
DEVELOPMENT AND NUTRITIONAL EVALUATION OF FUNCTIONAL ANTIOXIDANT-RICH ENERGY LADDU INCORPORATING WATERMELON RIND

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ABSTRACT

The present study focused on developing a nutritious and sustainable energy laddu by incorporating watermelon rind powder, an often-discarded by-product rich in dietary fiber, antioxidants, citrulline, minerals, and other beneficial bioactive compounds. The objective was to create a value-added functional food that promotes health while reducing food waste. Watermelon rind was cleaned, peeled, dried, and ground into a fine powder. This powder was blended with roasted oats, peanuts, flaxseeds, and jaggery to prepare energy laddus. The finished product was evaluated for its sensory and nutritional qualities. Sensory assessment indicated excellent consumer acceptance, with high scores for appearance, color, taste, texture, and overall acceptability, and no undesirable flavors were observed. Nutritional analysis revealed that the laddu provided 320 kcal of energy, 55.0 g of carbohydrates, 4.5 g of protein, 10.0 g of fat, and 6.5 g of dietary fiber, highlighting its potential as a healthy snack. The product also exhibited strong antioxidant activity, showing 65% inhibition in the DPPH assay. Overall, the watermelon rind energy laddu demonstrated good nutritional value, desirable sensory characteristics, and significant potential as an innovative functional food that supports both consumer health and sustainable food waste management practices.

KEYWORDS: Watermelon rind energy laddu, functional food, dietary fiber, antioxidant activity, sensory evaluation, sustainable food waste management.

INTRODUCTION

The increasing generation of food waste has become a major environmental and nutritional concern worldwide. Fruit and vegetable processing produces large quantities of by-products that are often discarded despite containing valuable nutrients and bioactive compounds. Among these, watermelon (*Citrullus lanatus*) rind constitutes nearly 30% of the whole fruit and is commonly treated as waste, even though it is edible and rich in dietary fiber, phenolic compounds, citrulline, vitamins, minerals, and antioxidants.¹

The effective utilization of watermelon rind in food products can therefore contribute to waste reduction while promoting sustainable food systems. Watermelon rind has gained considerable attention as a functional food ingredient because of its diverse nutritional and therapeutic properties. It contains bioactive compounds such as phenolics, flavonoids, carotenoids, L-citrulline, and dietary fiber, which exhibit antioxidant, anti-inflammatory, antihypertensive, and cardioprotective activities.² These phytochemicals help neutralize free radicals, reduce oxidative stress, and may lower the risk of chronic diseases including cardiovascular disease, diabetes, and certain cancers.³ Drying the rind into powder further improves its shelf life, concentrates nutrients, and enables its incorporation into a variety of value-added food products. Several studies have demonstrated the successful incorporation of watermelon rind powder into bakery and confectionery products such as cookies, cakes, fruit butter, dehydrated candy, and other functional foods without compromising sensory acceptability.⁴

These applications highlight the potential of watermelon rind as an inexpensive, sustainable, and nutrient-rich ingredient capable of enhancing dietary fiber and antioxidant content while minimizing food waste. Traditional Indian laddus are widely accepted as convenient, energy-dense snacks and provide an excellent platform for developing functional foods. Enriching laddus with watermelon rind powder, together with nutrient-dense ingredients such as flaxseeds, oats, peanuts, and jaggery, can substantially improve their nutritional profile. Flaxseeds are rich in omega-3 fatty acids, lignans, dietary fiber, and antioxidant compounds that support cardiovascular and metabolic health.⁵

Oats provide β -glucan, phenolic compounds, and soluble fiber that contribute to cholesterol reduction, glycemic control, and antioxidant activity.⁶ Peanuts supply high-quality protein, healthy fats, vitamins, minerals, and polyphenols, while jaggery contributes natural sweetness along with iron, calcium, potassium, magnesium, and antioxidant phytochemicals.⁷

Developing antioxidant-rich energy laddus using watermelon rind powder represents an innovative strategy to convert an underutilized agricultural by-product into a functional food

with enhanced nutritional quality. Such a product not only increases dietary fiber and antioxidant intake but also supports sustainable food production through the valorization of food-processing waste. Therefore, the present study aimed to develop functional antioxidant-rich energy laddus incorporating watermelon rind powder and evaluate their nutritional composition, dietary fiber content, and sensory acceptability.

MATERIALS & METHODS

Study Design

An experimental study was conducted to develop antioxidant-rich energy laddus using watermelon rind powder as the primary functional ingredient. Three formulations were prepared: a standard watermelon rind laddu, a watermelon rind–oats laddu (Variation 1), and a watermelon rind–bajra laddu (Variation 2) using watermelon powder, flaxseeds, peanuts, oats, bajra flour, and jaggery. The products were evaluated for sensory quality, nutritional composition, and antioxidant potential.

Selection of Raw Materials

A fresh whole watermelon was purchased from the supermarket and washed to remove any dirt or impurities from the surface. After cleaning, the tough green outer skin was peeled away, and both the white inner rind and the juicy red pulp were retained. These portions were then cut into small pieces to ensure even drying. The pieces were spread out neatly on clean trays and placed under direct sunlight, where they were allowed to dry naturally for about 4 to 5 days. During this period, the watermelon pieces gradually lost their moisture content, resulting in thoroughly sun-dried pieces suitable for further use. Ingredients such as dried watermelon rind powder, watermelon powder, flaxseeds, peanuts, oats, and jaggery were selected. All ingredients were procured from a local supermarket.

Preparation of Watermelon Rind powder and Red Pulp Powder

After the watermelon rind and pulp pieces were thoroughly sun-dried, they were separately ground into a fine powder using a grinder. The dried white rind pieces were processed to obtain watermelon rind powder, while the dried red pulp pieces were ground to produce watermelon pulp powder. The powders were then sieved to ensure a uniform texture.

Formulation of Watermelon Rind Energy Laddu

Three watermelon rind energy laddu formulations were developed using dried watermelon rind powder as the main functional ingredient. The standard formulation contained watermelon rind powder, red pulp powder, flaxseeds, peanuts, and jaggery. Variation-1 was enriched with roasted oats to improve dietary fiber content, while Variation-2 incorporated

bajra flour to enhance fiber and mineral levels. These formulations were designed to improve the nutritional value of the laddus while maintaining desirable sensory acceptability.

Preparation of Watermelon Rind Oats Energy Laddu

Energy laddus were developed using watermelon rind powder (10g), red pulp powder (5g), oats (5g), flaxseeds (3g), peanuts (4g) and jaggery (5g). The preparation process of energy laddu is presented in flow chart.

Remove the green outer peel of the watermelon and cut the white portion (rind) and red pulp into small pieces.



Sundry for 5 to 6 days until the moisture is completely removed. The dried rind is ground into a fine powder and sieve the powder to remove large particles



Roast oats, peanuts and flaxseeds on medium flame about 5-7 minutes until they turn light brown & they start to crackle slightly. This enhances flavour and digestibility.



Jaggery is grated or powdered and used directly without making syrup to retain minerals.



Combine ingredients and grind the mixture to obtain a uniform, slightly coarse texture.



Take small portions of mixture and shape into small round laddus. Prepared energy laddus can be stored in airtight containers at room temperature.

Process flowchart of watermelon rind oats laddu



Figure. 1 Watermelon Rind Oats Energy Laddu.

Anti-Nutritional Factors in the Ingredients Used for Preparation

The ingredients used in the watermelon rind oats energy laddu contain naturally occurring anti-nutritional factors such as phytates, tannins, oxalates, and trypsin inhibitors. To minimize their effects, flaxseeds, peanuts, and oats were roasted, while watermelon rind and pulp were dried before powder preparation. These processing methods help improve nutrient bioavailability and digestibility while retaining the nutritional and functional qualities of the ingredients.

Jaggery contributes negligible anti-nutritional factors, making the final product nutritionally beneficial.

Sensory Evaluation

Sensory evaluation of the antioxidant-rich watermelon rind oats energy laddus was carried out using a 5-point hedonic scale with 50 panel members. The sample is evaluated for appearance, colour, texture, taste, and overall acceptability. The oats-based formulation received the highest overall acceptability scores.

Statistical Analysis

The sensory evaluation data were subjected to statistical analysis using a one-sample t-test to determine the significance of overall acceptability scores. The test was performed using the mean hedonic scores obtained from the panel members, and the results were used to assess the acceptability of the developed watermelon rind oats energy laddu.

RESULTS & DISCUSSION

The developed energy laddu, after achieving overall acceptability in sensory evaluation, was subjected to laboratory analysis to determine its nutritional composition. Proximate parameters including energy, protein, carbohydrates, fat, dietary fiber and antioxidant content were analyzed to evaluate its nutritional and functional properties.

Table 1 Nutritional Analysis of Watermelon Rind Oats Energy Laddu.

S.no	Parameter	Unit of Measurements	Test Method	Result	Limits
1.	Energy	Kcal/100g	Calculation	320	280-350
2.	Protein	g/100g	Kjeldahl Method	4.5	≥3.0
3.	Carbohydrates	g/100g	By Calculation	55.0	-
4.	Total fat	g/100g	AOAC 920.39	10.0	8-15
5.	Dietary Fiber	g/100g	AOAC 985.29	6.5	≥4.0
6.	Antioxidant Activity	% inhibition	DPPH Assay	65	≥50

Nutritional Analysis

The developed watermelon rind oats energy laddu provided 320 kcal energy, 4.5 g protein, 55.0 g carbohydrates, 10.0 g fat, and 6.5 g dietary fiber per 100 g. The results indicate that the product is a good source of energy, protein, and dietary fiber, with carbohydrates contributing significantly to its caloric value. The antioxidant activity was 65% inhibition, as determined by the DPPH assay, demonstrating considerable antioxidant potential. Overall, the product exhibited a favourable nutritional profile and functional properties, making it a promising value-added health snack.

Analytical Methods

Protein content was determined using the Kjeldahl method, total fat by AOAC 920.39, dietary fiber by AOAC 985.29, and antioxidant activity by the DPPH assay. These standardized methods ensured accurate evaluation of the nutritional and functional characteristics of the developed product.

Sensory Characteristics

The sensory characteristics of the developed watermelon rind oats energy laddu were evaluated based on appearance, colour, texture, taste, and overall acceptability using a 5-point hedonic scale.

Appearance of the watermelon rind oats energy laddu

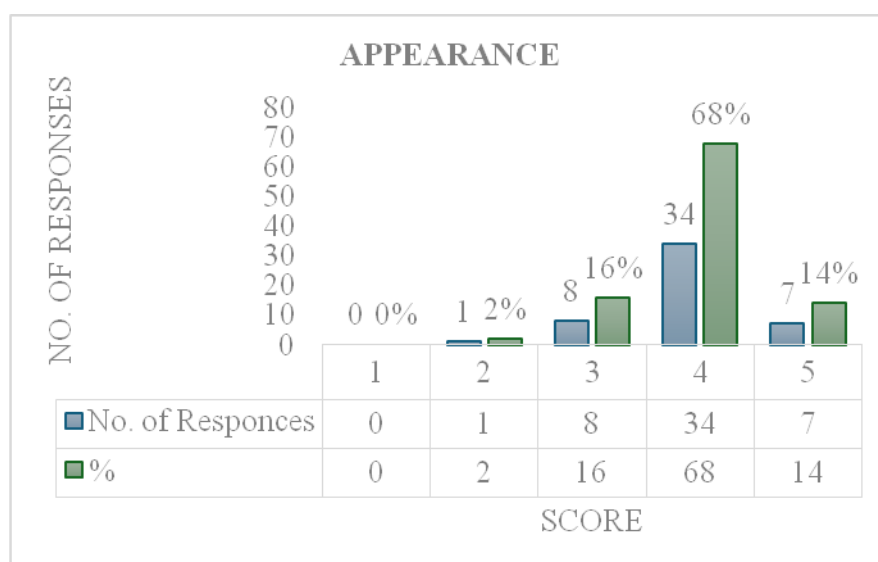


Figure. 2 Appearance of the product.

The above graph shows sensory evaluation of appearance indicated a high level of consumer acceptability. A majority of respondents (**68%**) assigned a score of 4, while (**14%**) gave the highest score of 5. About (**16%**) of participants rated it 3, and only a small proportion (**2%**) gave a score of 2, with no respondents selecting the lowest score of 1. Overall, these findings suggest that the product possesses an appealing and widely acceptable appearance among consumers.

Colour of the watermelon rind oats energy laddu

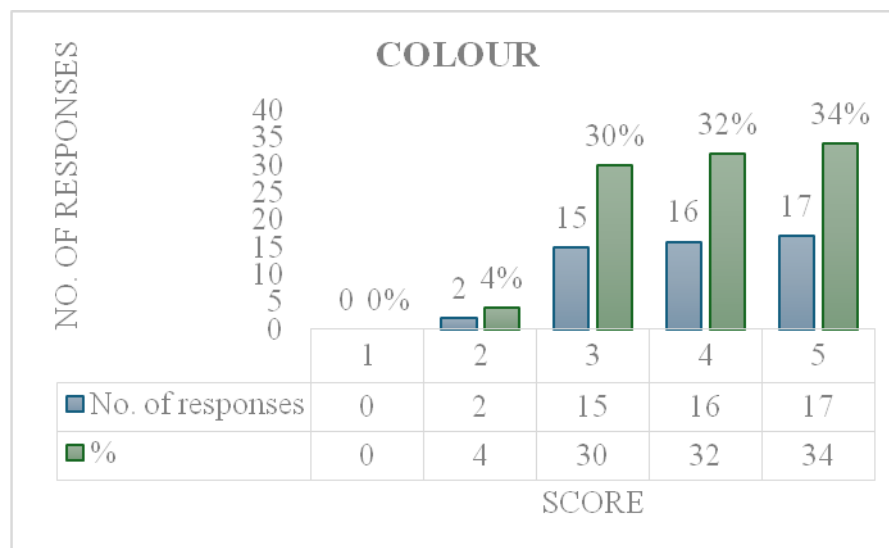


Figure. 3 Colour of the product.

The above graph shows most respondents gave higher scores, indicating good acceptability of the product's colour. The highest score was 5, received by 17 respondents (**34%**), followed by score 4 with 16 respondents (**32%**) and score 3 with 15 respondents (**30%**). Only 2 respondents (**4%**) gave a score of 2, and no respondents rated it as 1. Overall, the product colour was well accepted by the panelists.

Taste of the watermelon rind oats energy laddu

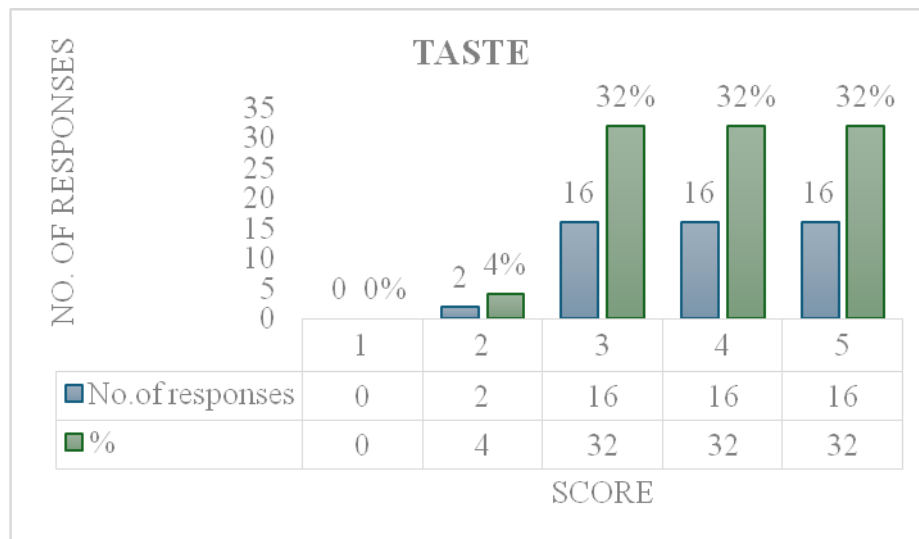


Figure. 4 Taste of the product.

The above graph shows the product was well accepted by the panelists. No respondents gave a score of 1 (**0%**), while only 2 respondents (**4%**) gave a score of 2. The majority of respondents rated the product positively, with 16 respondents each (**32%**) giving scores of 3, 4, and 5. This indicates that the product had a generally acceptable to highly preferred taste.

Texture of the watermelon rind oats energy laddu

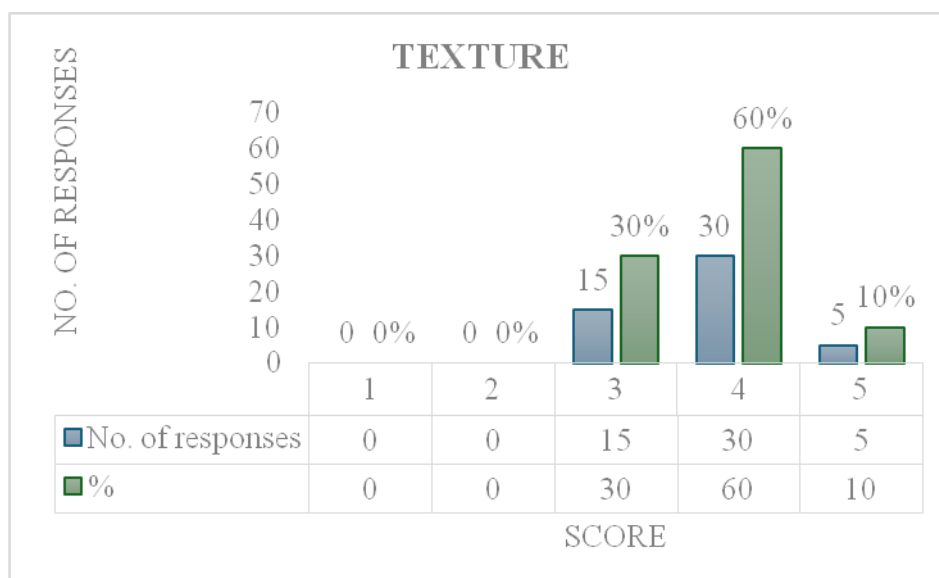


Figure. 5 Texture of the product.

The above graph shows most respondents rated the product positively. A majority of participants (**60%**) gave a score of 4, indicating they liked the texture, while (**30%**) rated it 3,

showing moderate acceptance. Only **(10%)** gave the highest score of 5, and no respondents rated it 1 or 2. Overall, the product's texture was generally well accepted.

Overall Acceptability of the watermelon rind oats energy laddu

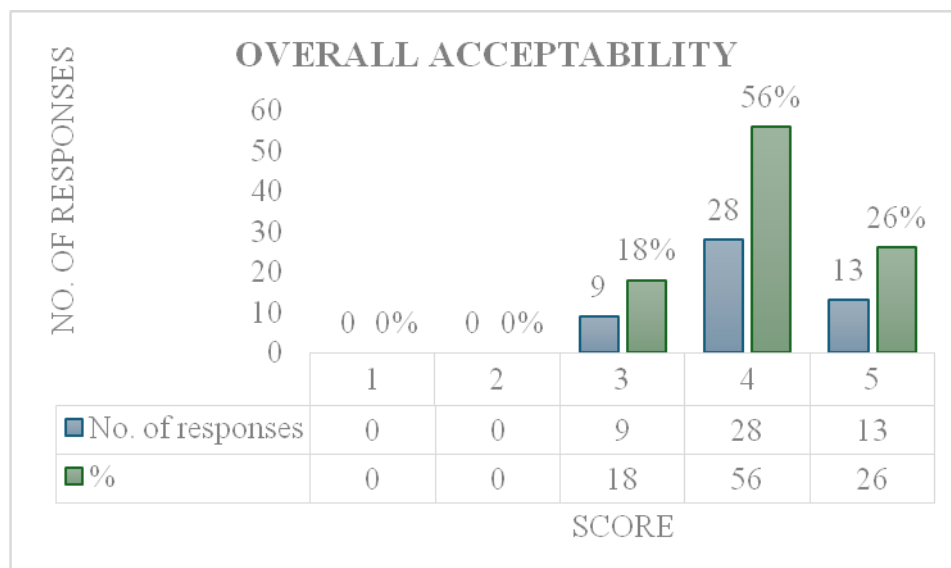


Figure. 6 Overall acceptability of the product.

The overall acceptability graph indicate that the product was generally well accepted by the panelists. The highest number of responses was recorded for score 4 **(56%)**, followed by score 5 **(26%)**, showing that most participants liked the product. A smaller proportion of respondents gave score 3 **(18%)**, while no responses were recorded for scores 1 and 2 **(0%)**. This suggests that the product had good overall acceptance among consumers.

Statistical test

One sample t-test was conducted for overall acceptability scores of sensory evaluations (Hedonic test) and it was observed that the p value is <0.05 . This concludes that the product is liked significantly. (mean >3) (calculated mean (4.08) $>$ hypothesized mean (3)).

CONCLUSION

The study successfully developed an antioxidant-rich watermelon rind energy laddu with good sensory acceptability and a favourable nutritional profile. The incorporation of watermelon rind powder, watermelon pulp powder, oats, flaxseeds, peanuts, and jaggery enhanced the product's dietary fiber, protein, energy, and antioxidant content. The results indicated that the developed laddu is a nutritious functional food with potential health benefits and can serve as a sustainable value-added product for regular consumption.

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