ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

Tropical Journal of Phytochemistry & Pharmaceutical Sciences

Available online at https://www.tjpps.org

Original Research Article

Development of a Functional Acceptable Weight Management Snack-Bar From Plant-Based Food Sources Including *Moringa Oleifera* Leaf Extract

Hafsat O. Abdulrasaq[1], Shekins O. Okere[2], Gabriel O. Anyanwu[3]*

[1]*Dorothy Njemanze Foundation, Gudu, Abuja, Federal Capital Territory, Nigeria*
[2]*Department of Biochemistry, Faculty of Science and Technology, Bingham University, Karu, Nasarawa State, Nigeria*

ABSRTACT

Obesity and overweight are conditions that increase the risk of type-2 diabetes, heart-disease, cancer, and metabolic syndrome. Plant-based diets, lower in saturated fats and rich in essential nutrients, can regulate appetite and support weight management. This study aims to develop a functional plant-based snack bar using *Phoenix dactylifera*, *Glycine max*, *Brassica oleracea*, *Anacardium occidentale*, dates, and *Moringa Oleifera* leaf. The raw materials were processed and used to formulate two snack-bar variants (PSB1 and PSB2), with different proportions. They were evaluated against a standard (PSB-SD) for nutritional, microbial, and sensory properties. Proximate analysis showed PSB1 contained 19.09% carbohydrate, 4.50% crude fiber, 29.40% lipid, and 20.15% crude protein; PSB2 contained 29.21% carbohydrate, 3.30% crude fiber, 16.55% lipid, and 16.64% crude protein. PSB-SD had significantly higher crude fiber (16%) and protein (28%), while PSB2 had the highest moisture (16.85%). All bars were low in minerals except manganese. PBS1 had a significantly higher Vitamin C (2.38%) content than PSB2 (1.21%), while Vitamins B12 and D were undetectable. Microbial analysis showed significantly higher bacterial (2.04 x 10^8) and fungal (5.08 x 10^7) counts in PSB2 at week 1, and significantly increased counts in PSB1 (2.85 x 10^8) and (7.00 x 10^8) by week 4. Sensory evaluation by 20 participants rated PSB-SD significantly highest in colour, appearance, taste, and overall acceptability. PSB2 was moderately preferred, PSB1 scored lowest in taste and color. This study demonstrates the possibility of plant-based ingredients to create healthy snack-bars for possible weight management and underscores the importance of ingredient balance for nutritional value and microbial safety.

Keywords: Overweight, Snack-bar, Plant-based, Proximate Analysis, Micronutrient Analysis, Microbial Analysis

Received 3 February 2026
Revised 30 May 2026
Accepted 30 May 2026
Published online 15 June 2026

Introduction

Obesity and overweight are terms used to describe the accumulation of excess anatomical fat that poses significant health risks. Globally, they rank as the fifth leading cause of mortality and are strongly linked with the growth of persistent illnesses, including type 2 diabetes mellitus, heart diseases, and certain cancers, and metabolic syndrome.[1] Since 1975, global obesity rates have nearly tripled, with about two billion adults overweight and over 650 million obese.[2] This trend highlights the importance of developing effective dietary strategies. The shift from traditional shift from plant-based diets toward greater intake of animal-derived and processed foods has paralleled the rise in obesity rates.[3] Plant-based diets provide all essential amino acids, support lower blood lipid levels, and are linked to improved body weight maintenance and reduced susceptibility to heart disease. They also supply a diverse range of carbohydrates, vitamins, minerals, and phytochemicals that benefit gut and overall health. Soy products are rich in calcium and nutrients that support bone health.

*Corresponding author, mail: gabrielanyanwu@binghamuni.edu.ng
Tel: +2347030524887

Citation: Abdulrasaq HO, Okere SO, Anyanwu GO. Development of a Functional Acceptable Weight Management Snack-Bar From Plant-Based Food Sources Including *Moringa Oleifera* Leaf Extract. Trop J Phytochem Pharm Sci, 2026, 5(3); 502 - 509
http://www.doi.org/10.26538/tjpps/v5i3.3

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria.

Interest in plant-based meals has grown for health, environmental, ethical, and economic causes.[4] *Glycine max* is a nutrient-dense protein source suitable for all ages. *Phoenix dactylifera* offer fiber, vitamins, minerals, and antioxidants that support digestive health. *Anacardium occidentale* is high in healthy fats and micronutrients. *Moringa oleifera* may help manage hyperlipidemia, hyperglycemia, diabetes, and fatty liver disease, providing potential benefits for obesity management.[5]

Snacking is the intake of calorie-containing foods or drinks consumed in addition to the three primary meals. The trend of 'snackification' has grown, with more individuals eating outside traditional meal times. In 2019, 69% of consumers considered any food a snack.[6] Ready-to-eat snack bars typically include dried fruits, coconut oil, peanut butter, honey, granola, chocolates, oats, and nuts.[7] Consumers are increasingly seeking snacks that support weight management, promote healthy eating habits, and aid in muscle development. There is a strong preference for snacks made from natural ingredients and free from added sugars, artificial sweeteners, dyes, and preservatives.[8]

The purpose of this study is to formulate a functional weight management snack bar using plant-based food sources that is nutritious, low-calorie, and satiating, targeted at health-conscious consumers. It aims to provide a convenient, healthy snack alternative that addresses the growing prevalence of obesity and the rise in consumer need for plant-based dietary options. The integration of *Moringa Oleifera* leaf extract into the snack bar is intended to utilize its potent anti-metabolic properties, including its ability to prevent and treat hyperlipidemia, hyperglycemia, NAFLD, and diabetes. These effects contribute to its possibility as an anti-obesity catalyst, enhancing the snack bar's role in supporting weight management and overall metabolic health

ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

Materials and Methods

Soybean seeds, cabbage heads, and date fruits were procured from the Orange Market in Karu, Nasarawa State, Nigeria. Fresh cashew nuts were sourced from Ankpa, Kogi State, Nigeria, and moringa leaves were collected from Gaduwa, Federal Capital Territory, Nigeria. All the plant materials were sourced in January 2025. All food materials were submitted to the National Institute of Pharmaceutical Research and Development (NIPRD), Abuja, to have the food materials identified. The plant voucher numbers were moringa (*Moringa Oleifera* NIPRD/H/7449), soya beans (*Glycine max*- NIPRD/H/7515), dates (*Phoenix dactylifera*- NIPRD/H/7513), and cabbage (*Brassica oleracea*- NIPRD/H/7516).

Glycine max Flour Production

Soya flour was produced using the dry heat method outlined by Yadav and Bhatnagar (2015), with minor adjustments. The *Glycine max* were first cleaned by removing foreign particles such as sand, leaves, and sticks, after which they were thoroughly washed. They were then soaked in water, using several times their volume, for approximately eight hours. Following the soaking process, the water was drained, and the beans were arranged in a single layer on a foil-lined baking tray. The beans were toasted in an oven at 170 °C for 20 mins, turned over, and further roasted for another 10 minutes. The roasted *Glycine max* were subsequently ground into fine flour using a mini grain mill.

Phoenix dactylifera Syrup Production

Phoenix dactylifera syrup was prepared according to the procedure outlined by Ajayi.[9] The dried *Phoenix dactylifera* fruits were first sorted to eliminate defects and remove dirt, then thoroughly washed. Exactly 250 g of the cleaned *Phoenix dactylifera* were immersed in 1000 mL of water, and cooked in 20 minutes. The softened fruits were blended using a Super Blend 1000 blender to obtain a slurry, which was then filtered through cheesecloth and manually squeezed. The remaining residue was washed and squeezed out again with 1 L of hot water for 8 minutes and strained twice to maximize extract recovery. The extracted juice was subsequently concentrated on a gas stove until the volume was reduced to approximately one-third of its original amount.

Brassica oleracea Flour Production

Brassica oleracea powder was processed according to Waseem.[10] *Brassica oleracea was* thoroughly rinsed with water to eliminate adhering debris or impurities. The leaves were then finely shredded using stainless steel knives and subsequently homogenized with a Super Blend 1000 blender. The resultant puree was sieved using a mesh cloth and hand-pressed to remove all the water. The resultant shaft was then dried in a cabinet dryer for 10-12 hours and subsequently milled to grain and preserved in hermetic glass bottles for further experiments.

Roasted Anacardium occidentale Production

Anacardium occidentale seeds were first decontaminated to get rid of dirt and other contaminants, after which they were soaked in water to minimize scorching during roasting. The nuts were immersed in a plastic bowl containing water and left for approximately 10 mins. Excess water was drained, and the nuts were left for about 4 hours to enable surface moisture absorption. Subsequently, 500 g portions of the *Anacardium occidentale* were pan-roasted for 20 minutes, allowed to cool slightly, and then manually de-shelled.[11]

Moringa Oleifera Leaf Extraction

The *Moringa Oleifera* leaf was extracted as per the technique described by Anyanwu.[12] Fresh *Moringa Oleifera* leaves were gathered and dried. A total of 750 g of dried, pulverized *Moringa Oleifera* leaves was subjected to maceration in ethanol for three days, with intermittent stirring every three hours using a sterilized glass rod. After the extraction period, the mixture was filtered through Whatman filter paper No. 1 (Whatman Ltd., England). The liquid fraction obtained after filtration was then concentrated using a rotary evaporator for three hours. The yield of 28.1g of final extract of *Moringa Oleifera* was obtained.

Proximate analyses

Determination of Moisture Content

Determination of moisture content was completed following the procedure outlined in AOAC.[13] The method relies on the removal of water through evaporation. Aluminum dishes were first cleaned, oven-dried, and left to go cold in a desiccator before weighing. Approximately 5.0 g of ground samples were placed into pre-measured sterile aluminum dishes, with duplicate measurements taken. The samples were dried sequentially in an oven, initially at 80 °C for two hours, followed by drying at 105 °C for three hours. Following the drying procedure, the dishes were cooled in a desiccator and reweighed using a balance. This heating, cooling, and weighing cycle was repeated at hourly intervals until a steady weight was attained. Moisture content was estimated as the variation between the original sample weight and final constant weight.

Calculation:

$$Moisture\ Content\ (\%) = \frac{W3 - W2}{W2 - W1} x\ 100 \ldots\ldots\ldots\ldots\ldots eqn\ 1$$

Where:

W1 = weight of the empty crucible
W2 = weight of crucible + sample before drying
W3 = weight of crucible + sample after drying

$$Total\ Solid\ (Dry\ Matter)\ \% = 100 - Moisture\ \%$$

Lipid content determination

Lipid content was completed according to AOAC.[13] About 15 g samples were measured and put into a thimble containing no fat, which was sealed with a cotton ball to protect the sample from escaping. The thimble then was inserted into a Soxhlet extractor. Approximately 200 mL of petroleum ether was put in a pre-measured Soxhlet flask, free of fat, and attached to the extractor. The flask was then positioned on a heating mantle to enable continuous reflux of the solvent. Cooling was maintained by running water through the condenser for about 7 hours, during which the dissolvent was repeatedly siphoned into the flask. After extraction, the solvent was evaporated using a rotary vacuum evaporator, remaining the lipid residue in the flask. The flask was then oven-dried at 60 °C till a fixed measurement was attained, cooled in a desiccator, and weighed again. All analyses were conducted in triplicate. The lipid content was calculated by subtracting the initial flask weight from the final weight.

$$Lipid\ Content\ (\%) = \frac{Weight\ of\ Extracted\ Lipid}{Weight\ of\ Dry\ Sample}\ x\ 100 \ldots\ldots\ldots\ldots\ldots eqn\ 2$$

Crude protein content determination

Protein content was analyzed using the Kjeldahl method, which estimates protein by determining the amount of reduced nitrogen contained in the sample.[13] Approximately 20 g of samples were measured, wrapped in filter paper, and transferred to a Kjeldahl digestion flask. To aid digestion, 10 tablets of Na_2SO_4 and 1 g of $CuSO_4$ were introduced, then 20 mL of concentrated H_2SO_4. The resultant mixture was digested in a fume hood till the solution turned clear. Following cooling overnight, the digest was mixed with 200 mL of water in a 500 mL flat-bottomed flask then further cooled using ice packs. Next, 60–70 mL 40% NaOH was included, and the released ammonia was distilled into a receiver. Distillation continued until all ammonia was contained in a flask with 50 mL of boric acid mixed with indicators (methyl red and bromocresol green). After that, the

distillate was titrated with 0.01 M HCl until a color change indicated the endpoint.
Calculation:
The amount of protein (%) was calculated using the formula below:

$$Protein\ Content\ (\%) = \%\ Nitrogen\ x\ 6.25 \ldots\ldots\ldots\ldots\ldots\ldots eqn\ 3$$

where 6.25 is the protein-nitrogen conversion factor for fish and fish by-products

Crude Fibre Determination
The crude fibre content was analyzed according to AOAC.[13] About 20 g of each sample were initially defatted using diethyl ether for 8 hours, then refluxed with 200 mL of 1.25% H_2SO_4 for thirty minutes. The combination was purified through cheesecloth in a fluted funnel and thoroughly rinsed using hot water to eliminate all residual acid. The remains were subsequently heated in 200 mL of 1.25% NaOH solution for an additional thirty minutes and passed through a pre-measured crucible. The crucible containing the remains was dried in the oven at 100 °C, left to cool in the desiccator, and measured. After which it was incinerated in a muffle furnace at 600 °C for 2–3 hours, left to cool again in a desiccator, and reweighed.

$$Crude\ Fiber\ (\%) = \frac{W2 - W3}{W1} x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots eqn\ 4$$

Where:
W1 = Weight of sample (g)
W2 = Weight of crucible + dried residue after digestion (g)
W3 = Weight of crucible + ash after incineration (g)

Total Ash Determination
Ash content was analyzed according to the AOAC.[13] Ash represents the mineral fraction of the sample remaining after removal of moisture and combustion of organic material. Samples were placed in a clean, dry, pre-weighed crucible. The crucibles were placed in a muffle furnace at 550 °C for 3 hours, followed by cooling in a desiccator, and reweighed.

Calculation:
Ash content (%) was estimated according to the formula:

$$Ash\ Content\ (\%) = \frac{W2 - W1}{W3} x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots eqn\ 5$$

Where:
W1 = Weight of empty crucible (g)
W2 = Weight of crucible + ash (g)
W3 = Weight of sample (g)

Carbohydrate Content Determination
The carbohydrate content was calculated by difference, using results obtained for other proximate components.

$$Total\ Carbohydrate\ (\%) = 100 - Moisture\ Content + Crude\ Protein + Crude\ Fat + Ash + Crude\ Fiber \ldots\ldots\ldots\ldots\ldots\ldots$$

Microbial Analyses
The prepared snack bar samples were subjected to serial dilution until 10^{-5} by moving 1 mL of homogenized stock sample to a 9 mL of sterilized distilled water. This procedure was carried out aseptically and repeated until the fifth dilution was obtained. Each diluted sample was inoculated into different culture media, including MacConkey Agar, Potato Dextrose Agar, and Nutrient Agar, utilizing the pour plate technique. The media were prepared following the manufacturer's specifications. Plates containing NA were incubated for about twenty hours at 37 °C, while PDA plates were left at room temperature for five days. After incubation, bacterial colonies on NA were enumerated using a colony counter, and the colony-forming units per gram of food were determined. Colony structure was noted, and representative colonies were sub-grouped to get unadulterated isolates for further testing. Fungal growth was observed on PDA after 5 days, the colonies were counted, shown as cfu/g, and sub-cultured to secure pure cultures for identification.[14]
The microbial characteristics of the snack bars was evaluated after storage at ambient temperature for a week and again after 4 weeks to assess microbial safety and stability.[15]

Vitamins Analyses
Vitamin C
The Vitamin C content was analyzed using the HPLC method. The snack bars were first homogenized, and a 0.1 g test sample was transferred to a 2 mL Eppendorf tube before adding 1 mL of 10% metaphosphoric acid solution. The mixture was then vortexed for 2 minutes and centrifuged at 12,000 rpm at 4°C for 10 minutes. The supernatant was filtered through a 0.22 µm membrane filter. The analysis was done on an HP 1049A programmable electrochemical detector and an Agilent 1290 HPLC technique equipped with a diode-array detector, using an SB-C18 reversed-phase column. The adjustable phase comprised methanol and an aqueous solution of 50 mM potassium dihydrogen phosphate with 2.5 mM hexadecyl trimethyl ammonium bromide. The electrochemical detector was set at a voltage of 900 mV with a response range of 500 nA. The adjustable phase was pushed at 0.7 mL/min with a 7-minute run at a gradient of ninety-five solvent A and five-percent solvent B. The temperature of the column was kept at 25°C. Finding wavelengths were set at 242 nm for the diode-array detector, with an infusion volume of 10 µL. Vitamin C identification was based on chromatographic holding periods and UV absorption spectra matching an original metric. Quantitative analysis of Vitamin C in samples was done using external calculation curves from approved solutions, with correlation coefficients (R^2) exceeding 0.9990.[16]

Vitamin B12
HPLC analysis was conducted using a Jasco Crestpak system. Chromatographic separation was achieved with a Jasco Crestpak C-18 T-5 column measuring 250 mm x 4.6 mm with a fragment mass of 5 µm. The injection volume was set at 20 µl. The adjustable phase consisted of a Methanol and Water mixture in a 60% to 40% ratio, flowing at 1 ml/min. Diagnosis was carried out using a Jasco UV-975 sensor equipped with a D2 lamp. pH measurements were made using a pH meter with a glass combination electrode. All experiments were done at an ambient temp of 25 ± 2°C. For preparation of standard solutions, 1 mg of vitamin B12 compound was dissolved in 10 mL of clarified deionized water and stored at 4°C. Operating stock solutions were prepared separately by mixing the stock solution to 5 mL with clarified deionized water, then retention at 4°C. All stock mixtures were covered in foil to escape light deterioration. The operating mixtures and samples were made everyday, within a concentration range of 1-10 µg/ml. HPLC analysis utilized the Jasco Crestpak system with chromatographic separation on the Jasco Crestpak C-18 T-5 column. The insertion volume was 20 µl. The adjustable phase was made up of Methanol:Water solution in a 60:40 gradient, flowing at 1 ml/min. Finding was completed using the Jasco UV-975 detector fitted with a D2 lamp, operating at 360 nm for vitamin B12. The total runtime per analysis was 12 minutes. Each standard solution within the 1-10 µg/ml concentration range was injected in triplicate under optimized chromatographic conditions.[17]

Vitamin D3
A high-performance liquid chromatography system, fitted with a diode array detector and a ChemStation data acquisition system, was employed for the analysis. Chromatographic separation was carried out using a reversed-phase Gemini C18 column (100 × 3.0 mm, 3 µm particle size) from Phenomenex, USA, maintained at 40°C. The mobile phase consisted of acetonitrile and water (99:1, v/v) delivered at a flow rate of 1 mL/min. The injection volume ranged from 3 to 50

µL, depending on the sample preparation type. Detection was performed at a wavelength of 265 nm.[18]

Minerals Analyses

Samples were placed in digestion containers with deionized water. Additional deionized water and nitric acid (HNO_3) were added to the containers, which were then capped and vortexed for one minute to ensure thorough mixing of the bars with the acid. Hydrogen peroxide (H_2O_2) was subsequently introduced, and the samples were left to pre-digest for fifteen minutes plus the tops off. For spiked samples, 2 mL of stock solution of a single analyte replaced the 2 mL of deionized water before sample loading. The concentration of the spikes was adjusted to approximate the expected analyte concentration in the samples. Microwave-assisted digestion was done. Following cooling, digests were put into 50 mL centrifuge tubes, and deionized water was included to increase the quantity. Instrumental parameters were optimized during method development, with the visual position set at 0 and nebulizer flow rates (l/min) entered manually based on prior recovery studies. Calibration ranges were tailored to the concentration levels of the analytes in the samples, and acceptable calibration curves required correlation coefficients (R^2) greater than 0.99. Five standards were prepared for each analyte: Ca (2–20 mg kg^{-1}), P (10–40 mg kg^{-1}),), Fe (0.5–10 mg kg^{-1}), and Zn (1–6 mg kg^{-1}). All analyses were conducted in five technical replicates. Quality control for each run included an unmarked measure, a digestion blank, a mid-range measurement metric, and a measurement metric near the upper range.[19]

Sensory evaluation

A hedonic sensory assessment of the plant-based snack bars was carried out using 20 untrained panelists drawn from Bingham University and the Abuja Municipal Area Council (AMAC). The participants were asked to rate the products based on six key sensory properties: appearance, texture, taste, flavour, color, and overall acceptability. The five-mark hedonic scale was used, where a score of 5 represented "excellent" and 1 indicated "poor.".[20]

Statistical analysis

All experiments were conducted thrice and results analyzed in terms of mean ± standard deviation (SD). One-way ANOVA and Independent Sample T -tests in SPSS version 16.0 were used to perform statistical analysis. Duncan multiple range test was used to conduct post hoc comparisons to establish significant group differences.

Results and Discussion

Proximate results of plant materials after processing

The results of the proximate analysis in percentages for carbohydrate, crude fiber, crude lipid, and crude protein of roasted *Glycine max* are 24.92, 16.80, 15.90, and 33.73, respectively, while those of roasted *Anacardium occidentale* are 12.50, 24.40, 32.30, and 25.40, respectively (Table 1). The proximate analysis in percentages of carbohydrate, crude fiber, crude lipid, and crude protein of dried *Brassica oleracea is* 36.70, 23.30, 1.25, and 18.40, respectively, while that of *Phoenix dactylifera* syrup is 25.95, 1.19, 0.05, and 3.50, respectively. The moisture content of *Glycine max* flour at 4% is a bit lower than the 4.5% recorded by Pokharel et al.[23] Ishak et al.[20] noted that the moisture level in flours and cereal-based products should remain below 15% in order to minimize the risk of bacterial spoilage. The crude protein content obtained for roasted *Glycine max* powder was 33.73%, aligning closely with the 35.5–44.1% range reported by Agume et al.[21] *Glycine max* are recognized as a rich source of high-quality protein, comparable to other protein-dense foods, making them suitable for individuals across all age groups, from infants to older adults.[22]

Carbohydrate content in roasted *Glycine max* flour was measured at 24.92%, which is in line with the 25.05% stated by Pokharel et al.[23] Its relatively high fiber level indicates potential health benefits, such as slowing digestion and moderating blood glucose responses, thereby reducing sharp insulin spikes and limiting fat accumulation. For *Brassica oleracea* flour, crude fiber, lipid, and carbohydrate contents were 23.20%, 1.25%, and 36.70% respectively, similar to the figures recorded by Waseem et al.[10] Dietary fibers are very important in reducing the risks of heart disease, diabetes, and obesity.[24] Comparatively, Brito et al.[25] reported lower protein and moisture levels for dried *Brassica oleracea* flour (12.28% and 10.35%), whereas the present findings were higher, at 18.40% and 15.85%.

In the case of *Phoenix dactylifera* syrup, crude fiber (1.19%), lipid (0.05%), and ash (0.70%) contents were lower than the 2.9%, 0.5%, and 1.4% values described by Munir et al.[26] *Phoenix dactylifera* are also known for their low glycemic index and antioxidant properties.[27]

For roasted *Anacardium occidentale*, moisture and fat levels were determined to be 2.35% and 32.30%, which are slightly below the 3.12% and 46.4% reported by Griffin et al.[28] Regular nut consumption has been associated with significant health benefits, with one serving (28 g) per day linked to a 21% reduction in cardiovascular disease risk and a 22% decrease in overall mortality.[24] Finally, the fiber content of roasted groundnuts was measured at 11.96%, substantially higher than the 3.09% reported for roasted peanuts by Kumar et al. in a separate study.

Proximate Analysis of Snack Bar Samples

The proximate results in percentages for carbohydrate, crude fiber, crude lipid, and crude protein of PSB1 is 19.09, 4.50, 29.40, and 20.15, respectively, while that of PSB2 is 29.21, 3.30, 16.55, and 16.64, respectively (Table 1). The proximate components of the formulated snack-bars are shown in Table 2. Moisture levels ranged between 9.14 ± 0.01% and 16.85 ± 0.15%, protein varied from 20.53 ± 0.48% to 28.00 ± 0.40%, ash from 0.86 ± 0.06% to 2.77 ± 0.03%, fat from 20.43 ± 0.13% to 35.42 ± 0.42%, crude fiber from 4.07 ± 0.03% to 16.00 ± 0.50%, and carbohydrate from 23.00 ± 0.50% to 36.06 ± 0.15%.

Table 1: Proximate Composition of Processed Raw Materials for Snack Bar Formulation

	Glycine max	***Anacardium occidentale***	***Brassica oleracea***	***Phoenix dactylifera***
NFE (%)	24.92 ± 0.25	12.50 ± 0.70	36.70 ± 0.40	25.95 ± 0.50
CP (%)	33.73 ± 1.56	25.40 ± 0.60	18.40 ± 0.60	3.50 ± 0.10
CL (%)	15.90 ± 0.10	32.30 ± 0.70	1.25 ± 0.04	0.05 ± 0.01
CF (%)	16.80 ± 0.20	24.40 ± 0.20	23.20 ± 0.40	1.19 ± 0.01
MC (%)	4.00 ± 0.05	2.35 ± 0.05	15.85 ± 0.15	68.64 ± 0.36
AC (%)	4.75 ± 0.25	3.15 ± 0.10	4.60 ± 0.40	0.70 ± 0.05
M.E (Kcal)	377.3 ± 11.43	441.40 ± 0.60	231.65 ± 3.35	118.25 ± 0.75

Data presented as mean ± standard deviation (n = 3). M.E - Metabolizable Energy, N.F.E - Nitrogen Free Extract, AC - Ash Content, CL - Crude Lipid, CF - Crude Fiber, CP - Crude Protein, MC - Moisture Content

Table 2: Proximate Composition of Formulated Snack Bars (PSB-SD, PSB1 and PSB2)

	PSB-SD	PSB1	PSB2
NFE (%)	25.00 ± 1.15^{b}	23.00 ± 0.50^{c}	36.06 ± 0.15^{a}
CP (%)	28.00 ± 0.40^{a}	24.28 ± 0.05^{b}	20.53 ± 0.48^{c}
CL (%)	21.00 ± 1.60^{b}	35.42 ± 0.42^{a}	20.43 ± 0.13^{b}
CF (%)	16.00 ± 0.50^{a}	5.42 ± 0.40^{b}	4.07 ± 0.03^{c}
AC (%)	0.86 ± 0.06^{c}	2.77 ± 0.03^{a}	2.04 ± 0.06^{b}
MC (%)	9.14 ± 0.01^{b}	9.16 ± 0.19^{b}	16.85 ± 0.15^{a}
ME (Kcal)	435.00 ± 2.00^{b}	507.90 ± 0.10^{a}	410.27 ± 0.73^{c}

Data presented as mean ± standard deviation (n = 3). M.E - Metabolizable Energy, N.F.E - Nitrogen Free Extract, AC - Ash Content, CL - Crude Lipid, CF - Crude Fiber, CP - Crude Protein, MC - Moisture Content

Among the bars, PSB2 recorded the highest moisture value (16.85%), whereas the standard snack bar (PSB-SD) and PSB1 had markedly lower values (9.14% and 9.16%, respectively). Moisture plays a key role in determining product stability, sensory quality, and shelf life.[26] Lower moisture levels are considered desirable, as they reduce the risk of microbial growth, enhance storage stability, and promote a crunchy texture.[29] The comparatively higher moisture in PSB2 may suggest reduced shelf stability relative to PSB1 and PSB-SD. Carbohydrate values varied considerably, with PSB2 showing the highest content (36.06%), which was significantly higher ($p < 0.05$) than PSB-SD and PSB1. The recorded carbohydrate levels were lower than those previously documented by Singh et al.[30] Carbohydrates remain an essential energy source, particularly for the brain, which relies heavily on glucose metabolism.[31] The elevated carbohydrate level in PSB2 could be linked to added sugars during formulation. Protein levels differed significantly across the bars. PSB-SD had the highest protein content (28.00%), which was significantly greater ($p < 0.05$) than PSB2 (20.53%) and PSB1 (24.28%). Furthermore, PSB1 was significantly higher than PSB2. The values align with the protein range of 23.91–32.08% reported by Zulaikha et al.[32] Protein intake is widely associated with weight management, improved HDL cholesterol, and enhanced satiety and thermogenesis.[33] Ash content was greatest in PSB1 (2.77%), surpassing both PSB2 and PSB-SD. Since ash reflects the mineral profile of a food product, these values indicate variations in the mineral contribution of the ingredients used. For comparison, Coello et al[29] reported a lower ash content (1.31%) than that observed in this study. Ash remains a reliable indicator of the mineral composition of foods.[20]

Fat and fiber levels across the formulations fell within ranges earlier documented by Olagunju et al.[15] although carbohydrate levels did not align. PSB1 had greater lipid content ($p < 0.05$) comparable to PSB-SD, while PSB2 showed no significant difference from PSB-SD ($p > 0.05$). No significant difference was noted between PSB1 and PSB2. For crude fiber, PSB-SD demonstrated the highest content, which was significantly increased ($p < 0.05$) than both PSB1 and PSB2. Fiber-rich snack bars have been shown to increase satiety for several hours post-consumption compared to those with low fiber.[34] Moreover, dietary fiber is very important in managing weights and metabolic health, including improvements in glycemia and insulin sensitivity.[30] Fat content contributed significantly to the caloric profile of the snack bars. The WHO recommends fat should contribute between 15–30% of daily energy intake. Lower calorie snacks are generally preferred, as meals containing increased fat have been shown to increase risks of diabetes and certain cancers.[32] Metabolizable energy values shown in this study were similar with those reported by Ajayi[9]. PSB1 exhibited significantly higher metabolizable energy ($p < 0.05$) compared to PSB-SD, while PSB2 was significantly lower. Variations in energy values were largely attributable to differences in fat, protein, and carbohydrate composition.[20]

In conclusion, the formulated snack bars provided substantial amounts of protein, carbohydrate, and energy, confirming their nutritional potential as healthy snack alternatives.

The levels of iron, zinc, and calcium in both formulated snack bars were significantly higher ($p < 0.05$) than the standard snack bar. In contrast, the phosphorus and manganese content of the PSB-SD exceeded that of PSB1 and PSB2 ($p < 0.05$). With the exception of manganese, the overall mineral contributions of the snack bars were relatively low, suggesting a potential need for supplementation or fortification to improve their micronutrient value. Minerals such as iron, zinc, and phosphorus are essential as cofactors or integral parts of enzymes that regulate glucose metabolism, and they contribute to insulin function by activating insulin receptors.[15]

Adequate mineral consumption is also vital in the context of weight management, as it helps maintain metabolic balance and supports overall micronutrient sufficiency. Evidence indicates that individuals who successfully sustain weight loss tend to have higher compliance with recommended mineral intakes compared to those living with obesity. This adequacy in micronutrients may therefore play a role in improving the effectiveness and long-term maintenance of weight management strategies.[35]

Vitamin C levels are inversely related to body weight, with heavier individuals typically having lower plasma vitamin C due to dilution and increased oxidative stress. Research has indicated that with a 10 kg increase in body weight, 10 mg of vitamin C a day is required to allow similar plasma levels to be maintained. Sufficient vitamin C is significant in metabolic wellness and loss of weight.[36] Vitamin B12 was not detected in either of the formulated snack bars, indicating a need for fortification. Higher vitamin B12 levels have been associated with significantly reduced risk of obesity, independent of age, gender, ethnicity, lifestyle, diet, and medication use. Adequate B12 status may support weight management by improving fat cell function and maintaining lean muscle mass.[37] Vitamin D was also not detected in either of the formulated snack bars in this study. This shows a need for Vitamin D supplementation, as reported by Musazadeh et al.[38] shows that Vitamin D deficiency contributes to obesity risk by directly promoting fat cell formation and indirectly affecting inflammation, oxidative stress, metabolism, preadipocyte differentiation, and gene regulation. Supplementation with active vitamin D may enhance insulin sensitivity, increase adiponectin secretion, and support weight loss.

The microbial quality of the snack bars was evaluated after one week and again after one month of storage at ambient temperature, and results are presented in Table 5. Results showed that the total microbial counts for the samples exceeded the maximum recommended limit for foods that are baked (< 5.0 × 10^3 cfu/g). Between formulated samples, PSB2 consistently recorded higher bacterial and fungal loads than PSB1, which is likely linked to its elevated moisture content. Since moisture is a critical factor for microbial survival, high levels tend to reduce product shelf life and compromise sensory attributes.[15] Importantly, no coliform growth was detected in any of the snack bars. This suggests that the products were prepared under proper hygienic and manufacturing standards, aligning with food safety regulations that stipulate zero tolerance for coliforms as they indicate possible fecal contamination.[15]

After four weeks of storage, a marked rise in microbial counts was observed compared to week one, with PSB2 maintaining the higher levels. The total plate counts (bacterial and fungal) ranged from 1.05×10^8 to 2.85×10^8 cfu/g and from 2.80×10^7 to 7.00×10^8 cfu/g, respectively. Microorganisms identified from both samples included *Bacillus licheniformis*, *Staphylococcus spp.*, *yeast cells*, and

ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

Table 3: Mineral Composition of Formulated Snack Bars (PSB-SD, PSB1 and PSB2**)**

	PSB-SD	PSB1	PSB2
Fe (mg/100g)	0.240 ± 0.01[b]	0.350 ± 0.005[a]	0.350 ± 0.002[a]
Mn (mg/100g)	0.890 ± 0.01[a]	0.060 ± 0.001[b]	0.040 ± 0.003[c]
Zn (mg/100g)	0.050 ± 0.01[b]	0.120 ± 0.004[a]	0.120 ± 0.003[a]
Ca (mg/100g)	0.500 ± 0.06[c]	0.750 ± 0.02[a]	0.650 ± 0.03[b]
P (mg/100g)	0.015 ± 0.002[a]	0.006 ± 0.001[b]	0.004 ± 0.00[c]

Data presented as mean ± standard deviation (n = 3). Fe (Iron), Mn (Manganese), Zn (Zinc), Ca (Calcium), P (Phosphorus).

Table 3: Vitamin Composition of Formulated Snack Bars (PSB1 and PSB2)

	PSB1	PSB2
Vitamin C (µg/ml)	2.38 ± 0.11	1.21 ± 0.07
Vitamin B12 (µg/ml)	N. D	N. D
Vitamin D3 (µg/ml)	N. D	N. D

Data presented as mean ± standard deviation (n = 3). N.D. = Not Detected.

Table 5: Total Microbial Load of Formulated Snack Bars at Week 1 and 4

	PSB1	PSB2
WEEK 1		
TBC (CFU/g) (x 10^8)	1.05 ± 0.05[b]	2.04 ± 0.02[a]
TFC (CFU/g) - (x 10^7)	2.80 ± 0.10[b]	5.00 ± 0.30[a]
TCC (CFU/g)	0	0
WEEK 4		
TBC (CFU/g) (x 10^8)	2.85 ± 0.02[a]	2.63 ± 0.03[b]
TFC (CFU/g) (x 10^8)	7.00 ± 0.10[a]	2.00 ± 0.20[b]
TCC (CFU/g)	0	0

Data presented as mean ± standard deviation (n = 3). Means having different alphabets in the same row are significantly different at P<0.05. TBC (Total Bacterial Count), TFC (Total Fungal Count), TCC (Total Coliform Count), CFU/g (Colony Forming Unit/g), PSB1 - Plant-Based Snack Bar Formulation 1, PSB2: Plant-Based Snack Bar Formulation 2.

Aspergillus fumigatus.

The taste, appearance, color texture and overall acceptability of the standard and formulated snack bar (PSB1, PSB2, and PSB-SD) were evaluated and compared with the control, as presented in Table 6. A significant variation in taste was observed among the samples. Both PSB1 and PSB2 were rated as less palatable ($p < 0.05$) when evaluated comparable to the control bar (PSB-SD). The sample sweetened with both sugar and *Phoenix dactylifera* syrup received a significantly higher ($p < 0.05$) score than the one prepared solely with *Phoenix dactylifera* syrup. Ishaq et al noted that sweet and savory snacks have been shown to positively influence consumers' acceptance.[39]

Table 6: Sensory Evaluation of Control and Formulated Snack Bars (PSB1 and PSB2)

	Control	PSB1	PSB2
Taste	4.80 ± 0.45[a]	1.60 ± 0.89[c]	3.40 ± 1.14[b]
Texture	3.80 ± 0.45[a]	2.80 ± 1.64[a]	3.00 ± 0.71[a]
Flavour	3.80 ± 0.45[a]	2.40 ± 1.34[a]	2.80 ± 1.10[a]
Appearance	4.00 ± 0.71[a]	2.20 ± 0.45[b]	2.80 ± 0.84[b]
Colour	3.80 ± 0.45[a]	2.00 ± 1.22[b]	2.20 ± 0.84[b]
Overall Acceptability	4.40 ± 0.55[a]	2.40 ± 1.34[b]	3.00 ± 1.22[ab]

Data presented as mean ± standard deviation (n = 5). Means with different alphabets in the same column are significantly different at P<0.05.

ISSN 2955-1226 (Print)
ISSN 2955-123(Electronic)

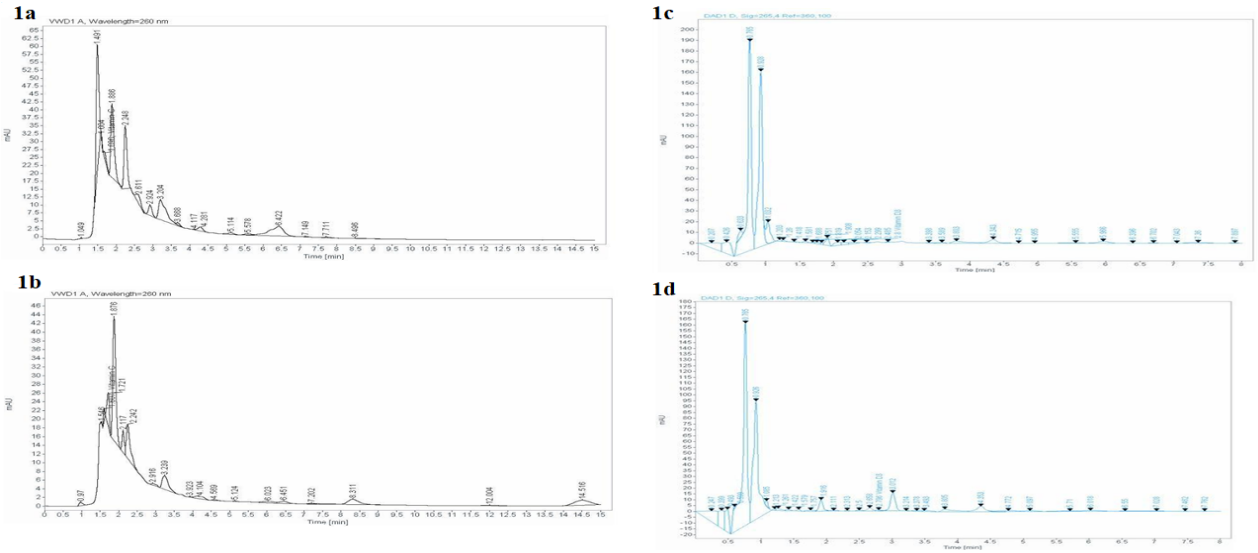

Figure 1: Vitamins composition of snack bar samples. A: Chromatogram for Vitamin B12 and C (PSB1), B: Chromatogram for Vitamin B12 and C (PSB2), C: Chromatogram for Vitamin D (PSB1), D: Chromatogram for Vitamin D (PSB2)

For texture, no significant differences ($p > 0.05$) detected amidst the samples. Texture plays a vital role in influencing not only consumer preference but also the storage stability of snack products.[40] In terms of color, the mean scores ranged between 2.0 and 3.80, indicating limited acceptance by the panelists. The greenish hue produced by the inclusion of *Moringa Oleifera* leaf extract in PSB1 and PSB2 contributed to reduced color preference, though still rated as somewhat acceptable. Since color strongly influences consumer attraction and purchase intent, the altered appearance may have contributed to the lower ratings.[39]

The overall acceptability of the samples ranked from 3.00 to 4.40, with PSB-SD emerging as the most favored snack bar. PSB1 received the lowest preference ($p > 0.05$), while PSB2 showed intermediate acceptance, demonstrating similarities to both PSB1 and PSB-SD. This finding suggests that modest adjustments in formulation could improve PSB2 to a level of consumer preference comparable to the standard snack bar (PSB-SD).

By using plant materials, they act as a rich storage of bioactive materials that have several health benefits, including anticancer, antitubercular, antiviral,, analgesic, and antioxidant properties, that can be exploited for functional foods development and health promotion.[41]

Conclusion

PSB1 and PSB2 snack bars, formulated from plant-based ingredients, demonstrated comparable carbohydrate, protein, and lipid profiles to the standard snack bar. They offer a nutritious alternative with beneficial protein and dietary fiber, supporting weight management through controlled energy intake and satiety. Both bars matched the standard in texture, with PSB2 preferred for overall acceptability. The inclusion of *Moringa Oleifera* leaf extract may offer anti-obesity benefits, including reduced body weight, improved lipid metabolism, and enhanced insulin sensitivity. These attributes position the snack bars as promising functional foods for weight management and overall health.

Conflict of Interest

The authors declare no conflict of interest.

Author's Declaration

The authors hereby declare that the work presented in this article are original and that any liability for claims relating to the content of this article will be borne by them.

References

1. World Health Organization. Obesity and overweight. World Health Organization. 2019; https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
2. Binou P, Yanni AE, Kartsioti K, Barmpagianni A, Konstantopoulos P, Karathanos VT, Kokkinos A. Wheat Biscuits Enriched with Plant-Based Protein Contribute to Weight Loss and Beneficial Metabolic Effects in Subjects with Overweight/Obesity. Nutrients. 022; 14(12):2516. https://doi.org/10.3390/nu14122516
3. Heianza Y, Zhou T, Sun D, Hu FB, Qi L. Healthful plant-based dietary patterns, genetic risk of obesity, and cardiovascular risk in the UK biobank study. Clin. Nutr. 2021; 40(7):4694–4701. doi: 10.1016/j.clnu.2021.06.018
4. Tran E, Dale HF, Jensen C, Lied GA, Hillesund ER. Dietary intake and nutritional status of vegetarians and vegans in Norway: A systematic review. Nutrients. 2020; 12(9):2799. https://doi.org/10.3390/nu12092799
5. Mbikay M. Therapeutic Potential of Moringa oleifera Leaves in Chronic Hyperglycemia and Dyslipidemia: A Review. Front Pharmacol. 2012; 3(24): 1-2. https://doi.org/10.3389/fphar.2012.00024
6. Boukid F, Klerks M, Pellegrini N, Fogliano V, Sanchez-Siles L, Roman S, Vittadini E. Current and emerging trends in cereal snack bars: Implications for new product development. Int. J. Food Sci. Nutr. 2022; 73(5):610–629. https://doi.org/10.1080/09637486.2022.2042211
7. Gbolagade OH, Oluwajuyitan TD, Aderinola TA, Oyeleye IS, Oboh G, Arogundade TJ, Fagbemi TN. Quality assessment and in-vivo glycemic indices of snack bar from blends of plantain flour, soy meal and oat bran. Discov. Food. 2024; 4(1):162. https://doi.org/10.1007/s44187
8. Baurina AV, Baurin DV, Shakir IV, Panfilov VI. Use of Sunflower Protein in Snack Bars. Chem. Eng. Trans. 2021; 87, 1–6. https://doi.org/10.3303/CET2187001
9. Ajayi OA, Ikechukwu AA. Effect of substitution of glucose syrup with date syrup on the nutritional quality of Granola bars. Am. J. Food Sci. Nutr. 2021; 3(1):239-250.
10. Waseem M, Akhtar S, Muhammad Qamar MQ, Saeed W, Ismail T, Esatbeyoglu T. Effect of Thermal and Non-Thermal Processing on Nutritional, Functional, Safety Characteristics and Sensory Quality of White Cabbage Powder. Foods. 2022; 11(23):1–13. https://doi.org/10.3390/foods11233802

11. Orhevba BA, Yusuf IB. Effect of roasting temperature on nutritional quality of cashew nut (*Anacardium occidentale*). Int. J. Sci. Eng. Res. 2016; 7(8):182-184.
12. Anyanwu GO, Iqbal J, Khan SU, Zaib S, Rauf K, Onyeneke CE, Ojo OO. Antidiabetic activities of chloroform fraction of Anthocleista vogelii Planch root bark in rats with diet- and alloxan-induced obesity-diabetes. J. Ethnopharmacol. 2019; 229:293–302. https://doi.org/10.1016/j.jep.2018.10.021
13. AOAC International. Official Methods of Analysis of AOAC International. 21st ed. AOAC International. 2020.
14. Ahmad MA, Rukayya MA, Zulaihat BA, Aminu AM. Assessment of the microbial quality of food sold in some restaurants within Katsina metropolis. UMYU J. Microbiol Res. 2023; 8(2):1–10. https://doi.org/10.47430/ujmr.2382.007
15. Olagunju AI, Arigbede TI, Makanjuola SA, Oyebode ET. Nutritional compositions, bioactive properties, and in-vivo glycemic indices of amaranth-based optimized multigrain snack bar products. Meas. Food. 2022; 7:1-9. https://doi.org/10.1016/j.meafoo.2022.100039
16. Wu F, Xu F, Liu W, Chen S, Luo H, Cheng N, Zhao H, Cao W. A High-Performance Liquid Chromatography with Electrochemical Detection Method Developed for the Sensitive Determination of Ascorbic Acid: Validation, Application, and Comparison with Titration, Spectrophotometric, and High-Performance Liquid Chromatography with Diode-Array Detection Methods. Foods. 2023; 12(16):1-12. https://doi.org/10.3390/foods12163100
17. Singh R, Harvinder P, Suryawanshi M. Development and validation of an HPLC analytical method for the simultaneous estimation of vitamin B12 and folic acid. Essential Chem. 2025; 2(1): 1–9.
18. Temova, Ž., and Roškar, R. (2016). Stability-Indicating HPLC–UV Method for Vitamin D3 Determination in Solutions, Nutritional Supplements and Pharmaceuticals. J. Chromatogr. Sci. , 54(7), 1180–1186. https://doi.org/10.1093/chromsci/bmw059
19. Braden JL, Klarquist EF, Kellogg JA. Determination of elements in cereals, pseudocereals, and legumes by microwave plasma-atomic emission spectrometry. Food Chem. 2024; 10(24):101844. https://doi.org/10.1016/j.fochx.2024.101844
20. Ishak SF, Mohd-AbdMajid HA, Mohd-Zin Z, Zainol MK, Jipiu LB. Sensorial and physicochemical characterisation of snack bar with gum Arabic (Acacia seyal) addition. Food Res. 2022; 6(2):319–329. https://doi.org/10.26656/fr.2017
21. Agume ASN, Njintang NY, Mbofung CMF. Effect of soaking and roasting on the physicochemical and pasting properties of soybean flour. Foods. 2017; 6(2):12. https://doi.org/10.3390/foods6020012
22. Yadav L, Bhatnagar V. Formulation and sensory evaluation of Ready-to-Eat Cereal Bars made with raw and processed soya flour. Trends Biosci. 2015; 8(9): 2455–2459.
23. Pokharel A, Dangal A, Karki S, Lamichhane S, Timsina P, Bohara A. Study on the effect of different treatments on soy flour, and quality and sensory evaluation of prepared biscuits incorporated with oats and soy flour. Legume Sci. 2023; 5(4):e181. https://doi.org/10.1002/leg3.181
24. Haș IM, Vodnar DC, Bungau AF, Tarce AG, Tit DM, Teleky BE. Enhanced Elderberry Snack Bars: A Sensory, Nutritional, and Rheological Evaluation. Foods. 2023; 12(19):1-15. https://doi.org/10.3390/foods12193544
25. Brito TBN, Pereira APA, Pastore GM, Moreira RFA, Ferreira MSL, Fai AEC. Chemical composition and physicochemical characterization for cabbage and pineapple by-products flour valorization. LWT. 2020; 124:1-6. https://doi.org/10.1016/j.lwt.2020.109028
26. Munir M, Nadeem M, Mahmood QT, Qayyum A, Suhaib M, Zeb F, ul-Haq I, Qureshi A, Ashokkumar M. Addition of Oat Enhanced the Physico-Chemical, Nutritional and Sensory Qualities of Date Fruit Based Snack Bars. J. Food Nutr. Res. 2025; 6(4):271–276. https://doi:10.12691/jfnr-6-4-10
27. Ibrahim SA, Fidan H, Aljaloud SO, Stankov S, Ivanov G. Application of Date (*Phoenix dactylifera L.*) Fruit in the Composition of a Novel Snack Bar. Foods. 202; 10(5):1-11. https://doi.org/10.3390/foods10050918
28. Griffin LE, Dean LL. Nutrient Composition of Raw, Dry-Roasted, and Skin-On Cashew Nuts. J. Food Res. 2017; 6(6):13. https://doi.org/10.5539/jfr.v6n6p13
29. Coello KE, Frias J, Martínez-Villaluenga C, Cartea ME, Velasco P, Peñas E. Manufacture of healthy snack bars supplemented with moringa sprout powder. LWT. 2022; 154:1-9. https://doi.org/10.1016/j.lwt.2021.112828
30. Singh A, Kumari A, Chauhan AK. Formulation and evaluation of novel functional snack bar with amaranth, rolled oat, and unripened banana peel powder. J. Food Sci. Technol. 2022; 59(9):3511–3521. https://doi.org/10.1007/s13197-022-05585-6
31. Momanyi D, Owino W, Makokha A. Formulation, nutritional and sensory evaluation of baobab-based ready-to-eat sorghum and cowpea blend snack bars. Sci Afr. 2020; 7:1-9. https://doi.org/10.1016/j.sciaf.2019.e00215
32. Zulaikha Y, Yao SH, Chang YW. Physicochemical and Functional Properties of Snack Bars Enriched with Tilapia (Oreochromis niloticus) By-product Powders. Foods. 2021; 10(8):1-15. https://doi.org/10.3390/foods10081908
33. Ahnen RT, Jonnalagadda SS, Slavin JL. Role of plant protein in nutrition, wellness, and health. Nutr. Rev. 2019; 77(11):735–747. https://doi.org/10.1093/nutrit/nuz028
34. Ho LH, Tang JYH, Mazaitul AS, Mohd AH, Roslan A. Development of novel " energy " snack bar by utilizing local Malaysian ingredients. Int. Food Res. J. 2016; 23(5):2280–2285. 10.12691/jfnr-6-4-10
35. Krukowski RA, Ross KM. Measuring Weight with Electronic Scales in Clinical and Research Settings During the Coronavirus Disease 2019 Pandemic. Obesity. 2020; 28(7):1182–1183. doi:10.1002/oby.22851
36. Moshtaghian H, Critchley JA, Peake JM, Granger CL. Estimation of Vitamin C Intake Requirements Based on Body Weight. Nutrients. 2022; 14(7):1301.
37. Shi Z, McEvoy M, Luu J. Inverse association between serum vitamin B12 concentration and obesity among US adults: A cross-sectional study. Front. Nutr. 2019; 10(41):1-7. https://doi.org/10.3389/fendo.2019.00414
38. Musazadeh V, Zarezadeh M, Ghalichi F, Kalajahi F H, Ghoreishi Z. Vitamin D supplementation positively affects anthropometric indices: Evidence obtained from an umbrella meta-analysis. Front. Nutr. 2022; 9:1-12. https://doi.org/10.3389/fnut.2022.980749
39. Ishaq RA., Adegbegi AJ, Okere SO, Anyanwu GO. Evaluation of Locally Produced Ready to Use Therapeutic Food (RUTF) for Prevention of Childhood Malnutrition. Trop J Phytochem Pharm Sci. 2025; 4(3):136 – 140. http://www.doi.org/10.26538/tjpps/v4i3.5
40. Bansal U, Bhardwaj A, Singh SN, Khubber S, Sharma N, Bansal V. Effect of incorporating plant-based quercetin on physicochemical properties, consumer acceptability and sensory profiling of nutrition bars. Funct. Foods Health Dis. 2022; 12(3):116–127. https://doi.org/10.31989/ffhd.v12i3.888
41. Ajani R, Hamzat S, Adeyi R, Ajamu M, Alabi W, Adeoye A. Assessment of Nutritional Potential and Phytochemical Constituents of Cocoyam (*Xanthosoma sagittifolium spp.*) Wheat Flour Composite Bread. Trop J Phytochem Pharm Sci. 2025; 4(6):243 –254. http://www.doi.org/10.26538/tjpps/v4i6.1