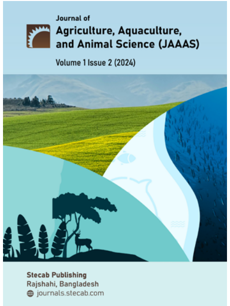

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Nutritional Profiling of Ready-To-Use Therapeutic Food (RUTF) From Sesame, Wheat, and Soybeans Blends: A Comprehensive Assessment

[1,2,4]Utah-Iheanyichukwu, Chioma, [2]Oguizu, Ada Daisy, *[3]Allison, Trust-Jah Tuaegwuchukwu, [4]Magnus, Samuel, [4]James, Stephen Becky, [1]Nwala, Scholastic Chinaza

About Article

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About Author

[1] Department of Human Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

[2] Department of Human Nutrition and Dietetics, Rivers State University of Science and Technology, Rivers State, Nigeria

[3] Interdisciplinary Research Unit, West African Society of Parenteral and Enteral Nutrition (WASPEN), Abuja, Nigeria and Georgia, USA

[4] Department of Nutrition and Dietetics, Temple Gate Polytechnic, Aba, Abia State, Nigeria

Contact @ Allison, Trust-JahTuaegwuchukwu
trustjah.allison.186731@unn.edu.ng

ABSTRACT

Ready-to-use therapeutic foods (RUTFs) are specialized nutritional products designed to treat severe acute malnutrition (SAM) in children and adults. This study aimed to develop a locally formulated RUTF using a Sesame-Wheat-Soybeans blend (SWS-RUTF). Three distinct formulations were created with varying proportions of sesame, wheat, and soybeans: SWS-RUTF1 (25:10:30), SWS-RUTF2 (25:15:25), and SWS-RUTF3 (20:10:35), with soy oil, sugar, and mineral-vitamin mix comprising the remaining 35%. A statistical analysis revealed significant differences ($p < 0.05$) in the proximate composition of the products – carbohydrates: 49-54%, crude protein: 24-28%, lipids: 9-11%, and energy value: 404-411 kcal. The amino acid scores for the three formulations were – SWS-RUTF1: 72 (PDCAAS), 62 (PDCAAS), and 1.08 (Protein Efficiency Ratio); SWS-RUTF2: 65 (PDCAAS), 55 (PDCAAS), and 1.07 (Protein Efficiency Ratio); SWS-RUTF3: 75 (PDCAAS), 67 (PDCAAS), and 1.10 (Protein Efficiency Ratio). These findings suggest that the developed SWS-RUTF formulations demonstrate potential as effective RUTFs, with opportunities for further optimization. Reformulation strategies should prioritize balancing protein and fat contents; enhancing mineral and essential amino acid profiles; optimizing anti-nutrient management; and ensuring adequate caloric density. By addressing these deficiencies and aligning with international RUTF standards, the revised SWS-RUTF formulation can effectively support the recovery and well-being of children suffering from SAM.

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1. INTRODUCTION

Malnutrition is a serious health condition characterized by inadequate or excessive intake of essential nutrients, leading to impaired physical and functioning abilities (World Health Organization, 2020). Undernutrition is inadequate intake of energy, protein, or essential micronutrients, leading to weight loss, wasting, or stunting (Black *et al.*, 2013). Overnutrition is excessive intake of energy or nutrients, resulting in obesity, insulin resistance, or other health problems (Johnson *et al.*, 2007); Micronutrient deficiencies is inadequate intake of vitamins or minerals, such as iron, vitamin D, or iodine (WHO, 2014). Causes of malnutrition includes – poverty and food insecurity (FAQ, 2020), lack of access to healthcare (UNICEF, 2019), and chronic diseases such as diabetes, HIV/AIDS (WHO, 2016). Consequences of malnutrition are impaired growth and development, increased risk of infections, cognitive impairment, and increased mortality risk (Black *et al.*, 2013; WHO, 2014; Granth Thorton *et al.*, 2016; WHO, 2020).

Malnutrition is a significant public health concern in Nigeria, affecting millions of children, adolescents, and adults (National Bureau of Statistics, 2018). Prevalence of malnutrition in Nigeria: Undernutrition – 37% of children under 5 years suffer from stunting (NBS, 2018), 22% of children under 5 years suffer from wasting (NBS, 2018), 12% of children under 5 years suffer from severe acute malnutrition (SAM) (NBS, 2018); Overnutrition – 35% of adults are overweight or obeses (WHO, 2019), and 14% of adults suffer from obesity (WHO, 2019).

In Nigeria, where malnutrition is prevalent, local production of Ready-to-Use Therapeutic Foods (RUTFs) is crucial for increasing availability, acceptability, accessibility, and efficiency in supply, while reducing costs (Abdu-Aguye & Abdulahi, 2014). However, the limited local availability of essential ingredients hinders RUTF production in some settings, necessitating research into alternative ingredients (Manary, 2006).

This study aimed to formulate and nutritionally evaluate a potential RUTF composed of a sesame-wheat-soybean blend.

2. LITERATURE REVIEW

Ready-to-Use Therapeutic Food (RUTF) is a key component for the treatment of Severe Acute Malnutrition, which is linked to dramatically increased childhood mortality (WHO, 2013). The term therapeutic food is used generally to refer to foods or food products that are improved nutritionally so as to have high energy and nutrients content, which are used in the treatment of malnutrition (UNICEF, 2020). Ready-to-use therapeutic foods, from the name are therapeutic foods that are consumed as given (without any form of cooking, or preparation) for the management of malnutrition (WHO, 2013). RUTF contains all the energy and nutrients required for rapid catch-up growth and are used particularly in the treatment of children over 6 months of age with severe acute malnutrition without medical complications (National Primary Health Care Development Agency, 2018). Some alternative RUTF formulations have been proposed and are based on four main ingredients: a cereal as the main ingredient, a protein source that can be of vegetal origin (beans, legumes, etc.) or animal origin (milk, red or white meat, fish meat, egg, etc.), a mineral and vitamin supplement (derived from vegetables, fruits, or a mixture of both), and an energetic supplement (e.g. lipids, oil, sugar, etc.) (UNICEF, 2020; WHO, 2013).

Sesame (Sesamumindicum) is a tropical plant prized for its edible seeds, which are rich in nutrients and have various culinary and medicinal uses (Kumar *et al.*, 2018). Sesame seeds are an excellent source of protein (20%), healthy fats (48%), and fiber (12%) (United States Department of Agriculture, 2020). They are also rich in antioxidants, vitamin E, and minerals such as calcium, iron, and magnesium (Kamel *et al.*, 2017). Research suggests that sesame seeds may support heart health by reducing cholesterol and triglycerides (Wang *et al.*, 2017), have anti-inflammatory and antioxidant properties (Hwang *et al.*, 2017), improve bone density and reduce the risk of osteoporosis (Zhang *et al.*, 2018), aid in digestion and relieve symptoms of constipation (Lui *et al.*, 2019).

Soybean (Glycine max) is a legume native to East Asia, prized for its nutritional value versatility, and economic importance (Liu, 2017). Soybean has been cultivated for over 3,000 years, originating in China (Hymowitz, 2010). Today, it is grown globally, with major producers including the United States, Brazil, and Argentina (Food and Agriculture Organization, 2020). Soybean is an excellent source of protein (40%) (Messina, 2016), fiber (10%) (Anderson *et al.*, 2013), isoflavones (phytoestrogens) (Kurzer, 2002), vitamins (B, E, K) and minerals (calcium, iron, potassium) (United States Department of Agriculture, 2020). Research suggests soybean consumption may have the following health benefits – reduce cardiovascular disease risk (Sacks *et al.*, 2006), support bone health (Weaver *et al.*, 2016), aid in weight management (Aoyama *et al.*, 2010), and have anti-cancer properties (Messina & Loprinzi, 2013)

Wheat (Triticumspp.) is a cereal grain and one of the world's most widely cultivated and consumed crops (Shewry, 2009). Wheat originated in the Middle East around 10,000 years ago (Dubcovsky & Dvorak, 2007). Today, it is grown globally, with top producers including China, India, and the United States (Food and Agriculture Organization, 2020). Wheat is a good source of carbohydrates (70%), fiber (10%), protein (12%), vitamin (B, E, K) and minerals (iron, selenium, manganese) (United States Department of Agriculture, 2020; Anderson *et al.*, 2013; Shewry, 2009; USDA, 2020). Research suggests wheat consumption support heart health, aid in weight management, have anti-inflammatory properties, and support gut health (Jacobs *et al.*, 2014; Astrup *et al.*, 2010; Kumar *et al.*, 2017; Gordon & Knight, 2013).

3. METHODOLOGY

3.1. Materials

Sesame seeds, Wheat, Soybeans, Soy oil, Sugar, Mineral and Vitamins mix. The wheat, sesame, soybean, milk, vegetable oil and sugar used for this study were purchased from Ariaria International Market Aba, Abia State, Nigeria.

3.2. Ethical approval

Approval was obtained from Health Research Ethics Committee of Federal Medical Center, Umuahia, Abia State (FMC/QEH/G.596/Vol.10/727).

3.3. Equipment

PTH analyzer, Vacuum oven, Muffle furnace, Soxhlet extractor, Weighing Scale, Hot plate, Centrifuge, Spectrophotometer, Water bath, pH meter,

3.4. Chemicals/ reagents

Sodium Sulphate (Na2SO4), Copper Sulphate (CuSO4), Selenium Oxide (SeO2), Hydrochloric acid (HCl), Sodium Potassium Tartrate (NaK), Potassium Iodide (KI), etc. All chemicals and reagents used are of analytical grade.

3.5. Materials preparation

The raw materials were washed with clean water to remove dust particles and then sun-dried in a dust-free area. Subsequently, the washed materials were roasted at 157°C for 15 minutes, with continuous stirring to ensure even heating.

Following roasting, the soybean hulls were removed using a clean local grinding stone, employing gentle and slow grinding to facilitate hull separation from the seeds. The hulls were then separated from the seeds.

The processed materials were subsequently ground into a fine powder using a hammer mill. To ensure uniform particle size, the powdered materials were sieved to remove larger particles. This processing step is critical in Ready-to-Use Therapeutic Food (RUTF) production, as the minimal particle size is essential for optimal texture and nutritional availability.

Table 1. Ingredients used for the formulation of the sesame-wheat-soya bean RUTF

Formulation of SWS-RUTF			
Ingredients	**Formulations (%)**		
	SWS-RUTF1	**SWS-RUTF2**	**SWS-RUTF3**
Sesame	25	25	20
Soya bean	30	25	35
Wheat	10	15	10
Soya oil	20.4	20.4	20.4
Sugar	13	13	13
Mineral and Vitamin Premix	1.6	1.6	1.6

Modification of Steve and Jeya (2004)

3.6. Production of ready-to-use therapeutic food (RUTF)

Soya oil was heated to 70°C for 2 minutes. The powdered ingredients, comprising sesame seeds, soybeans, wheat, sugar, and mineral/vitamin premix, were gradually added to the heated oil while stirring continuously. Following complete addition, the mixture was vigorously stirred for 15 minutes to facilitate uniform binding.

This process ensures the formation of a homogeneous blend, essential for RUTF texture and nutritional consistency. While mechanical mixing is recommended for large-scale production (Manary, 2006), small batches can be mixed manually.

The resultant RUTF products were packaged in nylon airtight bags and stored in cartons at ambient temperature.

3.7. Statistical analysis

Results are presented as mean ± standard deviation (SD). Data analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) version 23. To determine significant differences between groups, an analysis of variance (ANOVA) was conducted, followed by Bonferroni post hoc tests to identify specific pairwise differences. Statistical significance was set at $p < 0.05$.

4. RESULTS AND DISCUSSION

4.1. Results

The results of the proximate analysis conducted on the formulated sesame-wheat-soybean-based potential Ready-to-Use Therapeutic Food (RUTF) are presented in Table 2. Comparative analysis revealed significant differences ($p < 0.05$) among the formulations. Specifically - SWS-RUTF1 exhibited higher protein, dietary fiber, moisture, and caloric values compared to SWS-RUTF2 and SWS-RUTF3. SWS-RUTF3 demonstrated significantly lower values for all parameters, except lipid content. SWS-RUTF2 displayed the highest carbohydrate content.

Table 2. Proximate composition of the formulated potential SWS-RUTF

Nutrient	**SWS-RUTF1**	**SWS-RUTF2**	**SWS-RUTF3**
Energy (kcal)	411.56 ± 0.25^{b}	407 ± 0.12^{c}	404.24 ± 0.07^{d}
Protein (%)	28.88 ± 0.03^{a}	24.25 ± 0.21^{c}	26.19 ± 0.14^{b}
Carbohydrate (%)	49.47 ± 0.23^{b}	55.31 ± 0.10^{a}	54.91 ± 0.21^{c}
Fat (%)	11.16 ± 0.02^{b}	9.86 ± 0.20^{b}	9.01 ± 0.02^{b}
Moisture (%)	4.69 ± 0.10^{a}	4.12 ± 0.24^{b}	4.14 ± 0.28^{b}

Ash (%)	1.57±0.20^{d}	2.62±0.12^{c}	2.67±0.32^{b}
Fibre (%)	16.68±0.63^{a}	15.47±0.88^{b}	15.24±0.23^{c}

Values are mean ±SD for three determinations with different superscripts in rows signify a statistically significant difference (P< 0.05).

The mineral composition of the sesame-wheat-soybean-based Ready-to-Use Therapeutic Food (SWS-RUTF) formulations is presented in Table 3. A comparative analysis of the mineral content revealed significant variations among the formulations: SWS-RUTF2 exhibited the highest concentrations of zinc (Zn), calcium (Ca), iron (Fe), and manganese (Mn), with Fe being the most abundant. SWS-RUTF3 contained higher levels of sodium (Na) and potassium (K). In contrast, SWS-RUTF1 had lower levels of all minerals analyzed, except for magnesium (Mg), which was found in higher concentrations.

Table 3. Concentration of some minerals in the potential SWS-RUTF

Minerals	SWS-RUTF1	SWS-RUTF2	SWS-RUTF3
Zinc (Zn)	0.56±0.12^{d}	0.60±0.03^{b}	0.59±0.25^{c}
Calcium (Ca)	1.77±0.23^{d}	3.48±0.42^{b}	2.85±0.74^{c}
Sodium (Na)	4.55±0.32^{d}	4.99±0.12^{c}	5.21±0.16^{b}
Magnesium (Mg)	1.08±0.10^{b}	0.90±0.28^{c}	0.90±0.73^{c}
Iron (Fe)	7.43±0.01^{c}	8.43±0.03^{b}	7.25±0.14^{d}
Potassium (K)	2.45±0.13^{d}	2.58±0.52^{b}	3.06±0.26^{c}

Values are mean ±SD for three determinations with different superscripts in rows signifying statistically significant difference (P< 0.05)

The anti-nutrient composition of the sesame-wheat-soybean-based Ready-to-Use Therapeutic Food (SWS-RUTF) formulations is presented in Table 4. SWS-RUTF1 exhibited significantly lower levels of trypsin inhibitor, tannin, phytate, and saponin. Conversely, SWS-RUTF3 contained the lowest concentration of oxalate. These findings suggest that SWS-RUTF1 may have improved nutritional bioavailability due to reduced anti-nutrient content.

Table 4. Levels of Selected Anti-nutrients in the Potential SWS-RUTF

Anti-nutrients	SWS-RUTF1	SWS-RUTF2	SWS-RUTF3
Trypsin inhibitor(TUI/mg)	6.00±0.02^{a}	6.40±0.02^{b}	6.66±0.05^{b}
Tannin (%)	3.58±0.03^{a}	4.39±0.24^{b}	3.25±0.25^{a}
Oxalate (mg/100g)	5.44±0.23^{c}	4.32±0.33^{b}	2.30±0.12^{a}
Phytate (mg/100g)	1.70±0.20^{a}	3.90±0.14^{b}	7.90±0.02^{c}
Saponin (%)	17.00±2.00^{a}	24.00±1.00^{b}	23.00±0.21^{b}

Values are mean ±SD for three determinations with different superscripts in rows signify statistically significant difference (P< 0.05)

The amino acid composition of the sesame-wheat-soybean-based Ready-to-Use Therapeutic Food (SWS-RUTF) formulations is presented in Table 5. Similar ranges of essential amino acids (EAAs) – phenylalanine, threonine, histidine, and valine – among the three formulations. SWS-RUTF2 exhibited significantly lower ($p < 0.05$) values for most amino acids compared to SWS-RUTF1 and SWS-RUTF3. Glutamate, aspartate, leucine, and arginine were the most abundant amino acids across all formulations. Tryptophan, methionine, and cysteine had the lowest concentrations in all three formulations. These findings indicate that SWS-RUTF1 and SWS-RUTF3 may provide a more balanced amino acid profile compared to SWS-RUTF2.

Table 5. Amino acid (g/100g) profile of the potential SWS-RUTF

Amino acids	SWS-RUTF1	SWS-RUTF2	SWS-RUTF3
Leucine	6.74± 2.26^{b}	5.90±0.14^{a}	7.24±0.28^{b}
Lysine	3.71±1.83a^{b}	3.32±0.35^{a}	4.03±0.04^{b}
Isoleucine	3.24±0.42a^{b}	3.01±0.01^{a}	3.60±1.41^{b}
Phenylalanine	4.35±0.28^{a}	4.08±1.41^{a}	4.52±1.13^{a}
Tryptophan	1.42±0.14^{b}	1.21±0.28^{a}	1.58±0.14^{c}

Valine	4.03±0.18^{a}	3.89±1.41^{a}	4.24±0.23^{a}
Methionine	1.39±2.14^{b}	1.20±0.10^{a}	1.42±1.40^{b}
Histidine	2.49±1.42^{a}	2.33±0.30^{a}	2.81±1.40^{a}
Threonine	2.39±0.41^{a}	2.28±0.14^{a}	2.61±0.01^{a}
Total EAA	29.76	27.22	32.05
Arginine	5.49±0.09^{a}	4.99±1.42^{a}	6.19±0.40^{b}
Proline	3.45±1.91^{a}	3.25±0.42^{a}	3.65±0.42^{a}
Tyrosine	2.92±0.28^{b}	2.41±0.20^{a}	2.92±1.20^{b}
Cystein	1.33±0.14^{b}	1.21±0.01^{a}	1.45±0.01^{c}
Alanine	3.83±1.40^{b}	3.19±0.01^{a}	4.32±0.14^{c}
Glutamic acid	13.32±2.14^{b}	12.87±0.07^{a}	13.85±0.42^{b}
Glycine	3.56±0.28^{a}	3.37±1.41^{a}	4.04±0.56^{b}
Serine	3.51±1.27^{b}	3.03±0.04^{a}	3.78±1.41^{b}
Aspartic acid	9.55±0.35^{b}	9.12±1.83^{a}	9.80±0.01^{b}
Total NEAA	46.96	43.44	50.00

Values are mean ±SD for two determinations. Different superscripts in rows signify statistically significant difference (P<0.05). EAA = Essential Amino Acid, NEAA = Non-Essential Amino Acid.

The amino acid score (AAS), protein digestibility-corrected amino acid score (PDCAAS), and protein efficiency ratio (PER) of the formulations are presented in Table 6. SWS-RUTF3 exhibited the highest protein quality, with superior AAS, PDCAAS, and PER values, followed closely by SWS-RUTF1. Conversely, SWS-RUTF2 demonstrated the lowest protein quality, with significantly reduced values for all three parameters. These findings suggest that SWS-RUTF3 and SWS-RUTF1 offer satisfactory protein quality, whereas SWS-RUTF2 requires reformulation to enhance nutritional adequacy.

Table 6. Amino acid score, protein digestibility corrected amino acid score, and protein efficiency ratio of the potential SWS-RUTF

	SWS-RUTF1	**SWS-RUTF2**	**SWS-RUTF3**
AA Score (%)	72	65	79
PDCAAS (%)	62	55	67
PER	1.08	1.07	1.10

4.2. Discussion

Reducing child malnutrition requires a multifaceted approach, encompassing access to nutritious food, improved hygiene, quality healthcare, and adequate care. However, poverty and food insecurity significantly impede access to nutritious diets, characterized by optimal protein quality, micronutrient content, bioavailability, minimal anti-nutrient content, and high nutrient density. This vulnerability predisposes children to severe acute malnutrition. To address this, the World Health Organization (WHO, 2020) recommends Ready-to-Use Therapeutic Food (RUTF) for managing severe acute malnutrition without medical complications. RUTF production is scalable and straightforward, permitting small or large quantities. Nevertheless, localized ingredient availability constrains its use, highlighting the need for research into alternative ingredients to overcome this limitation (Manary, 2006).

The caloric content of the SWS-RUTF fell short of the minimum requirement (520-550 kcal/100g) for Ready-to-Use Therapeutic Food (RUTF) formulations, as recommended by the World Health Organization (WHO, 2013). This discrepancy is primarily attributed to insufficient calorie contribution from fats, which accounted for only 25% of total calories, significantly lower than the recommended range of 45-60% (UNICEF, 2020). Conversely, the SWS-RUTF exhibited excessively high protein levels, surpassing the recommended 10-12% of total energy (UNICEF, 2020). To align with international standards, adjusting the proportion of protein and fat source foods in the SWS-RUTF recipe is necessary to achieve an optimal balance. Adjusting the protein-to-fat ratio in the SWS-RUTF recipe could involve increasing the proportion of lipid-rich ingredients, such as vegetable oils, while optimizing protein sources, like soybean or pea protein, to achieve the recommended 10-12% of total energy.

Minerals are essential nutrients found in food, crucial for normal growth and bodily functions. However, the mineral content of the SWS-RUTF was significantly lower than the recommended values (UNICEF, 2020). This deficiency stems from two primary factors- inherent limitations of plant-based diets, which are naturally low in micronutrients (Liu, 2017); and insufficient mineral and vitamin content in the premix used, compared to the Nutriset Mineral/Vitamin premix specifically recommended for RUTF formulations. Inadequate micronutrient intake severely impacts children's health and development, potentially leading to life-threatening deficiency diseases, such as anemia and vitamin A deficiency (FAO, 2020). Consequently, the SWS-RUTF's suboptimal mineral profile renders it unsuitable for managing Severe Acute Malnutrition (SAM). To address these deficiencies, reformulating the SWS-RUTF with enhanced mineral and vitamin premixes, such as Nutriset, and incorporating micronutrient-rich ingredients could improve its suitability for SAM management.

Anti-nutrients, naturally occurring plant compounds, impede the body's ability to absorb essential nutrients. Phytates, oxalates, and tannins, in particular, have been shown to compromise nutrient utilization in human nutrition (USDA, 2020; FAO, 2020). Notably, the SWS-RUTF formulations exhibited – Oxalate and trypsin inhibitor levels below safe consumption thresholds (WHO, 2020); and trace amounts of anti-nutrients, including phytates and tannins, within safe concentration limits, posing no significant risk to dietary health (FAO, 2020). These findings suggest that the SWS-RUTF formulations have minimized anti-nutrient content, ensuring optimal nutrient bioavailability. The optimized anti-nutrient profile of SWS-RUTF formulations underscores the importance of careful ingredient selection and processing methods in RUTF production.

The essential amino acid profile of the SWS-RUTF formulation fell short of the recommended standards for Ready-to-Use Therapeutic Food (RUTF). Specifically, all measured values were below the suggested levels. This amino acid deficiency is concerning, as inadequate intake can impede growth and brain development in children (Sacks *et al.*, 2006; Anderson *et al.*, 2013). Protein quality is a critical determinant of a food's ability to meet metabolic demands for amino acids and nitrogen. As emphasized by the Food and Agriculture Organization (FAO, 2020), protein quality assessment predicts the efficiency of protein utilization in the body. Therefore, optimizing protein quality is crucial to ensure that dietary protein sources and diets adequately support amino acid requirements, nitrogen balance, and overall metabolic function. To address this shortfall, reformulation strategies should focus on enhancing the essential amino acid profile to align with RUTF standards. Targeted amino acid supplementation or alternative protein sources, such as soy or pea protein, may enhance the protein quality of SWS-RUTF, ensuring optimal growth and development outcomes for children.

5. CONCLUSIONS

In conclusion, the nutritional evaluation of the SWS-RUTF formulation revealed significant shortcomings in its caloric content, protein quality, mineral density, and essential amino acid profile. These deficiencies, particularly the inadequate protein-to-fat ratio, excessive protein levels, and insufficient mineral and amino acid content, compromise the formulation's efficacy in managing Severe Acute Malnutrition (SAM). The presence of anti-nutrients, although within safe limits, further underscores the need for optimized ingredient selection and processing methods. The formulation's inability to meet recommended RUTF standards (WHO, 2013; UNICEF, 2020) may impede growth, brain development, and overall health outcomes in children.

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