

Development and Nutritional characterization of Black Rice-based Laddu

Preeti Dhankhar^{1*}, Parvinder Kaur²

^{1*}Research Scholar, BPSIHL Department of Food and Nutrition, BPSMV, Email id: preetidabas5@gmail.com

²Associate Professor, BPSIHL Department of Food and Nutrition, BPSMV. Email id: doctorparvinder@yahoo.com

KEYWORDS

Black Rice; laddu;
Sensory Evaluation;
Nutritional Fortification;
Antioxidants; Consumer
Acceptability; Functional
Ingredients.

ABSTRACT

The present study laid emphasis upon the improvement in nutritional quality of traditional "laddu" by inclusion of black rice, which is rich in antioxidants, anthocyanins and micronutrients. Incorporation of black rice was done at three levels, namely 20, 40 and 60 percent, for evaluation of consumer acceptance. A panel comprising 10 trained judges evaluated the sensory characteristics, such as color, appearance, aroma, texture, taste, and overall acceptability, using a 9-point hedonic scale. Control sample (without black rice) showed the highest scores for color (8.6 ± 0.18) and overall acceptability (8.28 ± 0.22). 20% black rice (Type I) showed the best sensory performance, getting good scores for taste (7.6 ± 0.18) and aroma (7.60 ± 0.20) and an overall acceptability score was rated at 7.54 ± 0.21 which means their prime commercial value. Furthermore, the study puts forth how black rice, as a functional ingredient, boosts traditional foods like laddu while satisfying the consumers' growing preferences for health-oriented foods. These observations provide fertile ground for commercialization of black rice in fortifying the nutrition quotient while enhancing the aesthetic appeal in food inventions.

1. INTRODUCTION

This review primarily focuses on the development and organoleptic evaluation of laddu-Indian traditional sweets fortified with black rice. The aim of this investigation is to improve the nutritional value of popularly accepted traditional sweets with an eye to their sensory appeal and thereby promote their consumption (N. Kumari et al., 2021). This sector will surely find a market for the consumption of specialty rice cultivars. (Rathna Priya et al., 2019) confirmed that consumers are leaning toward nutrient-rich options, reddish or black rice. They also advocate for improved cultivation practices coupled with effective marketing to battle some of the issues faced by this variety of rice-global yields factor and high cost. This proves the need to implement agriculture-friendly policies and improvements in the overall management of the value chain. With the likely increase in demand for healthier options, especially those rich in antioxidants, vitamins, and minerals, it is time to develop novel food products from black rice (Das et al., 2023).

Rice is one of the most widely consumed staple foods globally, largely eaten as a whole grain. Grain quality is evaluated through cooking quality, nutritional content, grain characteristics, and physico-chemical properties (M et al., 2023). Among these factors, cooking quality and physico-chemical properties significantly affect consumer acceptance (A.O. et al., 2012). Physical and chemical characteristics of the rice grain such as amylose content, protein content, gel consistency, and gelatinization temperature, along with the properties of cooked grain, are extremely relevant for assessing their suitability for numerous applications in food. Collectively, these properties control the texture, aroma, and, finally, acceptance of rice products in different cultures (Lalremliani et al., 2025).

During ancient times, black rice, often referred to as "forbidden rice," was rice cultivated for the royal family of China (Kushwaha, 2016). The bluish-black color of black rice is mainly due to high levels of an antioxidant included in the grain called anthocyanins (Pakuwal & Manandhar, 2021). Anthocyanins detoxify free radicals and help prevent chronic diseases like cancer and heart diseases. One other heart-warming detail about black rice is its high dietary fiber content, integral for good digestion, and functionality, thus controlling constipation (Panda et al., 2022). With low glycemic index properties, it is highly recommended for diabetics to maintain normal blood sugar levels.

Black rice doesn't just offer antioxidants and fiber; it's an abundance of amino acids and plant protein (Bhandari et al., 2024). These provide significant contributions toward repairing worn muscles, growth of tissues, and development within the physical realm. Beyond that, it provides an exciting helping of iron and vitamin E-nutrients good for blood circulation and skin health. In other words, compared to the highly processed milled white rice, black rice is much less processed, with the end result being a powerhouse of nutrition (Tagliapietra et al., 2024). Hence, black rice truly has a premium positioning in healthy niche

markets, notwithstanding the various ills that plague high production costs, limited farming practices, and scant marketing realities(S. Kumari, 2020).

2. MATERIALS AND METHODS

2.1 Materials

The present study was planned to develop and evaluate a *laddu* made to be a nutritionally improved consumer acceptability-enhancing formulation from black rice complemented with gram flour(Singh & Raghuvanshi, 2021). For the preparation of *laddu*, black rice and gram flour (besan) were the main raw materials selected. Black rice was chosen for its various bioactive compounds, including anthocyanins, phenols, and flavonoids, which contribute to its rich health-promoting profile. It was also selected as an ingredient because the lack of gluten in it would help in the formulation of nutritious *laddu*, which could replace traditional *laddus*(Kanabur & Kamath, 2020).

Concerning composition and authenticity, quality black rice was obtained from a local grocery store(Chen et al., 2018). Black rice flour was milled using well-calibrated laboratory equipment to obtain a smooth and fine grainy flour for *laddus* that will remain valuable and desirable to consumers(Lee, 2013). The *laddu* was prepared in accordance with typical methods of producing *laddus*, even though there were slight modifications for the inclusion of black rice-flour(Widodo et al., 2024). The introduction of black rice flour would fortify the *laddu* with additional nutritional and functional properties while retaining the desired organoleptic characteristics for consumers. The selected ingredients were based on earlier research that documented the positive properties of black rice in food products(Sathya, 2018). The product developed was then evaluated for organoleptic properties, that is, appearance, taste, texture, and overall acceptability to determine consumer preference.

2.2 Formulation of black rice laddu

The preparation of Black Rice *laddu* requires a mixture of black rice flour, which acts as a base, along with a series of nutrition-rich ingredients to make a delicious snack ideal for Indian taste buds(Bhandari et al., 2024). Traditionally known as "*laddu*," these are small, round sweets which are portable and, depending on the recipe, generally made from gram flour, nuts, sugar, and various spices. The desired effect of the addition of black rice flour into *laddu* will enhance its valuable nutritional assets with a stream of antioxidants, along with an exciting dimension in its color. These *laddus* can also provide a healthy sweet option that can be snacked on without tussling over an unsweet tooth. Some versions of these *laddus* even add in dried fruits and nuts, adding to their nutritional value and calling them a healthier option for snacking. The organoleptic evaluation of these *laddus* focuses on the sensory attributes such as taste, texture, appearance, and aroma, which ensure consumer acceptance while revealing the unique characteristics imparted by black rice flour in taste and health aspects.

2.3 Experimental Design for Control and Best Treatment of "*laddu*"

Table. 1 Experimental Design for Control and Best Treatment of "*laddu*"

Value added product	Treatments				Replication
" <i>laddu</i> "	T ₀	T ₁	T ₂	T ₃	3
Gram Flour	100%	80%	60%	40%	
Black Rice Flour	-	20%	40%	60%	

Detail of Treatments and Replications:

T₀ (Control): 100 g of gram flour.

T₁: 80% of gram flour and 20% black rice flour.

T₂: 60% of gram flour and 40% black rice flour.

T₃: 40% of gram flour and 60% black rice flour.

Replications: Control and treatments were replicated 3 times respectively to get average value.

"*laddu*"

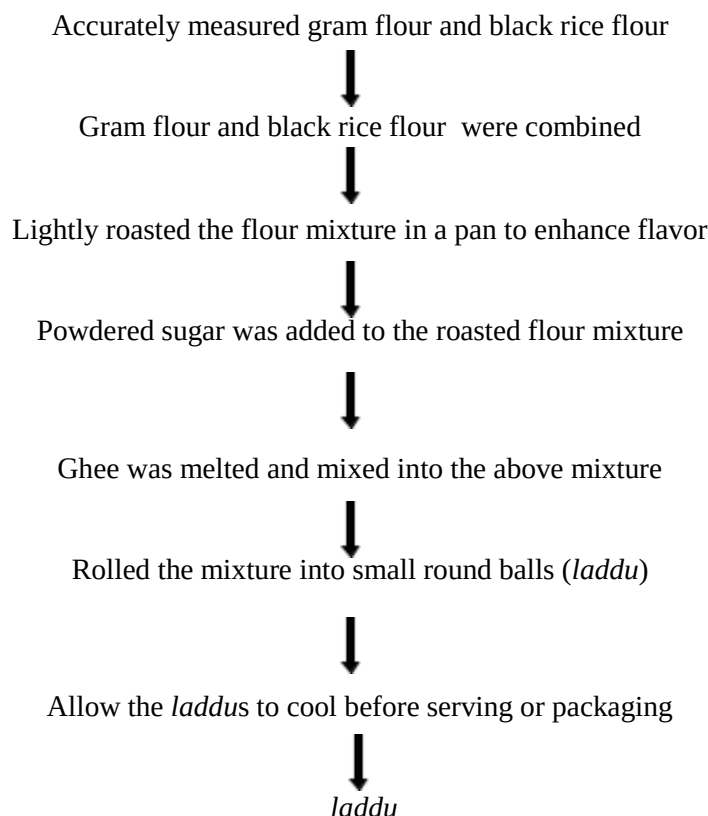


Fig.1 Flow Chart for Preparation of “laddu”

3. Sensory Analysis

The sensory evaluation of value-added *laddu* prepared from black rice flour was conducted using a trained panel of ten judges from B.P.S. Women University, Khanpur Kalan. A structured 0-to-9 rating scale measured critical sensory attributes of taste, flavor, aroma, texture, and appearance. Panelists received thorough definitions of each attribute, thus maintaining consistency and accuracy of evaluation. Incorporation of black rice flour raised the nutritional status of the product by fortifying it with antioxidants, dietary fiber, and essential amino acids. Further, the addition of black rice very much enhanced the sensory characteristics of *laddu*. The *laddu* obtained had an unusual flavor with deep purple color and significantly improved texture, thus visually appealing and sensory appealing. So, black rice flour enhanced nutritional quality and consumer acceptance and overall sensory acceptability of *laddu*, indicating its utility as a nutritious and appealing value-added food product.

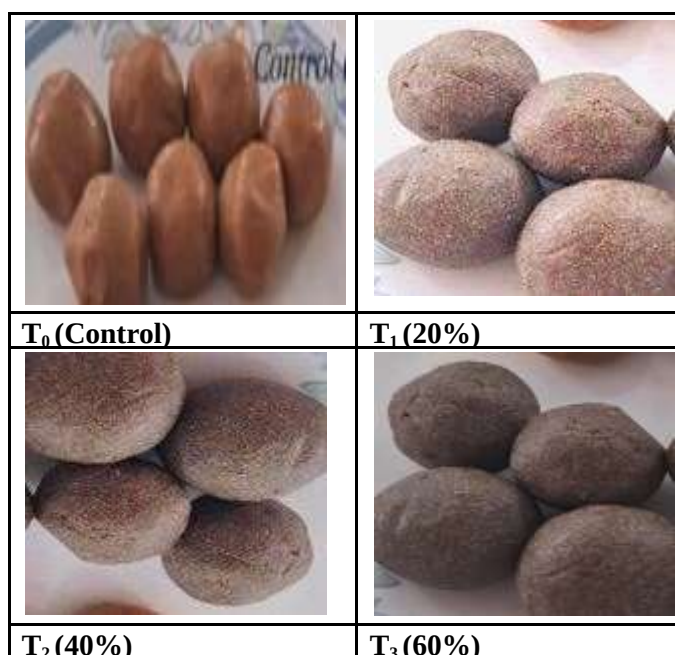
4 Statistical Analysis

Statistical analysis was carefully performed in the present study to validate the results. Mean values and their standard deviations (SD) have been shown for all determinations, which were performed in triplicates. This methodology enhances the reliability of this study and aids in interpreting the data in light of its variation. Other analytical typologies involved were analyzing the ANOVA. This valuable statistical tool in sensory evaluation studies of *laddu* provides viable information for identifying significant differences in sensory attributes across various formulations. While the statistical outcomes will further aid in the evaluation of valuable differences in nutrient composition. (Abu-Ghannam & Gowen, 2021), not only for fibre and anthocyanin but for minerals as well, with the statistical results emphasizing significant differences in nutritional content between the value-added products and conventional recipes, including an increase in fibre, anthocyanin, and mineral content. Therefore, there is a reasonable conclusion that scientific and valid conclusions drawn out of this study receive credence from proper application of statistical techniques. (Dhutmal *et al.*, 2020).

5. Results and Discussion

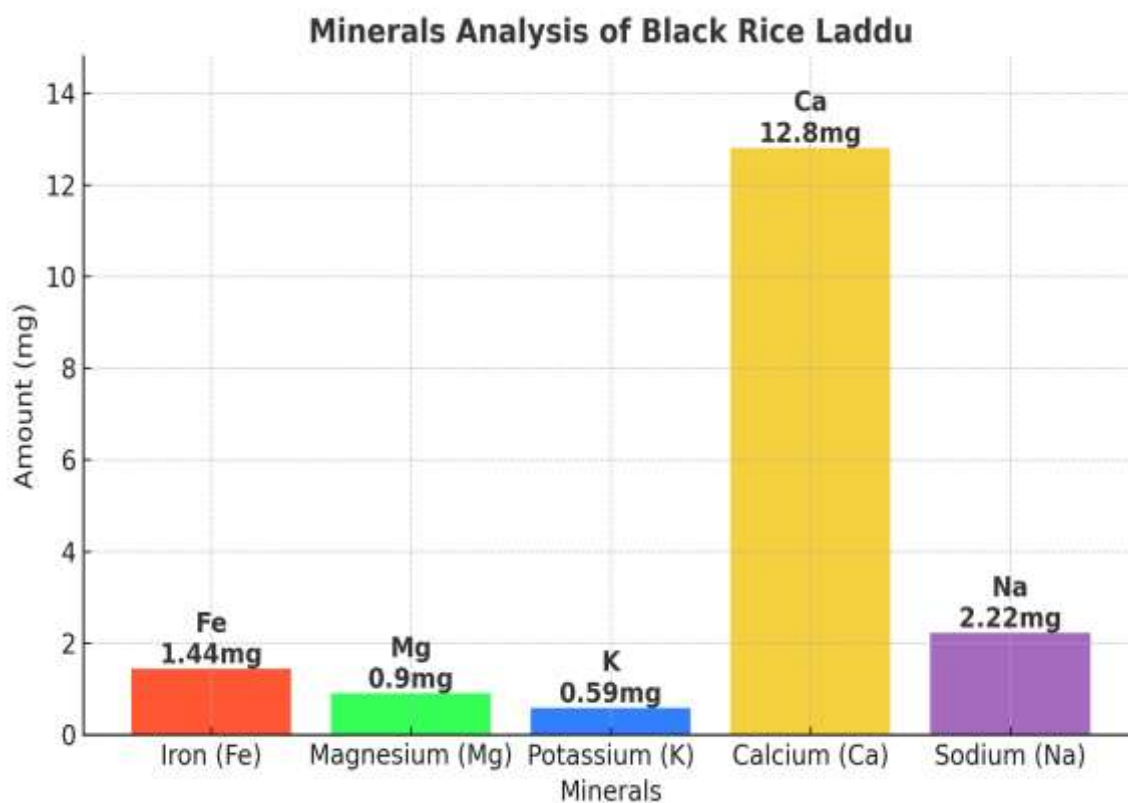
5.1 Black Rice Flour laddu

As such, black rice flour was used as one of the raw materials, and extensive analysis of it was done using standardized procedures. Tests included proximate composition, mineral content, vitamin analysis, and evaluation of physical properties. Such an analysis assessed moisture, protein, fat, ash, and fiber content. In the case of mineral assessment, the important minerals like calcium, magnesium, iron, and zinc were found to be in high concentration, proving their importance in human nutrition, health, and overall development. Additionally, antioxidant analysis identified compounds capable of preventing oxidation processes, thereby enhancing the functional attributes of the black rice flour. The analytical data detailed in Table 2 demonstrate that black rice flour holds promising potential as a functional ingredient. Such information supports its broader application in developing nutritionally enriched and health-promoting food products, including the specifically developed black rice flour laddu.



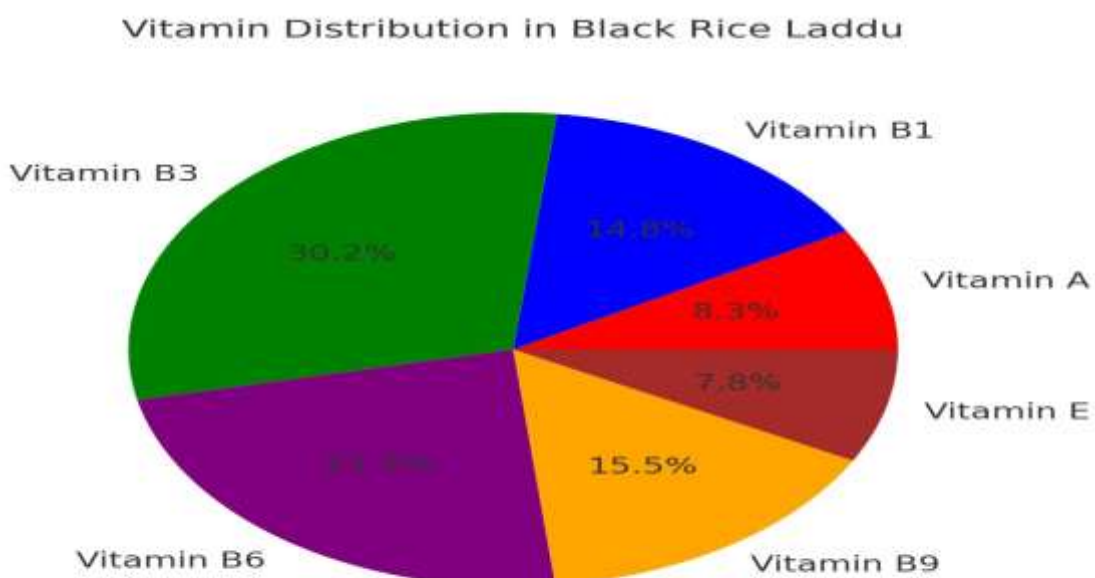
5.2 Proximate analysis Minerals content, Vitamins Analysis and Physical analysis of ingredients of Black Rice Flour “laddu”

Proximate Analysis of Black Rice laddu		
S. No.	Parameter	Test Result per 100gm
1	Total Moisture	11.28%
2	Total Ash	2.91%
3	Fat	17.27gm
4	Protein	3.27gm
5	Carbohydrate	42.87gm
6	Reducing Sugar	0.75gm
7	Non-Reducing Sugar	0.36gm
8	Starch	45.80gm
Minerals Analysis of Black Rice laddu		
1	Iron	1.44mg
2	Magnesium	0.90mg
3	Potassium	0.59mg
4	Calcium	12.80mg
5	Sodium	2.22mg



Vitamins Analysis of Black Rice laddu

1	Vitamin A	1.18 µg
2	Vitamin B1	2.10 µg
3	Vitamin B3	4.28 µg
4	Vitamin B6	3.30 µg
5	Vitamin B9	2.19 µg
6	Vitamin E	1.10 µg



Physical Analysis of Black Rice laddu		
1.	Iodine Value	108
2.	Saponification Value	190
3.	Peroxide Value	0.570 meq/kg
Microbiological Analysis of Black Rice laddu		
1	Total Plate Count	19280 cfu/gm
2	Yeast & Mould Count	Absent/gm

The proximate analysis of Black Rice Flour *laddu* presents a picture of its nutritional composition. The moisture content of 11.28% ensures moderate levels of water retention that contribute to texture and shelf life of the product. The total ash accounted for at 2.91% keeps presence of the essential minerals and inorganic composition. Black Rice *laddu* is high in fat at 17.27g/100g, classifying it as an energy-dense food. In contrast, protein at 3.27g is relatively low compared to other macronutrients, defining moderate protein content. The carbohydrate content is high at 42.87g; starch contributes 45.80g, indicating most of the carbohydrate is in starch form. In addition, reducing sugars (0.75 g) and non-reducing sugars (0.36 g) add to the overall sweetness and energy of the *laddu*.

The mineral composition of Black Rice *laddu* showcases its micronutrient density. Iron facilitates oxygen transport in the blood at a total of 1.44 mg per 100 g and supports hemoglobin production. Magnesium (0.90 mg) is crucial for muscle and nerve function and potassium (0.59 mg) has a role in fluid balance and heart health. Calcium (12.80 mg) is helpful for one's bone health; sodium is at a minimum (2.22 mg), contributing to *laddu* being a low-sodium food product. The vitamin analysis reveals some of the vitamins that are highly contributive to good health. Vitamin A contributes to vision and immunity (1.18 µg); vitamins of the B complex like vitamin B1 (2.10 µg), vitamin B3 (4.28 µg), vitamin B6 (3.30 µg), and vitamin B9 (2.19 µg) aid in metabolism, cognitive function, and red blood cell production; and vitamin E (1.10 µg) is an antioxidant to prevent oxidative cell damage.

Physical analysis of Black Rice *laddu* provides insights into its quality. Iodine value shows a degree of unsaturation; Saponification is indicative of the fatty acid chain length. The Peroxide Value (0.570 meq/kg) indicates a low level of fat oxidation indicating freshness. Microbiological analysis ensures the consumer safety of the product. The Total Plate Count (19,280 cfu/gm) still falls within acceptable limits for microbial safety. Absence of Yeast & Mould Count further attests to the *laddu* hygienic quality and placing it safe for consumption.

5.3 Average sensory scores of different parameters in Control and Experimental samples of value added “laddu”

Table 2. Average sensory scores of different parameters in Control and Experimental samples of value added “laddu”

Sr. No.	Sample	Colour	Appearance	Aroma	Texture	Taste	Overall Acceptability
1	Control	8.6±0.18	8.0±0.21	8.4±0.21	8.0±0.20	8.4±0.20	8.28±0.22
2	Sample 20%	7.4±0.20	7.1±0.19	7.6±0.20	8.0±0.21	7.6±0.18	7.54±0.21
3	Sample 40%	6.8±0.22	6.5±0.18	7.1±0.22	7.5±0.21	7.4±0.20	7.06±0.22
4	Sample 60%	6.4±0.25	6.0±0.20	6.8±0.21	7.0±0.21	6.7±0.22	6.58±0.21
	P-Values	0.61	0.62	0.63	0.61	0.66	0.6

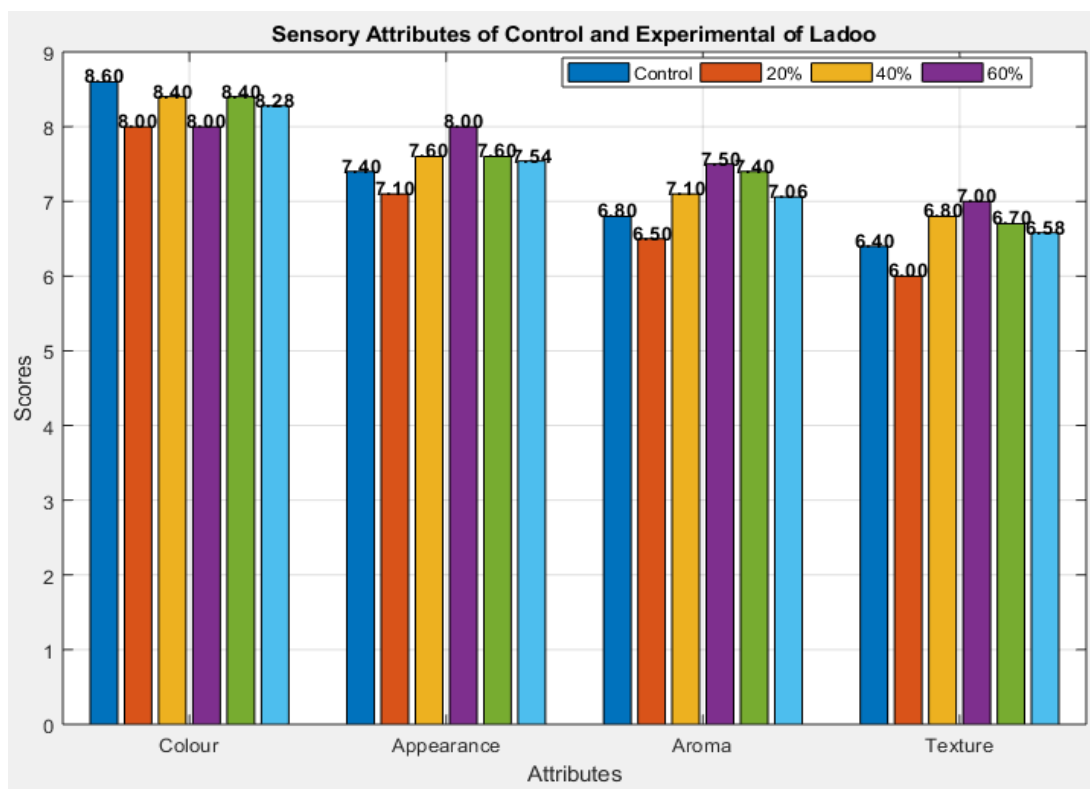


Fig.2 Sensory Attributes of Control and Experimental of “laddu”

The results of the sensory evaluations presented in Fig.2 indicate changes in the organoleptic characteristics of both control and the experimental black rice-based *laddus*. The control sample received higher mean scores on all parameters, with scores: colour 8.6, appearance 8.0, aroma 8.4, texture 8.0, taste 8.4 and overall acceptability as 8.28 meant marked preference by the panelists. In contrast, as the level of black rice went from 20% to 60%, sensory scores appeared to go down gradually. The samples of 20% black rice were rated significantly lower in sensory attributes: colour (7.4), appearance (7.1) and overall acceptability (7.54). The texture scores, however, did not change from 8.0, same as the control at that level also, indicating little effect on texture characteristics at this level.

Increasing further to behaviours of the black rice portion at 40% and 60% produced somewhat lower sensory values, suggesting lower acceptance by judges. The colour, appearance, and overall acceptability scores for the 40% black rice formulation (6.8, 6.5, and 7.06 respectively) were significantly lower than for the control and 20% samples. The 60% sample rated the lowest in all parameters, having the colour, taste, and overall acceptability scores of only 6.0, 6.7, and 6.58, respectively — it indicates that increasing the content of black rice reduced largely the sensory characteristics of the product. Nevertheless, the analysis performed to determine the significance of the differences (P-values ranging from 0.60 to 0.66) across all samples indicated that there was no statistically significant difference between all observed samples in this case. Despite the gradual decrease in sensory scores, black rice could be included in lesser concentrations (20%–40%) with relatively little effects on consumer acceptability.

6. CONCLUSION

The sensory evaluation revealed that, indeed, the incorporation of black rice in traditional formulations of *laddu* was found to be a determining factor in altering their organoleptic attributes. The highest value of sensory description was for control *laddu*, with the highest score ranges of color received as 8.6, aroma and taste 8.4, and overall acceptability 8.28. Among experimental variations and fortifications, the formulation of *laddu* incorporated with 20% black rice flour obtained the most favorable sensory scores, scoring comparatively high on aroma (7.6), taste (7.6), and overall acceptability (7.54). Inasmuch as the sensory scores slightly declined, at increased levels of black rice content of 40% and 60%, the 20% black rice was accordingly the best choice because of its least divergence from the control and greatest nutritional fortification of the end product's profile.

Although there was a significant difference in means, the sensory scores remained pretty much the same among the samples statistically, with P-values ranging from 0.60 to 0.66. Thus, while the decline in sensory acceptance at the higher levels of black rice was obvious; it was not statistically significant. This therefore supports the viability of black rice inclusion in *laddu* supplementation at moderate levels such as 20% that do not significantly adversely affect sensory quality. On the other hand, it is the addition of black rice that will significantly increase the health profile of the *laddu* by providing antioxidants, dietary fiber, and essential amino acids, putting it right into the category of health-promoting functional foods. Therefore, it is noted that incorporation of 20% black rice flour in *laddu* production meets the nutritional enrichment and complies with present consumer requirements for an increased commercial potential in the health-conscious market. Further, the work put across provides the opportunity to marvel at the meeting point of nutritional fortification with consumer acceptability in the development of new food products.

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