

Development and Quality Characterization of a Functional Confectionery: Physico-chemical and Sensory Evaluation of Beetroot (*Beta vulgaris* L.) Powder-Incorporated Besan Laddu

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Abstract: **Background:** Beetroot (*Beta vulgaris* L.) is some nutritionally dense root vegetable rich in betalains, inorganic nitrates, and essential minerals. Despite its therapeutic potential in combating oxidative stress and improving cardiovascular health, its application in traditional Indian confectionery remains limited. **Objective:** This study aimed to develop a value-added besan laddu incorporated with beetroot powder and to evaluate its sensory, physical, and biochemical properties, along with consumer acceptability and economic feasibility. **Methods:** Four formulations were developed: a control sample and three experimental variations incorporating beetroot powder at concentrations of 30 g, 40 g, and 50 g. Sensory evaluation was conducted using a 9-point hedonic scale by a semi-trained panel (n=10), and broader consumer acceptability was assessed using the Food Action Rating (FACT) scale (n=100). Statistical significance was determined using the Friedman test (p = 0.406). **Results:** Variation 2 (100 g besan, 40 g beetroot powder, and 60 g jaggery) emerged as the most acceptable formulation, achieving superior scores for taste (7.8 ± 0.62), flavor (7.6 ± 1.37), and overall acceptability (7.6 ± 0.71). Physical analysis of the optimized product revealed an average weight of 21.3 g, volume of 24.3 ml, and a bulk density of 0.86 g/ml. Biochemical profiling of the selected variation showed a moisture content of 15.69%, fat content of 13.98%, and total ash of 3.74%. Consumer evaluation yielded a FACT score of 7.15, indicating high market potential. **Conclusion:** The study demonstrates that moderate incorporation (40%) of beetroot powder significantly enhances the functional profile of traditional laddu without compromising sensory integrity. At a production cost of ₹110 per 100 g of raw ingredients, this product represents a viable strategy for delivering plant-based bioactive compounds through traditional snack formats.

Keywords: *Beta vulgaris* L., Functional foods, Product development, Sensory evaluation, Nutritional profiling, Besan laddu.

I. INTRODUCTION

Beetroot (*Beta vulgaris* L.), a member of the Chenopodiaceae family, is a versatile root vegetable globally recognized for its vibrant pigmentation, dense nutritional profile, and significant therapeutic potential. Cultivation is particularly concentrated in specific agro-

climatic zones; for instance, the south and southeast regions contribute approximately 77% of total production, with average yields ranging from 30–40 t/ha (Amaral et al., 2004; Mello et al., 2008).

Nutritional and Bioactive Profile:

Beyond its role as a culinary staple, beetroot is a "superfood" characterized by high concentrations of

carbohydrates, proteins, and dietary fiber. It is notably rich in essential minerals including potassium, magnesium, copper, calcium, and iron the latter of which has been reported to exceed the concentrations found in spinach (Joshi & Mathur, 2010). Furthermore, its biological value is driven by a diverse array of bioactive compounds, most notably betalains (responsible for its distinct red hue), phenolic compounds, flavonoids, and inorganic nitrates. These constituents impart potent antioxidant properties, which are critical in mitigating cellular oxidative stress (Biondo et al., 2014).

Health Benefits and Therapeutic Potential:

In the contemporary era of functional foods, increasing consumer health consciousness has shifted focus toward plant-based ingredients. Research suggests that the dietary nitrates in beetroot are converted into nitric oxide within the body, which plays a pivotal role in:

Improving blood circulation and cardiovascular health.
Enhancing athletic and exercise performance.
Supporting cognitive function and reducing systemic inflammation (Jones et al., 2018).

The Research Gap: Value Addition in Traditional Foods: Despite its validated health benefits, beetroot remains significantly underutilized in the processed food sector, particularly within the context of traditional Indian dietary patterns. Laddu, a spherical confection popular across the Indian subcontinent, serves as an ideal vehicle for fortification due to its widespread consumer acceptance and cultural significance. Incorporating beetroot in a dehydrated powder form offers a strategic opportunity to enhance the micronutrient and antioxidant density of this traditional sweet without compromising its palatability.

II. OBJECTIVES OF THE STUDY

Currently, there is a paucity of standardized scientific literature regarding the formulation and quality assessment of beetroot-incorporated sweets. This study, therefore, aims to:

Standardize the formulation of beetroot powder-incorporated laddu.

Evaluate the sensory attributes and consumer acceptability of the value-added product.

Analyze the physical characteristics and biochemical composition to determine the nutritional impact of the fortification.

Through this research, we seek to promote the utilization of Beta vulgaris in the functional food industry, providing a nutritious alternative to conventional high-calorie sweets.

III. MATERIALS AND METHODS

Procurement of Raw Materials

Fresh, mature beetroot (*Beta vulgaris* L.) and other primary ingredients including Bengal gram flour (besan), jaggery, almonds, cashew nuts, desiccated coconut, clarified butter (ghee), and cardamom were procured from the Ima Market in Imphal, Manipur, India. The research was conducted across the facilities of the Department of Home Science, Ghanapriya Women's College, Dhanamanjuri University, and the State Public Health Laboratory, Lamphel, Imphal West.

3(b). Preparation of Beetroot Powder

The beetroot powder was prepared following the method of dehydration to ensure the retention of bioactive pigments.

Pre-treatment: Fresh roots were thoroughly washed under potable running water to remove extraneous soil and debris, followed by manual peeling.

Size Reduction: The peeled roots were grated manually to increase the surface area for efficient drying.

Dehydration: The grated material was subjected to open sun-drying for approximately 72 hours (three consecutive days) until a constant weight was achieved, indicating complete moisture removal.

Milling and Storage: The dehydrated beetroot was pulverized using a mechanical laboratory grinder to achieve a fine consistency. The resulting powder was passed through a standard sieve to ensure uniform particle size distribution.

Packaging: The final powder was stored in moisture-resistant, airtight polyethylene terephthalate (PET) containers at ambient temperature (25 ± 2°C) to prevent hygroscopic degradation and pigment oxidation (Figure 1).

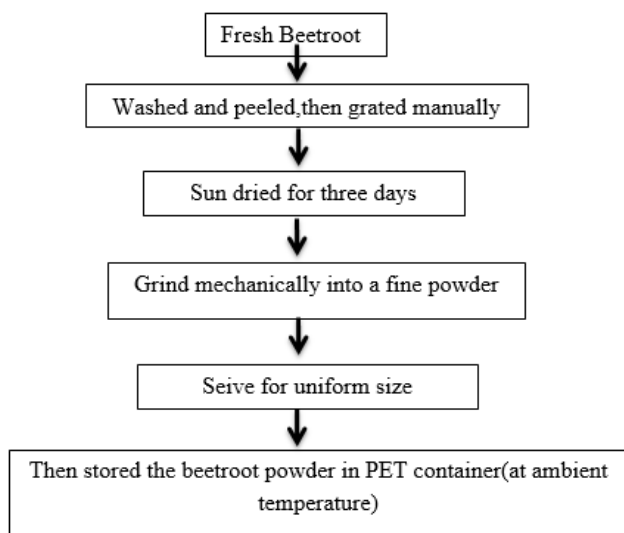


Fig. 1 Preparation of Beetroot Powder

3(c). Formulation and Standardization of Laddu: Proportions of the Variations 1, 2, and 3

Ingredients (g)	Control (V ⁰)	Variation 1 (V ¹)	Variation 2 (V ²)	Variation 3 (V ³)
Bengal Gram Flour (Besan)	100	100	100	100
Beetroot Powder	0	30	40	50
Jaggery	60	60	60	60
Ghee / Nuts / Cardamom	Constant	Constant	Constant	Constant

3(d). Preparation of Beetroot Laddu

The formulation of the laddu followed a standardized traditional processing technique with controlled modifications for beetroot powder incorporation. The preparation was executed in the following stages:

Roasting Phase: Bengal gram flour (100 g) was roasted in clarified butter (ghee 30 g) using a heavy-bottomed stainless steel vessel over a low-to-medium flame. Roasting continued until a characteristic nutty aroma and a uniform light-golden hue were achieved, signifying the completion of the dextrinization of starch and flavor development.

Syrup Preparation: A jaggery solution was prepared concurrently by dissolving 60 g of crushed jaggery in 60 ml of distilled water. The mixture was heated, filtered to remove physical impurities, and simmered to achieve a specific consistency suitable for binding.

Blending and Fortification: To the roasted gram flour, a standardized blend of roasted and coarsely pulverized almonds (5 g), cashew nuts (5 g), desiccated coconut (5 g), and cardamom powder (2 g) was added.

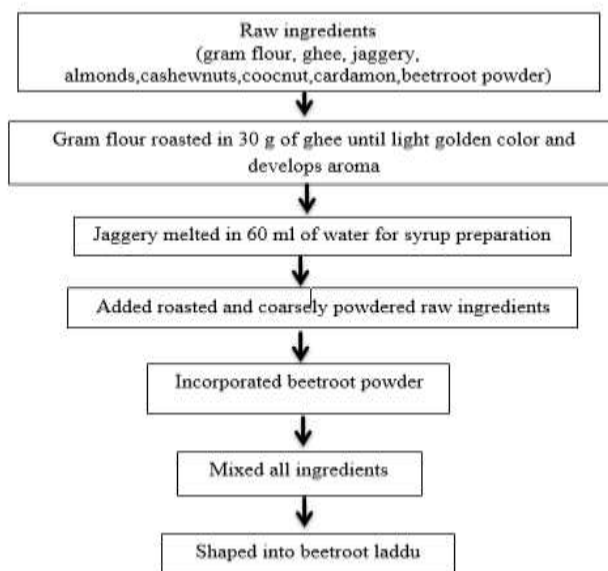


Fig. Flow chart showing preparation of beetroot powder incorporate laddu

Incorporation of Functional Ingredient: Beetroot powder was then integrated into the mixture at three distinct levels: 30 g (Variation V¹), 40 g (Variation V²), and 50 g (Variation V³). A control sample (V⁰) was maintained without the addition of beetroot powder to serve as a baseline for comparison.

Molding: The prepared mixtures were thoroughly homogenized while warm and manually molded into spherical units (approx. 20–25 g each). The finished products were cooled to room temperature and stored in air-tight containers for further quality assessment (Figure 2 and Plate 1: a, b, c, d).



Fig. (a)-Besan laddu(standard) Plate 1(b)- Besan laddu mix with 30g of IV. powder



Plate 1(c)- Besan laddu mix with 40g of IV powder
Plate 1(d)- Besan laddu mix with 50g of beetroot powder
Plate 1(a,b,c and d)- Products prepared from standard and formulated beetroot powder

3(e). Organoleptic Evaluation

The sensory profile of the beetroot powder-incorporated laddu samples was evaluated to determine consumer appeal and the impact of fortification on palatability.

Panel Selection: A semi-trained panel consisting of ten judges ($n = 10$) was selected from the Department of Home Science, Ghanapriya Women's College. The panelists were chosen based on their familiarity with the product's sensory characteristics and their ability to differentiate between subtle variations in flavor and texture.

Methodology: Evaluation was performed using a 9-point Hedonic Scale, where a score of 9 represented "Like Extremely" and 1 represented "Dislike Extremely." The samples, including the control (V^0) and experimental variations (V^1 , V^2 , V^3), were presented in a randomized order to eliminate positional bias.

Sensory Parameters: The samples were assessed for six critical organoleptic attributes:

Color: Intensity and uniformity of the characteristic red-purple hue.

Appearance: Surface smoothness and visual appeal.

Taste: Balance of sweetness and the earthiness of beetroot.

Flavor: Aromatic profile and absence of off-notes.

Texture: Mouthfeel, graininess, and structural integrity.

Overall Acceptability: A composite score reflecting the holistic sensory experience.

Testing Conditions: Assessments were conducted in a standardized sensory evaluation laboratory under neutral white lighting to ensure accurate color perception. Panelists were provided with potable water to rinse their palates between sample tastings to prevent flavor carry-over.

3(f). Physical Properties

Shape of beetroot laddu: Three laddus in triplicate were observed for the shape. Measurements were recorded in triplicate and mean values were calculated.

Weight of beetroot laddu: The weight of individual freshly prepared beetroot laddu was determined using electronic balance with a sensitivity of 0.01mg (Mishra and Gupta,1995). The average weight of laddu was recorded in gram (g) and calculated.

Volume of beetroot laddu: The volume of the laddu was determined by seed displacement method. The results were expressed as ml. The reading was taken in triplicate.

Bulk density: The bulk density was taken and expressed as gram per ml (Mishra and Gupta,1995).

Length (mm), breadth (mm) and L/B ratio of beetroot laddu: The average length and breadth of the randomly picked three laddu were measured in mm with a help of vernier calipers (Mityoto, Japan; least count, 0.02). The length/breadth ratio was obtained by dividing the length of a single laddu by the corresponding breadth to determine the size and shape (Graham, 2002). Measurements were recorded in triplicate and mean values were calculated.

3(g). Biochemical Analysis: Moisture, fat, total ash, and acid-insoluble ash contents of the best selected sample was determined using FSSAI Manual(2016).

3(h). Consumer Acceptability: Consumer acceptability of the developed beetroot powder laddu was evaluated by 100 college-going female students of G.P Women's

College using the Food Action (FACT) rating scale a nine point successive category for measuring food acceptance (Schutz, 1964). Responses were recorded and mean acceptability scores were calculated.

3(i). Cost of the beetroot laddu: The beetroot powder incorporated besan laddu was calculated by the cost of raw materials, ingredients and the cost of packaging materials as well as labelling charge.

3(j). Statistical Analysis: The data obtained from physical properties of beetroot laddu were statistically analysed for mean value. Biochemical properties of the beetroot laddu were subjected to percentage. The sensory evaluation were subjected to mean and standard deviation and it was statistically calculated by Friedman test (p value-0.406) using a significance of 0.05.

IV. RESULTS AND DISCUSSION

Sensory Quality Attributes and Consumer Preference

The organoleptic profile of the beetroot powder-incorporated laddu is summarized in Table 1 and illustrated in Figure 3. The data indicates that the incorporation of Beta vulgaris powder significantly influenced the sensory characteristics of the traditional sweet, with variations in scores reflecting the panel's response to increased fortification levels.

Color and Appearance: These attributes received the highest scores across all experimental variations, ranging from 7.2 ± 0.62 to 8.1 ± 0.54 . This suggests that the natural betalain pigments provided a visually appealing, vibrant red-purple hue that was well-received, effectively shifting the rating from "liked moderately" to "liked very much."

Taste and Flavor: The control (V^0) and V^2 (40% incorporation) recorded the most favorable scores for taste (7.8 ± 0.62). While the earthy notes of beetroot were detectable, they were perceived as complementary to the nutty profile of roasted gram

flour and the sweetness of jaggery in the V² formulation. However, a slight decline was observed in V³ (6.9 ± 2.1), likely due to the over-concentration of earthy saponins inherent in beetroot.

Texture: Texture scores remained relatively stable across the variations (7.1 to 7.7), indicating that the fine particle size of the beetroot powder successfully integrated with the gram flour matrix without causing undesirable grittiness or compromising the structural integrity of the laddu.

Overall Acceptability: Variation 2 (V²) emerged as the most preferred formulation among the experimental groups, with an overall acceptability score of 7.6 ± 0.71.

The mean sensory scores across all parameters primarily fell within the “liked moderately” to “liked very much” categories on the 9-point hedonic scale. Statistical analysis (Friedman test, p = 0.406) indicated that while the sensory scores varied numerically, the differences between the control and the 40% incorporation level (V²) were not statistically detrimental to consumer acceptance. This identifies V² as the optimum formulation for maximizing nutritional value while maintaining high palatability.

Table 1 Mean and standard deviation of different samples for sensory attributes

Attribute	Standard	Variation 1	Variation 2	Variation 3
Appearance	7.9 ± 0.88	7.5 ± 1.08	7.4 ± 0.97	7.3 ± 0.82
Taste	7.5 ± 1.08	7.7 ± 0.82	7.8 ± 0.79	7.1 ± 0.99
Flavour	7.6 ± 0.70	7.4 ± 1.17	7.6 ± 1.17	6.9 ± 1.45
Colour	8.1 ± 0.74	7.3 ± 0.82	7.2 ± 0.79	7.1 ± 1.10
Texture	7.2 ± 1.03	6.9 ± 1.29	7.6 ± 0.70	7.4 ± 1.07

Overall	7.3 ±	7.5 ±	7.6 ±	7.4 ±
Acceptability	1.25	0.85	0.84	0.84

*Results are means ± standard deviation (n=10).



Figure 3 Effect on sensory quality attributes of beetroot laddu

Statistical analysis indicated no significant differences among the formulations at the 5% level; however, variation 2 (100 g besan + 40 g beetroot powder + 60 g jaggery) achieved comparatively higher scores for taste, flavor, texture, and overall acceptability. This suggests that moderate incorporation of beetroot powder provided a balanced sensory profile. In contrast, variation 3 (50 g beetroot powder) recorded the lowest acceptance, possibly due to stronger earthy notes and slight changes in texture.

The enhanced color and appearance of beetroot laddus can be attributed to the presence of natural betalain pigments in beetroot, which impart an attractive red hue to the product. Similar improvements in visual appeal due to natural pigments have been reported in functional food formulations by Agrahar-Murugkar (2016) and Londhe et al., (2000). Furthermore, the minimal variation in taste and flavor is consistent with the findings of Singh et al., (2021), who reported that

functional ingredient incorporation did not significantly alter flavor and texture profiles.

Overall, the results indicate that beetroot powder can be successfully incorporated into laddu without adversely affecting sensory quality. The formulation containing 40 g beetroot powder (variation 2) provided the most acceptable balance of color, flavor, and texture, making it the most preferred variation among the panelists.

Physical Characteristics of Beetroot Laddu

The physical properties of beetroot laddu are presented in Table 1. The laddus were round in shape and exhibited a color ranging from deep reddish-pink to dark magenta due to beetroot incorporation. The average weight, volume, bulk density, length, and breadth ranged from 19–22 g, 23–25 ml, 0.86 g/ml, 1.4–1.6 cm, and 1.4–1.5 cm respectively with mean values of 21.3 g, 24.3 ml, 0.86 g/ml, 1.53 cm, and 1.43 cm. An increase in color darkness was observed with higher levels of beetroot powder incorporation; however, the difference was not statistically significant. Similar results were reported by Sudha et al., (2016).

Biochemical Composition of Beetroot Laddu

The selected variation (V2) showed a moisture content of 15.69%, indicating good shelf stability and reduced microbial spoilage, which is consistent with the findings of Yadav (2023) and Gupta and Paul (2012), who reported minimal changes in moisture with incorporation of functional ingredients. The fat content (13.98%) remained within the normal range, suggesting that beetroot powder had negligible influence on fat levels, similar to observations by Kimothi (2022) and Sudha (2016).

A significant increase in total ash content (3.74%) was observed, indicating improved mineral composition due to beetroot incorporation. This aligns with studies by Aakriti et al., (2022) and Kumari et al., (2021), who also reported enhanced mineral content in fortified traditional foods. The acid-insoluble ash content (0.60%) showed a slight increase, which is in agreement with findings of Aakriti et al., (2022), reflecting the presence of natural plant residues without affecting product safety.

Table 2 Biochemical composition of the selected beetroot powder laddu

Blends Gram flour + beetroot powder	Moisture (%)	Fat (%)	Total Ash (%)	Acid Insoluble Ash (%)
Beetroot powder (V2)	15.69	13.98	3.74	0.60

Consumer Acceptability of Beetroot Powder Laddu

Consumer acceptability of the developed beetroot laddu was evaluated among 100 adult female consumers using the FACT scale, and the results are presented in Table 3. The findings indicated good consumer acceptance of the product. The highest proportion of respondents (28%) rated the product with a score of 9, indicating that they “would eat this at every opportunity.” About 19% of the consumers gave a score of 8 (“would eat very often”), while 13% rated it 7 (“would frequently eat this”). Additionally, 26% of respondents assigned a score of 6, suggesting that they “liked the product and would eat it occasionally.”

Lower preference levels were recorded for scores 5 (8%) and 4 (6%), while no respondents selected the lowest scores (1–3). The cumulative FACT score recorded was 715, indicating overall positive consumer acceptance. These results demonstrate that beetroot laddu was well appreciated by the consumers and has good potential for wider acceptance due to its appealing taste, convenience, and attractive appearance.

Cost of the prepared beetroot powder laddu

Table 3 Cost calculation of the prepared beetroot laddu (Variation 2)

Ingredients	Actual rate/ g (Rs)	Amount (g)	Cost (Rs)
Besan	40 / 500g	100g	8
Jaggery	100 / 500g	60g	12
Almonds	180 / 100g	5g	9
Cashewnuts	180 / 100g	5g	9
Coconut	70 / 250g	5g	1.4
Cardamom	78 / 8g	2g	19.5
Ghee	150 / 250g	30g	18
Beetroot powder	110 / 1000g	40g	4.4
Cost of the product	Cost of the product	Cost of the product	81.3
Cost of packaging	Cost of packaging	Cost of packaging	10
Cost of labelling	Cost of labelling	Cost of labelling	10
Expected other expenses	Expected other expenses	Expected other expenses	9
Total amount (Rs.)	Total amount (Rs.)	Total amount (Rs.)	110

The cost analysis was conducted for the best Variation 2 (besan laddu mixed with 40 g beetroot powder). The total ingredient cost was ₹81.3. When additional expenses such as packaging, labelling, and other processing costs were included, the final production cost of the developed product was ₹110 per unit.

Proper standardization of processing methods, evaluation of nutritional properties, and appropriate packaging and labelling of beetroot laddu can enhance product acceptability and contribute to market expansion and economic development (Soibam et al., 2018).

V. CONCLUSION

The present investigation successfully establishes the viability of beetroot (*Beta vulgaris L.*) powder as a functional adjunct in the fortification of traditional Indian confectionery. Empirical data suggests that the incorporation of dehydrated beetroot powder significantly enhances the micronutrient and bioactive density of besan laddu while maintaining high levels of organoleptic integrity and physical stability. Analysis of the experimental variations reveals that the formulation containing 40 g of beetroot powder per 100 g of Bengal gram flour Variation 2 (V²) constitutes the optimal balance between nutritional enrichment and sensory appeal, recording superior scores in taste, textural profile, and overall acceptability.

Beyond its sensory merits, the developed product exhibits a robust biochemical profile, notably in terms of mineral content and antioxidant potential, addressing the research gap in underutilized root vegetable applications within processed food systems. Furthermore, the favorable consumer acceptability ratings and production cost-efficiency underscore the commercial potential of this value-added product. This study concludes that beetroot-fortified "laddu" represents a sustainable and efficacious vehicle for

delivering health-promoting phytochemicals, offering a promising strategy for dietary diversification and the advancement of plant-based functional foods.

Acknowledgements

The authors extend their sincere gratitude to the **Department of Home Science, Ghanapriya Women's College (South Campus), Dhanamanjuri University**, and the **State Public Health Laboratory, Lamphel, Imphal, Manipur**, for providing the essential infrastructure, analytical facilities, and technical guidance required for the successful completion of this research. Special thanks are due to the faculty and administrative staff for their consistent encouragement and cooperation throughout the study. The authors also gratefully acknowledge the technical staff and all individuals who contributed to the laboratory analysis and consumer evaluation phases. This work was supported by the institutional resources of the aforementioned organizations, and their contribution is duly appreciated.

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