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The Effect of Germination Time and *Aloe vera* Rind Ratio on Physicochemical and Nutritional Properties of Peanut Sprout Snack Bars: ROC-SAW Approach for Product Optimization

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Abstract— This study examined the effects of peanut germination time and the ratio of germinated peanut sprout flour to aloe vera rind flour on snack bar quality. Two experimental parameters were used in the study: flour proportions of 90:10, 80:20, and 70:30, and germination times of 12, 24, and 36 hours. The first evaluation concentrated on proximate composition, which included quantities of moisture, ash, fat, protein, fiber, and carbohydrates. Both factors and their interaction had a substantial ($p < 0.05$) impact on all proximal metrics. In order to determine the best formulation, these proximate data were then integrated into a multi-criteria decision-making framework using the Rank Order Centroid (ROC) and Simple Additive Weighting (SAW) techniques. The ROC–SAW results showed that the best combination of a 36-hour germination period and a 70:30 flour ratio yielded 23.79% protein, 8.81% fiber, 15.15% fat, and 31.37% carbohydrates. Additional analyses of the optimized formulation included antioxidant evaluation, amino acid profile, and FT-IR spectroscopy. FT-IR spectra revealed the presence of functional groups such as hydroxyl, carbonyl, amide, alcohol, and ether. Aspartic acid, glutamate, and arginine were the most frequently detected amino acids. The antioxidant activity IC50 value obtained from the DPPH experiment was 10,734.27 ppm. All things considered, combining germinated peanut sprout flour with aloe vera rind flour shows promise for producing a functional snack bar with enhanced nutritional content and bioactive potential.

Keywords— *Aloe vera; Amino acids; Antioxidant activity; Decision-making, Peanut sprout snack bar*

1. INTRODUCTION

Snack bars are a popular kind of snack food that provide consumers with convenience and nutritional advantages. They are often produced from cereals and legumes. They can be developed utilizing a variety of plant-based substances that can improve both health value and sensory quality because of their attractive look and adaptability [1]. They are frequently eaten in between meals as quick, ready-to-eat snacks to satisfy hunger and increase daily nutrient intake [2]. Snack bars are often rectangular in shape, high in nutrients, and portable [3]. The use of legumes or flour-based ingredients in many formulations leads to differences in nutrient profiles, especially in protein content, which is highly dependent on the protein source. Protein becomes a significant factor in snack bar production because it is essential to the human body's structure and function [4].

For instance, chikki, a classic peanut-based snack bar in India, is made by crushing and boiling peanuts before covering them with sugar or palm sugar. Many studies have experimented with different additives to improve nutritional quality. For example, Falah et al. [5] created snack bars using edamame flour and red rice, obtaining favorable sensory scores and a balanced nutritious content. Asriasih et al. [6] created snack bars that were high in fiber and carbs using mocaf and red kidney bean flour. The potential of peanuts in snack bar creation has been emphasized by several studies. While Taula'bi et al. [7] discovered significant variance in nutrient content across snack bars produced from maize starch, tapioca, sugar, eggs, and maltodextrin.

To the best of the authors' knowledge, no previous studies have reported the combined use of aloe vera rind and peanut sprout flour in snack bar formulations. Therefore, present study adopts a state-of-the-art approach by combining dried aloe vera rind and peanut sprout flour as functional ingredients in snack bar formulation, a strategy that remains largely unexplored. Aloe vera rind, commonly regarded as a processing by-product, contains various phenolic and phytochemical

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compounds that potentially contribute to antioxidant and metabolic health benefits. In parallel, peanut sprout flour represents an advanced ingredient derived from controlled germination, a bioprocess known to activate endogenous enzymes that modify macromolecules and enhance nutritional quality. During sprouting, enzymatic activity promotes the synthesis and release of bioactive compounds while simultaneously improving protein digestibility and mineral bioavailability through the reduction of antinutritional factors. As a result, peanut sprout exhibit superior functional and nutritional properties compared with their raw counterparts, particularly in terms of antioxidant capacity and metabolic health relevance [8].

This study demonstrates scientific novelty by integrating dried aloe vera rind and peanut sprout flour into a snack bar matrix, extending beyond the nutritional strategies reported in previous plant-based snack bars. Unlike earlier formulations of plants [5][6] that primarily emphasize macronutrient balance and sensory acceptance, the present work valorizes underutilized plant by-products and bioprocessed legumes to deliver added functional bioactivity. The use of dried aloe vera rind introduces phytosterols, phenolic compounds, and triterpenoids that are rarely explored in solid snack bar systems, particularly from rind material typically regarded as waste. Concurrently, peanut sprouting enhances protein digestibility, antioxidant capacity, and micronutrient availability through enzymatic activation, distinguishing this approach from conventional peanut-based formulations that focus mainly on energy and protein contribution, as highlighted in prior studies [7]. Therefore, this formulation not only differs in ingredient composition but also advances the concept of snack bars as functional foods with targeted bioactive enrichment, supporting sustainability, waste valorization, and improved nutritional functionality compared with previously reported plant-based snack bars.

Multiple Attribute Decision-Making (MADM) techniques, namely Rank Order Centroid (ROC) and Simple Additive Weighting (SAW), were used in this work to optimize the product, as already done by Sariati et al. [9] and Pratama et al [10]. Criteria weights are determined using the ROC approach according to their priority ranking, which is commonly stated as "the first criterion is more important than the second, the second is more important than the third," and so on. The ROC method is advantageous because it enables objective and consistent weight determination based solely on priority ranking, without requiring complex pairwise comparisons or large expert panels, as is the case with methods such as AHP.

The Simple Additive Weighting (SAW) approach is then used to make decisions based on these ROC-generated weights. In order to determine which alternative is the most desirable, SAW calculates the weighted sum of performance scores for each alternative across all criteria. The SAW method complements ROC by providing a simple yet robust aggregation mechanism, in which normalized performance scores are multiplied by their respective ROC-derived weights and summed to generate a final preference value. Compared with more complex techniques such as TOPSIS, VIKOR, or fuzzy-based optimization, SAW offers higher interpretability and ease of implementation, allowing clear identification of how each criterion contributes to the final decision.

2. EXPERIMENTAL SECTION

2.1. Materials

Aloe vera rind, peanuts, margarine, powdered sugar, salt, and eggs are among the ingredients needed to make snack bars; these are purchased from Pontianak local markets. Additionally, concentrated H_2SO_4 (Merck) for protein digestion, diluted sulfuric acid H_2SO_4 1.25% and diluted NaOH 1.25% (Merck) for crude fiber analysis, concentrated NaOH for the distillation process in the Kjeldahl method, hexane as solvents for fat extraction, and alcohol for washing fiber residues were the reagents used for proximate analysis based on the SNI method.

2.2. Equipments and Instrumentation

The equipment categorized into processing (snack bar preparation) and analytical (laboratory analysis) equipment. Processing equipment for snack bar preparation included mixing bowls, knives, cutting boards, trays, cabinet dryers, blenders, mesh strainers, snack bar molds, weighing scales, measuring plastics, tissues, napkins, wooden stirrers, spatulas, and ovens.

The details on analytical equpment: proximate analysis was performed using a Kjeldahl apparatus for protein determination, a Soxhlet apparatus for fat analysis, ovens and desiccators for moisture and ash content determination, and analytical balances for precise weighing. Phytochemical and functional compound analyses employed UV-Vis spectrophotometers to quantify total phenolic content and antioxidant activity, HPLC apparatus for the separation and quantification of specific bioactive compounds, and FT-IR instruments for functional group characterization. Sample preparation and handling involved the use of centrifuges, water baths and water bath shakers, freeze dryers, mortars, dropper pipettes, and thin trays, while routine laboratory work utilized standard glassware such as beaker glasses, Erlenmeyer flasks, test tubes, Petri dishes, weighing bottles, and tube clamps.

2.3. Snack Bar Preparation

Fresh aloe vera leaves were washed thoroughly under running water to remove adhering impurities. The rind was separated manually from the gel, cut into small pieces, and dried using a cabinet dryer at 90 °C until a constant weight was achieved. The dried rind was then ground using a blender and sieved through a

40-mesh sieve to obtain a uniform aloe vera rind powder, which was subsequently stored in airtight containers until further use.

Raw peanuts were first sorted and washed, then soaked in distilled water for 6 h at room temperature. Germination was carried out under controlled conditions for 20, 24, and 36 h until sprouts developed. followed by cooling to room temperature. The sprouts were then driedground into flour, and sieved through a 40-mesh sieve to obtain uniform peanut sprout flour. The resulting flour was stored in airtight containers prior to formulation.

Snack bars were formulated using different ratios of aloe vera rind powder and peanut sprout flour, namely 90:10, 80:20, and 70:30. These ratios were selected based on preliminary trials to balance functional ingredient incorporation with acceptable processing characteristics and sensory properties. Auxiliary ingredients, including egg yolk, margarine, powdered sugar, and salt, were added to improve texture, binding, and flavor. These ingredients were kept constant across all formulations to ensure that any observed differences in product characteristics were solely attributable to variations in aloe vera rind powder and peanut sprout flour proportions. All ingredients were mixed until homogeneous, molded into snack bar shapes, and baked. The snack bars were then cooled to room temperature prior to analysis.

2.4. Proximate Analyses

Proximate analyses of moisture, ash, protein, fat, crude fiber contents were conducted using AOAC standard methods [11]. Carbohydrate content was calculated by difference by Equation (1).

$$\%\ \text{carbohydrate} = 100\% - (\%\ \text{moisture} + \%\ \text{ash} + \%\ \text{protein} + \%\ \text{fat}) \quad (1)$$

The experimental design in this study consisted of two factors: (1) the peanut germination duration (12, 24, and 36 hours), and (2) the formulation ratio between peanut sprouts and aloe vera rind (90:10, 80:20, and 70:30).

2.5. Decision-making Approach using ROC and SAW for Product Optimization

The laboratory data obtained from proximate analyses were then calculated using decision-making techniques, which were Rank Order Centroid (ROC) and Simple Additive Weighting (SAW), following the approach previously applied by Sariati et al. [9] and Pratama et al. [10]. The criteria used in the evaluation were assigned weights through the ROC method. The mathematical expression for calculating the ROC weights is presented in Equation (2).

$$Wn = \frac{1}{k}\sum_{i=n}^{k}\left(\frac{1}{i}\right) \quad (2)$$

In the equation (1), *Wn* represents the final weight assigned to each criterion at the *n*-th priority level, *k* denotes the total number of criteria, and i refers to the priority level of each criterion as defined by its ranking order. In this study, the ranking of criteria was established through interviews with experts in agro-industrial engineering. The resulting criterion weights, together with the sensory evaluation scores of each alternative, were then analyzed using the Simple Additive Weighting (SAW) method. The SAW procedure was carried out through the following steps: (1) Identifying the criteria (*Cj*) and alternatives (*Ai*) to be used in the decision-making process, where *i* indicates the number of alternatives (*i = 1, 2, ..., n*) and *j* indicates the number of criteria (*j = 1, 2, ..., m*); (2) Assigning performance ratings for every alternative under each criterion. These ratings were derived from the average values of sensory evaluation results and antioxidative properties; (3) Establishing the criterion weights (W), which were obtained from the Rank Order Centroid (ROC) calculations; (4) Constructing the decision matrix (X) using the performance ratings of each alternative across all criteria. The structure of the matrix is shown in Equation (3); (4) Normalizing the decision matrix by converting the performance ratings (r_{ij}) according to the type of criterion, which were benefit or cost. The normalization formulas are presented in Equation (4). In this study, all criteria were classified as benefit criteria; (5) Computing the final preference value (V_i) for each alternative by calculating the weighted sum of its normalized ratings, as presented in Equation (5).

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{bmatrix} \quad (3)$$

$$r_{ij} = \begin{cases} \dfrac{X_{ij}}{\max_{x_{ij}}} & \text{if } j \text{ is } benefit \\ \dfrac{\min_{x_{ij}}}{X_{ij}} & \text{if } j \text{ is } cost \end{cases} \quad (4)$$

$$Vi = \sum_{j=1}^{n} W_j\, r_{ij} \quad (5)$$

The sample that achieved the highest preference score (*Vi*) based on the combined ROC and SAW analysis was selected as the optimal snack bar formulation. This formulation was then used as the reference for the subsequent FT-IR analysis, amino acid profiling, and antioxidant activity assessment (IC_{50} using the DPPH method).

2.6. FT-IR Characterization

Fourier Transform Infrared (FT-IR) spectroscopy was employed to identify the functional groups present in the samples. Approximately 0.01 g of the snack bar powder was mixed with 0.01 g of anhydrous KBr, homogenized, and pressed into a transparent pellet using a hydraulic press at 1.2 psi. The infrared spectra were then recorded using an FTIR-8400S spectrophotometer (Shimadzu) over the wavenumber range of 500–4000 cm^{-1}.

2.7. Amino Acid Profiling

Amino acid profiling was performed using high-performance liquid chromatography (HPLC) following acid hydrolysis and pre-column derivatization with *o*-phthalaldehyde (OPA), adapted from AOAC guidelines and a previously published HPLC–OPA protocol (AOAC, 2019; Lindroth & Mopper, 1979). Approximately 60 mg of sample was hydrolyzed with 4 mL of 6 N HCl at 110 °C for 24 h under a nitrogen atmosphere to minimize oxidative degradation, particularly of sulfur-containing amino acids. After cooling, the hydrolysate was neutralized to pH 7.0 with 6 N NaOH, diluted to 10 mL with distilled water, and filtered through a 0.2 µm membrane filter.

For derivatization, a 50 µL aliquot of the filtered hydrolysate was reacted with 300 µL of freshly prepared OPA reagent. The OPA reagent was prepared according to Lindroth and Mopper (1979) and consisted of *o*-phthalaldehyde dissolved in methanol, sodium borate buffer, and a thiol reagent. After mixing, a 10 µL portion of the derivatized solution was injected into an HPLC system (Agilent Technologies, USA) equipped with a fluorescence detector and a LiChrospher® 100 RP-18 column (250 mm × 4.6 mm i.d., 5 µm particle size).

Chromatographic separation was performed using solvent A (methanol:50 mM sodium acetate:tetrahydrofuran, 2:96:2 v/v/v, pH 6.8) and solvent B (65% methanol) at a flow rate of 1.5 mL/min, with fluorescence detection at an excitation wavelength of 300 nm and an emission wavelength of 500 nm. Amino acids were identified and quantified using external calibration curves constructed from commercially available amino acid standards analyzed under identical conditions. Tryptophan was not determined due to its degradation during acid hydrolysis. Results were expressed as g amino acid per 100 g sample on a dry weight basis.

2.8. Antioxidant Activity

Antioxidant activity was assessed using the DPPH (1,1-diphenyl-2-picrylhydrazyl) method following Sriharti et al. (2022). The radical-scavenging capacity of each sample was expressed as milligrams of vitamin C equivalent per 100 grams of extract, determined from a vitamin C calibration curve prepared at concentrations of 10–50 ppm. In this study, all experiments were carried out in triplicate, and the resulting data were analyzed using Minitab version 22. A factorial completely randomized design (CRD) ANOVA was employed to assess whether significant differences existed among the various formulations.

3. RESULT AND DISCUSSION

3.1. Proximate Analyses

The physical appearance of the snack bars produced in this study is shown in **Fig. 1**, while the results of the proximate analysis are summarized in **Table 1**. ANOVA indicated that germination time, the proportion of peanut sprouts to aloe vera rind, and their interaction significantly affected the moisture content of the product ($p < 0.05$). Several formulations exhibited moisture levels higher than the limits set by both USDA and SNI standards, reaching up to 6.10% [12]. In this study, the lowest moisture content (4.46%) was observed in the formulation using a 36-hour germination time and a 70:30 peanut sprouts–aloe vera rind ratio, whereas the highest moisture content (6.33%) was recorded at 12-hour with an 80:20 ratio. Moisture content plays a crucial role in determining product quality and shelf-life [12]. Differences among formulations may be attributed to the intrinsic moisture of the raw materials, as well as factors such as product size and shape, thickness, and processing duration [7].

Fig. 1 Snack bars developed from peanut sprouts and aloe vera rind

Table 1. Proximate analysis results of peanut sprouts and aloe vera rind snack bars

Germination Time	Proportion of Peanut Sprouts: Aloe Vera Rind	Moisture Content (%)	Ash Content (%)	Fat (%)	Protein (%)	Fiber (%)	Carbohydrate (%)
12	90:10	5,41 ± 0,05	2,56 ± 0,07	25,32 ± 0,41	16,81 ± 0,24	7,32 ± 0,23	40,32 ± 0,29
24	90:10	5,57 ± 0,15	2,41 ± 0,05	19,82 ± 0,87	18,56 ± 0,17	7,94 ± 0,15	38,25 ± 0,12
36	90:10	6,28 ± 0,18	2,68 ± 0,08	17,18 ± 3,59	19,99 ± 1,07	8,16 ± 0,52	35,63 ± 1,15
12	80:20	6,33 ± 0,06	2,44 ± 0,08	23,21 ± 0,76	16,34 ± 0,42	7,45 ± 0,15	41,27 ± 0,26
24	80:20	5,15 ± 0,27	2,76 ± 0,04	18,45 ± 0,28	19,08 ± 0,21	7,79 ± 0,12	38,06 ± 0,14
36	80:20	5,81 ± 0,10	2,58 ± 0,08	16,13 ± 0,13	20,28 ± 0,17	8,60 ± 0,27	32,46 ± 0,53
12	70:30	6,08 ± 0,18	2,39 ± 0,16	20,07 ± 0,38	17,23 ± 0,13	7,66 ± 0,22	40,11 ± 0,13
24	70:30	4,85 ± 0,23	2,45 ± 0,00	17,51 ± 0,15	19,24 ± 0,14	7,90 ± 0,23	36,73 ± 0,11
36	70:30	4,46 ± 0,06	2,31 ± 0,07	15,15 ± 0,15	23,79 ± 0,02	8,81 ± 0,06	31,37 ± 0,55

Although several formulations exhibited moisture contents exceeding the limits established by USDA and SNI standards, this condition has important practical implications for product shelf-life and safety. Elevated moisture levels may accelerate microbial growth, increase susceptibility to spoilage, and reduce storage stability, particularly under ambient conditions. Consequently, formulations with higher moisture content may require additional post-processing steps, such as extended drying, modified baking conditions, or moisture-barrier packaging, to ensure compliance with quality standards and acceptable shelf-life. From a product development perspective, these findings highlight the need to balance functional ingredient incorporation with adequate moisture control to maintain product acceptability and safety.

ANOVA results also showed that germination time did not significantly influence ash content ($p \geq 0.05$), while the proportion of peanut sprouts to aloe vera rind and their interaction did. The lowest ash content (2.31%) was obtained at 36-hour with a 70:30 ratio, whereas the highest value (2.76%) occurred at 24-hour with an 80:20 ratio. Variations in ash content were closely linked to differences in the proportion of peanut sprout flour and aloe vera rind flour in each formulation. This trend is consistent with findings by Dewi et al. [13], who reported that altering ingredient ratios in snack bars made from Dioscorea esculenta and Musa paradisiaca flours resulted in changes in ash levels. However, all ash values in the present study exceeded the USDA standard of 1.9% [12][13].

Although all formulations exhibited ash contents exceeding the USDA standard of 1.9%, this condition may be considered acceptable within the context of plant-based and high-fiber functional snack products. Elevated ash content generally reflects a higher mineral contribution, which is commonly associated with the incorporation of fiber-rich plant materials and by-products, such as aloe vera rind and germinated legumes. Similar trends have been reported in previous studies on functional snack bars formulated with tuber, legume, or rind-based flours, where ash contents frequently exceeded conventional standards while still being regarded as nutritionally advantageous rather than detrimental. Therefore, the increased ash levels observed in this study likely indicate enhanced mineral density attributable to the higher proportion of aloe vera rind and peanut sprout flour, rather than a decline in product quality.

For fat content, ANOVA confirmed that germination time, ingredient proportion, and their interaction all had significant effects ($p < 0.05$). The lowest fat content (15.15%) was found in the formulation using 36 -hour and a 70:30 ratio, while the highest (25.32%) occurred at 12-hour with a 90:10 ratio. A clear declining trend in fat content was observed as germination time increased, reflecting the use of stored lipids as an energy source during sprout development [14]. This aligns with Li et al. [15], who reported a reduction in fat content in peanut sprouts with longer germination periods. Moreover, increasing the proportion of aloe vera rind further reduced fat levels due to its naturally low lipid content. Añibarro-Ortega et al. [16] noted that aloe vera fillet, which contains approximately 31% rind, contains only about 1 g of fat per 100 g dry weight.

Protein content was also significantly influenced by all three factors ($p < 0.05$). The lowest protein content (15.15%) was found at 12 hours of germination with an 80:20 ratio, while the highest (23.79%) was achieved at 36 hours with a 70:30 ratio. Protein levels increased with longer germination, a trend also reported by Ferdiawan et al. [17] and Anggrahini [18], who attributed the increase to the synthesis of essential amino acids required for sprout growth.

During germination, endogenous hydrolytic enzymes are activated to support seedling growth. Increased protease activity over longer germination periods hydrolyzes storage proteins into peptides and amino acids; however, the measured protein content often increases due to the simultaneous degradation and respiration of starch and lipids, which concentrates nitrogenous compounds, as well as de novo synthesis of enzymatic and structural proteins during embryo development. Consequently, longer germination times result in higher extractable and analytically detectable protein levels.

Fiber content showed a similar pattern, with all factors exerting significant effects ($p < 0.05$). Fiber levels increased with both longer germination and higher proportions of aloe vera rind. The lowest fiber content (7.32%) occurred in the 12-hour, 90:10 formulation, while the highest (8.81%) was found in the 36-hour, 70:30 formulation. This is consistent with Megat et al. [19], who reported that extended germination increases fiber content in legume sprouts, and with findings by Añibarro-Ortega et al. [16] showing that aloe vera is naturally high in fiber. ANOVA also revealed significant effects of germination time, formulation ratio, and their interaction on carbohydrate content ($p < 0.05$). Carbohydrate levels tended to decrease with longer germination due to amylase activity, which breaks down starch into simpler sugars. As a result, simple sugar concentrations typically rise during early germination stages [20].

The dietary fiber content increases as extended germination promotes starch hydrolysis and its utilization as an energy source, reducing digestible carbohydrates and increasing the relative proportion of non-starch polysaccharides. In addition, cell wall remodeling and synthesis of structural polysaccharides during root and shoot elongation contribute to fiber accumulation, leading to higher fiber content in germinated seeds.

3.2. ROC-SAW Approach for Product Optimization

The proximate analysis results served as the foundation for subsequent decision-making to determine the most preferred snack bar formulation. The first step in this process was assigning weights to the evaluation criteria using the Rank Order Centroid (ROC) method. The prioritization of criteria was established through consultations with agro-industrial engineering experts.

Based on the assessments, the criteria were ranked in the following order of importance: protein > fiber > fat > carbohydrate.In the context of snack bar formulation, protein content is given the highest priority because of its essential role in supporting tissue growth and repair, as well as enhancing the product's functional value—particularly for consumers with active lifestyles.

Dietary fiber is ranked second due to its well-known benefits for digestive health. Fat is placed next, as it contributes not only to energy density but also to key sensory attributes such as flavor, texture, and product stability. Carbohydrates are ranked last among the four components; although they serve as the primary energy source, their levels must be managed carefully to maintain a balanced and health-oriented formulation.

The resulting criterion weights generated through the ROC method are presented in **Table 2**. Once weighting was completed, decision-making proceeded using the Simple Additive Weighting (SAW) method. The process began by constructing a decision matrix based on the proximate values provided in Table 1, followed by normalization using Equation (3). The normalized values are shown in **Table 3**.

In the final step, preference scores (Vi) were calculated for each alternative—representing each combination of germination time and peanut sprouts–aloe vera rind ratio. The results are summarized in **Table 4**. From the integrated ROC–SAW analysis, the formulation using peanut sprouts germinated for 36-hour with a 70:30 proportion to aloe vera rind emerged as the optimal alternative, achieving the highest preference score of 0.93.

Table 2. Rank Order Centroid (ROC) calculation for each criterion

Criterion	Weight Calculation Using ROC
Protein	$\frac{1+\frac{1}{2}+\frac{1}{3}+\frac{1}{4}}{4} = 0.520833$
Fiber	$\frac{0+\frac{1}{2}+\frac{1}{3}+\frac{1}{4}}{4} = 0.270833$
Fat	$\frac{0+0+\frac{1}{3}+\frac{1}{4}}{4} = 0.145833$
Carbohydrate	$\frac{0+0+0+\frac{1}{4}}{4} = 0.062500$

Table 3. Normalized data of proximate analysis results

Germination Time (h)	Proportion of Peanut Sprouts: Aloe Vera Rind	Fat (%)	Protein (%)	Fiber (%)	Carbohydrate (%)
12	90:10	1.00	0.71	0.83	0.98
12	80:20	0.92	0.69	0.85	1.00
12	70:30	0.79	0.72	0.87	0.97
24	90:10	0.80	0.78	0.90	0.93
24	80:20	0.73	0.80	0.89	0.92
24	70:30	0.69	0.81	0.90	0.89
36	90:10	0.70	0.84	0.93	0.84
36	80:20	0.64	0.85	0.98	0.79
36	70:30	0.60	1.00	1.00	0.76

Table 4. The results of the final preference score calculation (Vi)

Germination Time (h)	Proportion of Peanut Sprouts: Aloe Vera Rind	Criterion Weight				Final Preference Score (Vi)
		Fat (%) 0.145833	Protein (%) 0.520833	Fiber (%) 0.270833	Carbohydrate (%) 0.0625	
12	90:10	1.00	0.71	0.83	0.98	0.80
12	80:20	0.92	0.69	0.85	1.00	0.78
12	70:30	0.79	0.72	0.87	0.97	0.79
24	90:10	0.80	0.78	0.90	0.93	0.82
24	80:20	0.73	0.80	0.89	0.92	0.82
24	70:30	0.69	0.81	0.90	0.89	0.82
36	90:10	0.70	0.84	0.93	0.84	0.84
36	80:20	0.64	0.85	0.98	0.79	0.85
36	70:30	0.60	1.00	1.00	0.76	0.93

3.3. FT-IR Characterization

The FT-IR spectrum of the snack bar formulated with 36-hour peanut sprouts and a 70:30 ratio of peanut sprout flour to aloe vera rind is shown in **Fig. 2**. A broad band at 3280 cm⁻¹ with low transmittance reflects the presence of hydroxyl (–OH) groups, which are typically associated with water, alcohols, and polysaccharides. These functional groups are abundant in aloe vera rind and may also arise from alcoholic, phenolic, amino, and carboxylic compounds naturally found in peanuts.

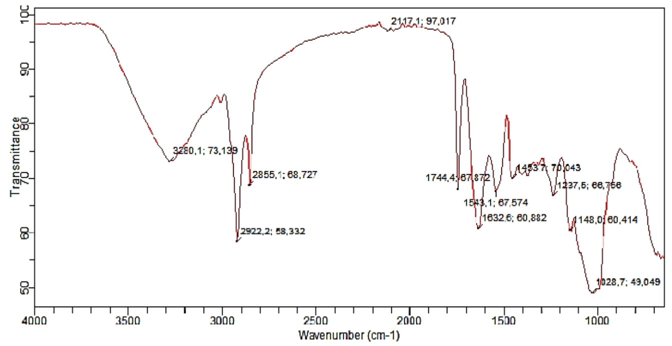

Fig. 2. The FT-IR result of snack bar developed by 36-hour germination of peanut sprouts with propotion of 70:30 to aloe vera rind

A peak appearing near 1744 cm^{-1} corresponds to ester or carbonyl (C=O) functional groups, likely originating from fatty acids, polysaccharide esters, or membrane-associated components of plant tissues, the features commonly found in aloe vera rind. Meanwhile, the characteristic protein-related bands of peanut sprouts are evident through the presence of amide I (1600–1700 cm^{-1}), amide II (~1542 cm^{-1}), and amide III (1220–1350 cm^{-1}), reflecting C=O, C–N, and N–H vibrational modes. Additionally, the sequential peaks at 1237, 1148, and 1028 cm^{-1} suggest the presence of alcohol and ether groups linked to polysaccharides such as cellulose, hemicellulose, and pectin, which are widely distributed in plant rind structures [21-24].

3.4. Amino Acids Profiling

The amino acid composition is presented in **Table 5**. Several amino acids, including aspartic acid, threonine, serine, glutamate, glycine, alanine, valine, methionine, leucine, histidine, lysine, and arginine, which are commonly found in aloe vera rind, as previously reported by Haque et al. [25]. Many of these amino acids, such as aspartic acid, threonine, histidine, lysine, and arginine, as well as phenylalanine, are also naturally present in peanuts.

Table 5. Amino acid composition of snack bar developed by 36-h germination of peanut sprouts with propotion of 70:30 to aloe vera rind

The Type of Amino Acid	Composition (%w/w)
Aspartic Acid	2.42
Threonine	0.64
Serine	1.05
Glutamate	4.31
Glycine	1.46
Alanine	1.12
Valine	1.06
Methionine	0.4
Ileucine	0.84
Leucine	1.56
Tyrosine	0.57
Phenylalanine	1.02
Histidine	0.63
Lysine	0.82
Arginine	2.34

Phenylalanine acts as a key precursor in the development of the characteristic aroma formed during peanut roasting [26]. During snack bar processing, heating may trigger the Maillard reaction, involving interactions between glucose and amino acids. This reaction can contribute to the product's aroma profile: phenylalanine may impart a dried rose-like note; alanine can produce fruity and floral nuances; and aspartic acid and serine may add fruity impressions. Meanwhile, glycine, lysine, threonine, and valine are associated with caramel-like aromas [21].

CONCLUSION

The results show that both germination time and the proportion of peanut sprout flour to aloe vera rind flour significantly affect the physicochemical characteristics of the snack bars. Using the ROC-SAW method, the optimal formulation was identified as the 36-hour peanut sprout flour combined with aloe vera rind flour at a 70:30 ratio. This formulation produced the highest protein content (23.79%), the highest fiber content (8.81%), the lowest fat content (15.15%), and an antioxidant activity (IC_{50}) of 10,734.27 ppm.

The amino acid profile and bioactive compounds from both key ingredients further contribute to the functional properties of the product. Overall, these findings highlight the promising potential of developing nutrient-dense, locally sourced functional snack bars that support innovation in sustainable food product development. Future work may focus on improving antioxidant capacity—such as by incorporating additional natural antioxidant-rich ingredients or refining processing conditions—to further enhance the product's functional and health-promoting attributes.

SUPPORTING INFORMATION

There is no supporting informationin this paper. The data that support the findings of this study are available on request from the corresponding author.

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CONFLICT OF INTEREST

The authos have no conflict of interest in this publication.

AUTHOR CONTRIBUTIONS

N and BSP carried out the experiment, data calculations, and revision. N prepared manuscript draft. BSP finalized manuscript. All authors collaborated on writing and revising manuscript. All authors approved the final version of the manuscript.

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