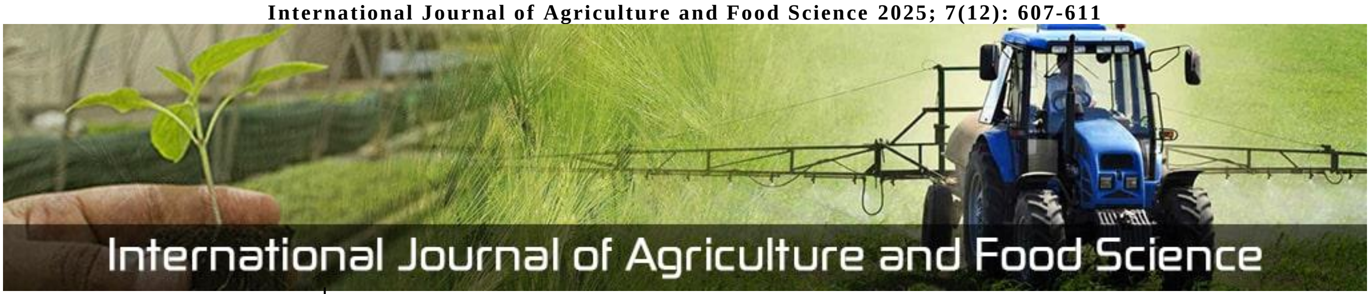

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(12): 607-611
www.agriculturaljournals.com
Received: 20-10-2025
Accepted: 25-11-2025

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Studies on physico - chemical attributes of gulabjamun incorporated with barley (*Hordeum vulgare*) flour

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DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i12h.1098

Abstract
The present study investigated the preparation of gulabjamun incorporated with barley (*Hordeum vulgare*) flour as a partial substitute for maida, with the aim of optimizing its level of inclusion and evaluating the resultant product's physicochemical, sensory, textural, and cost characteristics. Preliminary trials were conducted to determine the suitable form (raw or roasted barley flour) and stage of addition, after which roasted barley flour was incorporated at 10%, 15%, and 20% levels and compared with a control. Barley incorporation led to a significant increase in moisture (32.18-33.19%), protein (10.07-11.44%), fiber (0.55-3.81%), ash (1.56-1.85%), carbohydrates (41.32-44.60%), and total solids (73.19-74.65%) compared to the control, while fat content showed a slight reduction. Production cost increased marginally with higher barley inclusion. Overall, the study concluded that roasted barley flour can be incorporated up to 15% in gulabjamun to enhance nutritional quality without compromising sensory acceptability.

Keywords: Gulabjamun, Barley flour, Physico-chemical properties, Moisture content, Protein content, Fat Content

Introduction
India is the largest milk-producing country in the world with an annual growth rate of 6.4 per cent. The total milk production stands at 239.3 MT with per capita availability of 471 g/day, whereas in Maharashtra it is 329 g/day (NDDB, 2023-24). Among different species, buffalo milk contributes about 55 per cent of the total production, followed by cow milk at 40.5 per cent. Owing to its higher fat, SNF and protein contents, buffalo milk is preferred for khoa manufacture, resulting in a soft -bodied, smooth- textured, and nutritionally superior product (Basaragi, 2025) [6].

Khoa is a heat-desiccated indigenous milk product that serves as a base for numerous sweets such as peda, burfi, kalakand and gulabjamun. Nearly 7 per cent of milk produced in India is converted into khoa annually Khoa prepared from buffalo milk is superior in yield (21-23%) compared to *et al* cow milk (17-19%) and provides desirable texture and flavour in sweetmeats (Rasane, *et al* 2015) [26].

Gulabjamun is one of the most popular khoa-based confections consumed across India. Traditionally made from khoa and refined wheat flour (maida), gulabjamun is characterized by its golden-brown colour, soft body, smooth texture and pleasant flavour of rose water. It is commonly prepared using Dhapkhoa (40-45% moisture) and widely consumed during festivals, marriages, and celebrations. Despite its popularity, gulabjamun production is still dominated by small-scale, unorganized sectors (Devrani, 2018) [7]. Although milk is recognized as a nearly complete food, it lacks certain micronutrients such as dietary fiber, iron, copper and vitamins (Rasane, *et al.* 2015) [26]. Thus, there is a need to incorporate suitable cereal-based ingredients to enhance nutritional quality of dairy-based sweets.

Barley (*Hordeum vulgare L.*) is one of the oldest cultivated cereals and is widely grown across the world. It is rich in proteins, carbohydrates, β-glucans, resistant starch, vitamins, and minerals such as calcium, phosphorus, iron, zinc and magnesium (Abebaw, 2021) [2]. B-glucan from barley have been reported to reduce cholesterol, regulate blood glucose, improve gut health, and lower the risk of cardiovascular diseases (Kaur, 2024) [14]. The high dietary fiber content of barley also improves satiety, relieves constipation, and supports weight management.

Barley flour can be used in bakery and confectionery preparations, enhancing fermentation, texture, and flavour of products (Geng *et al*., 2022) [9]. Malted barley flour, in particular, improves dough quality and is already utilized in breads, cookies, and snacks (Kaur, 2024) [14]. Its incorporation in dairy-based products may provide additional nutritional and functional benefits.

Materials and Methods

Raw Materials

Fresh buffalo milk used for khoa preparation was obtained from the Department of Animal Husbandry and Dairy Science, College of Agriculture, VNMKV, Parbhani. Barley flour of food-grade quality was procured from the local market, whereas refined wheat flour (maida), sugar, baking powder, cardamom powder and vegetable oil were purchased from retail outlets in Parbhani, India. All chemicals and reagents employed for analytical work were of analytical grade.

Preparation of khoa

Khoa was prepared by concentrating buffalo milk in a traditional iron *karahi* (capacity: 2 L; diameter: 31 cm; depth: 8.5 cm) on a domestic gas stove. The milk was continuously stirred using a flat-edged metal scraper (*kunthi*) to prevent scorching and ensure uniform evaporation until a semisolid khoa consistency was obtained. Mixing and grinding operations were performed using an electric mixer-grinder.

Analytical instruments and measurements

Physico-chemical analyses of the prepared samples were conducted using standard laboratory glassware and equipment available in the Departmental laboratory. Textural properties of the Gulabjamun samples were evaluated using an Instron Texture Analyzer at the College of Food Technology, VNMKV, Parbhani.

Selection of form of barley flour

Among the three forms of barley flour evaluated, raw barley flour, roasted barley flour, and sprouted barley flour, roasted barley flour was selected for further experimentation based on its superior sensory acceptability in the preliminary gulabjamun trials.

Treatment details

- SF_1: khoa + 25 parts maida (control)
- SF_2: khoa +10 parts maida + 15 parts raw barley flour
- SF_3: khoa + 10 parts maida + 15 parts roasted barley flour
- SF_4: khoa + 10 parts maida + 15 parts sprouted barley flour

Selection of stage of addition of barley flour

Roasted barley flour was incorporated at three different stages during gulabjamun preparation: (1) after boiling the milk, (2) during pat formation stage, and (3) after the complete preparation of khoa. Based on the sensory evaluation of gulabjamun prepared using all three incorporation stages, the addition of roasted barley flour after the final preparation of khoa demonstrated superior acceptability and was therefore selected for subsequent formulation.

Treatment details

- S_1: khoa + 25 parts maida (control)
- S_2: khoa +10 parts maida + 15 parts roasted barley flour added after boiling of milk
- S_3: khoa + 10 parts maida + 15 parts roasted barley flour added at pat formation stage
- S_4: khoa + 10 parts maida + 15 parts roasted barley flour added after preparation of khoa

All the formulated products were subjected to sensory evaluation and the most acceptable variant was selected for subsequent analyses, including chemical characterization and textural profiling

Preparation of gulabjamun by using roasted form of barley flour

Receiving of Fresh milk
↓
Filtration
↓
Continuous heating in open pan with continuous stirring and scrapping
↓
Pat formation
↓
Preparation of khoa
↓
Addition of selected form of, Roasted barley flour, maida and baking soda as per treatment
↓
Formation of dough
↓
Ball formation (approx. 10 g each)
↓
Frying of balls in vegetable oil (110 °C)
↓
Holding of fried gulabjamun (5 minutes)
↓
Dipping in hot sugar syrup (65 °C)
↓
Soaking gulabjamun for overnight

Fig 1: Flow chart for Preparation of *gulabjamun*

Treatment details

The experiment was designed to incorporate barley flour into gulabjamun at different levels (10, 15 and 20 parts) in place of maida. Treatments were as follows:

- T_1: 75 parts khoa + 25 parts maida (control)
- T_2: 75 parts khoa + 10 parts barley flour + 15 parts maida
- T_3: 75 parts khoa + 15 parts barley flour + 10 parts maida
- T_4: 75 parts khoa + 20 parts barley flour + 5 parts maida

Chemical analysis of *Gulabjamun*

Total solids

Total solids content in *gulabjamun* determined as per the procedure described in ISI:1479 (part II) 1961.

Fat

The total fat content of the gulabjamun sample was determined using the Soxhlet Extraction Method (Gravimetric Analysis), a highly reliable technique widely applied in food science and consistent with Bureau of Indian Standards (BIS) principles for dairy-based sweets (IS 4079:1967)

Protein

Protein content in *gulabjamun* sample was determined by estimating the per cent nitrogen by micro Kjeldhal method as recommend in ISI: 1479 (Part II) 1961

Ash

Ash content in *gulabjamun* determined by method described in ISI: 1479 (part II), 1961

Sensory evaluation

Sensory evaluation of *gulabjamun* was carried out by the panel of judges. The product was evaluated by using 9 points hedonic scale. The product was evaluated for flavour, colour and appearance, body and texture, taste and overall acceptability attributes.

Cost estimation of gulabjamun

The cost per kilogram of the newly formulated products was calculated by considering the current market prices of the ingredients and including any additional expenses incurred during the manufacturing of gulabjamun.

Statistical analysis

Completely randomized design (CRD) was used for data analysis. The entire data of the experiment has been properly tabulated, analyzed and interpreted as described by Panse and Sukhatme (1985) [22].

Results and Discussion

Physico-chemical analysis of gulabjamun by using barley flour

Moisture

The moisture content of gulabjamun prepared with varying levels of roasted barley flour is presented in Table 1. The control sample (T_1) recorded a mean moisture content of 32.18%, while treatments incorporating barley flour exhibited significant differences ($P<0.05$). The lowest moisture value was observed in T_2 (31.22%), whereas T_4 showed the highest moisture content (33.19%). The gradual increase in moisture from T_2 to T_4 may be attributed to the enhanced water-binding capacity of the dietary fiber present in roasted barley flour, which helps retain more moisture during mixing and frying. These findings are consistent with earlier reports by Matkar (2006) [19] and Sirsat (2012) [31], who also noted increased moisture levels in burfi and peda with the inclusion of fig and ash gourd, respectively.

Fat

The fat content of Gulabjamun varied significantly among treatments (Table 4.36). The control sample (T_1) exhibited the highest fat content (16.06%), while the incorporation of roasted barley flour resulted in slightly lower yet significantly different values in T_2 (15.42%), T_3 (15.66%), and T_4 (15.89%). The observed trend may be attributed to the fiber-rich nature of barley flour, which can influence oil absorption during frying. The swelling and porous structure of dietary fiber can facilitate moderate oil uptake, thereby affecting the fat content of the final product. These findings are in line with earlier reports, where Shikalgar (1996) [28] documented an increase in fat content in gulabjamun with the addition of lesser yam powder, and Mahale *et al*. (2011) observed a significant rise in fat content when coconut milk was blended with cow milk during gulabjamun preparation.

Protein

The protein content of gulabjamun increased significantly with the incorporation of roasted barley flour (Table 1). The control treatment (T_1) exhibited the lowest protein content (10.07%), while the values increased progressively in T_2 (10.83%), T_3 (11.11%), and T_4, which recorded the highest level (11.44%). This upward trend is attributed to the comparatively higher protein content of barley flour (11-13%) than that of maida, leading to an overall improvement in the protein profile of the product. These results are consistent with the observations of Javiya *et al.* (2025) [13], who reported an increase in protein levels in pearl millet-based gulabjamun as millet incorporation increased. Similar enhancement in protein content was noted by Shikalgar (1996) [28] in gulabjamun prepared with lesser yam powder and by Singh *et al*. (2009) [30], who documented significant protein enrichment when defatted soy flour was used at varying inclusion levels.

Ash

The ash content of gulabjamun showed a significant rise with increasing levels of roasted barley flour incorporation (Table 1). The control sample (T_1) recorded the lowest ash content (1.56%), while the highest value (1.85%) was observed in T_4, which contained 20% barley flour. This upward trend can be attributed to the naturally higher mineral concentration in barley flour compared to maida, as barley is rich in essential minerals such as potassium, phosphorus, magnesium and iron, which contribute to elevated ash levels. The present findings align with those of Sahana and Vijayalaxmi (2024) [27], who reported an increase in ash content (1.19-1.28%) in gulabjamun with higher levels of foxtail millet incorporation. Similar results were documented by Javiya *et al.* (2025) [13], where ash content rose from 1.31 to 2.20% as pearl millet substitution increased from 25% to 100%.

Crude fiber

The fiber content of gulabjamun prepared with roasted barley flour is shown in Table 1. A significant increase

($P<0.05$) was observed across treatments, with values rising from 0.55% in the control (T_1) to 1.52% (T_2), 2.68% (T_3), and 3.81% (T_4). This progressive increase corresponds to the higher dietary fiber content of barley flour, which contributes both soluble and insoluble fiber fractions to the formulation. Similar trends were reported by Sakate (2000) [29], who observed increased dietary fiber levels in wood apple-based burfi with higher fruit incorporation. The present findings confirm the effectiveness of roasted barley flour in enhancing the fiber content of gulabjamun.

Carbohydrate

The carbohydrate content of gulabjamun samples is presented in Table 1. The control (T_1) recorded 41.32%, while treatments containing roasted barley flour showed a significant and progressive increase, with values of 42.66% (T_2), 43.37% (T_3) and 44.60% (T_4). This rise in carbohydrate content corresponds to the higher levels of complex carbohydrates present in barley flour compared to maida. Similar increasing trends with millet incorporation in gulab Jamun were reported by Javiya (2025) [13] and by Sahana and Vijayalaxmi (2022). Conversely, reductions in carbohydrate levels with high-moisture ingredients such as bottle gourd and coconut were noted by Waghmare (2012) [35] and Talekar (2015) [32]. The present results confirm that roasted barley flour effectively enhances the carbohydrate content of gulabjamun.

Total solid

The total solid content (%) of gulabjamun samples incorporated with roasted barley flour, along with the control, is shown in Table 1. The control treatment (T_1) recorded a total solid content of 73.19%, while treatments supplemented with roasted barley flour exhibited progressively higher values: 74.16% (T_2), 74.40% (T_3), and 74.65% (T_4). This consistent increase in total solids with increasing incorporation levels of roasted barley flour may be attributed to its higher dry matter contribution, as barley flour contains substantial amounts of dietary fibre and complex carbohydrates that enhance water absorption and solid retention compared to refined wheat flour (maida). Similar trends have been reported by Patel *et al.* (2020) [21], who observed an increase in total solids (66.15-71.29%) in Amaranthus-based gulabjamun. Conversely, earlier studies by Wakchaure (1998) [36], Waghmare (2012) [35] and Talekar (2013) [32] reported reductions in total solids in products such as burfi prepared with sapota pulp, bottle gourd, and coconut, respectively, which were attributed to increased moisture content. The present findings therefore confirm the role of roasted barley flour in enhancing the total solid content of Gulab Jamun.

Syrup Absorption

The syrup absorption capacity of gulabjamun varied significantly across treatments ($P<0.05$). The control sample (T_1) exhibited the highest absorption (136.31 g/100 g), which may be attributed to the finer texture and superior moisture-holding ability of maida. Substitution with roasted barley flour resulted in reduced syrup absorption, with values ranging from 127.33 g/100 g (T_2) to 130.00 g/100 g (T_4). The lower absorption in barley-incorporated treatments is likely due to the presence of higher fiber and β-glucans, which alter the product's internal structure and limit syrup uptake. However, the slight increase from T_2 to T_4 suggests that, at higher levels, the water-binding properties of barley components partially compensate for reduced porosity, leading to moderate syrup retention. Overall, barley addition influenced syrup absorption but remained within acceptable functional limits for gulabjamun quality.

Beta glucan

The β-glucan content of gulabjamun samples prepared with varying levels of roasted barley flour is presented in Table 1. As expected, the control treatment (T_1) showed no detectable β-glucan (0.00%), as khoa and maida do not naturally contain this soluble dietary fibre. Incorporation of roasted barley flour resulted in a significant and progressive increase in β-glucan levels across treatments, with T_2, T_3, and T_4 recording mean values of 3.75%, 4.45%, and 5.13%, respectively. This linear increase reflects the contribution of barley flour, which is inherently rich in β-glucan, thereby enhancing the functional value of the product. These findings are consistent with those reported by Kaur *et al.* (2020) [14], who observed a significant rise in β-glucan content in yoghurt with increasing barley flour substitution, and by Khorshidian *et al.* (2017) [16], who noted improved functional properties in cereal-fortified dairy sweets. Ahmad *et al.*, similarly reported β-glucan yields ranging between 3.74% and 5.14% from oat extractions, supporting the values observed in the present study. Given the recognized health benefits of β-glucan including cholesterol reduction, attenuation of postprandial glycemic response, and improved gut health the incorporation of roasted barley flour effectively enhances the nutritional profile of gulab Jamun without adversely affecting its quality. These results demonstrate the potential for developing value-added functional dairy products enriched with β-glucan.

Table 1: Mean value of chemical composition of developed gulabjamun

Chemical constituent (%)	T_1	T_2	T_3	T_4	SE(m) ±	CD at 5%
Moisture	32.18	31.22	32.17	33.19	0.039	0.121
Fat	16.06	15.42	15.66	15.89	0.013	0.040
Protein	10.07	10.83	11.10	11.44	0.028	0.082
Ash	1.56	1.67	1.78	1.85	0.015	0.045
Crude Fiber	0.55	1.52	2.68	3.81	0.045	0.141
Carbohydrate	41.32	42.66	43.37	44.60	0.058	0.178
Total solids	73.19	74.16	74.40	74.65	0.085	0.251
Syrup absorption	136.31	127.33	128.22	130.00	0.648	1.998
Beta-glucan (mg/g)	0.00	3.75	4.45	5.13	0.001	0.003

Cost of Production

The cost of production of gulabjamun prepared using different levels of roasted barley flour showed a gradual increase from T_1 to T_4 due to the progressive incorporation of barley flour and the corresponding reduction of maida.

Among the treatments, the control sample T_1 recorded the lowest production cost (Rs. 257.36 per kg), as it did not include barley flour. The cost increased slightly in T_2 (Rs. 259.46 per kg) and T_3 (Rs. 260.52 per kg), reflecting the additional expense of barley flour at 10% and 15% levels, respectively. The highest production cost was observed in T_4 (Rs. 262.22 per kg), where barley flour substitution was maximum (20%).

Conclusion

The incorporation of barley flour in gulabjamun significantly affected its physicochemical, sensory, and textural qualities. Moisture, ash, protein, carbohydrate, and fat contents increased with barley addition due to its β-glucan, soluble fibers, minerals, and higher carbohydrate levels, while syrup absorption also improved, making the product softer, juicier, and visually appealing.

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