

Development and nutritional characterization of a functional herbal oats laddu: sensory quality and microbiological safety evaluation

Abstract

The present study aims to analyse proximate composition of raw oats, jaggery, *Canthium coromandelicum* and herbal oats laddu. In addition to this, sensory evaluation and microbiological analysis was also conducted to detect the presence of yeast and mold in herbal oats laddu. Herbal Oats laddu was prepared using a blend of oats, broken wheat and *Canthium coromandelicum* leaf powder to enhance its nutritional and therapeutic properties. Oats and broken wheat contribute significant amounts of dietary fiber, protein and essential minerals, while *Canthium coromandelicum*, a medicinal herb, provides antioxidant, antimicrobial and therapeutic benefits. Sensory evaluation was conducted using a nine-point hedonic scale to assess parameters such as color, texture, taste, aroma and overall acceptability. Proximate composition of the product analyzed are moisture content using Gravimetric method, crude fiber using AOAC official method (962.09), protein by Kjeldahl Method, fat by AOAC official method (948.22), ash content using AOAC official method (923.03) and carbohydrate content by Anthrone method. The values obtained for the above said parameters are moisture 9.7%, crude fiber 4.1%, protein 6.9%, fat 2.7%, ash 1.2% and carbohydrate 70.6% respectively. Total energy content of herbal oat laddu was 334.3 kcal. One month old oat laddu was subjected to total microbial plate count, yeast and mold count, which revealed the absence of both the organisms. These results indicated that the formulated herbal oats laddu is not only organoleptically acceptable but also offers enhanced nutritional and health promoting benefits, positioning it as a functional food alternative to traditional desserts.

Volume 14 Issue 1 - 2026

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Received: January 20, 2026 | **Published:** March 4, 2026

Introduction

Oats (*Avena sativa*) belong to the grass family Poaceae, which includes major cereal crops such as wheat, rice, and barley. Oats are abundant in soluble fiber, especially β -glucan, which is recognized for its ability to lower cholesterol levels, enhance heart health, and assist in glycemic management. The grain is also a valuable source of protein, unsaturated fatty acids, B-complex vitamins, minerals such as iron, magnesium, and zinc, as well as antioxidants like avertanhamides.¹ Oats contain significant amounts of protein, crude fiber, fat, and carbohydrate showing the high nutritional potentiality. Significant amounts of vital minerals, including iron, zinc, calcium, and magnesium, which is critical for metabolic processes and general health, are present in oats. They are a nutrient-dense cereal grain that may help with micronutrient deficits and enhance the quality of diets. It is a crucial functional food component in goods with added value and nutrition-based therapies.¹ Oats can be incorporated into various food items, including baked goods, breakfast cereals, snacks, beverages, and dairy alternatives. Due to the growing consumer demand for functional and health-oriented foods, there is a potential for increased use of oats in food markets in both developed and developing regions. Additionally, processing techniques such as milling, fermentation, and enzymatic treatment that can enhance the bioavailability and sensory attributes of products made from oats.²

Oats significantly contribute to metabolic and cardiovascular wellness due to their high levels of β -glucan, soluble fiber, proteins, and bioactive phytochemicals. Regular inclusion of oats in the diet is linked to decrease in overall and low level lipoprotein cholesterol, better glycemic control, and increased feeling of fullness, all of which help to lower the risk of cardiovascular diseases and type 2 diabetes.

Oats serve as a versatile dietary element supported by compelling evidence for aiding chronic disease prevention, weight management, and gut health. Incorporating oats into daily diets, especially for groups at risk of cardio metabolic disorders, and emphasize the opportunities for developing functional foods that utilize oat derived fibers, proteins, and bioactive compounds.³

There has been a transition from traditional diets, which were abundant in cereals and legumes, to diets that are more prevalent in fats, sugars, and animal products, reflecting Western eating habits. Despite an increase in the consumption of certain nutrients, deficiencies in micronutrients like iron, vitamin A and iodine remain, signifying a dual challenge of malnutrition.⁴ There is an increasing consumer demand and market trend for natural ingredients instead of refined sugars. Traditional Indian desserts typically depend heavily on sugar, thus incorporating natural sweeteners like jaggery is known for their greater nutritional content and the presence of advantageous compounds that can help counteract the negative effects of refined sugar.^{5,6}

There is substantial presence of trans fatty acids in traditional Indian fast foods, emphasizing the necessity for public health measures aimed at decreasing trans fatty acids intake and alleviating related health risks.⁷ Regular intake of these functional foods is linked to better digestive health, strengthened immune response, effective weight control and a lower likelihood of chronic illnesses such as heart disease, diabetes and certain cancer. Incorporating traditional Indian functional foods into contemporary diets can significantly aid in the prevention and management of chronic diseases. It is important to promote and preserve these dietary traditions to utilize their health advantages.⁸

Canthium coromandelicum is a valuable source of bioactive substances that exhibit antioxidant, antibacterial and enzyme inhibitory effects. These characteristics endorse its historical use in treating different health issues and imply possible uses in contemporary medicine.⁹ The dry matter holds a moderate level of carbohydrates and proteins, while the fat content is low. The presence of fiber and ash is notable, indicating possible advantages for digestion and mineral intake. *C. coromandelicum* leaf exhibits significant potential as a nutrient rich leafy vegetable and as a medicinal resource, owing especially to their high antioxidant activity.¹⁰ The present study focus on the proximate analysis of raw oats, jaggery, *C. coromandelicum* and formulation of herbal oats laddu using a blend of oats, broken wheat and *C. coromandelicum* leaf powder to enhance its nutritive, preservative properties and also to evaluate the sensory, nutritional and microbiological parameters.

Materials and methods

Ingredients of herbal oats laddu

Oats was used as the main component and the other ingredients are broken wheat, herbal leaf (*Canthium coromandelicum*) and jaggery. These ingredients were purchased from a nearby store, Kalady, Karamana, Thiruvananthapuram, Kerala, India and then dried and made to powder form.

Preparation of herbal oats laddu

The raw oats and wheat were washed thoroughly, sundried and ground separately into a fine powder. The herbal leaf was washed, shade dried, and pulverized into a fine powder. Separately, to 40 g of molten jaggery, 30 g of powdered oats, 25 g of finely ground wheat, and 5 g of powdered herbal leaves were added and mixed well. The mixture was stirred continuously until uniform, allowed to cool, and then shaped into small, uniform, round laddus.

Sensory evaluation

To validate consumer acceptability, a sensory panel was constituted. The ratings from all panelists were collected into a data sheet where each participant's scores for each attribute were recorded. Demographic data of the panelists was collected, rated overall liking and specific dimensions (taste, aroma, texture, appearance and color) in a sensory evaluation sheet. Using a hedonic scale (9-point scale from "dislike extremely" to "like extremely"), computed the mean hedonic score of the sample.¹¹

Proximate analysis

Proximate analysis is to determine the total amount of nutritional contents of raw oats, jaggery, *C. coromandelicum* and herbal oats laddu and the results are reported as mean \pm SE (standard error).

Determination of total protein (Kjeldahl method)

Total protein content was determined using the Kjeldahl method in accordance with AOAC¹² Official Method 976.05. Approximately 0.7–2.0 g of the sample was accurately weighed and transferred into a 500 or 800 mL Kjeldahl flask, ensuring that no material adhered to the neck of the flask. To this, 0.7 g of copper sulfate, 15 g of anhydrous sodium sulfate, 25 mL of concentrated sulfuric acid, and 2–3 glass beads were added. The flask was placed in an inclined position in the digestion chamber and heated until a clear, white digest was obtained.

After digestion, the flask was allowed to cool, and 200 mL of distilled water was slowly added. Following cooling, a small amount

of granulated zinc or anti-bumping granules was introduced, and sufficient sodium hydroxide solution (approximately 110 mL) was carefully added along the side of the flask to render the contents strongly alkaline, without prior mixing of the acid and alkaline layers. The flask was then connected to a Kjeldahl distillation apparatus equipped with an efficient splash head and condenser. The distillate was collected through a delivery tube immersed just below the surface of a known volume of standard acid in a conical receiving flask. Distillation was continued until approximately 150 mL of distillate was collected, which was subsequently titrated with 0.1 N hydrochloric acid to determine the nitrogen content

$$\% \text{ Nitrogen} = Y \times 100 / \text{Weight of sample}$$

$$\text{Total protein \% by weight} = \text{Total Nitrogen} \times 6.25$$

$$1 \text{ ml} \times 0.1 \text{ N HCl} = 0.0014 \text{ g N,}$$

$$X \text{ ml} \times 0.1028 \text{ N HCl} = Y, X = \text{Titre Volume, } Y = \text{Nitrogen in g}$$

Determination of crude fat

Crude fat content, defined as the total extractable lipid fraction in the sample, was determined using the Soxhlet extraction method in accordance with AOAC¹² Official Method 948.22. The test sample was thoroughly mixed and finely ground. An accurately weighed portion of the powdered sample was placed in a thimble and loaded into a Soxhlet extractor. Petroleum ether (200 mL) was used as the extraction solvent in a flat-bottom flask containing a few glass beads. The extraction was carried out for 4 h.

Following extraction, the solvent was recovered and the extracted fat was transferred to a pre-weighed porcelain China dish. The solvent was completely evaporated, and the residue was dried in a hot air oven at 80 °C for 1 h. The dish was then cooled in a desiccator and weighed. The crude fat content was calculated gravimetrically based on the weight of the extracted lipid residue.

$$\text{Total fat (\%)} \text{ by weight} = (\text{Weight of Fat} / \text{Weight of sample}) \times 100$$

Estimation of total carbohydrate

Total carbohydrate content was estimated using the anthrone method.¹³ Carbohydrates in the sample were initially hydrolyzed to simple sugars by treatment with dilute hydrochloric acid. Under hot acidic conditions, glucose was dehydrated to hydroxymethyl furfural, which reacted with anthrone to form a green coloured complex exhibiting maximum absorbance at 630 nm.

Briefly, 100 mg of the sample was accurately weighed into a boiling tube and hydrolyzed with 5 mL of 2.5 N HCl in a boiling water bath for 3 h. After cooling to room temperature, the hydrolysate was neutralized with solid sodium carbonate until effervescence ceased. The volume was adjusted to 100 mL with distilled water and centrifuged, and the clear supernatant was collected. Aliquots of 0.5 and 1.0 mL were used for analysis.

Standard solutions were prepared by pipetting 0, 0.2, 0.4, 0.6, 0.8, and 1.0 mL of working glucose standard, with the zero concentration serving as the blank. The volume in all tubes, including samples, was adjusted to 1 mL with distilled water. Anthrone reagent (4 mL) was added to each tube, followed by heating in a boiling water bath for 8 min. The tubes were rapidly cooled, and the intensity of the green to dark green colour was measured at 630 nm using a spectrophotometer. A standard calibration curve was constructed by plotting glucose concentration against absorbance, and the total carbohydrate content of the samples was calculated from the standard curve.

Estimation of crude fiber

Crude fiber content was determined following AOAC¹² Official Method 962.09, which is based on the sequential acid and alkali digestion of the sample. During these treatments, oxidative hydrolytic degradation of native cellulose and substantial degradation of lignin occur. The residue remaining after digestion is dried, weighed, incinerated, and reweighed; the loss in weight upon ignition corresponds to the crude fiber content.

Briefly, 2 g of the finely ground sample was defatted by extraction with ether or petroleum ether; this step was omitted when the fat content was below 1%. The defatted, dried sample was boiled with 200 mL of dilute sulfuric acid for 30 min in the presence of anti-bumping chips. The mixture was filtered through muslin cloth and washed with boiling water until the washings were free of acid. The residue was then boiled with 200 mL of sodium hydroxide solution for 30 min, filtered again through muslin cloth, and sequentially washed with 25 mL of boiling sulfuric acid, three 50 mL portions of boiling water, and 25 mL of alcohol. The final residue was transferred to a pre-weighed ashing dish (W1), dried at 130 ± 2 °C for 2 h, cooled in a desiccator, and weighed (W2). The residue was then ignited at 600 ± 15 °C for 30 min, cooled in a desiccator, and reweighed (W3). Crude fiber content was calculated from the loss in weight after ignition and expressed as a percentage of the sample weight.

$$\% \text{ crude fiber in sample} = W1 - W2 / W3 \times 100$$

Determination of total ash

Total ash content was determined according to AOAC¹² Official Method 923.03 and BIS¹⁴ 12711:1989, followed by the procedure described by James.¹⁵ Approximately 2 g of the prepared sample was accurately weighed into a clean, dry, and pre-weighed silica dish. The sample was initially ignited over a low flame using a suitable burner for about 1 h to remove volatile matter. Final ashing was carried out in a muffle furnace at 500 ± 10 °C until a uniform grey ash was obtained.

The dish was cooled in a desiccator and weighed. The processes of ignition, cooling, and weighing were repeated at 1 h intervals until the difference between two successive weights was less than 1 mg, indicating constant weight. The lowest recorded mass was noted, and the ash obtained was preserved for subsequent determination of acid-insoluble ash.

$$\text{Total ash, percent by mass} = (M2 - M) / (M1 - M) \times 100$$

Where, M2 mass, in g, of the dish with the ash; M mass, in g, of the empty dish; M1 mass, in g, of the dish with the material taken for the test; W is the percentage of moisture in the sample.

Moisture content

Moisture content was determined by gravimetric method according to AOAC¹⁶ official method (925.40), BIS.¹⁴12711. Weighed 5 g of the prepared sample in the moisture dish, previously dried in the oven and weighed. Place the dish in the oven maintained at 105 ± 1 °C for 4 h. Cooled in the desiccator and weighed. Repeated the process of drying, cooling and weighing at a 30 minutes interval until the difference between two consecutive weights is less than one milligram and recorded the lowest mass.

$$\text{Moisture, percent by weight} = (M1 - M2) / (M1 - M) \times 100$$

Where, M is the mass in g of the empty dish, M1 is mass in g of the dish with the material before drying, M2 is mass in g of the dish with the material after drying to constant mass.

Determination of total energy

Energy was calculated according to the following equation Ref: method: AOAC¹⁶

$$\text{Energy (k cal)} = 4 \times (\text{protein (g)}) + 4 \times (\text{carbohydrate (g)}) + 9 \times (\text{fat (g)})$$

Microbiological analysis of herbal oats laddu

The formulated herbal oats laddu was evaluated for microbiological quality by determining the total plate count using the protocol of Food and drug administration,¹⁷ Bacteriological Analytical Manual (BAM) method and by assessing yeast and mold counts in accordance with BIS 5403:1999.¹⁸

Total plate count

Total plate count was performed to enumerate the viable aerobic and facultative anaerobic bacteria using pour plate technique, following the FDA, Bacteriological Analytical Manual.¹⁷ Aseptically, 25 g of the sample was weighed and homogenized with 225 mL of Butterfield's phosphate buffer (pH 7.2) to obtain a 10^{-1} dilution using a stomacher. Serial decimal dilutions (1:9) were prepared up to 10^{-3} and for plating, 1 mL aliquots from appropriate dilutions were aseptically transferred in duplicate to sterile Petri dishes, followed by the addition of 18-20 mL of molten agar medium cooled to 45-50 °C. The plates were gently rotated in both clockwise and anticlockwise directions to ensure uniform distribution of the inoculum and allowed to solidify. The plates were then incubated at 35 °C for 48 h. After incubation, colonies were counted and results were expressed as colony forming units per gram (CFU/g) of sample.

$$N = \frac{\sum C}{(n_1 + 0.1n_2) \times d}$$

where:

N = number of colonies per gram of sample (CFU g⁻¹),

$\sum C$ = sum of colonies counted on all selected plates,

n1 = number of plates counted at the first (lower) dilution,

n2 = number of plates counted at the second (higher) dilution,

d = dilution factor corresponding to the first dilution selected for counting.

Enumeration of yeasts and molds

Yeasts and molds were isolated and enumerated using the spread plate technique as per FDA, Bacteriological Analytical Manual.¹⁷ For sample preparation, the product was crushed using a sterile mortar and pestle, and 25 g of the homogenized sample was aseptically weighed into a sterile container. The sample was then transferred to 225 mL of sterile 0.1% peptone water (pH 7.0) to obtain a 10^{-1} dilution and homogenized thoroughly. Serial decimal dilutions (1:9) were prepared up to 10^{-3} and for enumeration, 1 mL aliquots of appropriate dilutions were aseptically spread onto pre-poured and solidified agar plates using a sterile bent glass spreader. Each dilution was plated in triplicate. The plates were incubated at 25 °C for 5 days in an upright position, stacked no more than three plates per stack, and left undisturbed until enumeration. Yeast and mold counts were calculated and expressed as colony-forming units per gram (CFU g⁻¹) of sample using the dilution factor.

Shelf life evaluation

Shelf-life assessment was conducted to determine the duration for which the product retained acceptable quality and safety under defined storage conditions. In the present study, the prepared laddu

exhibited a shelf life of one month based on combined sensory and microbiological evaluations. Sensory analysis was performed to monitor changes in aroma, appearance, flavour and texture over time. Microbiological analysis was used to assess product quality and safety by monitoring changes in the population of spoilage microorganisms, including yeasts, molds, and bacteria, during the storage period.

Results and discussion

Herbal oats laddu

The formulated herbal oats laddu (Figure 1) comprised of oats as the primary ingredient, supplemented with wheat, jaggery and *Canthium coromandelicum* leaf to enhance its nutritional value and shelf life. All ingredients were thoroughly cleaned, roasted separately to improve flavour, and ground into fine powder. The powders were then blended in an appropriate proportion to obtain a uniform mixture. The prepared herbal oats laddu exhibited a pleasant nutty aroma, a light brown coloration, and desirable textural properties.



Figure 1 Herbal oats laddu.

Sensory evaluation of herbal oats laddu

The sensory characteristics of laddu were evaluated using a hedonic scale and the results of sensory evaluation of laddu were given in Table 1. Sensory evaluation includes parameters such as appearance, taste, texture, aroma and overall acceptability. The score was assigned for excellent as 9, good as 8 and 6 for fair. The prepared laddu was assessed by a ten member committee. The hedonic scale is given in Figure 2.

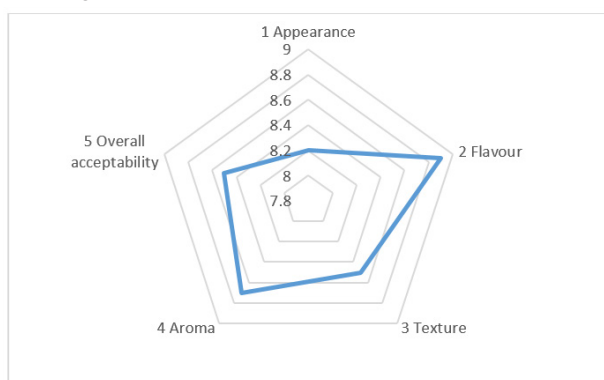


Figure 2 Hedonic scale of laddu.

The sensory evaluation results indicated a high level of acceptability of the formulated laddu across all assessed parameters. Appearance received a mean score of 8.2, reflecting good visual appeal. Flavour and taste recorded the highest score (8.9), suggesting

strong consumer preference and palatability. Texture (8.5) and aroma (8.7) also achieved high scores, indicating desirable mouthfeel and pleasant sensory characteristics. The overall acceptability score of 8.5 demonstrates that the product was well received by the sensory panel and confirms the favourable sensory quality of the formulated laddu.

Table 1 Score of sensory evaluation

Sl. No.	Parameters	Total score
1	Appearance	8.2
2	Flavour and Taste	8.9
3	Texture	8.5
4	Aroma	8.7
5	Overall acceptability	8.5

Proximate composition

Total protein

The protein content of raw oats was 11.5 % per 100g, where as in the case of prepared herbal oats laddu the protein was reduced to 6.9 % per 100g (table 2). This was mainly due to the heat treatment process in laddu making and too much heat can lead to protein denaturation, aggregation, and decreased extractibility. Heating causes conformational rearrangements due to change in secondary and tertiary structures, such as decrease in alpha helix content and an increase in beta sheet formation. These structural changes have a direct impact on the emulsification capabilities, foaming ability, and water-holding capacity. Oat protein functioning can be maximized by regulated industrial heat treatment, thus the processing and formulation of functional foods made from oat can be improved.^{19,20} Proteins are essential biomolecules made up of amino acids, crucial for the structure, function, and regulation of the body's tissues and organs. In addition to this protein have various functions, such as constructing and repairing tissues, acting as enzymes to speed up biochemical reactions, transporting molecules like oxygen with hemoglobin, defending the body through antibodies, and regulating bodily processes via hormones. Sufficient intake of protein is essential for promoting growth, generating energy, and maintaining overall health, mentioning that a lack of protein can result in issues like muscle wasting, fatigue, and diseases related to malnutrition.²¹ The protein content observed in the formulated product was nutritionally significant, contributing to its enhanced dietary value and the protein content observed for jaggery and *C. coromandelicum* are given in (Table 2).

Total fat

The total fat content of raw oats was 5.47 % in 100g, jaggery and the herbal oats laddu reported 1.25 % and 2.7% in 100g respectively (table 2). The amount of total fat is more significant in influencing health outcomes. Substituting saturated fats with unsaturated fats, especially polyunsaturated fatty acids, was linked to a lower risk of cardiovascular diseases and enhanced lipid profiles. On the other hand, a high consumption of trans fats was consistently associated with adverse health effects, including a greater risk of mortality and heart disease.²² The quality of fat is more important than its quantity and stressed the need to promote healthy fat sources like nuts, fish, and vegetable oils in dietary recommendations to encourage long term health.²³

Carbohydrate

Carbohydrate is the single most important source of food energy in the world, making up 40% to 80% of total food energy, benefit to human behaviour and health. It also contributes food to taste and

texture. In the present investigation the herbal oats laddu showed a value of 70.6% per 100g and a lower value of 51.1 % per 100g (table 2). Carbohydrates serve as the body's main energy source, and their quality plays a crucial role in influencing metabolic results. The significance of dietary fiber and resistant starch, which enhance digestive health, manage blood sugar levels, lower cholesterol, and encourage feelings of fullness. Consuming diets rich in whole grains, fruits, and vegetables are the important sources of complex carbohydrates which is linked to a lower risk of obesity, type 2 diabetes, and heart disease.²⁴ On the other hand, high consumption of refined carbohydrates and added sugars is associated with negative health outcomes.²⁵

Crude fiber

The crude fiber content of 4.1% per 100 g was present in prepared herbal oats laddu, whereas raw oats, jaggery and *C. coromandelicum* showed a value of 11.5, 0.8 and 6.8 % per 100 g respectively (table 2). Dietary fiber is crucial for gut health, lowering cholesterol, regulating glucose, and preventing diseases, yet these advantages are overlooked when solely relying on crude fiber values. Contemporary analytical methods, such as enzymatic-gravimetric and AOAC techniques, offer a more precise evaluation of total dietary fiber, making them more appropriate for assessing the fiber content and nutritional value of human foods.²⁶ Dietary fiber consists of both soluble and insoluble components primarily sourced from plant foods such as grains, fruits, vegetables, and legumes. Essential functions of fiber in maintaining digestive wellness, lowering blood cholesterol levels, moderating blood sugar, and preventing chronic illnesses such as obesity, diabetes, and heart disease. It also explores how fiber enhances bowel function and promotes feelings of fullness, which supports weight control.²⁷

Ash content

The ash content is a measure of the total amount of minerals present within a food. 1.2% per 100 g was the calculated ash content in the oats laddu sample and the values obtained for raw oats, jaggery and *C. coromandelicum* are 3.14, 1.9 and 6.17 respectively (table 2). Ash is the inorganic mineral residue left after completely oxidizing the organic matter found in a food sample, which signifies its total mineral content. The variations in ash content can reflect differences in mineral composition, processing impacts, and potential adulteration.²⁸ Elevated ash content is a sign of a greater total mineral presence.²⁹

Moisture content

The moisture content of laddu sample was 9.7% in 100 g. The values obtained for raw oats, jaggery and *C. coromandelicum* are given in table 2. Total moisture content, water activity indicates the quantity of free water accessible for microbial growth and biochemical processes in food. It also emphasizes the importance of water availability (a_w) in forecasting microbial stability, enzymatic processes, and chemical degradation. Additionally, the combination of water activity management with contemporary preservation methods, including modified atmosphere packaging and dehydration.³⁰ Moisture content is recognized as one of the key factors in food analysis because it directly impacts the stability, texture, flavor, weight, and shelf life of food items. Moisture plays a role in almost all physical, chemical, and microbiological properties of food excess moisture encourages microbial growth and spoilage, while insufficient moisture can result in undesirable hardness or weight loss. Measuring moisture content is crucial for quality control, processing operations, and nutritional labelling.³¹

Total energy

The total energy content of the prepared laddu sample was found to

be 334.3 k cal per 100g. The energy content of raw oats, jaggery and *C. coromandelicum* are given in table 2.

Total plate count

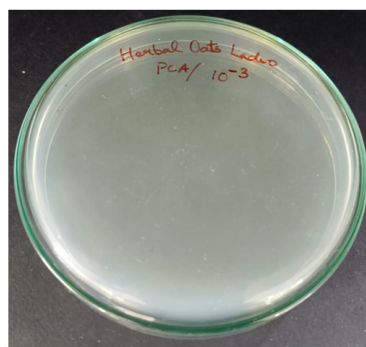
The colony count was recorded as 0 CFU/mL, indicating the absence of detectable viable bacterial growth in the tested sample (Figure 3). The absence of bacterial colonies in all dilution plates suggests that the microbial load in the herbal oats laddu sample was extremely low, signifying the product was microbiologically safe for consumption. This result indicates that the product was processed and stored under hygienic conditions and that the moisture content was likely low, minimizing the possibility of microbial proliferation. Ingredients such as oats, jaggery, wheat and herbal leaf when properly roasted or heat-treated, undergo microbial reduction, further improving shelf stability. Similar observation was also made by Subbaiyan³² in foxtail millet laddu.

Table 2 Proximate composition of raw materials and herbal oats laddu

Parameters	Raw oats	Jaggery	<i>C. coromandelicum</i>	Herbal oats laddu
Protein (%)	11.5±0.22	0.85±0.02	9.0±0.19	6.9 ±0.31
Total Fat (%)	5.47 ±0.07	1.25±0.18	2.0±0.05	2.7±0.02
Carbohydrate (%)	51.1 ± 0.19	97.50±0.20	11.85±0.02	70.6 ± 0.21
Crude Fiber (%)	11.5±0.13	0.8±0.05	6.8±0.25	4.1 ± 0.8
Moisture (%)	6±0.13	9.0±0.22	67.0±0.11	9.7±0.11
Total Ash (%)	3.14±0.02	1.9±0.90	6.17±0.04	1.2 ±0.02
Energy (Kcal)	299.63±1.47	404.65±1.55	101.4± 1.13	334.3 ± 1.45

Data expressed as mean ± standard error of replicate (n = 3)

Figure 3 Plate count of oats laddu sample.



Presence of yeast and mold

The five day incubated plates were examined for the presence of yeast and mold. As seen in the 10⁻³ dilution plate (Figure 4), no visible yeast or mold colonies were observed after the incubation period. Similarly, microbial colonies were not found in 10⁻¹ to 10⁻⁵ dilutions. Therefore, the yeast and mold count of the laddu sample was recorded as 0 CFU/g, indicating no detectable contamination.

The absence of yeast and mold colonies in the PDA plates indicates that the laddu sample was free from fungal contamination and microbiologically safe for consumption. The absence of fungal colonies reflects good hygienic practices, proper ingredient handling and low moisture content, which prevented the fungal growth during storage. Similar observation was also reported by Geetha³³ in the anti-fungal activity of millet mix tested fungal pathogens was evaluated using this method showcased well controlled snack product.

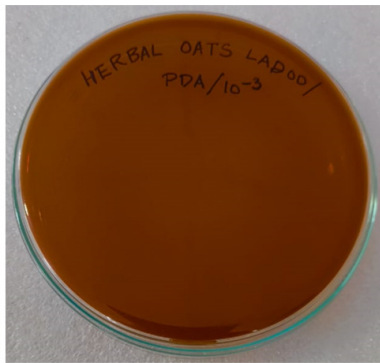


Figure 4 Plate count of oats laddu sample.

Conclusion

The present study successfully demonstrated the development of a nutritionally enriched herbal oats laddu as a healthier alternative to conventional Indian sweets. Incorporation of oats, broken wheat, jaggery, and *Canthium coromandelicum* leaf powder resulted in a product with improved nutritional quality, characterized by appreciable levels of carbohydrates, dietary fiber, protein, and minerals, along with moderate fat and moisture contents. Sensory evaluation revealed high acceptability across all attributes, particularly flavour, aroma, texture, and overall acceptability, indicating strong consumer appeal. Microbiological analysis confirmed the product's safety, with no detectable bacterial, yeast, or mold growth, supporting its one-month shelf life under the studied conditions. Overall, the findings validate the hypothesis that combining whole grains with medicinal plant ingredients can yield a functional food that aligns with current dietary recommendations aimed at reducing refined sugar intake while enhancing nutritional and health-promoting properties. The herbal oats laddu thus holds promise as a convenient, acceptable, and nutritious snack suitable for health-conscious consumers and potential commercial development.

Acknowledgments

None

Conflicts of interest

The authors declare that they have no conflicts of interest.

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