



Development and Evaluation of a High-Protein Energy Ball Using Sprouted Green Gram and Natural Ingredients

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ABSTRACT

The present study aimed to develop a high-protein, nutrient-dense energy ball using sprouted green gram and natural ingredients without the addition of refined sugar or preservatives. Sprouted green gram flour, dates, almonds, ghee, and cardamom were used to formulate three variations (T1, T2, and T3) with differing proportions of green gram and dates. Sensory evaluation was conducted using a 9-point hedonic scale by a panel of 20 semi-trained judges. Among the formulations, T3 showed significantly higher scores for color, texture, flavor, aroma, and overall acceptability ($p < 0.001$). Nutritional analysis of T3 revealed a favorable profile with high energy (427.7 kcal/100 g), protein (9.5 g/100 g), carbohydrates (62.1 g/100 g), healthy fats (15.7 g/100 g), and essential micronutrients. Antioxidant activity and microbial analysis confirmed the product's functional value and safety. Shelf-life studies indicated improved stability under vacuum-packed refrigerated conditions. The findings suggest that sprouted green gram-based energy balls have strong potential as a clean-label, plant-based functional snack with commercial applicability.



Introduction

There is a growing global demand for functional, plant-based snack foods driven by increasing health consciousness and awareness of diet-related chronic diseases. Conventional energy-dense snacks are often rich in refined sugars, saturated fats, and artificial additives, which may negatively impact health when consumed regularly. Consequently, consumers are increasingly seeking nutrient-rich, minimally processed alternatives.

Sprouted legumes are recognized for their enhanced nutritional quality and functional properties. Green gram (*Vigna radiata*), in particular, is a rich source of plant protein, dietary fiber, minerals, and bioactive compounds. Germination improves protein digestibility, mineral bioavailability, and antioxidant activity while reducing antinutritional factors (Kumari & Singh, 2021; Sangsukiam & Duangmal, 2017).

Dates serve as a natural sweetener and binding agent while contributing dietary fiber, minerals, and antioxidants (Al-Farsi & Lee, 2008). Almonds provide healthy fats, protein, and micronutrients linked to cardiovascular health (Liu et al., 2022). Ghee contributes fat-soluble vitamins and improves mouthfeel, while cardamom enhances flavor and provides antioxidant and antimicrobial properties (Patel et al., 2021).

The present study focused on developing a culturally acceptable, high-protein energy ball using sprouted green gram and natural ingredients, evaluating its sensory quality, nutritional value, antioxidant activity, microbial safety and shelf life.

Materials and Methods

Raw Materials

Green gram, dates, almonds, ghee, and cardamom were procured from a local market. All ingredients were of food-grade quality.

Preparation of Ingredients

Green gram: Soaked for 8–10 h, germinated for 24–48 h, sun-dried, roasted and ground into coarse flour. **Dates:** Deseeded and blended into a paste. **Almonds:** Roasted and coarsely ground. **Ghee:** Melted prior to mixing. **Cardamom:** Ground into fine powder.

Formulation of Energy Balls



Three formulations were prepared by varying the proportion of green gram flour and dates while keeping other ingredients constant (Table 1).

Table 1. Standardization of energy ball formulations

Ingredient	T1	T2	T3
Green gram (g)	100	80	70
Dates (g)	250	250	250
Almonds (g)	30	30	30
Ghee (ml)	15	15	15

The ingredients were mixed uniformly and shaped into 20 g balls, followed by cooling at room temperature.

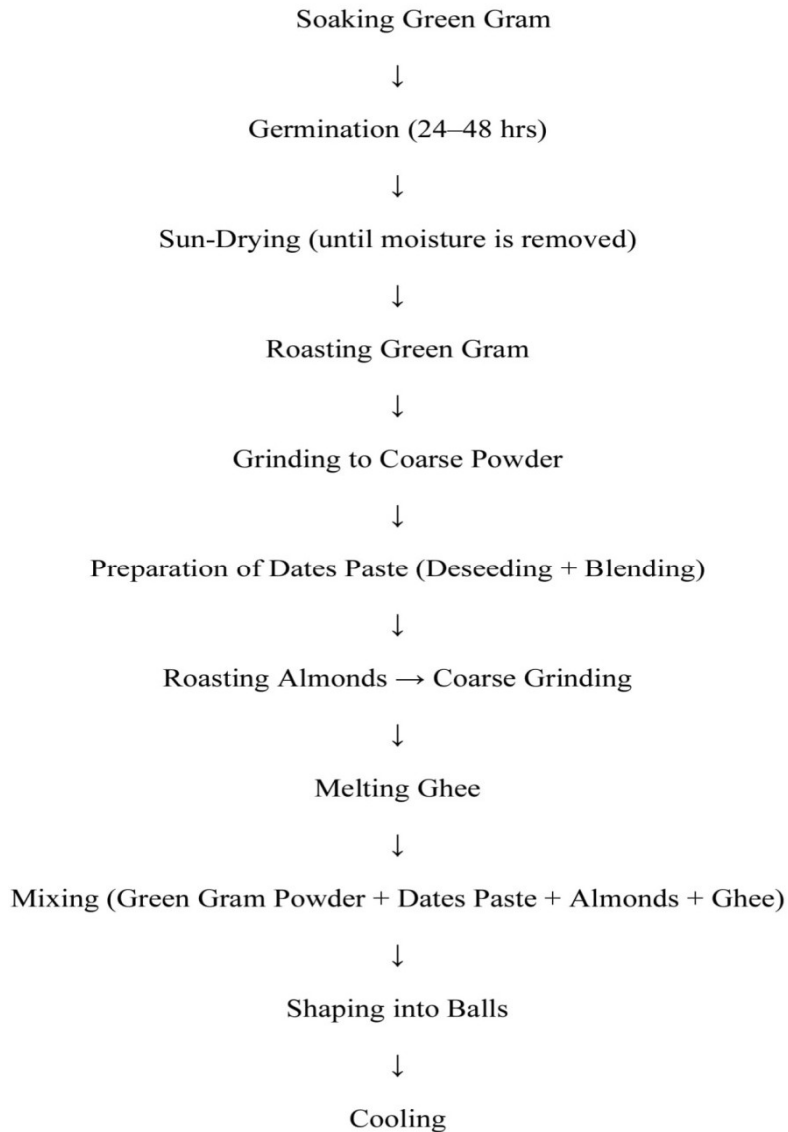


Fig 1: flowchart of Energy ball**Sensory Evaluation**

Sensory evaluation was carried out by 20 semi-trained panelists using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely). Attributes evaluated included color, texture, aroma, flavor, and overall acceptability (Gupta & Bhatt, 2023).

Nutritional, Antioxidant, and Microbial Analysis**Nutritional Analysis**

Nutritional composition was analyzed using standard AOAC 2016 methods (AOAC 925.10).

Antioxidant Activity

Antioxidant potential was evaluated using DPPH, ABTS and FRAP assays (Sangsukiam and Duangmal 2017).

Microbial Analysis

Microbial quality was assessed by determining total viable count, yeast and mold count, coliforms, *E. coli*, and *Salmonella* presence.

Shelf-Life Study

Energy balls were stored under room temperature (25–30°C), refrigerated (4–8°C), and vacuum-packed refrigerated conditions. Shelf life was monitored over 15–90 days.

Statistical Analysis

Data were expressed as mean \pm standard deviation. One-way ANOVA followed by Tukey's post hoc test was performed to determine significant differences among formulations ($p < 0.001$).

Results and Discursions**Formulation of High-Protein Energy Balls**



The standardized formulations of the high-protein energy balls prepared using sprouted green gram flour, dates paste, almonds, ghee, and cardamom (Table 2). Three experimental formulations (T1, T2, and T3) were developed by varying the proportion of sprouted green gram flour while maintaining constant levels of dates, almonds, ghee, and cardamom. The gradual reduction in green gram content from T1 to T3 was intended to evaluate the effect of legume concentration on sensory attributes, texture, and overall acceptability. This formulation strategy enabled identification of an optimal balance between protein enrichment and palatability.

Table 2: Formulation of High-Protein Energy Balls

Ingredient	T1 (g/ml)	T2 (g/ml)	T3 (g/ml)
Sprouted green gram flour (g)	100	80	70
Dates paste (g)	250	250	250
Almonds (g)	30	30	30
Ghee (ml)	15	15	15
Cardamom (g)	2	2	2

Sensory evaluation of Energy Ball Formulations

The sensory evaluation results of the three energy ball formulations assessed using a 9-point hedonic scale (Table 3). T3 exhibited significantly higher mean scores across all sensory attributes, including color (7.6 ± 0.5), texture (8.0 ± 0.4), aroma (8.2 ± 0.4), flavor (8.5 ± 0.3), and overall acceptability (8.6 ± 0.3). The enhanced sensory performance of T3 can be attributed to the higher proportion of dates, which improved sweetness, binding, and mouthfeel. In contrast, T1 recorded the lowest scores, likely due to the higher green gram content imparting a comparatively dense texture and mild legume flavor. These findings indicate that formulation significantly influenced consumer preference. The increased date content improved sweetness, texture and binding, consistent with earlier findings on traditional legume-based snacks (Agrahar-Murugkar et al., 2016; Gupta & Bhatt, 2023). ANOVA results confirmed a statistically significant difference among formulations ($p < 0.001$)

Table 3: Mean Sensory Scores of Energy Ball Formulations (9-Point Hedonic Scale)

Sensory Attribute	T1 (Low Dates)	T2 (Moderate Dates)	T3 (High Dates)
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Color	6.8 ± 0.4	7.3 ± 0.5	7.6 ± 0.5
Texture	6.5 ± 0.5	7.2 ± 0.6	8.0 ± 0.4
Aroma	6.4 ± 0.6	7.0 ± 0.5	8.2 ± 0.4
Flavor	6.6 ± 0.5	7.4 ± 0.6	8.5 ± 0.3
Overall Acceptability	6.7 ± 0.4	7.5 ± 0.5	8.6 ± 0.3

Values expressed as mean ± standard deviation ($n = 20$).

Nutritional Composition of Energy Ball (T3)

The nutritional composition of the most acceptable formulation (T3) per 100 g (Table 4). The energy balls provided 427.7 kcal, reflecting their suitability as an energy-dense snack. The protein content (9.5 g/100 g) highlights the contribution of sprouted green gram and almonds, while carbohydrates (62.1 g/100 g) primarily originated from dates, serving as a natural energy source. The protein enrichment is attributed to sprouted green gram and almonds, in agreement with Kumari and Singh (2021). The total fat content (15.7 g/100 g) was largely derived from almonds and ghee, contributing to satiety and fat-soluble vitamin availability. Additionally, T3 contained appreciable levels of essential minerals such as potassium, calcium, magnesium and iron, supporting its functional nutritional value.

Table 4: Nutritional Composition of T3 Energy Ball (per 100 g)

Parameter	Unit	Value
Energy	kcal	427.7
Protein	g	9.5
Carbohydrates	g	62.1
Total fat	g	15.7
Vitamin A	ng	451
Vitamin C	mg	1.2
Vitamin D	mg	0.18
Potassium	mg	470
Magnesium	mg	83
Iron	mg	2.3
Calcium	mg	70
Moisture content	%	11.2

Ash content	%	1.5
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Antioxidant Activity of Energy Ball (T3)

The antioxidant activity of the T3 formulation measured using DPPH, ABTS and FRAP assays (Table 5). The observed antioxidant capacity indicates the presence of bioactive compounds contributed by sprouted green gram, dates, almonds, and cardamom. The relatively high FRAP value suggests strong ferric reducing power, while DPPH and ABTS results confirm effective radical scavenging activity. These findings support the functional potential of the energy balls in combating oxidative stress and enhancing overall health benefits.

Table 5: Antioxidant Activity of T3 Energy Ball

Assay	Unit	Result
DPPH radical scavenging activity	mg/100 g	103.2
ABTS radical scavenging activity	mg/100 g	184.7
FRAP	mg/100 g	3098

Microbial Analysis of Energy Ball (T3)

The microbial quality of the developed energy ball. The total viable count and yeast and mould counts were below detectable limits (<10 CFU/ml), while coliforms, *Escherichia coli*, and *Salmonella* were absent (Table 6). These results confirm that the product met microbiological safety standards and was suitable for human consumption. The low microbial load can be attributed to proper hygienic processing, low moisture content, and the antimicrobial properties of ingredients such as cardamom.

Table 6: Microbial Analysis of Energy Ball (T3)

Test Parameter	Unit	Result
Total viable count	CFU/ml	<10
Yeast and moulds	CFU/ml	<10
Coliforms	CFU/ml	Absent
<i>E. coli</i>	CFU/ml	Absent



<i>Salmonella</i>	CFU/25 ml	Absent
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Shelf-Life Evaluation of Energy Balls

The shelf-life assessment of the energy balls under different storage conditions. The product remained stable for 15–20 days at room temperature (25–30°C), 30–45 days under refrigerated storage (4–8°C), and up to 60–90 days when vacuum packed and refrigerated (Table 7). The extended shelf life under vacuum refrigeration highlights the effectiveness of oxygen removal and low-temperature storage in preserving product quality and microbial safety. These results indicate strong potential for commercial storage and distribution.

Table 7: Shelf-Life Evaluation of Energy Balls

Storage Condition	Temperature	Duration	Test Method
Room temperature	25–30°C	15–20 days	AOAC 925.10
Refrigerated	4–8°C	30–45 days	AOAC 925.10
Vacuum packed + refrigerated	4–8°C	60–90 days	AOAC 925.10

Conclusion

The study demonstrated that high-protein energy balls developed using sprouted green gram and natural ingredients are nutritionally rich, sensory acceptable, and microbiologically safe. Among the formulations, T3 was identified as the most acceptable due to improved sweetness, texture, and overall quality. The product offers a clean-label, plant-based snack option suitable for children, athletes and elderly populations; holds potential for microenterprises and institutional nutrition programs.

References

- AOAC International. (2016). *Official methods of analysis of AOAC International* (20th ed.). AOAC International.
- Agrahar-Murugkar, D., Gulati, P., Kotwaliwale, N., & Gupta, C. (2016). Evaluation of nutritional, textural, and sensory quality of traditional laddoos. *Food and Nutrition Bulletin*, 37(2), 234–245.



- Al-Farsi, M. A., & Lee, C. Y. (2008). Nutritional and functional properties of dates: A review. *Critical Reviews in Food Science and Nutrition*, 48(10), 877–887. <https://doi.org/10.1080/10408390701724264>
- Gupta, M., & Bhatt, R. (2023). Sensory quality of biscuits enriched with sprouted green gram flour. *Indian Journal of Nutrition*, 10(1), 45–52.
- Kumari, P., & Singh, R. (2021). Nutritional enhancement of germinated green gram (*Vigna radiata*). *Journal of Food Science*, 56(4), 123–128.
- Liu, R., Wang, Y., & Zhang, L. (2022). Almond consumption and cardiovascular risk factors: A meta-analysis. *Nutrition Reviews*, 80(5), 987–1001.
- Patel, D., Shah, P., & Desai, S. (2021). Phytochemistry and bioactivity of cardamom (*Elettaria cardamomum*): A comprehensive review. *Journal of Ethnopharmacology*, 266, 113–127.
- Sangsukiam, P., & Duangmal, K. (2017). Antioxidant activity of sprouted mung beans. *Food Chemistry*, 224, 113–120.
- Sattar, A., Khan, M. I., & Ahmad, N. (2023). Functional properties of sprouted legume flours and their applications in food products. *Journal of Functional Foods*, 95, 105–118.