Nutritional evaluation and effects of pretreatment methods on *Arachis hypogaea* cultivars for Ready-to-Use Therapeutic Food (RUTF)

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ABSTRACT

Background: *Integrated Community-Based Management of Acute Malnutrition (ICMAM) model, endorsed by World Health Organization (WHO), relies on Ready-to-Use Therapeutic Foods (RUTF) due to their effectiveness in treating severe acute malnutrition (SAM). However, the high cost of imported RUTF, driven by supply chain challenges, restricts accessibility in developing nations. Locally produced RUTF using nutrient-rich leguminous crops like groundnuts presents a cost-effective alternative. Nonetheless, raw groundnuts contain antinutritional factors (ANFs) (phytic acid, tannins, cyanide, and oxalates) that may limit nutrient bioavailability and pose potential health risks.*

Objective: *This study aimed to identify the most nutritionally suitable groundnut cultivar among SAMNUT-23, SAMNUT-24, and SAMNUT-26 sourced from Sokoto, Nigeria, and to evaluate the effects of different pretreatment methods on the selected cultivar's nutritional composition and ANF profile.*

Methodology: *The three cultivars were subjected to proximate and ANF analyses, after which the most nutritionally balanced, underwent ten different pretreatment methods, including soaking, roasting, oven drying, and their combinations.*

Results: *SAMNUT-23 emerged as the most nutritionally balanced, having higher crude protein (35.15%), lipid (23.17%), fibre (0.92%), energy content (489.73 kcal/100g), and lowest ANFs compared to other cultivars. Hot water soaking + roasting of SAMNUT-23 also emerged as the most effective pretreatment method, having significantly enhanced protein content by 24.06% and reduced ANFs, particularly cyanide and tannins.*

Conclusion: *These results support the use of appropriately pretreated SAMNUT-23 groundnuts as a viable, low-cost ingredient for locally produced RUTFs.*

Keywords: *Arachis hypogaea*, Ready-To-Use Therapeutic Food (RUTF), SAMNUT-23, Undernutrition

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INTRODUCTION

Severe Acute Malnutrition (SAM), or wasting, is a condition characterized by insufficient intake of nutrients, energy, or essential micronutrients required for healthy living (1). This imbalance can arise due to reduced nutrient intake, for instance, in situations of food insecurity, or because of increased physiological requirements, for instance, in a disease condition. Poor hygiene and sanitation, lack of education, conflicts, and climate-related events undermine food security and consequently the nutritional status, increasing the rate of wasting. When nutrient intake is inadequate, it can lead to several physiological complications, including stunted growth, depletion of fat and muscle mass, reduction in visceral organs, and decreased overall energy expenditure (2). It may also disrupt hormonal balance, particularly involving thyroid hormones, insulin, and growth hormone (GH), resulting in decreased levels of triiodothyronine (T3), insulin, and insulin-like growth factor-1 (IGF-1), while increasing the levels of GH and cortisol (3). Infants and children aged 6–59 months are considered to suffer from SAM if they have a mid-upper arm circumference (MUAC) <115 mm, or a weight-for-height <–3 Z-score of the WHO growth standards, or have bilateral oedema (4,5).

Globally, undernutrition remains a major public health challenge, with sub-Saharan Africa being one of the most affected regions (6). Among older adults, the global prevalence is approximately 18.6%, with Africa reporting the highest rate at 35.7%, followed by the Americas at 20.3% (7). In children, global undernutrition rates vary widely, ranging from 4.2% to 73.0%, with Asia experiencing the highest rates (8). Nigeria bears a particularly heavy burden, ranking second globally in the number of undernourished children. Nationally, 32% of children under five years are undernourished, with undernutrition contributing to 11% of child mortality (9,10). The northern region of Nigeria is disproportionately affected, especially by severe acute malnutrition (SAM). Between May 2023 and October 2024, an estimated 4.4 million children aged 0–59 months in northwest Nigeria were affected by acute malnutrition. Of these, approximately 1.04 million suffered from SAM and 3.37 million from moderate acute malnutrition (MAM) (9). This crisis poses serious risks to the region's socioeconomic and educational development and places significant strain on the national budget, underscoring the urgent need for effective intervention.

The World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) recommend the Integrated Community-Based Management of Acute Malnutrition (ICMAM) as the standard therapeutic approach (11). This strategy includes the use of Ready-to-Use Therapeutic Food (RUTF), which has proven effective in managing SAM in community settings due to its convenience, stability, and ability to promote rapid recovery (11). RUTF is a high-energy, nutrient-dense food designed specifically to treat SAM, containing a balanced composition of carbohydrates, proteins, lipids, and essential micronutrients (12). However, the high cost of RUTF, driven by factors such as importation, supply chains, and logistics, limits access. In Nigeria, imported RUTF costs around ₦146 per sachet, making it unaffordable for many (13). Encouragingly, locally produced RUTF made from leguminous crops has been shown to be equally effective and significantly cheaper. The cost of producing legume-based RUTF locally ranges between ₦54.17 and ₦56.57 per 100g sachet (13). Therefore, promoting the use of locally produced, legume-based RUTF could enhance access to therapeutic nutrition and reduce the overall burden of undernutrition in the country.

Leguminous crops are a vital and affordable source of plant-based protein, offering a sustainable alternative to animal-derived products. Commonly consumed legumes include cowpeas, soybeans, groundnuts, and Bambara groundnuts (14). Among these, groundnuts (*Arachis hypogaea*), also known as peanuts, are widely used in the formulation of RUTF due to their high caloric density and rich nutritional profile, which includes proteins, healthy fats, vitamins, and essential minerals (15,16). However, raw groundnuts contain antinutritional factors (ANFs) like phytic acid, tannins, cyanide, and oxalates, which can hinder nutrient absorption, reduce palatability, and pose health risks when consumed in excess (17,18). These compounds can interfere with digestion and nutrient bioavailability, potentially leading to issues such as nausea, vomiting, irritable bowel syndrome, and kidney stone formation (19). Fortunately, various food processing methods such as roasting, soaking, boiling, and fermentation have been shown to effectively reduce or eliminate these antinutrients while improving the overall nutritional quality of legumes. However, there remains a gap in comparative research on how different pre-treatment methods affect their nutritional properties, especially in the context of RUTF production. This is particularly relevant in addressing the persistent challenges of malnutrition and food insecurity in northern Nigeria. Therefore, this study aims to identify the most nutritionally suitable groundnut cultivar among SAMNUT-23, SAMNUT-24, and SAMNUT-26, and to evaluate the effects of various pretreatment techniques on the selected cultivar's nutritional composition and antinutritional contents.

MATERIALS AND METHODS

Source of groundnut cultivars

Three freshly harvested groundnut cultivars, SAMNUT-23, SAMNUT-24, and SAMNUT-26, were procured from Sokoto Central Market, Sokoto State, Nigeria, on February 10, 2025. The seeds were identified and authenticated by a botanist at the herbarium of Usmanu Danfodiyo University, Sokoto. Voucher specimens of the authenticated cultivars were documented under the reference number UDUH/ANS/0982 and deposited in the university's herbarium.

Sample preparation and processing

The groundnut seeds (SAMNUT-23, SAMNUT-24, and SAMNUT-26) were sorted and then subjected to proximate composition and antinutritional factors (ANFs) analyses to determine the cultivar with the most favorable nutritional profile and the lowest levels of ANFs. The best-performing cultivar was then subjected to ten (10) different pretreatment methods, including roasting, soaking in various media (10% hot saline, 10% normal saline, distilled water, and hot distilled water), combinations of soaking and roasting, as well as oven drying under controlled conditions (17,20,21). The effects of these treatments on proximate composition and antinutritional factors were assessed to identify the most effective processing method for improving the nutritional quality of groundnuts.

Roasting method

Groundnuts were roasted at 150 °C for 15 minutes in an open pan until the seeds turned golden brown. Roasted groundnut seeds were cooled and stored in an airtight container for further analysis.

Soaking in hot saline and roasting

Ten grams (10 g) of sodium chloride (NaCl) were dissolved in 100 mL of hot distilled water to prepare a 10% NaCl solution. The groundnut seeds were soaked in this hot saline solution and left to stand for 4 hours. After soaking, the excess solution was drained off, and the seeds were roasted at 150 °C until they developed a golden-brown color. The roasted samples were then allowed to cool, properly labeled, and stored in airtight containers for subsequent analysis.

Soaking in normal saline and roasting

Exactly 10 grams of sodium chloride (NaCl) were dissolved in 100 mL of distilled water at room temperature to prepare a 10% NaCl solution. The groundnut seeds were soaked in this solution and left to stand for 4 hours. After soaking, the excess liquid was drained, and the seeds were roasted at 150 °C until they turned golden brown. The roasted samples were then allowed to cool, labeled appropriately, and stored in airtight containers for further analysis.

Soaking in hot distilled water and roasting

Exactly 50 grams of groundnut seeds were soaked in 100 mL of hot distilled water and left to stand for 4 hours. After soaking, the excess water was drained, and the seeds were roasted at 150 °C until they turned golden brown. The roasted samples were then allowed to cool, properly labeled, and stored in airtight containers for further analysis.

Soaking in normal distilled water and roasting

Fifty grams (50 g) of groundnut seeds were soaked in 100 mL of distilled water at room temperature and left to stand for 4 hours. After soaking, the excess water was drained, and the seeds were roasted at 150 °C until they turned golden brown. The roasted samples were then allowed to cool, labeled appropriately, and stored in airtight containers for further analysis.

Soaking in normal saline

Ten grams (10 g) of sodium chloride (NaCl) were dissolved in 100 mL of distilled water to prepare a 10% NaCl solution. The groundnut seeds were soaked in this saline solution and left to stand for 4 hours. After soaking, the excess water was drained, and the seeds were sun-dried. The dried samples were then labeled and stored in airtight containers for further analysis.

Soaking in hot saline

Exactly 10 grams (10 g) of sodium chloride (NaCl) were dissolved in 100 mL of hot distilled water at 60 °C to prepare a 10% NaCl solution. The groundnut seeds were soaked in this hot saline solution and left to stand for 4 hours. After soaking, the excess water was drained, and the seeds were sun-dried. The dried samples were then labeled and stored in airtight containers for further analysis.

Soaking in distilled water

Exactly 50 g of groundnut seed was dissolved in 100 mL of distilled water and allowed to stand for 4 hours. Thereafter, the excess water was strained, and the groundnuts were then sun-dried. The samples were labeled and stored in an airtight container for further analysis.

Soaking in hot distilled water

Fifty grams (50 g) of groundnut seeds were dissolved in 100 mL of distilled water at room temperature and allowed to stand for 4 hours. Then, the excess water was strained, and the groundnuts were sun-dried. The samples were labeled and stored in an airtight container for further analysis.

Oven-drying

The groundnut seeds were oven-dried at 60 °C for 14 hours, then labeled and stored in airtight containers for further analysis.

Proximate composition and antinutritional factors (ANFs) analyses

The proximate composition (moisture content, ash, crude lipid, crude protein, fibre, and carbohydrate) of the samples was determined according to the standard methods of the Association of Official Analytical Chemists (AOAC) (22). Specifically, moisture content was determined by oven drying at 105 °C to constant weight (Method 925.10), ash by dry ashing in a muffle furnance (Gallenkamp, Model OV 880, London, England) at 550 °C (Method 923.03), crude protein by Kjeldahl method using a nitrogen conversion factor of 6.25 (Method 960.52), crude lipid by soxhlet extraction (Method 920.39) and crude fibre by acid-alkali digestion. Carbohydrate content was calculated by difference:

$$Carbohydrate\ (\%) = 100 - (\%\ moisture\ +\ \%\ +\ \%\ protein\ +\ \%\ fat\ +\ \%\ fibre).$$

Energy value (kcal/100g) of the RUTF was estimated using the Atwater general conversion factors of 4:4:9 kcal/100g for available crude protein, carbohydrate, and fat, respectively, as shown in the equation:

$$Energy\ (kcal/100g) = (Carbohydrate\ \times\ 4) + (Protein\ \times\ 4) + (Fat\ \times\ 9)$$

Antinutritional factors (ANFs) analysis was performed following previously reported methods for nitrate, tannins, oxalate, cyanide, and phytate (23). Tannins were quantified using the Flin-Denis method, phytate by the Wade reagent method, oxalate by titration with standard potassium permanganate, cyanide using alkaline picrate colorimetry, and nitrate by spectrophotometric analysis. Absorbance readings were measured using a UV-visible spectrophotometer at appropriate wavelengths.

Data analysis

Data were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test for multiple comparisons. Statistical significance was determined at a 95% confidence level ($p < 0.05$). All analyses were performed using GraphPad Prism version 6.0.

RESULTS

Proximate composition of raw groundnut cultivars

Table 1 shows the proximate composition of the three cultivars of groundnuts. The three cultivars showed significant variations ($p < 0.05$) across all measured parameters. SAMNUT-26 had the highest ash content (1.912 ± 0.008%), followed by SAMNUT-23 (1.805 ± 0.005%), while SAMNUT-24 had the lowest (1.657 ± 0.013%). Moisture content was significantly highest in SAMNUT-24 (3.942 ± 0.008%) and lowest in SAMNUT-26 (2.173 ± 0.008%). Regarding crude lipid content, SAMNUT-23 recorded the highest value (23.172 ± 0.008%), while SAMNUT-24 had the lowest (17.037 ± 0.008%). Crude fibre was also highest in SAMNUT-23 (0.917 ± 0.076%), while SAMNUT-24 (0.562 ± 0.010%) and SAMNUT-26 (0.598 ± 0.013%) had significantly lower but comparable levels. The crude protein content was highest in SAMNUT-23 (35.146 ± 1.101%) and lowest in SAMNUT-24 (30.188 ± 0.438%). Conversely, the carbohydrate content was highest in SAMNUT-24 (46.616 ± 0.045%) and lowest in SAMNUT-23 with 35.149 ± 1.216%. SAMNUT-23 exhibited the highest calorific value (489.728 kcal/100g) while SAMNUT-24 had the lowest (460.549 kcal/100g). Overall, SAMNUT-23 stood out with the highest values for crude lipid, fibre, protein, and caloric content, suggesting its superior nutritive profile compared to the other cultivars.

Anti-nutritional factors in raw groundnut cultivars

Table 2 shows antinutritional factors in the cultivars. The analysis revealed significant differences ($p<0.05$) among the three cultivars in their content of phytate, cyanide, tannins, and nitrate, but not oxalate. SAMNUT-23 recorded the highest value (0.00753 ± 0.00098 mg/g) of oxalate, followed by SAMNUT-24 (0.00651 ± 0.0083 mg/g) and SAMNUT-26 (0.00585 ± 0.00450 mg/g). Phytate content was lowest in SAMNUT-23 (4.64695 ± 0.4225 mg/g) and highest in SAMNUT-26 (10.9837 ± 0.4225 mg/g). SAMNUT-23 had the lowest concentration of cyanide (33.49133 ± 0.9609 mg/g), while SAMNUT-24 showed the highest value (74.8289 ± 0.7793 mg/g). Tannin content was significantly lower in SAMNUT-23 (50.14935 ± 0.322 mg/g), while SAMNUT-24 (80.75117 ± 0.2665 mg/g) and SAMNUT-26 (77.167 ± 5.067 mg/g) had comparably high values. Nitrate content was highest in SAMNUT-23 (13.1313 ± 0.7121 mg/g) and lowest in SAMNUT-26 (3.0303 ± 0.6993 mg/g). Overall, SAMNUT-23 contained the lowest levels of phytate, cyanide, and tannins, but the highest nitrate content.

Table 1: Proximate composition of three cultivars of raw groundnuts

Parameters	SAMNUT-23	SAMNUT-24	SAMNUT-26
Ash (%)	1.805 ± 0.005^{b}	1.657 ± 0.013^{c}	1.912 ± 0.008^{a}
Moisture (%)	3.482 ± 0.018^{b}	3.942 ± 0.008^{a}	2.173 ± 0.008^{c}
Crude lipid (%)	23.172 ± 0.008^{a}	17.037 ± 0.008^{c}	18.59 ± 0.013^{b}
Crude fibre (%)	0.917 ± 0.076^{a}	0.562 ± 0.010^{b}	0.598 ± 0.013^{b}
Crude protein (%)	35.146 ± 1.101^{a}	30.188 ± 0.438^{c}	32.375 ± 0.875^{b}
Crude CHO (%)	35.149 ± 1.216^{c}	46.616 ± 0.045^{a}	44.352 ± 0.850^{b}
Calorie (kcal/100g)	489.728^{a}	460.549^{c}	474.218^{b}

Values are mean ± standard deviation of three replicates. Means with different superscripts within a row differ significantly (p<0.05).

Table 2: Levels of anti-nutritional factors in three cultivars of raw groundnuts

Parameters	SAMNUT-23	SAMNUT-24	SAMNUT-26
Oxalate (mg/g)	0.00753 ± 0.00098^{a}	0.00651 ± 0.0083^{a}	0.00585 ± 0.0045^{a}
Phytate (mg/g)	4.64695 ± 0.4225^{c}	7.32247 ± 0.4878^{b}	10.9837 ± 0.4225^{a}
Cyanide (mg/g)	33.49133 ± 0.9609^{c}	74.8289 ± 0.7793^{a}	60.08426 ± 0.0130^{b}
Tannins (mg/g)	50.14935 ± 0.322^{b}	80.75117 ± 0.2665^{a}	77.167 ± 5.0670^{a}
Nitrate (mg/g)	13.1313 ± 0.7121^{a}	6.6046 ± 0.5864^{b}	3.0303 ± 0.6993^{c}

Values are mean ± standard deviation of three replicates. Means with different superscripts within a row differ significantly (p<0.05).

Effect of pretreatment methods on proximate compositions of SAMNUT-23

SAMNUT-23, having the best proximate composition and lowest antinutritional factors, was selected among the three cultivars and subjected to various pretreatment methods to improve its nutritional qualities. Table 3 shows the effect of different pretreatment methods on the proximate compositions of SAMNUT-23. Significant differences (p<0.05) were observed in all parameters across the different treatment methods. Pretreatment with normal saline soaking (I) recorded the highest ash content at 3.07 ± 0.01%, followed by hot saline + roasting (C) and hot saline soaking (F) treatments at 2.48 ± 0.01% and 2.48 ± 0.03%, respectively. The lowest ash value was observed in the roasting (E) treatment at 0.54 ± 0.013%. Hot saline soaking (F) produced the highest moisture at 5.76 ± 0.01%, followed by hot water soaking (A) at 4.70 ± 0.08%. The lowest moisture content was observed in oven dry (G) at 0.17 ± 0.02%, indicating that drying significantly reduced water content. Hot saline + roasting (C) had the highest crude lipid content (29.03 ± 0.01%), followed by roasting (E) and normal water + roasting (J) at 22.72 ± 0.01% and 22.60 ± 0.16%, respectively. The lowest lipid content (11.13 ± 0.01%) was produced by hot water soaking (A). Crude fibre content showed minimal variation across treatment methods, ranging from 1.01 ± 0.06% in oven dry (G) to 1.06 ± 0.01% in most other treatment methods, indicating pretreatment had little effect on fibre content. The highest protein content was produced under hot water soaking (A) and hot water + roasting (H) treatments, both producing 24.06%, while the lowest (4.96 ± 0.67%) was produced by the oven dry (G) method. This suggests that soaking and roasting may help preserve or enhance protein content. Carbohydrate content was highest (77.08 ± 0.68%) under the oven dry (G) method, followed by normal water + roasting (J) and roasting (E) methods at 66.90 ± 0.76% and 66.10 ± 0.87%, respectively. The lowest value (48.27 ± 0.53%) was recorded under the hot water + roasting (H) method. Caloric value (energy content) was highest (522.07 kcal/100g) under hot saline + roasting (C) treatment, followed by roasting (E) at 503.88 kcal/100g and normal water + roasting (J) at 500.76 kcal/100g. The lowest caloric value (420.39 kcal/100g) was produced by normal saline soaking (I).

Table 3: Proximate composition of SAMNUT-23 subjected to different pretreatment methods

Pretreatment methods	Parameters Ash (%)	Moisture (%)	Crude lipid (%)	Crude fibre (%)	Crude protein (%)	Crude CHO (%)	Calorie (kcal/100g)
A	2.02±0.22^{c}	4.70±0.08^{b}	11.13±0.01^{h}	1.06±0.01^{a}	24.06±0.09^{a}	57.03±1.04^{d}	424.53^{i}
B	1.64±0.02^{d}	1.66±0.00^{f}	15.74±0.01^{f}	1.06±0.01^{a}	14.00±0.09^{c}	65.92±0.88^{b}	461.34^{g}
C	2.48±0.01^{b}	2.25±0.02^{e}	29.03±0.01^{a}	1.05±0.01^{a}	7.00±0.88^{de}	58.20±0.88^{d}	522.07^{a}
D	2.29±0.01^{b}	2.98±0.08^{c}	21.38±0.03^{d}	1.06±0.01^{a}	7.88±0.09^{d}	64.42±0.88^{b}	481.62^{e}
E	0.54±0.01^{e}	0.08±0.01^{g}	22.72±0.01^{b}	1.05±0.01^{a}	8.75±0.88^{d}	66.10±0.87^{b}	503.88^{b}
F	2.48±0.03^{b}	5.76±0.01^{a}	18.28±0.01^{e}	1.04±0.01^{a}	8.75±0.87^{d}	63.72±0.86^{bc}	454.40^{h}
G	1.69±0.02^{d}	0.17±0.02^{i}	15.10±0.01^{g}	1.01±0.06^{a}	4.96±0.67^{e}	77.08±0.68^{a}	464.06^{f}
H	1.52±0.00^{d}	2.45±0.01^{d}	21.98±0.05^{c}	1.05±0.01^{a}	24.06±0.88^{a}	48.27±0.53^{e}	487.14^{d}
I	3.07±0.01^{a}	4.64±0.02^{b}	11.07±0.04^{g}	1.04±0.01^{a}	18.81±0.88^{b}	61.38±0.90^{c}	420.39^{i}
J	1.97±0.01^{c}	0.27±0.01^{h}	22.60±0.16^{b}	1.05±0.01^{a}	7.44±0.88^{d}	66.90±0.76^{b}	500.76^{c}

Values are mean ± standard deviation of three replicates. Means with different superscripts within a column differ significantly ($p<0.05$).
Keys: A: Hot water soaking; B: Normal water soaking; C: Hot saline + roasting; D: Normal saline + roasting; E: Roasting; F: Hot saline soaking; G: Oven dry; H: Hot water + roasting; I: Normal saline soaking; J: Normal water + roasting.

Effect of pretreatment methods on anti-nutritional factors in SAMNUT-23

Table 4 shows the effect of different pretreatment methods on antinutritional factors in SAMNUT-23. The anti-nutritional factors were significantly ($p<0.05$) influenced by various pretreatment methods. The lowest oxalate concentration (0.0009 ± 0.0005 mg/g) was observed under normal water soaking, while normal water + roasting produced the highest (0.0053 ± 0.0007 mg/g). Normal saline + roasting and hot saline soaking produced the lowest phytate levels at 1.2674 ± 0.4225 mg/g, while normal water + roasting produced the highest (6.1616 ± 2.268 mg/g). Normal water soaking produced the highest cyanide levels at 125.4810 ± 0.0481 mg/g, while hot water + roasting recorded the lowest value (2.4103 ± 0.2777 mg/g). Hot water soaking produced the lowest concentration (13.6347 ± 0.0577 mg/g) of tannin, while the highest value (51.6247 ± 0.2527 mg/g) was produced by normal saline soaking. Hot saline soaking produced the highest nitrate content at 114.5266 ± 0.4492 mg/g, followed by oven dry at 109.079 ± 0.0225 mg/g and hot water + roasting at 108.6900 ± 0.8102 mg/g, and the lowest value was recorded by hot water soaking at 89.8830 ± 0.3890 mg/g.

Table 4: Levels of anti-nutritional factors in SAMNUT-23 subjected to different pretreatment methods

Pretreatment methods	Anti-nutritional factors Oxalate (mg/g)	Phytate (mg/g)	Cyanide (mg/g)	Tannins (mg/g)	Nitrate (mg/g)
A	0.0014±0.0005^{ce}	3.3796±0.4225^{bc}	32.2117±0.4805^{c}	13.6347±0.0577^{h}	89.8830±0.3890^{e}
B	0.0009±0.0005^{e}	2.5347±0.4225^{bc}	125.4810±0.0481^{a}	30.9443±0.6861^{c}	98.8330±0.3890^{d}
C	0.0015±0.0007^{cde}	2.5347±0.4225^{bc}	56.249±0.9635^{b}	27.2697±0.2898^{de}	88.9753±0.8098^{e}
D	0.0014±0.0005^{cde}	1.2674±0.4225^{c}	15.2243±0.7343^{f}	30.9487±0.9482^{c}	90.2720±0.3890^{e}
E	0.0018±0.0005^{bcde}	2.2531±0.6453^{bc}	11.2177±1.0010^{f}	26.3316±0.2657^{e}	100.0000±3.0390^{cd}
F	0.0027±0.0005^{bcd}	1.2674±0.4225^{c}	27.7243±0.7343^{d}	18.3917±0.1005^{g}	114.5266±0.4492^{a}
G	0.0027±0.0005^{bcd}	2.1123±0.4225^{bc}	22.1153±0.4805^{e}	40.0330±1.1910^{b}	109.079±0.0225^{b}
H	0.0030±0.0007^{bd}	2.1123±0.4225^{bc}	2.4103±0.2777^{g}	21.8090±0.6271^{f}	108.6900±0.8102^{b}
I	0.0032±0.0005^{b}	3.8021±0.4225^{ab}	57.6923±0.4805^{b}	51.6247±0.2527^{a}	107.7820±0.3890^{b}
J	0.0053±0.0007^{a}	6.1616±2.2680^{a}	34.4553±4.3090^{c}	28.3420±0.2653^{d}	101.9453±0.3890^{c}

Values are mean ± standard deviation of three replicates. Means with different superscripts within a column differ significantly ($p<0.05$).
Keys: A: Hot water soaking; B: Normal water soaking; C: Hot saline + roasting; D: Normal saline + roasting; E: Roasting; F: Hot saline soaking; G: Oven dry; H: Hot water + roasting; I: Normal saline soaking; J: Normal water + roasting.

DISCUSSION

The present study commenced with a comparative evaluation of three raw groundnut cultivars (SAMNUT-23, SAMNUT-24, and SAMNUT-26) to determine the most nutritionally viable sample for subsequent food applications. SAMNUT-23 exhibited superior nutritional qualities, with significantly higher crude protein (35.15%), lipid (23.17%), fibre (0.92%), and energy content

(489.73 kcal/100g) compared to the other cultivars. These attributes are crucial for nutrient-dense food formulations and are consistent with previous reports of comparable advantages in protein and lipid values for SAMNUT-23 (24,25). In contrast, SAMNUT-24, despite its highest carbohydrate content (46.62%), displayed the lowest protein, lipid, and fibre values, making it less ideal for protein-energy-based interventions. SAMNUT-26 presented intermediate values but recorded the highest phytate content (10.98 mg/g), a known inhibitor of mineral bioavailability (26).

The assessment of antinutritional factors further supported the selection of SAMNUT-23. It had the lowest levels of phytate (4.65 mg/g), cyanide (33.49 mg/g), and tannins (50.15 mg/g). Although its nitrate content (13.13 mg/g) was relatively higher, it remained within acceptable dietary limits (27). These findings suggest that SAMNUT-23 offers an optimal balance of high nutritional content and a low antinutrient burden, justifying its selection as the candidate for subsequent optimization.

Legumes are primarily subjected to various processing methods to enhance their utilization by consumers. As characteristic of legumes, they possess hard and fairly brittle cellular arrangements that bar the entry of water and other tenderizers in most cases (28). When this barrier is broken, there is disruption of these interlinkages, and hence, vital nutritional components present in the seeds tend to be favored by getting increased or decreased in the process (28). To improve the nutritional safety and functional value of SAMNUT-23, various pretreatment methods were evaluated. Among these, the method combining hot water soaking and roasting yielded the most effective in maintaining a balanced nutritional profile. It preserved a high protein content (24.06%), retained acceptable levels of lipid (21.98%), and caloric content (487.14 kcal/100g). In contrast, oven drying produced the highest carbohydrate level but had drastically reduced protein content (4.96%), limiting its value in nutrition-sensitive interventions. Similarly, hot saline + roasting yielded the highest fat (29.03%) and caloric content (522.07 kcal/100g), but at the cost of a sharp drop in protein content (7.00%). These nutrient variations can be attributed to water leaching and thermal degradation, as previously described (14,29). These findings also align with previous studies showing that the nature and intensity of thermal and hydration treatments significantly impact nutrient retention in legumes (20,24,30). Notably, hot water + roasting provided a balance of high protein, acceptable lipid, and moderate energy, making it the most suitable for therapeutic food production. It also indicates that groundnut is a good source of protein and can improve the nutrition status of humans.

The amount of crude fiber reported for this study ranged from 1.01 to 1.05% with no significant effects been observed among the different processing techniques. The results obtained in this study were within the range of 1.98–7.22%, as previously estimated (31). Importantly, the smaller levels of dietary fiber are desired because non-digestible dietary fiber can attach to minerals and provide a physical border to digestive enzymes, and maintain internal distention for a normal peristaltic movement of the intestinal tract (32). Diets that are low in crude fiber are undesirable because it can lead to constipation and such diets have link with diseases of colon like piles, appendicitis and cancer (33). Therefore, it would be prudent to process groundnut seeds in an attempt to reduce the fiber content. Additionally, pretreatments affected moisture and ash contents, both of which are essential indicators of shelf stability and mineral content. Moisture contents below 12% enhance shelf life and reduce microbial susceptibility (34,35). Most pretreatments, especially those involving roasting, resulted in reduced moisture levels, consistent with shelf-stable requirements (36). Furthermore, ash content was notably higher in samples treated with normal saline soaking, suggesting enhanced mineral retention, in line with the findings of (24).

Anti-nutritional factors are mostly deemed negative constituents when they are up to the levels that inhibit the metabolic activities of living systems (24). Anti-nutritional factors are reduced in foods by pretreating them (37,38). Evaluation of the impact of pretreatment methods on antinutritional factors revealed that hot water + roasting significantly lowered phytate, cyanide, tannins, and oxalate contents. Phytate, a known chelator of Zn^{2+}, Ca^{2+}, and Fe^{2+}, was effectively reduced to levels far below the safe limit of 301 mg/100g reported by (39), enhancing mineral bioavailability. While low phytate levels can have health benefits such as antioxidant and cholesterol-lowering benefits (40,41,42), excessive levels, as seen in SAMNUT-26, compromise nutritional quality. Similarly, tannins were significantly reduced, enhancing protein digestibility. These results align with previous observations of similar reductions in climbing beans through thermal and aqueous treatments (26). The loss of tannins during the pretreatments was probably due to the leaching of the tannins in soaking and heating (roasting). Trace amounts of oxalates and cyanide found in the treated samples remained within safe limits, confirming the effectiveness of the processing steps. The lethal level for cyanogenic glycoside has been reported to be 50-60 mg/kg (27). In their work on the chemical composition of two cultivars of *Arachis hypogaea*, only trace amounts of cyanogenic glycoside and nitrate were detected (27).

CONCLUSION

The results revealed that SAMNUT-23 had the highest values of crude lipid, fibre, protein, and calories, and the lowest levels of antinutritional factors, including phytate, cyanide, and tannins, but the highest nitrate content. This suggests the superior nutritive profile of SAMNUT-23 over other cultivars. Among all pretreatment methods, hot water soaking combined with roasting emerged as the most effective and practical method for enhancing the nutritional value and safety of groundnuts, particularly SAMNUT-23. This information is important in the production of ready-to-use therapeutic foods. It is therefore recommended that the pretreatment method using hot water soaking followed by roasting should be adopted as a standard groundnut treatment prior to consumption or therapeutic and supplementary food formulations. However, further studies should be conducted to determine its shelf stability, antioxidant properties, mineral and heavy metal constituents, and vitamin profiles in order to further ascertain its full nutritional properties and safety prior to use in the formulation of RUTF.

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