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Development of Legume-Based Snack Bar and its Nutritional, Sensory, Texture, and Microbial Properties

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Abstract— This study focused on the formulation and evaluation of protein-rich snack bars developed using Green gram (*Vigna radiata*), Chickpea (*Cicer arietinum*), and Black-eyed pea (*Vigna unguiculata*) in four different ratios (A: 1:1:1, B: 2:1:1, C: 1:2:1, D: 1:1:2). Sensory evaluation revealed that formulation B (2:1:1) achieved the highest scores across most attributes, including appearance, aroma, taste, and overall acceptability, followed by formulation C, while formulation D performed the poorest due to its higher proportion of BP. Proximate composition analysis of formulation B demonstrated a balanced nutritional profile, highlighting its potential as a protein- and fiber-rich snack alternative to conventional cereal-based bars. Color analysis indicated a desirable golden-brown appearance with reddish-yellow hues, enhancing consumer appeal. Texture analysis showed that formulation B was firmer and more resistant (hardness: 1405.8 g; fracturability: 1405.8 g) compared to a commercial sample, reflecting improved structural integrity though slightly higher bite force requirement. Microbial analysis confirmed that the product was within acceptable safety limits over two weeks of storage. Overall, the optimized 2:1:1 formulation effectively balanced sensory, nutritional, and textural qualities, making it a promising functional snack bar.

Index Terms— Color analysis; Legume-based snack bar; Proximate composition; Sensory evaluation; Texture analysis

1 Introduction

GreengramG (*Vigna radiata*), Chickpea (*Cicer arietinum*), and Black-eyed pea (*Vigna unguiculata*) are nutrient-dense legumes that play an important role in promoting balanced diets [1], [2], [3], [4]. They are excellent sources of plant-based protein, dietary fiber, complex carbohydrates, essential minerals, and bioactive compounds. Regular consumption of legumes has been associated with improved satiety, better glycemic control, and reduced risk of chronic diseases [2], [5], [6]. Despite these benefits, their direct consumption is often limited due to tough texture, long cooking times, and the presence of anti-nutritional factors such as phytates and tannins, which can interfere with nutrient absorption [7], [8]. Traditional processing methods such as soaking, cooking, or sprouting are usually required to improve their digestibility and nutritional bioavailability [9], [10].

In the context of modern lifestyles, there is growing consumer demand for ready-to-eat, convenient, and health-oriented snack products [11], [12]. Snack bars, in particular, have gained popularity as portable and energy-dense foods that can be tailored for specific nutritional purposes [13]. However, most commercially available snack bars are cereal-based and often low in protein and fiber while being high in sugar and fat, limiting their health-promoting potential [14]. Incorporating legumes into snack bars offers a promising approach to address these limitations by enhancing their nutritional quality while supporting plant-based dietary trends [15], [16].

This study was therefore undertaken to develop legume-based snack bars using GG, CP, and BP in varying proportions. Four formulations were prepared (1:1:1, 2:1:1, 1:2:1, and 1:1:2), and evaluated for their sensory attributes, proximate composition, color, texture, and microbial safety. The objective was to identify the formulation that achieves an optimal balance between consumer acceptability and nutritional functionality, thereby offering a convenient, protein-rich, and fiber-enhanced alternative to conventional snack bars.

2 METHODOLOGY

This section outlines the methods used for sample collection, snack bar development and subsequent analysis.

2.1. Raw materials

GG, chick pea, BP, egg, brown sugar, milk and margarine were purchased from Pambahina, Belihuloya, Sri Lanka local markets.

2.2. Development of Snack Bar

GG, CP and BP were washed thoroughly and oven dried at 40 °C for 8 hrs. The dried legumes were ground by a laboratory blender. Then the blends were stored in stored in clean glass containers for further analysis following methods described by earlier studies with certain modifications [17], [18]. The snack bar was developed as shown in the Table 1. Each of the four composite flour blends (80% of the total formulation) was combined with equal proportions of sugar, margarine, milk, and egg to achieve a uniform consistency suitable for bar formation. The mixture was shaped and baked at 165°C for 15 minutes to produce the snack bars.

Table 1: Ingredient formulation of snack bars expressed in percentage (%)

Blends	GG	CP	BP	MR	BS	EG	MI
A	33.3	33.3	33.3	5	5	5	5
B	40	20	20	5	5	5	5
C	20	40	20	5	5	5	5
D	20	20	40	5	5	5	5

Where, F1-F4 = Different snack bar formulations, GG= GG, BP= BP, CP= Chick pea, MR= Margarine, BS= Brown Sugar, EG= Egg, MI= Milk

2.3. Sensory evaluation

A five-point hedonic test was conducted using 30 semi-trained panelists to evaluate the samples. In both sensory evaluations, 8 sensory parameters (Appearance, Color, Aroma, Hardness, Fracturability, Taste, After taste, and Overall acceptability) were analyzed.

2.4. Proximate analysis

Moisture, protein, fat, and ash contents of the selected sample from the sensory analysis were determined using AOAC (2000) methods 925.10, 920.87, 920.85, and 923.03, respectively. The carbohydrate content was calculated by difference [19].

2.5. Color Analysis

The color of the ground snack bar was determined using a chromameter following the procedure described by Kince et al. (2018) with minor modifications. The L*, a*, and b* color scale was used, where L* indicates lightness (0 = black, 100 = white), a* represents redness (+a*) to greenness (−a*), and b* represents yellowness (+b*) to blueness (−b*) [20].

2.6. Texture profile analysis

Texture was compared with a commercial snack bar following the procedure described in Rathnayake et al. (2018) with few modifications. Texture profile analysis of the PB was conducted at room temperature using a Brookfield CT3 texture analyzer with a trigger load of 15.0 g and a test speed of 1.00 mm/s [21].

2.7. Shelf-life analysis.

During the shelf-life study, the samples were stored in glass containers at room temperature (27 °C, 60% relative humidity) until all analyses were performed. The shelf life of snack bars were evaluated based on microbial counts.

2.8. Statistical analysis

Data were analyzed using Minitab 19 software, employing one-way ANOVA, Tukey pairwise comparison, and linear regression analysis with 95% confidence interval as mean ± SD.

3. RESULTS AND DISCUSSION

This section presents the findings of the study along with their interpretation.

3.1. Sensory analysis

Mean sensory scores for different attributes of the snack bar formulations are presented in Table 2.

Table 2: Sensory evaluation scores of snack bar formulations

Attribute	**Sensory score**			
	A	**B**	**C**	**D**
Apperance	2.16±0.91	3.00±0.94	2.96±0.96	1.80±0.21
Color	2.36±0.99	2.96±0.96	3.00±0.94	1.66±0.06
Aroma	2.10±0.71	3.20±0.84	3.16±0.95	1.53±0.97
Hardness	2.23±0.99	3.16±0.79	2.90±0.84	1.60±0.13

Fracturability	2.00±0.91	3.13±0.93	2.96±0.92	1.96±0.15
Taste	2.10±0.99	3.03±0.17	2.90±0.17	1.93±0.08
After taste	2.20±0.96	3.04±0.76	2.56±0.84	2.27±0.33
Overall acceptability	2.03±0.85	3.43±0.72	3.03±0.76	1.56±0.95

Values are expressed as means ± standards deviation (n=3)

The sensory evaluation revealed clear differences in consumer acceptability among the four snack bar formulations prepared with varying ratios of GG, CP, and BP. Formulation B (2:1:1) consistently received the highest scores across most sensory attributes, including appearance (3.00±0.94), aroma (3.20±0.84), hardness (3.16±0.79), fracturability (3.13±0.93), taste (3.03±0.17), aftertaste 3.04±0.76), and overall acceptability (3.43±0.72), indicating that the higher proportion of GG enhanced the sensory quality of the product. Formulation C (1:2:1) also performed well, with good acceptability in appearance, color, and aroma, suggesting that a higher proportion of CP contributed positively to sensory perception, although its scores were slightly lower than B in overall acceptability. In contrast, formulation D (1:1:2), with the highest proportion of BP, consistently scored the lowest in all attributes, particularly appearance (1.80±0.21), aroma (1.53±0.97), and overall acceptability (1.56±0.95), reflecting possible limitations in consumer preference for BP-dominant formulations. Formulation A (1:1:1) showed moderate acceptability but was inferior to B and C in most attributes, suggesting that equal proportions did not optimize flavor or texture. Overall, the findings indicate that increasing the proportion of GG, as in formulation B resulted in the most favorable sensory profile, making it the best formulation in terms of consumer acceptability.

3.2. Proximate Analysis

Proximate analysis results of the selected snack bar (B) are given in Table 3.

Table 3. Proximate composition of selected snack bar B

Attributes	**Value (%)**
Crude fat	9.72±0.074
Crude protein	17.43±0.003
Crude fiber	9.54±0.321
Total ash	3.41±0.001
Carbohydrate	57.03±0.147
Moisture	2.87±0.057

Values are expressed as means ± standards deviation (n=3)

A balanced nutritional profile with crude protein content of 17.43%, which is relatively high and highlights its potential as a protein-rich snack suitable for improving dietary protein intake [2], [16], [22]. The crude fat content was 9.72 ± 0.074 %, contributing to energy density and palatability without being excessively high. The crude fiber content of 9.54 ± 0.321 % suggests potential benefits for digestive health and satiety. The crude ash value of 3.41 ± 0.001 % indicates the presence of appreciable mineral content. Carbohydrates formed the major component at 57.03 ± 0.147 %, making the snack bar a good source of energy, while the moisture content of 2.87 ± 0.057 % was within an acceptable range for shelf stability. According to the quality parameters reported by Anandito et al. (2020), which specify maximum moisture content of ~3.0 %, maximum ash content of 4.0 %, minimum fat content of 7 %, minimum protein content of 5 %, and minimum carbohydrate content of 60 %, the formulation can be considered of good quality [23]. The relatively high protein and fiber content, coupled with moderate fat, positions formulation B as a nutritionally beneficial and acceptable snack option compared with conventional cereal-based snack bars that are typically lower in protein and fiber.

3.3. Color analysis

Color measurements of the selected snack bar B are presented in Table 4.

Table 4: Color analysis of snack bar formulation B

Parameter	Value (Mean ± SD)
L* (Lightness)	42.86 ± 0.03
a* (Red–Green)	10.11 ± 0.07
b* (Yellow–Blue)	31.33 ± 0.43

Values are expressed as means ± standards deviation (n=3)

It indicated a moderate lightness value (L = 42.86)*, suggesting a relatively dark appearance compared to cereal-based snack bars that generally exhibit higher L values. The positive a value (10.11)* reflected a noticeable red hue, which may be attributed to the presence of GG and CP proteins undergoing Maillard reactions during processing. The b value (31.33)* was comparatively high, indicating a strong yellow tone that is typical of legume-based formulations and enhances product appeal by imparting a golden-brown appearance. Together, these color parameters suggest that formulation B possessed an appealing balance of brownish-yellow tones with a slight reddish tint, aligning with its higher sensory scores for appearance and overall acceptability.

3.4. Texture analysis

The texture analysis results are shown in Table 5.

Table 5: Texture analysis results of formulated and commercial snack bars

Attributes	Selected sample (B)	Commercial sample
Hardness (g)	1405.8 ± 2.76	663.2± 3.33
Deformation at Hardness (mm)	3.94 ± 0.03	1.88 ± 0.02
Deformation at Target (mm)	4.82 ± 0.16	4.99 ± 0.04
Fracturability (g)	1405.8 ± 2.33	545.4 ± 2.11

Values are expressed as means ± standards deviation (n=3)

It highlights clear differences between the formulated sample (B) and the commercial sample. Sample B, exhibited significantly higher hardness (1405.8 ± 2.76 g) and fracturability (1405.8 ± 2.33 g) compared to the commercial snack bar (663.2 ± 3.33 g and 545.4 ± 2.11 g, respectively). This suggests that the formulated bar is denser and requires greater force to break, likely due to the higher legume content contributing to stronger structural integrity. Deformation at hardness (3.94 mm ± 0.03 in B vs. 1.88 ± 0.02 mm in the commercial sample) indicates that B was less brittle and could withstand greater deformation before breaking, reflecting improved chewiness and resilience. However, deformation at target values was quite similar (4.82 ± 0.16 mm vs. 4.99 ± 0.04 mm), indicating comparable overall flexibility. These findings imply that the 2:1:1 formulation (sample B) produced a firmer and more resistant texture, and future studies should be conducted to obtain better hanrness in the snack bar.

3.5. Shelf-life analysis

Microbial analysis of the selected snack bar was carried out over 2-week period, and the results are presented in Table 6.

Table 6: Shelf-life analysis of snack bar B

Test	Prepared day	Week 01	Week 02
Yeast and mold (CFU/g)	N/A	N/A	N/A
Total plate count	N/A	0.4×10^2	0.78×10^2

The observed counts were acceptatble and is in line with the Micorbial limits for dried and instant processed cereal products requiring re-constitution; Aerobic plate count per gram: 5×10^4; Yeast and mold counts per gram: 1×10^2 as per Food act No. 26 of 1980 [24].

4. CONCLUSIONS

Among the four legume-based snack bar formulations, the 2:1:1 ratio of GG, CP, and BP (formulation B) was identified as the most suitable, achieving superior sensory acceptability, favorable nutritional composition, and desirable textural properties compared to both other formulations and a commercial sample. The high protein and fiber content of formulation B, along with its appealing color and acceptable microbial quality, establishes it as a nutritionally enhanced and consumer-preferred snack option. The study confirms that optimizing legume proportions can significantly improve the functional and sensory quality of snack bars, supporting their potential as healthy alternatives to conventional cereal-based products.

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