

PROXIMATE COMPOSITION AND PHYSICOCHEMICAL QUALITY OF A FORMULATED PLANT-BASED READY- TO-USE SUPPLEMENTARY FOOD (RUSF) COOKIES TO ADDRESS NUTRIENT DEFICIENCIES IN MODERATE ACUTE MALNUTRITION (MAM), CONVALESCENCE AND GENERAL HEALTH MAINTENANCE

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ABSTRACT: Moderate Acute Malnutrition (MAM) remains a critical public health burden in Nigeria, exacerbated by the high cost, dairy-dependence, and limited cultural acceptability of many imported Ready-to-Use Supplementary Foods (RUSF). Leveraging locally available, nutrient-dense plant ingredients offers a promising strategy for developing sustainable and acceptable nutritional interventions. This study aimed to formulate a plant-based RUSF in a cookie format using indigenous Nigerian ingredients and evaluate its proximate composition and physicochemical quality against international standards. Two cookie formulations (FPP A for MAM/convalescence; FPP B for general

health) were developed using a composite flour of oat, sesame, and baobab, supplemented with pumpkin seed flour, peanut butter, sunflower oil, coconut milk, date syrup, and lemon. Proximate composition was determined using standard AOAC methods. The quality of extracted sunflower oil was assessed via acid value, peroxide value, free fatty acids, and iodine value. Results were benchmarked against Codex Alimentarius standards and a commercial RUSF. The formulated RUSF cookie (FPP A) yielded an energy density of 526.32 kcal/100g, statistically equivalent to the commercial control (518.99 kcal/100g) and meeting the RUSF energy standard (510-560 kcal/100g). Fat content (37.75%) was similar to the control (35.10%) and supported the high energy density. Similarly, the protein content (11.07%) was within the range of RUSF standard (11-16%). The extracted sunflower oil showed excellent oxidative stability (Peroxide Value: 3.65 meq O₂/kg) but was at the permissible limit for hydrolytic rancidity (Acid Value: 0.60 mg KOH/g). All products exhibited low moisture content (<8.71%), crucial for shelf-stability. The plant-based cookie successfully met the key energy requirement for a RUSF, demonstrating the viability of using local ingredients to create a nutritious, shelf-stable supplement. The slight protein deficit identifies an area for future optimization, but the formulation presents a significant step towards an affordable, culturally appropriate, and locally sustainable solution for managing MAM in Nigeria.

Keywords: *Moderate Acute Malnutrition, Ready-to-Use Supplementary Food, Plant-based, Cookie, Proximate Composition, Local Ingredients, Nigeria.*

INTRODUCTION

Moderate Acute Malnutrition (MAM), defined by a weight-for-height Z-score between -2 and -3 standard deviations or a mid-upper arm circumference (MUAC) of 115-125mm, affects millions of children globally, with a disproportionate burden in sub-Saharan Africa (WHO, 2020). In Nigeria, the National Demographic and Health Survey (NDHS, 2021) reveals that 7% of children under five are wasted, a condition that significantly increases the risk of mortality, morbidity, and impaired cognitive development. The management of MAM is critical not only for saving lives but also for preventing its progression to Severe Acute Malnutrition (SAM) and breaking the intergenerational cycle of poverty and poor health. The World Health Organization (WHO) endorses the community-based management of acute malnutrition (CMAM), wherein Ready-to-Use Supplementary Foods

(RUSF) play a pivotal role (WHO, 2020). RUSFs are energy-dense, lipid-based food designed to be consumed without cooking, providing a targeted nutritional intervention for children with MAM over a 2–3-month period (Goal Global, 2023).

Despite their proven efficacy, significant barriers impede the widespread and sustainable use of RUSFs in Nigeria. Firstly, many existing RUSF products are imported, leading to high costs, supply chain dependencies, and limited affordability for government programs and vulnerable households (Ogunlade et al., 2023). Secondly, the standard formulation of many RUSFs relies on dairy ingredients, which are expensive, prone to spoilage in tropical climates without a cold chain, and culturally unsuitable for some populations, particularly in Northern Nigeria where dairy consumption is less common. Thirdly, the paste-like consistency of traditional RUSFs is sometimes met with low acceptability by children and caregivers who are accustomed to solid or semi-solid foods (Lazzerini et al., 2020). To address these challenges, there is a growing impetus to develop RUSFs using locally available, plant-based ingredients (Bahwere, 2021). Nigeria is endowed with a rich diversity of underutilized crops that are nutritionally dense and culturally familiar. Ingredients such as pumpkin seeds (*Cucurbita pepo*) are an excellent source of protein and zinc; groundnuts (*Arachis hypogaea*) provide high-quality protein and healthy fats; and baobab leaves (*Adansonia digitata*) are rich in calcium, iron, and vitamin C. Combining these ingredients through appropriate food processing techniques can create a synergistic blend that meets nutritional requirements (Sani et al., 2022).

Transforming this blend into a familiar food format, such as a cookie, presents a strategic advantage. Cookies are a widely accepted snack across all demographic groups in Nigeria. Their solid form is culturally aligned with local eating habits, requires no additional preparation, and allows for precise portion control. Furthermore, the baking process inherently reduces moisture content and water activity, thereby enhancing shelf-stability without the need for chemical preservatives (Olagunju & Arigbede, 2021).

Therefore, this study was aimed to bridge the gap between the pressing need for effective MAM interventions and the limitations of current RUSF products. The specific objectives were to: (1) formulate a nutrient-dense, plant-based RUSF cookie using a scientifically designed composite of locally sourced Nigerian ingredients; (2) comprehensively analyze its proximate composition (moisture, protein, fat, ash, fiber, carbohydrates, and energy)

and key physicochemical properties of its constituent oil; and (3) benchmark its nutritional profile against international RUSF standards and a commercially available RUSF product. The ultimate goal is to contribute to the development of a sustainable, acceptable, and effective local solution for combating childhood malnutrition in Nigeria.

MATERIALS AND METHODS

Raw Materials and Sourcing

All plant materials were procured from local markets in Abuja, Nigeria. A taxonomist at the National Institute for Pharmaceutical Research and Development (NIPRD), Abuja, authenticated all botanical specimens. Voucher numbers were deposited in the NIPRD Herbarium (Table 1). This step ensures the scientific validity and reproducibility of the ingredient base.

Table 1. Authentication of Plant Materials

Common Name	Scientific Name	Family	Voucher Specimen No.
Oat	<i>Avena sativa</i>	Poaceae	NIPRD/H/7458
Sesame Seed	<i>Sesamum indicum</i>	Pedaliaceae	NIPRD/H/7457
Baobab Leaf	<i>Adansonia digitata</i>	Bombacaceae	NIPRD/H/7462
Pumpkin Seed	<i>Cucurbita pepo</i>	Cucurbitaceae	NIPRD/H/7460
Groundnut	<i>Arachis hypogaea</i>	Fabaceae	NIPRD/H/7465
Date	<i>Phoenix dactylifera</i>	Palmaceae	NIPRD/H/7464
Sunflower Seed	<i>Helianthus annuus</i>	Asteraceae	NIPRD/H/7459
Coconut	<i>Cocos nucifera</i>	Palmaceae	NIPRD/H/7463
Lemon	<i>Citrus limon</i>	Rutaceae	NIPRD/H/7466

Ingredient Processing and Flour Formulation

A systematic approach was employed to ensure safety, functionality, and nutrient retention:

Heat Stabilization & Roasting: Rolled Oats were roasted at 120°C for 10 minutes to inactivate lipase and prevent rancidity. Pumpkin seeds, groundnuts, and sesame seeds were dry-roasted at 160°C for 10-15 minutes in a conventional oven (Model: MAXI 60X90) to develop flavor, reduce anti-nutritional factors, and improve microbiological safety.

Soaking and Blanching: Pumpkin seeds were soaked for 8 hours and Baobab leaves were blanched at 85 °C for 2 minutes to reduce antinutrients.

Drying: Baobab leaves were dried using a dehydrator at 45°C for approximately 8 hours to preserve heat-labile nutrients like vitamin C.

Milling and Particle Size Reduction: All roasted seeds and dried materials were milled using a high-speed blender (Buchy mix turbocrush BX250) and subsequently sieved through a 0.045 mm (325 mesh) stainless steel sieve to achieve a uniform fine flour. This fine particle size is critical for ensuring a smooth texture and high digestibility, especially for malnourished individuals with sensitive guts.

Composite Flour Blending: Two distinct composite flours, OSB-1 and OSB-2, were formulated to serve as the functional base for the cookies, with varying ratios of Oat, Sesame, and Baobab to create different nutritional profiles (Table 2).

Table 2. Formulation of OSB Composite Flours (g/100g)

Ingredient	OSB-1	OSB-2	Primary Nutritional/Functional Role
Oat Flour	50	70	β-glucan (soluble fiber), complex carbohydrates.
Sesame Seed Flour	30	20	Calcium, iron, zinc, lignans (antioxidants), protein
Baobab Leaf Powder	20	10	Vitamin C, calcium, iron, polyphenols, prebiotic fiber

Cookie Dough Formulation and Baking

Three cookie formulations were developed (Table 3). FPP A was designed as a high-energy RUSF for MAM and convalescence. FPP B was formulated for general health maintenance with a higher fiber and carbohydrate content. A commercial RUSF served as the control (Sample 3). The dough was prepared by creaming the fat-based ingredients (peanut butter, sunflower oil, coconut milk) with the date syrup and lemon juice, followed by the gradual incorporation of the dry composite flours and pumpkin seed flour. The dough was sheeted to a uniform thickness, cut into 75g portions using a cookie cutter, and baked at 160°C for 15 minutes in a pre-heated oven. This time-temperature combination was optimized to ensure sufficient cooking while minimizing nutrient degradation. The

baked cookies were cooled to ambient temperature and packaged in airtight aluminum foil ziplock bags for analysis.

Table 3. Formulation of Plant-Based RUSF Cookies (g/100g)

Ingredient	FPP A (MAM/Convalescence)	FPP B (Health Maintenance)	Control (Sample 3)
OSB-1 Flour	20	-	-
OSB-2 Flour	-	40	-
Pumpkin Seed Flour	30	10	-
Peanut Butter	20	20	-
Sunflower Oil	8	8	-
Coconut Milk	5	5	-
Date Syrup	15	15	-
Lemon Juice/Zest	2	2	-
<i>Commercial RUSF</i>	-	-	100

Proximate Composition Analysis

Proximate analysis was performed on the individual ingredients, composite flours, and final cookie products in triplicate at the Chemistry Advanced Research Centre, Sheda Science and Technology Complex, Abuja, following the official methods of the Association of Official Analytical Chemists (AOAC, 2019).

Moisture Content: Determined by gravimetric method (AOAC 925.10) by drying 2g of sample at 105°C to constant weight.

Ash Content: Determined by incineration in a muffle furnace (Carbolite Gero ELF) at 550°C for 5 hours (AOAC 923.03).

Crude Protein: Determined by the Micro-Kjeldahl method (AOC, 1990). A nitrogen conversion factor of 6.25 was used to calculate crude protein content.

Crude Lipid: Determined by continuous solvent extraction using petroleum ether (40-60°C) in a Soxhlet apparatus for 5 hours (AOAC 920.39).

Crude Fiber: Determined by the sequential acid and alkali digestion method (AOAC 978.10).

Total Carbohydrates: Calculated by difference: $100 - (\% \text{Moisture} + \% \text{Protein} + \% \text{Fat} + \% \text{Ash} + \% \text{Fiber})$.

Energy: Calculated using the Atwater specific energy factors: $\text{Energy (kcal/100g)} = (\text{Protein} \times 4) + (\text{Fat} \times 9) + (\text{Carbohydrates} \times 4)$.

2.5. Sunflower Oil Quality Analysis

The quality of the locally extracted sunflower oil was assessed to ensure its stability and suitability for the product.

Acid Value (AV) & Free Fatty Acids (FFA): Determined by titrimetric method (AOAC, 1990), indicating hydrolytic rancidity.

Peroxide Value (PV): Measured primary oxidation products (Ranken, 1988).

Saponification Value (SV): Indicated the average molecular weight of the fatty acids (AOAC, 1990).

Iodine Value (IV): Determined the degree of unsaturation (AOAC, 1990).

Statistical Analysis

All analyses were conducted in triplicate. Data were expressed as mean $\pm$ standard error of the mean (SEM). One-way analysis of variance (ANOVA) was performed using SPSS Statistics Version 28. Where significant differences were found ($p < 0.05$), LSD post-hoc test was used for mean separation.

RESULTS AND DISCUSSION

Proximate Composition of the individual ingredients analysed

In the current study (table 1), there is a significant variation in the proximate composition of the analysed ingredients which reflect their distinct and complementary roles in human

nutrition. These analyses are critical for strategic food formulation, particularly in developing nutrient-dense food products tailored to address specific dietary needs in regions like Nigeria. The high crude protein content in pumpkin seed (32.49 %) indicated that it has a high plant-based protein source. This finding corroborates with global research; for instance, Badoe et al. (2023) identified pumpkin seeds as an underutilised protein resource with a complete essential amino acid profile. This result is also in concordance with a research conducted on Nigerian pumpkin seed such as that of Aletor et al., (2002), which reported similar high protein values for fluted pumpkin (*Telfairia occidentalis*), highlighting its traditional importance and nutritional potential. The protein values for peanut butter (27.47%) and sesame seed (22.64%) are consistent with the ranges (22-30% and 17-25% respectively) reported for Nigerian varieties by Gullón et al. (2020) and Adeola and Oyewole (2016). The high fat content and energy value of these oilseeds make them ideal candidates for combating Protein-Energy Malnutrition (PEM). This supports the work of Storz and Will (2021), who emphasised the need for energy-dense ready-to-use therapeutic foods (RUTFs) and the potential of locally sourced ingredients, in their production.

The predominant carbohydrate content in Date (71.99%) and Baobab (64.08%) proves their traditional use as energy-giving foods. This is in line with the work of Maqsood et al. (2020) who characterised dates as a source of simple sugars (fructose and glucose), providing rapid energy release. The high fibre in Baobab (14.09 %) is well-documented. Ibrahim and Mena (2021) reviewed the composition of Baobab pulp, confirming its high fibre content and prebiotic potential, which is crucial for digestive health and metabolic regulation. The high ash content in Sesame Seed (6.83%) and Baobab (6.54 %) is a strong proxy for high mineral density.

The low moisture content of Sesame Seed (2.23%) is ideal for storage in tropical climates, reducing the risk of microbial spoilage and lipid oxidation. Conversely, the high moisture in Date syrup (20.25%) necessitates processing for stability. Silva et al., (2020) reported how dehydration techniques are critical for preserving high-moisture fruits. In a Nigerian context, this highlights the importance of adopting and improving traditional sun-drying and modern dehydration techniques to reduce post-harvest losses, a significant challenge for the agricultural sector.

Overview of Quality Assessment

The quality of edible oils (table 2) is paramount for ensuring safety, stability, and consumer acceptability. The current study analysed the sunflower oil sample against the international benchmark of the Codex Alimentarius Standard (Codex Stan 210-2015) which provides a critical evaluation of its suitability for consumption and its oxidative status. The results present a mixed profile; the oil demonstrates excellent stability in terms of primary oxidation but is at the critical threshold for hydrolytic rancidity. The Acid Value and its direct correlate, Free Fatty Acid (FFA) content, are primary indicators of hydrolytic rancidity, resulting from the breakdown of triglycerides into free fatty acids.

The finding that both the AV and FFA values are exactly at the maximum permissible Codex limit is highly significant. It suggests that the oil has undergone some degree of hydrolysis. This could be due to several factors as explained by Adejumo et al. (2020) relating to the quality of the sunflower seeds and the efficiency of the refining process, such as seeds that are damaged, stored in high-humidity conditions, or contaminated with moulds (which produce lipases) prior to crushing will yield oil with a higher FFA (Adejumo et al., 2020). Crude oils have high FFA and must be neutralised (refined) to reduce this value. An FFA value at the limit suggests the refining process was only marginally sufficient to meet the minimum standard. Khatoon & Reddy (2021) emphasise that effective neutralization is crucial not only for taste but also because FFAs act as pro-oxidants, accelerating the oxidation of the oil. In contrast to the FFA results, the Peroxide Value (PV) is exceptionally low and well within the Codex limit. The PV measures primary oxidation products (hydroperoxides), and a low value indicates that the oil is fresh and has not been significantly exposed to pro-oxidants like oxygen, light, or metal ions since production (Shahidi & Zhong, 2020).

The Iodine Value (IV) and Saponification Value (SV) provide insights into the fatty acid composition and purity of the oil. The IV, which measures the degree of unsaturation, was slightly above the Codex typical value. This minor deviation is not a cause for concern regarding safety but could reflect natural variation in the sunflower cultivar grown, the climate, or the soil conditions (Olanrewaju et al., 2022). It confirms the oil is high in polyunsaturated fatty acids (PUFAs), particularly linoleic acid, which is characteristic of sunflower oil. In contrast to the FFA results, the Peroxide Value (PV) is exceptionally low

and well within the Codex limit. The PV measures primary oxidation products (hydroperoxides), and a low value indicates that the oil is fresh and has not been significantly exposed to pro-oxidants like oxygen, light, or metal ions since production (Shahidi & Zhong, 2020). This dissociation between FFA (high) and PV (low) suggests that the hydrolysis likely occurred before or during the extraction process, but that the subsequent handling, storage, and packaging have been effective in preventing significant oxidative rancidity. The oil can be considered fresh from an oxidation perspective.

Specific Gravity value is consistent with that of most vegetable oils and aligns closely with the Codex standard (0.90). This physical property is often used as a quick check for gross adulteration with substances of different densities (Adejumo et al., 2020), which is not indicated here.

Proximate Compositions of Processed Flour Samples

There are highly significant differences in lipid and carbohydrate content. Sample 1, with its significantly higher lipid content and consequent higher energy value is nutritionally positioned as an energy-dense food. This profile is characteristic of formulations designed for addressing energy deficits. It aligns with the nutritional principles of Ready-to-Use Therapeutic Foods (RUTFs) and Supplementary Foods (RUSFs), which are crucial for managing malnutrition, particularly in children, by providing a large amount of energy in a small volume (Storz & Will, 2021). The high lipid content likely contributes to a richer mouthfeel and improved palatability. Samples 2 and 3, with their significantly lower lipid and higher carbohydrate contents, function more as energy-giving and bulking agents. This composition is typical of complementary food blends and weaning cereals, which are designed to provide affordable energy primarily from carbohydrate sources like cereals and tubers (Olagunju et al., 2021).

The dietary fiber content is a notable strength across all samples. This moderately high level is beneficial for promoting satiety, regulating blood sugar response, and supporting gut health (Gill et al., 2021). It indicates that the formulations successfully incorporated fiber-rich ingredients, moving beyond refined cereals to create more functional food products.

Formulated Cookies Characteristics

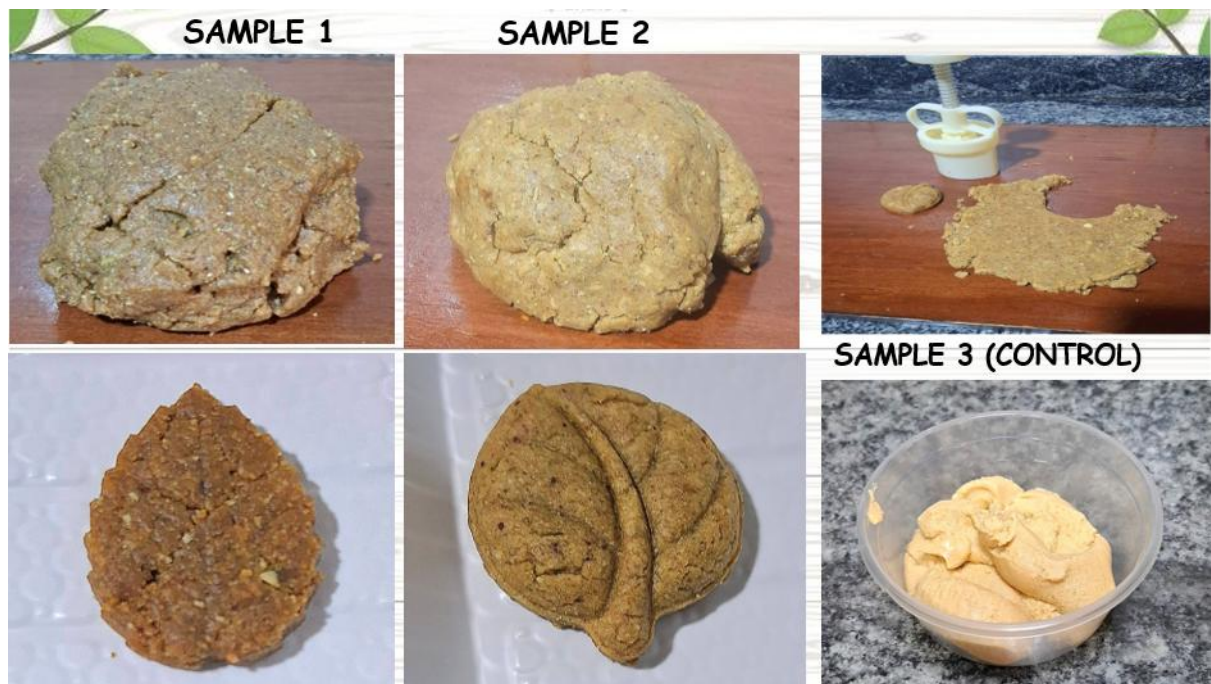
The proximate analysis of the three Formulated Food Products (table 4) (FFP A, FFP B and FFP C) and a Control against the benchmark against the requirements of Ready-to-Use Supplementary Food (RUSF) and Growth and Recovery–High Macronutrient (GR-HM) standards, reveals a clear and strategic nutritional differentiation. The proximate analysis of the three formulated flour samples reveals distinct nutritional profiles, primarily driven by significant variations in lipid and carbohydrate content, which directly influence their energy density. While the samples share similarities in moisture, ash, fiber, and protein content, the differences in macronutrient distribution suggest they are suited for different dietary applications and target populations.

Similarly, the consistent ash content across the formulations indicates a standardized and uniform mineral content. Ash content serves as a reliable proxy for the total mineral matter in a food sample. The moderately low values suggest the flours are not exceptionally high in minerals but provide a baseline level (Sani, Okonkwo, & Makun, 2022).

The results indicate that FFP A and the Control are engineered as energy-dense lipid-based supplements, closely mirroring the RUSF profile, while FFP B and C transition towards high-carbohydrate, moderate-energy products. The protein content of FFP A is also similar to that of the GR-HM standard. RUSFs are designed not only to address energy deficits but also to support catch-up growth and tissue repair in moderately malnourished children, processes that are highly dependent on adequate protein intake (Storz & Will, 2021). The GR-HM standard, with its extremely high protein content, is designed for severe catabolic states (e.g., severe acute malnutrition with complications, burn recovery) and is a different class of product altogether (Bahwere, 2021). The fat content in FFP A (37.75%) and the Control (35.10%) is high and slightly exceeds the RUSF expected value (31.0%). This, combined with the low moisture and high carbohydrate content, results in an energy density (526.32 and 518.99 kcal/100g, respectively) that is nearly identical to the RUSF standard (535 kcal/100g).

The high lipid content is intentional in RUSF design to achieve high energy density in a small volume, which is crucial for meeting the high energy needs of malnourished children who have poor appetites and small gastric capacities (Lazzerini et al., 2020).

The higher ash content in FFP A and the Control (4.71-4.72%) compared to FPP B and FPP C suggests a higher mineral content. This is a positive attribute for a RUSF-type product, as malnutrition is often accompanied by micronutrient deficiencies. The low moisture content across all samples, especially in FPP C (4.46%), is excellent for product stability. It inhibits microbial growth and lipid oxidation, ensuring a longer shelf-life without the need for refrigeration (a critical feature for products distributed in challenging environments) (Adejumo et al., 2020).



CONCLUSION

This study successfully formulated a plant-based RUSF cookie (FPP A) using a blend of locally sourced ingredients. The key achievement of the formulated cookies is meeting the critical energy density and protein benchmark for RUSF, with a profile identical to a leading commercial product. The formulation represents a significant stride towards a sustainable, culturally appropriate, and nutritional solution for managing Moderate Acute Malnutrition. The excellent stability of the lipid component and the low moisture content further support its potential for real-world application. Future work will focus on conducting more research on efficacy trials.

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Table 4.1: Proximate content of the Individual Recipe

	Crude Protein (%)	Crude Fibre (%)	Fat (%)	Moisture (%)	Ash (%)	Carbohydrate (%)	Energy Kcal
Oat	12.21±0.08 ^a	11.64±0.10 ^a	7.69±0.11 ^a	8.39±0.10 ^a	3.12±0.03 ^a	56.94±0.20 ^a	345.84±0.36 ^a
Pumpkin Seed	32.49±0.04 ^b	3.72±0.40 ^b	42.62±0.11 ^b	8.58±0.08 ^a	2.84±0.02 ^a	9.97±0.33 ^b	551.71±0.84 ^b
Baobab	8.35±0.10 ^c	14.09±0.11 ^c	2.450±0.08 ^c	4.50±0.05 ^b	6.54±0.25 ^b	64.08±0.39 ^c	311.43±1.42 ^a
Peanut Butter	27.47±0.28 ^b	3.34±0.04 ^b	36.28±0.13 ^b	11.10±0.28 ^d	3.54±0.11 ^a	18.31±0.18 ^d	509.61±1.14 ^b
Sesame Seed	22.64±0.08 ^d	13.49±0.04 ^c	29.83±0.35 ^d	2.23±0.09 ^b	6.83±0.09 ^b	24.99±0.27 ^c	458.960.69 ^b
Date	2.47±0.02 ^c	1.45±0.35 ^d	1.63±0.02 ^c	20.25±0.09 ^e	2.21±0.13 ^a	71.99±0.24 ^f	312.53±0.88 ^a
F Value	7930.571	8887.594	28384.632	1559.829	609.643	7026.545	10775.235
P value	<0.000001	<0.000001	<0.000001	<0.000001	<0.000001	<0.000001	<0.000001

Values are mean±standard error of the mean of the proximate contents of the individual recipe analysed. Values with different superscripts on the same column are significantly different at $p<0.05$ at 95 % confidence interval.

Table 4.2: the physicochemical constituent of Sunflower oil analysed in the study

Physicochemical	Sunflower Oil	Permissible limit Codex Stan 210-2015	t-value	P<value
Acid value	0.60±0.10	0.60±0.0	0.000	1.000
Peroxide value	3.65±0.04	10.00±0.0	-152.522	<0.00001
Free fatty acid	0.30±0.02	0.30±0.0	-0.189	0.888
Iodine value	133.71±0.03	132.00±0.0	48.379	0.427
Saponification	188.43±0.53	191.00±0.0	-4.164	0.053
Viscosity	68.04±0.0	-	NA	NA
Specific gravity	0.91±0.01	0.90±0.0	2.000	0.184

Values are mean±standard error of the mean of the proximate contents of the individual recipe analysed.

Table 4.3: Formulated Flour Proximate

Sample	Moisture (%)	Ash (%)	Fibre (%)	Protein (%)	Lipid (%)	Carbohydrate (%)	Energy Kcal
Sample 1	5.75±0.06	4.86±0.02	7.30±0.01	3.90±0.01	18.39±0.01 ^a	59.68±0.09 ^a	419.83±0.42 ^a
Sample 2	4.16±0.03	4.48±0.33	7.54±0.01	3.92±0.01	12.81±0.02 ^b	67.33±0.04 ^b	400.31±0.12 ^b
Sample 3	3.5033±0.01	2.63±0.03	7.42±0.02	3.89±0.01	9.63±0.02 ^b	72.82±0.04 ^b	393.44±0.23 ^b
F-value	2.915	2.322	1.868	1.209	21.368	19.511	4.373
P<value	>0.05	>0.05	>0.05	>0.05	<0.001	<0.001	0.015

Values are mean±standard error of the mean of the proximate contents of the formulated flour analysed. Values with different superscripts on the same column are significantly different at p<0.05 at 95 % confidence interval.

Table 4.4: Proximate Analysis of the FPPs, expected range for RUSF, expected range for GHM and Controls

Sample	Moisture (%)	Ash (%)	Fibre (%)	Protein (%)	Lipid (%)	Carbohydrate (%)	Energy Kcal
FPP A	8.71±0.02 ^a	4.72±0.08 ^a	2.17±0.05 ^a	11.07±0.01 ^a	37.75±0.05 ^a	35.58±0.15 ^a	526.32±0.10 ^a
FPP B	6.16±0.05 ^{ab}	3.53±0.08 ^b	3.68±0.12 ^{ab}	6.65±0.11 ^b	29.45±0.05 ^b	50.00±0.40 ^b	491.79±2.41 ^a
FPP C	4.46±0.02 ^b	3.54±0.06 ^b	5.28±0.07 ^c	4.02±0.01 ^b	22.40±0.09 ^c	60.30±0.06 ^c	458.97±0.75 ^a
Control	6.88±0.07 ^{ab}	4.71±0.10 ^a	2.53±0.02 ^a	10.95±0.01 ^a	35.10±0.06 ^a	39.87±0.21 ^a	518.99±0.84 ^a
expected range for RUSF	-	-	-	11-16	26-36	35-45	510-560
expected range for GHM	-	-	-	45-50 ^c	≤20.00 ^c	45-65	1900-2500
F-value	42.507	5.428	10.993	19.254	60.794	250.835	1014.309
P<value	<0.001	0.025	0.001	<0.000001	<0.001	<0.00001	<0.000001

Values are mean±standard error of the mean of the proximate contents of the FPP samples analysed. Values with different superscripts on the same column are significantly different at p<0.05 at 95 % confidence interval. Expected range for RUSF (Goal Global 2023)