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OPTIMIZING THE FORMULATION OF READY-TO-USE THERAPEUTIC (RUTF) FOOD FROM INDIGENOUS SEEDS FOR ACUTE MALNUTRITION MANAGEMENT

Bakhtawar Saleem[1*], Rizwana Batool[2], Mahwash Aziz[3], Sana Aslam[4]

[1*,2,3]Department of Food Science and Technology, Government College Women University, Faisalabad, Pakistan.
[4]Department of Chemistry, Government College Women University, Faisalabad, Pakistan

***Corresponding Author:** Bakhtawar Saleem
*Department of Food Science and Technology, Government College Women University, Faisalabad, Pakistan Email: sbakhtawar098@gmail.com

Abstract
The research investigated the nutritional content and stability of a locally developed ready-to-use therapeutic food (RUTF) formulation derived from indigenous seeds. The objective was to provide a sustainable treatment for acute malnutrition in children. Three formulations of Ready-to-use Therapeutic Food (RUTF) were prepared, including different ratios of watermelon, melon and pumpkin soybean, and sunflower seed flour, were assessed for their vitamin and mineral levels throughout storage durations of 0, 60 and 120 days. The different formulations of RUTF were also analyzed for their amino acid content. Product 3 demonstrated the maximum level of essential vitamins and minerals. The initial concentration of vitamin B1 was 7.39mg/100g, vitamin B2 was 7.01mg/100g, and vitamin B3 was 7.60mg/100g. Following a period of 120 days, the values slightly decreased to 6.33mg/100g, 4.97mg/100g, and 6.32mg/100g, respectively. In comparison to product 1, product 3 showed a considerably higher maximum amount of amino acids, indicating a better nutritional profile. These findings indicate the potential for locally produced RUTF as a sustainable alternative to imported products, which can be used for the management of severe acute malnutrition in children in limited resource settings.

Keywords: Ready-To-Use Therapeutic Food, Severe Acute Malnutrition, Management, Minerals Vitamins

1. Introduction
Malnutrition is a broad term that includes both undernutrition and overnutrition, however it is mostly used to refer to undernutrition. The substantial repercussions of this health condition, such as increased morbidity, medical expenses, and death, have led to its recognition as a key concern for older people worldwide (Nishioka *et al.*, 2024). Malnutrition is a pervasive nutritional problem in impoverished nations. This mostly occurs as a result of inadequate intake and utilization of nutrients that are crucial for several physiological activities (Endris *et al.*, 2017). Pakistan has struggled tremendously amid widespread destruction from devastating floods in 2022. Economic uncertainty, volatile politics, and deteriorating security have left the nation in a dire state regarding child malnutrition. However, with an immense burden of undernutrition and high food insecurity,

Pakistan remains highly vulnerable, even as the evolving Covid-19 health crisis persists. Rates of wasting among young children exceed internationally recognized emergency levels at an alarming 17.7%, while an astoundingly high 40.2% of children are stunted and 28.9% malnourished. Malnutrition manifests in several forms, including moderate and severe wasting, stunting, micronutrient deficiencies, and obesity. Specifically, undernutrition accounts for approximately 45% of deaths among those under five, with most fatalities in low and middle-income countries, as noted by Idris in (2021).

The latest analysis of acute malnutrition across parts of Pakistan is bleak, with over two million young children found to be suffering. The Integrated Food Security Phase Classification conducted their examination in thirty-two districts spread across Balochistan, Khyber Pakhtunkhwa, and Sindh provinces. Within the regions studied, twenty-three districts are rated at the highest level of concern in Phase 4, denoted as Critical. Another five districts fall under Phase 3, termed Serious. The final four areas are classified as Phase 2, or Alert. It is significant that this period of assessment coincides with the post-harvest, summer, and monsoon cycle. Typically, levels of acute malnutrition peak during this timeframe. The elevated prevalence of malnutrition uncovered in the districts underscores an urgent requirement for a comprehensive public health response. More than 2 million children aged 6 to 59 months living in the thirty-two districts are affected by malnutrition and require immediate therapy. The total number suffering from moderate and severe forms respectively 1,544,910 and 598,802 is grave. Among the locations, Tharparkar District contains the highest frequency of acute malnourished children at 240,140. Following this are Quetta with 186,803, Khairpur at 170,143, Umerkot with 151,008 and Dadu at 129,673, all classified in IPC AMN Phase 4 (Critical) (IPC, 2024).

Severe acute malnutrition (SAM), sometimes called as severe wasting, is a common and serious type of undernutrition. About 16.4 million children worldwide have this disorder (UNICEF, 2021). Pakistan has 1.4 million people and a 6.2% case fatality rate. The condition causes systemic inflammation, muscle and fat loss, and infection susceptibility. SAM is classified as complicated (20%) or uncomplicated (80%) based on medical complications like hypothermia, hypoglycemia, severe dehydration, acute lower respiratory tract infection, severe edema severe anemia, loss of appetite, and high-grade fever ((Ahmed *et al.,* 2020).

Sever acute malnutrition was addressed by a 2001 public health policy called community-based treatment of severe acute malnutrition. Early identification and treatment of children in the community are its foundation. This strategy was originally called community-based therapeutic treatment. Community-based therapy care is more cost-effective and reaches more people, so it works better than facility-based treatments in places with limited resources (Saleem *et al.,* 2021).

Ready to Use Therapeutic Food (RUTF) and basic medical care are typically utilized in a community setting for the management of uncomplicated severe acute malnutrition. RUTF is a calorie-dense, energy-rich, and micronutrient-fortified food. It is a peanut-based paste wrapped in foil, weighing approximately 92g and containing around 5.5 kcal/g with a high amount of protein and calories. It offers a balanced assortment of all essential macronutrients and micronutrients. Children aged 6–59 months can ingest RUTF as a treatment for six to eight weeks according to their weight as advised by the WHO (Fetriyuna *et al.,* 2023). However, since RUTF is not manufactured domestically and must be imported by donor organizations at great expense. Furthermore, the acceptance of imported RUTF is suboptimal perhaps because the unfamiliar flavor of peanut-based food is unlike what people are accustomed to feeding their infants (Akram *et al*., 2016).

Supplies of Ready-to-Use Therapeutic Food for the treatment of severe acute malnutrition were imported into Pakistan. Unpredictable program needs and delays in distributing the RUTF from ports after arrival, as well as additional costs due to taxes and tariffs often led to interruptions in the pipeline. In response, the Government and UNICEF initiated local production of Ready-to-Use Therapeutic Food, though refinement of the process is still ongoing. Ready to Use Therapeutic Food is a crucial lifesaving provision for treating severe wasting in children under five years old, yet approximately 65-70% of youngsters suffering from grave malnutrition globally lack access to care, most residing in areas receiving comparatively little consideration in non-humanitarian contexts. This ambitious project aims to curb importing Ready-to-Use Therapeutic Food and make it widely available at low prices, potentially boosting the economy. For this important research, we investigated utilizing assorted indigenous vegetable, fruit, and legume seeds such as pumpkin, watermelon, melon, sunflower, and soy to develop alternative products. Main objective of this study is to prepare the low cost diet by utilization of fruit and vegetable waste to treat the acute malnutrition during the natural crisis of Pakistan.

2. Materials and Methods

The present study was conducted at the Food Technology Lab, Food Processing and Preservation Lab and Food Analytical Lab Department of Food Science and Technology, Govt College Women University, Faisalabad

2.1.Raw Material Procurement

The whole raw material will purchase from the market. All the standards will be purchased from Sigma Aldrich (Sigma- Aldrich Tokyo, Japan Merck (KGaA Merck Dermstadt, Germany).

2.1.1. Preparation of Raw Material

The various types of seeds, such as pumpkin seed, watermelon seed, melon seed, sunflower seed, and soybean, were thoroughly washed, sorted, and then soaked in hot water for duration of 10-20 minutes. Subsequently, the seeds were subjected to drying in a cabinet drier at a temperature of 50°C for duration of 5 hours. Following the drying process, the seeds were roasted and ground using a grinder. Finally, the resulting flour was sieved and stored in airtight plastic bags for future use. Pumpkin, watermelon, melon seed, soybean, and sunflower seed flour was blended with milk powder, sugar, and mineral salt to acquire the necessary vitamins, minerals, proteins, etc. For RUTF paste, the right quantity of oil was added after mixing. After being kept at ambient temperature, the finished item was assessed for the following attributes until the specified period (Javed *et al.,* 2021).

2.2. Physicochemical Assay of RUTF

2.2.1. Proximate Analysis

Proximate analysis was carried out after the preparation of product according to the method of AOAC (2019).

2.2.2. Determination of Vitamin Content

The vitamin content of prepared RUTF was determined according to the method of Wagh and Deore (2015).

2.2.3. Determination of Minerals Content

The mineral (Magnesium, calcium, Phosphorus, Potassium, Sodium) contents of various purposed RUTF was evaluating by the method described in Belete *et al.,* (2018) and zinc, iron was determined by Atomic Absorption Spectroscopy method described in Wagh (2017).

2.2.4. Amino Acids Profile

The prepared RUTF was analyzed for its amino acid content according to the Oyet and Chibor (2020).

2.2.5. Statistical Analysis

The data will be analyzed statistically by using software (Statistix 8.1) (Montgomery *et al.,* 2013).

3. Result and Discussion

The statistical results regarding iron content have been indicated in Table 1. There was a significant difference (P≤0.05) observed within treatments. This study examined the vitamin content Vitamins B1, B2, B3, B5, B6, B9, A and C in three different RUTF of formulations of different proportions of pumpkin seed flour, watermelon seed flour, melon seed flour or soybean seed flour or sunflower seed. Therefore, the proportion impact of a blend of these seed flours fed into ready to use therapeutic food on vitamins content was analyzed within a 120-day storage period. On the first day of storage, the vitamin B1 content of RUTF varied from 5.19 to 7.39mg/100g. The RUTF produced using Product 3 had the greatest score of 7.39±0.28mg, while the lowest score of 5.19±0.17mg was recorded in Product 1. The vitamin 1 content in the RUTF varied from 5.04 to 6.28mg/100g after 60

days of storage. Product 3 had the greatest score of 6.28C±0.19, while Product 1 obtained the lowest value of 5.04E±0.06. After a storage period of 120 days, the concentration of vitamin 1 varied from 4.36 to 6.33mg/100g. The vitamin B2 content of RUTF varied from 3.89-7.01mg/100g on the first day of storage. Product 1 had the minimum score 3.89mg, meanwhile product 3 had the maximum content recorded. The mean value of vitamin B2 after 60 days analysis was 3.65-5.15mg/100g. Product 1 had the minimum mean value, perhaps product 3 had the maximum mean value. After storage of 120 days the concentration of vitamin B2 in the sample varied from 3.04 to 4.97mg/100g. The highest score was recorded in product 3 with a value 6.32±0.09mg, where's product 1 had a minimum value 3.04±0.06mg/100g. The vitamin B3 content in the RUTF varied between 4.76-7.60mg/100g on zero day. The highest score was seen in Product 3 which produced the RUTF with a mean value of 7.60±0.51mg whereas; the lowest results were for Product 1 which was 4.76±0.20mg.
Results for vitamins content were in accordance to previously report by Joshi and Chauhan (2022). Meanwhile the levels of vitamin 3 in Ready-to-Use Therapeutic Food (RUTF) varied from 4.77–6.66mg/100g over a storage time up to 60 days. The vitamins result were consistent to the earlier findings as reported by Gumeniuk *et al.,* (2021). Product 3 showed the highest score of 6.66B±0.32 and Product 1 attained the lowest score of 4.77±0.1mg. The concentration of Vitamin B3 in the sample ranged from 4.12 to 6.32mg100g after storage at period of 120 days. The highest score was recorded in Product 3 with the value of 6.32±0.09mg while lower level was seen in Product 1, it had a value of 4.12±0.10 mg/100g (Table-2), and these data are not corroborated by an earlier report on vitamins content (Falade *et al.*, 2020).
The vitamin B5 content of the Ready-to-Use Therapeutic Food (RUTF) on day 0 of storage ranged from 3.57 to 6.94mg/100g. Product 3 exhibited the highest content at 6.94±0.10, whilst product 1 had the lowest score at 3.57±0.31. After 60 analyses, the mean vitamin B5 value was 3.1-6.24mg/100g. The vitamin B5 score of RUTF at day 0 of storage varied from 3.57 to 6.94 mg/100g. Product 3 had the highest content at 6.94±0.10, while Product 1 had the lowest score at 3.57±0.31. The mean value of vitamin B5 after 60 days of analysis was 3.15–6.24 mg/100g. Product 1 had the lowest mean value, and Product 3 had the highest score. Vitamin B5 levels after 120 days of storage ranged from 3.32 to 5.64 mg/100g. Product 3 received the highest score of 5.64±0.21 mg/100g, while Product 1 received a less score of 3.32±0.11 mg/100g. Vitamin 6 concentrations during 0 days of storage ranged from 13.12 to 19.66 mg/100g. Product 3 had the greatest score of 19.66±0.55 mg, whereas Product 1 had the lowest score. The range of RUTF after 60 days on vitamin 6 was 12.08–17.27 mg/100g. Product 1 had the lowest score 12.08±0.07, while Product 3 had the highest score, 17.27±0.2 mg/100g. Following 120 days of storage, the range of vitamin 6 in RUTF was 10.05–16.41 mg/100g. The vitamin 9 score of RUTF at day 0 of storage was 11.84–14.88 mg/100g. Product 1 received the lowest score of 11.84±0.07mg/100g, while Product 1488±0.10 mg received the greatest score. Vitamin 9 levels after 60 days of storage ranged from 10.71 to 13.76 mg/100g. Product 1 had the lowest score, 10.71 ±0.51mg, while Product 3 had the highest value, 13.76 ±0.57mg. Following 120 days of storage, the range of vitamin 9 in RUTF was 10.04–13.47 mg/100g. Product 3 had the greatest score, 13.47±0.35mg, whereas Product 1 received a lesser score, 10.04±0.33mg/100g. On the first day of storage, RUTF vitamin A concentration ranged from 84.83 to 113.20 IU. With 84.83IU, Product 1 earned the lowest score while Product 3 had the highest quantity ever recorded. After 60 days of analysis, the average vitamin A value was 79.06–100.68 IU. Product 3 received the greatest score, and Product 1 got the lowest average value. Following 120 days of storage, the sample's vitamin A concentration ranged from 76.78 to 99.87 IU. Product 3 had the highest score of 99.87±0.35 IU, whereas Product 1 scored lower at 76.78±1.16 IU. This observation was in contrast to the earlier report that level of these vitamins (Gade *et al.*, 2022).
The vitamin C content of RUTF at day 0 of storage ranged from 69.06-76.19mg/100g. Product 3 had the highest content at 76.19±0.32mg/100g, while Product 1 had the lowest content at 69.06±0.88mg/100g. After 60 days of analysis, the mean value of vitamin B5 was 67.55-

74.54mg/100g. Product 1 had the lowest mean value, and Product 3 had the highest value. After 120 days of storage, the vitamin C levels ranged from 64.48-73.77mg/100g. Product 3 had the highest level at 73.77±0.55mg/100g, while Product 1 had a lower level at 64.48±0.72mg/100g.

Table 1: Effect of treatments and days on mean values for Vitamins of RUTF

Treatment	Vitamins	Days			
		0	60	120	Mean
Product 1	Vit B1 mg/100g	5.19E±0.17	5.04E±0.06	4.36F± 0.31	4.86C
Product 2		6.75B±0.15	6.03C±0.06	5.59D±0.17	6.12B
Product 3		7.39A±0.28	6.28C±0.19	6.33C±0.17	6.67A
Mean		6.44A	5.78B	5.43C	
Product 1	Vit B2 mg/100g	3.89DE±0.02	3.65E±0.09	3.04F±0.06	3.53C
Product 2		4.70C±0.32	4.15D±0.16	3.97DE±0.05	4.27B
Product 3		7.01A±0.39	5.15B±0.14	4.97BC±0.04	5.71A
Mean		5.20A	4.32B	3.99C	
Product 1	Vit B3 mg/100g	4.76E±0.20	4.77E±0.1	4.12F±0.10	4.55C
Product 2		5.70C±0.10	5.28D±0.06	5.16D±0.11	5.38B
Product 3		7.60A±0.51	6.66B±0.32	6.32B±0.09	6.86A
Mean		6.02A	5.57B	5.20C	
Product 1	Vit B5 mg/g	3.57FG±0.31	3.15H±0.15	3.32GH±0.11	4.550C
Product 2		4.47D± 0.35	3.85EF±0.35	4.04E±0.06	5.385B
Product 3		6.94A±0.10	6.24B±0.20	5.64C±0.21	6.866A
Mean		4.99A	4.41B	4.33B	
Product 1	Vit B6 mg/100g	13.12F±0.06	12.08G±0.07	10.05H±0.03	11.75C
Product 2		15.54D±0.19	14.19E±0.26	10.43H±1.19	13.39B
Product 3		19.66A±0.55	17.27B±0.24	16.41C±0.42	17.78A
Mean		16.111A	14.516B	12.301C	
Product 1	Vit B9 mg/100g	11.84DE±0.07	10.71F±0.51	10.04G±0.33	10.867C
Product 2		13.07C±0.04	12.10D±0.04	12.10D±0.55	12.17B
Product 3		14.88A±0.10	13.76B±0.57	13.47BC± 0.35	14.04A
Mean		13.26A	12.19B	11.62C	
Product 1	Vit A IU	84.83F± 3.61	79.06G± 0.47	76.78G± 1.16	80.22C
Product 2		96.41CD±1.01	92.58 DE±0.81	89.09 E±1.12	92.70 B
Product 3		113.20 A±0.10	100.68B±0.57	99.87BC±0.35	104.58A
Mean		98.14A	90.77B	88.58B	

Product 1	Vit C mg/100g	69.06E±0.88	67.55F±0.41	64.48G±0.72	67.03C
Product 2		74.67B±0.48	72.63C±0.54	70.37D±0.55	72.55B
Product 3		76.19A±0.32	74.54B± 0.67	73.77B±0.55	74.83A
Mean		73.31A	71.57B	69.54C	

Product 1 =10% Pumpkin seed flour,10% Watermelon seed flour, 10% Melon seed flour,35% Soybean seed flour, 35% sunflower seed flour
Product 2 =20% Pumpkin seed flour, 20% Watermelon seed flour, 20% Melon seed flour, 20% Soybean seed flour, 20% sunflower seed flour
Product 3=30% Pumpkin seed flour, 30% Watermelon seed flour, 30% Melon seed flour, 5% Soybean seed flour, 5% sunflower seed flour

3.2. Minerals Content of RUTF

Table 2 exhibited the statistical results of different mineral contents of RUTF. There was a significant difference (P≤0.05) observed within the treatments. The calcium score of RUTF at day 0 of storage varied from 120.08 to 67.56mg/100g. Product 1 had the lowest score of 67.56±1.09 mg, while 120.08±3.58 mg was the highest value recorded. The calcium range of RUTF after 60 days in storage was 103.41-63.83 mg/100g. The lowest score for Product 3 was 63.83±0.53, while the highest value for Product 1 was 103.41±3.46. At 120 days, the calcium range of RUTF was 96.62-63.26 mg/100g. Similar findings were reported by Falade *et al.* in 2020. Product 3 got the lowest score, 63.26±0.75mg, while Product 1 had the highest value, 96.62±2.89mg/100g. Calcium is important for bone health, blood clotting, making milk, and absorbing vitamin D. Deficits in calcium may lead to rickets, osteomalacia, and osteoporosis (Hassan *et al.,* 2007). The range of Cupper in RUTF during the 0 day storage period was 103.14-139.54 mg/100g. Product 1 had the lowest score, while Product 3 gained the highest, at 139.54±0.86. The range after 60 days was 97.47–136.57 mg/100g. At 97.47±0.85 mg, Product 1 got the lowest score, while at 136.57±2.10mg Product 3 had the highest. Following 120 days of storage the RUTF cupper varied from 95.14 to 118.29 mg/100g. Magnesium scores during the zero day of storage varied from 374.77 to 593.10 mg/100g. Magnesium was in accordance with the findings reported by Devi *et al.* (2018a). Product 3 had the maximum score of 593.10±5.07 mg, while Product 1 got the lowest value of 374.77±3.85 mg. after a 60-day storage period. Copper is a necessary cofactor in oxidation-reduction activities that include copper-containing oxidase enzymes, as well as in the production of collagen and the functioning of the immune system (Guo *et al.,* 2013). The range for magnesium was 321.42-543.10 mg/100 g. Product 1 had the lowest score, 321.42±3.76, while Product 1 had the highest score, 543.10±2.97 mg. Results obtained were well correlated with the findings of Egbuonu, (2015). Magnesium levels after 120 days of storage varied from 302.82 to 505.78mg/100g. Phosphorus levels during the zero-day storage period varied from 304.16-423.55 mg/100g. Product 1 got a minimum score of 304.16±4.33mg, while Product 3 exhibited the highest score of 423.55±1.76 mg. The phosphorus content in the stored sample varied from 287.16 to 346.89 mg /100g after 60 days. Product 1 had the lowest score of 287.16±2.67mg, while Product 3 had the highest score of 346.89±4.32mg. After a storage period of 120 days, the concentration of Phosphorus varied from 264.16 to 303.55 mg /100g. The highest score was recorded in Product 3 with a value of 303.55±5.22mg while Product 1 had the lowest value. Day 0 of storage showed a range in the potassium score from 867.5 to 1136.8 mg/100g. These results agreed with the ranges reported by Devi *et al.,* (2018b). The results match the ranges that Devi *et al.* (2018b) reported. Phosphorus is mostly found in the blood and cells, with the majority of non-skeletal phosphorus existing in an inorganic state as nucleic acids, phospholipids, ATP, and sugar phosphate. Phosphates have a crucial function as buffers in maintaining the stability of physiological fluids' acidity by effectively binding with excess hydrogen ions. The presence of phosphorus facilitates the transport of nutrients across the cell membrane (Elinge *et al.,* 2012).

The lowest score for Product 1 was 867.5±3.44mg, and the highest score was 1136.8±2.54mg. After 60 days, the potassium level in the Ready-to-Use Therapeutic Food (RUTF) ranged from 794.8 to 1001.1 mg/100g. At 794.8±1.53 mg, Product 1 had the lowest score, while Product 3 had the highest concentration at 1001.1±1.31 mg. After 120 days in storage, the potassium content of RUTF ranged from 791.5 to 996.7 mg/100g. On the 0 day, the sodium concentration varied from 4.70 to 8.32 mg/100 g. At 794±1.53 mg, product 1 had the lowest score, while at 1001.1±1.31 mg, product 3 received the greatest rating. After being stored for 120 days, the potassium level of RUTF fluctuated between 791.5 and 996.7 mg/100g. RUTF sodium level on the zero day of storage varied from 4.70 to 8.32 mg/100g. Product 1 had the lowest score, while Product 3 got the highest maximum score of 8.32±0.57mg. After being stored for 60 days, the sodium content ranged from 4.04 to 7.12mg/100g. Product 1 had the minimum sodium content, with a range of 4.04±0.03mg, while product 2 had the maximum sodium content, measuring 7.12±0.07mg. After being stored for 120 days, the sodium content of the RUTF ranged from 3.86 to 6.72 mg/100g. In addition, Elinge *et al.,* 2012 reported pumpkin seeds as a rich source of minerals such potassium, sodium, calcium, magnesium phosphorus iron cobalt manganese and zinc.

3.2.1. Zinc content of RUTF

The figure 1 show the analysis of zinc in which average absorbance noted was 0.23260 with a standard deviation (SD) of 0.00398. The relative standard deviation (RSD) was calculated to be 1.7%, reflecting high precision in the absorbance measurement and the showed single absorbance values were 0.23542 and 0.22978. The figure 2 manifest the average absorbance (Abs) was 0.31361 with a standard deviation 0.00284. The led to relative standard deviation (RSD) of 0.9% which was extremely high in terms of absorbance measurement accuracy. The single absorbance values noted for each sample were 0.31160 and 0.31562, with only slight variations between the individual measurements. In the figure 3 the mean Absorption value obtained was 0.58740. The standard deviation (SD) of the absorbance was 0.01223. The Relative standard deviation was calculated to be 2.1% hence moderately precise in the absorbance measurements. The values of the single absorbance were 0.57875 and 0.59604. The statistical result regarding zinc content have been indicate in Table 3 there was a highly significant (P≤0.05) difference observed within the treatments. Zinc content of Product 3 was 812.93A ±4.40mg/100g which was more than the Product 2 which is 583.31B±3.27 mg/100g and 496.27C±1.24 mg/100g. However, the results of present study were found in agreement with the range as reported by Devi *et al.,* (2018).

Table 2: Effect of treatments and days on mean values for minerals of RUTF

Treatment	Vitamins	Days			
		0	60	120	Mean
Product 1	Calcium mg/100g	120.08A±3.58	103.41B±3.46	96.62C±2.89	106.70A
Product 2		93.74C±2.22	91.74C±2.09	94.51C±2.45	93.33B
Product 3		67.56D±1.09	63.83D±0.53	63.26D±0.75	64.88C
Mean		93.790 A	86.324 B	84.797 B	
Product 1	Cupper mg/100g	103.14D±5.33	97.47DE±0.85	95.14E±5.04	98.58C
Product 2		123.28B±0.73	115.54C±3.92	97.87DE±3.69	112.23B
Product 3		139.54A±0.86	136.57A±2.10	118.29BC±1.09	131.46A
Mean		121.99A	116.53B	103.77C	
Product 1	Magnesium mg/100g	374.77G±3.85	321.42H±3.76	302.82I±5.07	333.01C
Product 2		471.46D±4.37	421.45E±6.01	397.56F±5.51	430.15B

Product 3		593.10A±5.07	543.10B±2.97	505.78C±3.28	547.32A
Mean		479.77A	428.66B	402.05C	
Product 1	Phosphorus mg/100g	304.16E±4.33	287.16EF±2.67	264.16F±1.76	285.15B
Product 2		383.11B±5.11	343.1CD±2.67	313.11DE±2.67	346.44A
Product 3		423.55A±1.76	346.89C±4.32	303.55E±5.22	358.00A
Mean		370.27A	325.72B	293.61C	
Product 1	Potassium mg/100g	867.5CD±3.44	794.8EF±1.53	791.5F±4.35	817.9C
Product 2		974.5B±4.86	903.3C±1.30	837.0DE±1.47	905.0B
Product 3		1136.8A±2.54	1001.1B±1.31	996.7B±1.20	1044.9A
Mean		992.95A	899.75B	875.05 B	
Product 1	Sodium mg/100g	4.70D±0.36	4.04E±0.03	3.86F±0.08	4.20C
Product 2		5.87C±0.14	5.33C±0.35	4.62D±0.53	5.27B
Product 3		8.32A±0.57	7.12B±0.07	6.72C±0.09	7.38A
Mean		6.30A	5.49B	5.07C	

Product 1 =10% Pumpkin seed flour,10% Watermelon seed flour, 10% Melon seed flour,35% Soybean seed flour, 35% sunflower seed flour
Product 2 =20% Pumpkin seed flour, 20% Watermelon seed flour, 20% Melon seed flour, 20% Soybean seed flour, 20% sunflower seed flour
Product 3=30% Pumpkin seed flour, 30% Watermelon seed flour, 30% Melon seed flour, 5% Soybean seed flour, 5% sunflower seed flour

Table 3: Mean values for Minerals of RUTF

Treatments	**Minerals mg/100g**	
	Iron	**Zinc**
Product 1	399.59C±0.62	496.27C±1.24
Product 2	473.93B±2.63	583.31B±3.27
Product 3	779.73A±4.64	812.93A±4.40

Product 1 =10% Pumpkin seed flour,10% Watermelon seed flour, 10% Melon seed flour,35% Soybean seed flour, 35% sunflower seed flour
Product 2 =20% Pumpkin seed flour, 20% Watermelon seed flour, 20% Melon seed flour, 20% Soybean seed flour, 20% sunflower seed flour
Product 3=30% Pumpkin seed flour, 30% Watermelon seed flour, 30% Melon seed flour, 5% Soybean seed flour, 5% sunflower seed flour

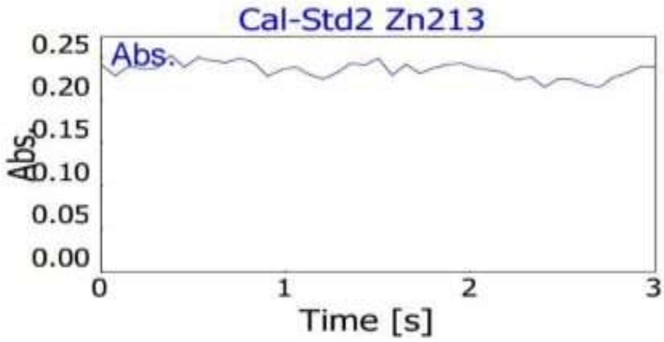

Figure 1: Graphical Absorption of Zinc by AAS for product

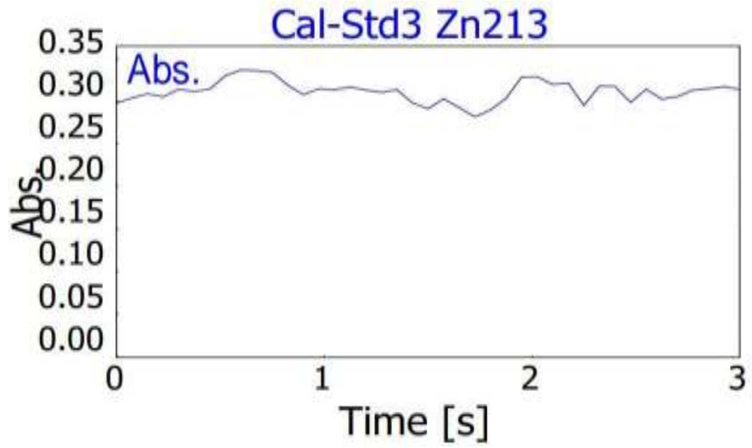

Figure 2: Graphical Absorption of Zinc by AAS for product 2

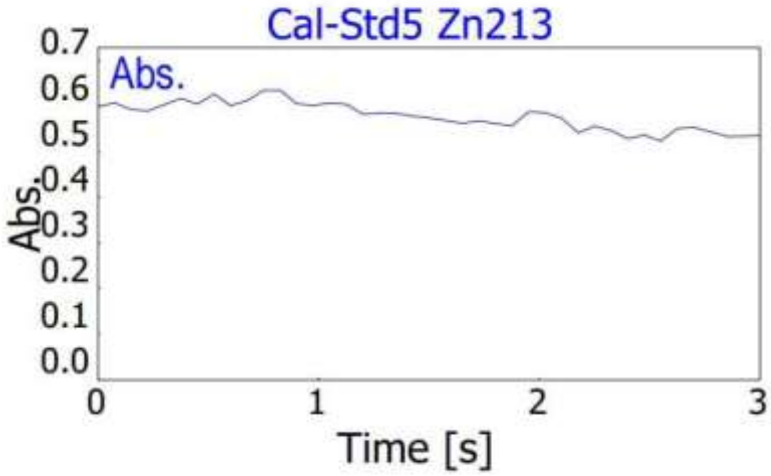

Figure 3: Graphical Absorption of Zinc by AAS for product 3

3.2.2. Iron Content of RUTF

The figure 4 shows the analysis of iron in which relatively standard deviation of 0.5 % for the absorbance specifies a reasonable level of precision. The single absorbance values for the 0.07681 and 0.07733) are close to the average absorbance value of 0.07707. Figure 5 demonstrate the value of absorbance (Abs) noted is 0.14497 with a standard deviation (SD) of 0.00112, and a relative standard deviation (RSD) of 0.8%, which shows that the measurements have high levels of accuracy. The single absorbance values taken were 0.14577 and 0.14418 having almost the same values for the two readings indicating that the method is highly reproducible. Looking at the graph (from 0 to 3 seconds) it can be seen that the method produced consistent measurement values. In the figure 6 the average absorbance (Abs.) was 0.06109 with a very low standard deviation of 0.00043 with the relative standard deviation (RSD) of 0.7%. This small RSD means that the absorbance readings are highly precise and very little. The absorbance for this concentration was as follows individual absorbance 0.06078 and 0.06139 which are quite near to each other. The statistical results regarding iron content have been indicated in Table 6. There was a highly significant difference ($P \leq 0.05$) observed within treatments. The lowest value of iron was indicated in Product 1 (399.59 C±0.62) while Product 2 had (473.93B±2.63) and the highest value of iron was observed in Product 3 (779.73A±4.64). Iron is a vital element for the survival of all living beings. Iron-containing proteins and metabolic pathways are essential for almost all physiological and cellular processes. The wide range of activities and functions of iron, as well as its related diseases, depend on its ability to establish bonds with adjacent ligands and the overall structure of the iron complex in proteins or other biomolecules (Kontoghiorghes *et al.,* 2020).

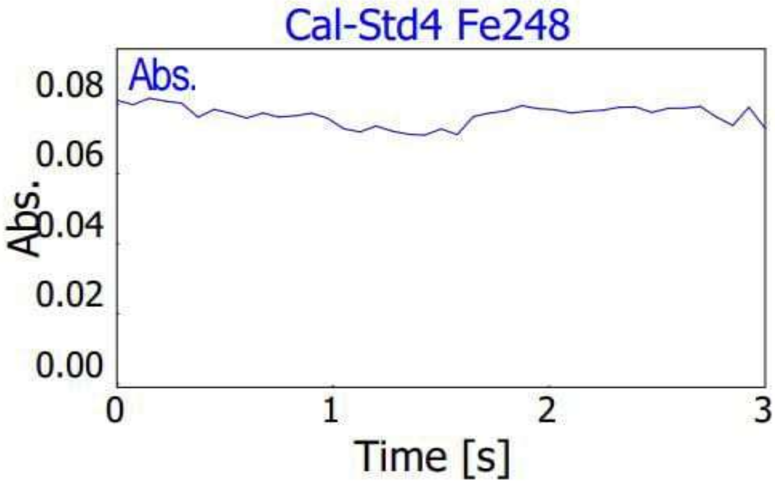

Figure 4: Graphical Absorption of Iron by AAS for product 1

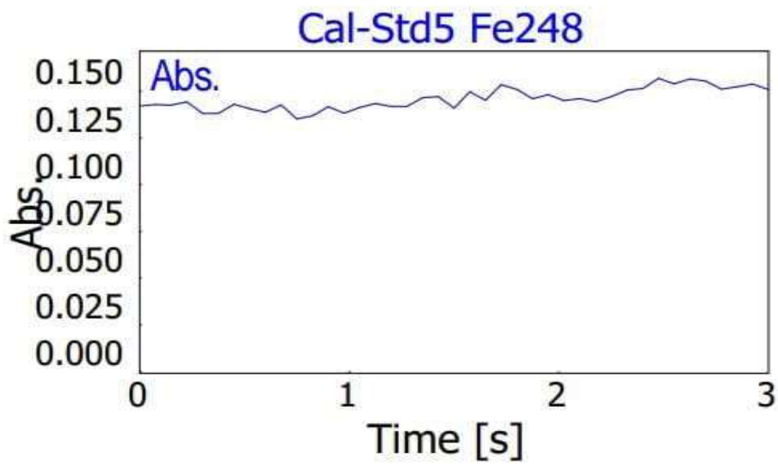

Figure 5: Graphical Absorption of Iron by AAS for product 2

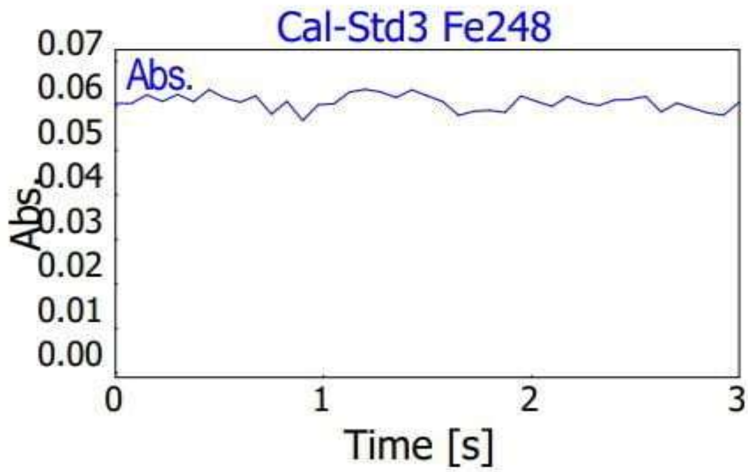

Figure 6: Graphical Absorption of Iron by AAS for product 3

3.2.2. Amino acids of RUTF

The mean values regarding amino acid profiles exhibited in table 4. Statistically, there are significant differences $p \leq 0.05$ between all types' treatments. Meanwhile, Product 3 indicated the highest values for amount of amino acid 10.46±0.13 mg/100g for arginine, 7.08 ±0.40mg/100g for histidine, 12.84±1.21 mg/100g for isoleucine, 17.68±0.59 for leucine, 7.98±0.29 mg/100g for lysine, 7.89 mg/100g for methionine and 3.65 ±0.38 mg/100g for tyrosine. In contrast, Product 1, where the soybean and sunflower seed flours were used in the largest proportions, demonstrated the lowest levels of these amino acids 6.89 ±0.08 mg/100g for arginine, 2.99±0.09 mg/100g for histidine, 4.69 ±0.14 mg/100g for isoleucine, 7.96 ±0.05 mg/100g for leucine, 3.20±0.21 mg/100g for lysine, 3.04 ±0.05 mg/100g for methionine and 2.15±0.11 mg/100g for tyrosine respectively. In addition, a similar pattern was seen for non-essential amino acids. The findings were comparable to the data reported for the protein fractions of pumpkin and watermelon seeds. (Vinayashree *et al.,* 2021).Product 3 had significantly elevated levels of aspartic acid 7.19±0.70 mg/100g, glutamic acid 9.75±0.24 mg/100g, glycine 3.71±0.11 mg/100g, phenylalanine 19.26 ±0.57mg/100g, serine 4.22±0.22mg/100g, threonine 9.40± 0.12 mg/100g), and valine 14.31 ±0.57mg/100g. Product 1 had the lowest values for several amino acids, including 3.61±0.14mg/100g for aspartic acid, 6.78±0.08mg/100g for glutamic acid, 1.96±0.08mg/100g for glycine, 6.88±0.08/100g for phenylalanine, 3.05±0.04mg/100g for serine, 4.22±0.78 mg/100g for threonine, and 9.81±0.07mg/100g for valine. The results of the amino acid content were discovered to be comparable to the previous discoveries documented by Akpabio *et al.* (2008).

Table 4: Mean values for Amino Acids profile of RUTF

Treatment	Arginine	Histidine	Isoleucine	Leucine	lysine	Methionine	Tyrosine
Product 1	6.89C±0.08	2.99B±0.09	4.69B±0.14	7.96B±0.05	3.20C± 0.21	3.04C± 0.05	2.15B± 0.11
Product 2	7.50B±0.47	3.46B±0.26	5.25B±0.11	8.65B±0.20	4.07B± 0.07	3.74B± 0.11	2.57B± 0.24
Product 3	10.46A±0.13	7.08A±0.40	12.84A±1.21	17.68A± 0.59	7.98A± 0.29	7.89A± 0.38	3.65A± 0.37
Treatment	**Aspartic**	**Glutamic**	**Glycine**	**Phenyl**	**Serine**	**Threonine**	**Valine**
Product 1	3.61B±0.14	6.78C±0.08	1.96C± 0.08	6.88B± 0.08	3.05C± 0.04	4.22B± 0.78	9.81C± 0.07
Product 2	4.39B±0.52	7.42B±0.14	2.28B± 0.146	7.25B± 0.23	3.72B± 0.09	8.27A± 0.28	11.47B± 0.52
Product 3	7.19A± 0.70	9.75A±0.24	3.71A± 0.11	19.26A± 0.57	4.22A± 0.22	9.40A± 0.12	14.31A± 0.57

Conclusion

The present study showed that among the tested RUTF formulations, Product 3 prepared from a mixture of indigenous seed flours (pumpkin, watermelon and melon seeds), soybean, and sunflower seeds gives a nutritionally stronger profile. The highest values for heat sensitive vitamins (B_1, B_2, B_3, B_5, B_6, B_9, A, and C) and minerals (Calcium, Magnesium, Potassium, Phosphorus, Sodium and Iron) were constantly noticeable. In comparison to product 1, product 3 showed a considerably higher maximum amount of amino acids, indicating a better nutritional profile. These results indicates that locally manufactured RUTF have the capacity to treat SAM in children feasible and sustainable alternatives to imported ready-to-use therapeutic foods.

Conflict of Interest: The authors declared that there is conflict of interest.

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