0.05	10-14 mg

RSG-RUTF – rice, soybean, groundnut, ready-to-use therapeutic food

Table 4. Sensory properties and acceptability evaluation of the gruels made with the RUTF products

Sample	Colour	Taste	Texture	Appearance	GA
RGS-RUTF-1	6.72^{a}± 0.29	5.73^{b}± 0.31	5.52^{c}± 0.31	6.83^{a}± 0.27	5.43^{b}± 0.39
RGS-RUTF-2	7.07^{a}± 0.22	6.75^{a}± 0.27	6.53^{b} ± 0.28	6.72^{a}± 0.25	6.71^{a}± 0.32
RGS-RUTF-3	7.41^{a}± 0.20	7.42^{a}± 0.23	7.33^{a}± 0.23	7.20^{a}± 0.22	7.17^{a}± 0.25

RGS-RUTF = Rice, groundnut, soybeans ready-to-use therapeutic food. Values are means ± standard deviation of triplicate determinations. GA = General acceptability. Values with the same superscript in the same columns are not statistically different (ANOVA, P<0.05).

Table 5. Anti nutrient content of the formulated RUTF per 100g

Anti-nutrient (mg)	RGS-RUTF-1	RGS-RUTF-2	RGS-RUTF-3
Tannins	0.87 ± 0.12	1.40 ± 0.20	2.00 ± 0.20
Oxalate	1.37 ± 0.15	1.93 v 0.12	2.47 ± 0.12
Phytate	2.47 ± 0.12	3.27 ± 0.12	4.00 ± 0.20

RSG-RUTF – rice, soybean, groundnut, ready-to-use therapeutic food

DISCUSSION

The highest (478±0.44) energy value of the formulated products was be slightly lower than the 520 – 550 kcal/100g recommended for RUTF formulation (UNICEF, 2010) but higher than 302.76 kcal obtained in a locally made RUTF in India by Bharaniidharan & Reshmi (2019), and in Kenya by Wakhu-Wamunga & Wamunga (2017). The RGS-RUTF-3 energy was similar to the 478 kcal reported by Oakley et al. (2010) for RUTF containing 10% milk. All the experimental RUTF products had energy values higher than the F-75 (75 kcal), the P-519 (95.7 kcal), the F-135 (135 kcal), and the F-100 (100 kcal) but lower than 545 kcal in Plumpy'Nut (Bharaniidharan & Reshmi, 2019). The low energy recorded in this study might be attributed to low calorie content of the most of the fixed ingredients (snail, date palm, and carrot).

The experimental RUTF products' protein content was higher than those of F-75 (0.9g), the P-519 (1.61g), the F-135 (3.3g), and the F-100 (2.9g) but lower than 13.6g in Plumpy'Nut Bharaniidharan & Reshmi (2019), in Indian local RUTF (Bharaniidharan & Reshmi, 2019), in METU-2 (Amegovu et al., 2018) and in RUTF-AOB (Sosanya, et al., 2018). However, the RGS-RUTF-3 protein compares with 9.5% protein reported by Sandeep & Mona (2014) in a locally made RUTF Agra.

The fat content (26.5%) of RSG-RUTF-3 was above the minimum requirement of 24.8-36.3 g/100g by weight recommended for RUTF by WHO (WHO/FAO, 2022). The value is in line with the 27.7% in LTF (Ashish et al., 2022) and the 26.3% in RUTF Agra (Sandeep & Mona, 2014). However, the value recorded in this study is lower than the 55.4% - 70.6% in those three locally produced RUTF products and the 56.6% in Plumpy'Nut (Sosanya, et al., 2018).

The crude fibre content (2.59%) of the formulated RSG-RUTF-3 was in line with the recommended daily allowance of <5% fibre in complementary foods (WHO/UN, 2007). This could be attributed to different processing methods (dehulling, milling, and sieving) involved in the production of the formulated diet. The low crude fibre content of the formulated RUTFs in the current study was an advantage. This finding is similar to 1.2% in METU-2 reported by Amegovu et al. (2018).

The moisture content of the formulated RSG-RUTF-3 was found to be within the limit of <10% WHO/UN (2007). This is similar to the 9.89% in METU-2 reported by Amegovu et al. (2018) in Uganda but in higher than the 2.73% in RUTF AOB (Sosanya, et al., 2018) in Bauchi, Nigeria.

All the formulated RUTFs had vitamins A and E within the recommended levels, but vitamins C did not meet recommendations. The high content of vitamin A could be attributed to the addition of carrot to the products, while vitamin E could be as a result of peanut and soybean which are good sources of vitamin E (Sanders, 2003). This finding is similar to the 23.97mg of vitamin E reported by Rimbawan et al. (2024). Amegovu et al. (2018) reported a low vitamin A content of 0.52mg in RUTF-METU2.

Except for sodium, the mineral contents of the formulated RUTFs were lower than the recommended values of WHO (2012) standards proposed for the therapeutic foods for the management of MAM children. This likely reflects the mineral content of the ingredients and the absence of the mineral/vitamin premix recommended for RUTF formulations. However, the current findings were similar to results from Jibril (2017) in Zaria, Nigeria, who reported significantly lower mineral content in SWS-RUTF.

The concentrations of phytate found in this present study (2.47mg – 4.0mg) were lower than the value 5 – 10mg reported to interfere with iron absorption (Domina, 2013) and the 6.72mg in METU-2 (Amegovu et al., 2018). The tannin content of the formulated RUTFs was low (0.87mg – 2.00mg), which could be attributed to washing, soaking, dehulling and grinding of the ingredients during processing. This contrasts with Amegovu et al., 2018 who reported high tannins (9.43mg) in METU-2.

There were significant ($p<0.05$) differences in taste, texture, and general acceptability of the 3 samples. The RGS-RUTF-3 was rated highest in all the sensory attributes assessed. However, consumers reacted favourably to all three of the RUTF products, which might have been attributed to their familiarity with the locally sourced ingredients employed in the products' formulations. Mosha (2004) found that creating novel food formulations with elements that are frequently found in households leads to a greater level of product acceptability. Similarly, three cereal-legume RUTF products developed by Wakhu-Wamunga & Wamunga (2017) were generally accepted by the consumers.

CONCLUSION

The present study demonstrated that production of RUTF from locally sourced novel ingredients would meet recommended standards as well as meeting the culinary requirements of the local community. The experimental RUFT products compared favourably with other locally made RUTF; their nutritive values were within the complementary food recommended standards, and they were all highly rated on all sensory attributes. They therefore have high potential for being adopted for the management of SAM and CMAM in children in Nigeria. In addition, the RSG-RUTF-3 could be used as a supplementary food for children who are at risk of malnutrition and if the protein content is increased to provide 10 – 12% of the total energy, they could serve as an alternative to the imported RUTF. However, increased levels of locally available sources of some vitamins and minerals should also be increased in the RSG-RUTF.

AUTHOR CONTRIBUTIONS

LOE and VNI participated in the conceptualization and design of the study, LOE, NGO and IO participated in food processing, formulation and analysis, IO analysed laboratory data. VNI participated in project administration and supervision. LOE, VNI, NGO and IO participated in reviewing and editing the final draft of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no other potential conflicts of interest.

ACKNOWLEDGEMENTS

The authors wish to thank all those we whom we had the pleasure of working with during this project. Also, we wish to thank all the support staff of Institute of Child Health, Alex Ekwueme Federal University Teaching Hospital Abakaliki for their assistance

FUNDING

None.

Received: November 17, 2024; **Revised:** December 13, 2024; **Accepted:** March 15, 2025; **Published:** March 31, 2025.

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