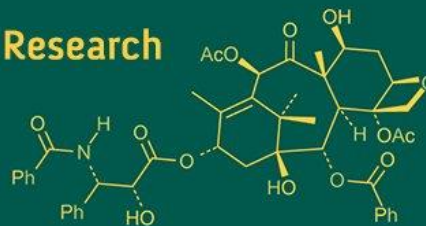


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(7): 1898-1904
www.biochemjournal.com
Received: 04-05-2026
Accepted: 08-06-2026

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Development and quality evaluation of chhana Jhilli utilizing Rajgara (*Amaranthus hypochondriacus* L.) as a substitute for Maida

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i7Sw.9334>

Abstract

Chhana jhilli is a traditional Indian dairy dessert prepared from *Chhana* and *Maida*. The present study aimed to develop a value-added *Chhana jhilli* by replacing *Maida* with *Rajgara* as a gluten-free binder and to evaluate its physicochemical, textural and sensory characteristics. Five formulations were prepared by replacing *Maida* with *Rajgara* at levels of 0, 25, 50, 75 and 100%, while maintaining the binder level at 10% (w/w) of the *Chhana* weight. The developed products were analyzed for physicochemical composition, sugar syrup absorption, texture profile and sensory attributes. Replacement of *Maida* with *Rajgara* significantly ($P < 0.05$) improved the nutritional composition of *Chhana jhilli* by increasing fat, protein, ash, total solids, carbohydrate content and sugar syrup absorption, while pH and acidity exhibited only minor variations among the treatments. Texture profile analysis revealed a significant increase in hardness and a slight decrease in springiness, whereas cohesiveness, gumminess and chewiness remained statistically comparable. Sensory evaluation demonstrated that *Chhana jhilli* prepared with 100% *Rajgara* exhibited overall acceptability comparable to the control while providing superior nutritional quality. The findings indicate that *Rajgara* can successfully replace *Maida* as a binder in *Chhana jhilli*, resulting in a nutritionally enhanced product with desirable physicochemical, textural and sensory properties.

Keywords: Chhana jhilli, *Amaranthus hypochondriacus*, Rajgara, Maida

1. Introduction

India is the largest milk producer in the world contributing over 25% of global milk production, with a production of around 247.4 million tonnes in 2024-25 ^[1]. Milk and milk products have a important place in the diets of Indian subcontinents. It has a cultural and religious value in India beyond its nutritive value.

Traditional Indian dairy products (TIDPs) are important part of Indian diet. *Ghee*, *Dahi*, *Paneer*, *Chhana* and *Khoa* are commonly consumed dairy products supplying important nutrients, but they are also used as preparation of traditional sweets such as *Gulabjamun*, *Rasogolla*, *Chhana jhilli* and *Burfi*. Traditional dairy product consumption is increasing at an annual growth rate (AGR) of over 11-20% ^[2].

Recently, dairy technologists have shown increased interest in these products. This is due to their potential for process standardization, defining quality attributes, extending keeping quality and developing viable industrial approaches. Such advancements could lead to global export and recognition. For the commercial production of traditional dairy products, mechanization and optimization of operating conditions are crucial to ensure consistent and acceptable quality ^[3]. According to ^[4], approximately 10% of milk is utilized for manufacturing *Chhana* and *Khoa*-based sweets.

Chhana is a primary ingredient found in most dairy products that are coagulated with heat and acid. *Chhana* is a significant traditional milk product, typically made by precipitating milk proteins with acid. It serves as a base ingredient for a variety of milk-based sweets, such as *Chhana jhilli*, *sandesh* and *rasogolla*.

Chhana jhilli, a sweet from Nimapada, Odisha, is primarily made by local, small-scale producers, often within the unorganized sector. It is one of the items in the *chhapan-bhog* at Lord Jagannath temple, Puri. It's usually made by local, small-scale producers, mostly in unorganized sectors.

The dough for *Chhana jhilli* is made with *Chhana*, *Maida* (or semolina), sugar, cardamom powder and baking powder. The purpose of this *Maida* is to provide cohesion and assist in preventing the disintegration of *Chhana jhilli* while they are being fried. Due to its starchy nature, *Maida* possesses good water-binding properties, contributing to the desired texture [5]. The protein found in *Maida* called gluten keeps the dough together, gives the flour its pliability and thickness and allows it to be kneaded.

However, use of *Maida* as a binder in *Chhana jhilli* presents several disadvantages, primarily due to *Maida* containing gluten which is not appropriate for that person who was suffering from celiac disease [6, 7]. Other reason is that its glycaemic index is high, which causes rapid blood sugar spikes and can be detrimental for people with diabetes. [8]. Furthermore, *Maida* lacks significant fibre and essential nutrients, potentially leading to digestive issues and offering minimal nutritional value to the product. *Rajgara* is rich in dietary fiber (6.75 to 9.79%). The fiber will act as a prebiotic, nourishing the beneficial bacteria in the gut. This helps to resolve the digestive issues caused by low fiber content of *Maida* [9] furthermore, as a gluten-free cereal, it serves as an alternative for people who have celiac disease. Since there is a great potential in value added products from under-utilized grains like *Rajgara* to eradicate malnutrition and micronutrient deficiencies, an attempt has been made to supplement *Amaranthus* in the preparation of *Chhana jhilli*. The current research aims to formulate an easily digestible and health-beneficial version of *Chhana jhilli* by incorporating value-added ingredients i.e. *Amaranthus*. Therefore, the present study was undertaken to develop *Chhana jhilli* utilizing *Rajgara* (*Amaranthus hypochondriacus* L.) as a substitute for *Maida* and to evaluate its physicochemical, textural and sensory characteristics.

2. Material and Method

2.1 Material

Fresh mixed milk standardized to 4.5% fat and 8.5% SNF was procured from local market in Dantiwada. *Rajgara* flour, *Maida*, sugar and other ingredients were purchased from the local market. Citric acid was used as the coagulant. The *Rajgara* flour had an average composition of 5.94% fat, 14.89% protein, 9.80% moisture and 2.55% Ash. Four different experimental *Chhana jhilli*, i.e., A1 (25% replacement of *Maida*), A2 (50% replacement of *Maida*), A3 (75% replacement of *Maida*), A4 (100% replacement of *Maida*) and control (100% *Maida*) was prepared using different proportion of *Rajgara*: *Maida* were replicated four times.

2.2 Preparation of *Chhana*

Milk was standardized to 4.5% fat and 8.5% SNF. The mix milk was analyzed for its fat, SNF, acidity, pH and sensory qualities. The milk was slowly heated to 90°C and then cooled to 70°C for coagulation. At the same time, a solution of 1% citric acid is heated to 70°C. Heating the coagulant to the same temperature as the milk ensures a more uniform and controlled coagulation process, preventing uneven coagulation and producing a smoother texture in the *Chhana*. With gentle swirling, milk is gradually mixed with the hot citric acid solution. The curdled milk is carefully transferred to a cheese cloth, allowing the whey to drain away and excess moisture is removed from the *Chhana*, which is then cooled to ambient temperature.

2.3 Preparation of *Chhana jhilli*

Chhana jhilli was developed using a method described by [10] with minor alterations. The flow diagram for the development of *Chhana jhilli* is given below in Figure 1. Minor modification was made in manufacturing flow diagram as per our requirements.

Chhana was broken down into tiny pieces and manually kneaded for about 10 to 15 minutes until it has smooth and crack free texture. Following the *Chhana* kneading, a calculated amount of *Maida*, *Rajgara* (10% by weight of *Chhana*), baking powder (1%) & Cardamom Powder (1%) were added. A small quantity of water was added to form smooth dough if required or if *Chhana* is too dry. The dough was divided into small pieces, each weighing around 8 g. The pieces were then filled into the piping bag for shaping *jhilli*. A *jhilli* does not have any cracks on the surface. After that, *jhilli* are fried in ghee.

One of the most crucial steps in production of *Chhana jhilli* is frying. Properly frying is needed to obtain a good quality *Chhana jhilli* with desirable appearance. Frying in *ghee* contributes to volume expansion and changes in the mouth feel quality of *Chhana jhilli*. One litre of *ghee* was taken in a karahi and heated till 130 to 140 °C temperature was obtained. By manually adjusting the flame, the temperature was managed. 15 to 20 *jhillis* were carefully placed in the hot *ghee*, fried for about 15 minutes until the golden-brown colour and then transferred to the 50-55 °Brix sugar syrup kept at 60 °C. In order to make sugar syrup, sugar was dissolved in water at a 55:45 ratio. The sugar syrup was boiled until it reached a 50-55 °Brix concentration.

2.4 Sample Preparation for Analysis

Chhana jhilli soaked in sugar syrup was heated to 40 °C for 20 minutes. The sugar syrup was then allowed to drain for ten minutes on a sieve with a mesh size of roughly one centimetre square. After that, the *Chhana jhilli* was broken up into tiny pieces and blended well to make a paste that could be used for various analyses.

2.5 Compositional Analysis of *Chhana jhilli*

Fat content of *Chhana jhilli* was determined as per the method described in [11] and results were expressed in percentage.

Protein content in *Chhana jhilli* was determined by semi-micro Kjeldahl method [12]. Total solids were estimated by the protocol described in [13]. The process outlined in [12] was used to determine the ash content. The total carbohydrates of *Chhana jhilli* were determined using the method described by [14].

2.6 Physico-chemical attribute of *Chhana jhilli*

The acidity of the *Chhana jhilli* sample was estimated according to procedure specified for paneer under [15]. The pH of *Chhana jhilli* was determined via technique that [16] employed for cheese. A digital pH meter was used to determine the pH of *Chhana jhilli*. The method described by [14] was used for the sugar syrup absorption of *Chhana jhilli*.

2.7 Sensory Evaluation

The 9-point hedonic scale was used to evaluating sensory perception. Sensory evaluation of control *Chhana jhilli* and experimental *Chhana jhilli* was done by eight semi-trained judges.

The sensory evaluation including flavour, body and texture, colour and appearance and overall acceptance were documented.

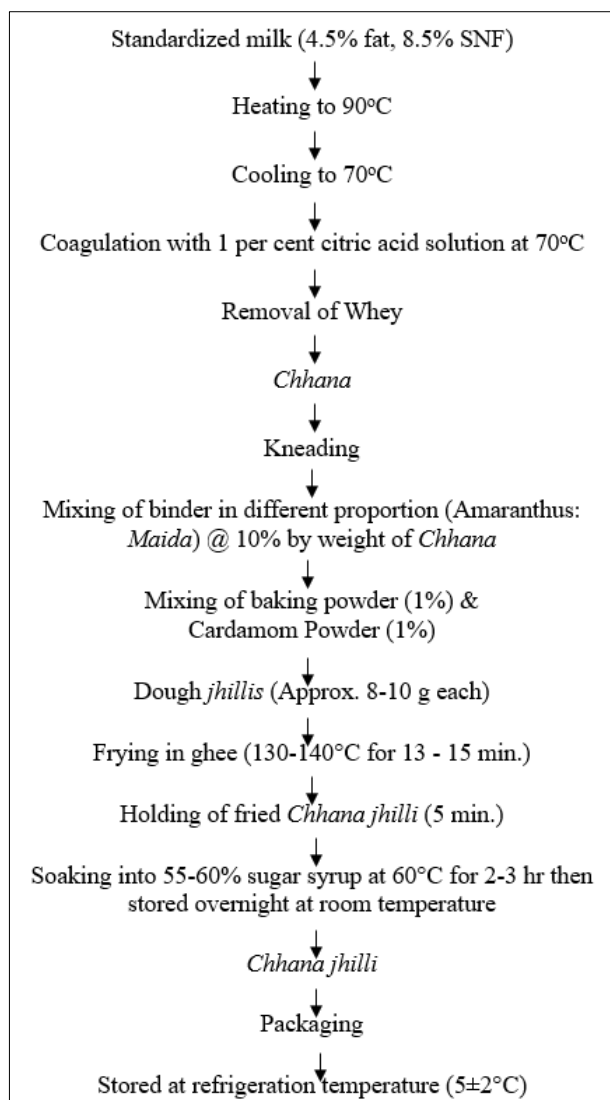


Fig 1: Flow diagram for the Manufacturing of *Chhana jhilli*

2.8 Textural Analysis

Using a Food Texture Analyzer of Stable Micro Systems TA. XT Plus, equipped with a 0-500 kg load cell, four samples of each *Chhana jhilli* were uniaxially compressed to 50% of their initial height.

2.9 Statistical Analysis

Statistical analysis of data obtained from various samples during optimization was done by using statistical software SAS with completely randomized design (CRD).

3. Results and Discussion

Based on the pre-liminary trials, five blends of *Rajgara* and *Maida* were tested as binding agents in ratios of C (0:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:0). It was observed that when the total binder concentration was less than 10% of the *Chhana* weight, the *Chhana jhilli* units lacked structural integrity and disintegrated during the frying process.

Consequently, a fixed binder level of 10% (by weight of *Chhana*) was established for further investigation. The study compared four experimental treatments were A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) against a control sample (C) containing 100% *Maida*. All batches were produced according to the standardized protocol illustrated in Fig. 1.

The subsequent sections detail the impact of these different *Rajgara* substitution levels on the chemical composition, physical properties, sensory appeal and textural profile of the final product.

3.1 Effect of Rate of Addition of *Rajgara* on the Chemical Composition of *Chhana jhilli*

The chemical composition included total solids, fat, protein, ash and total carbohydrate as shown in Table 1.

Statistical analysis revealed that the incorporation of *Rajgara* had a highly significant effect ($P < 0.01$) on the total solid levels of the final product. The total solid content for the different treatment groups: C (0:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:0) was recorded at 58.45%, 59.78%, 60.39%, 60.89% and 61.42%, respectively. The total solid content of *Chhana jhilli* increased significantly from 58.45% in C (0:100) to 61.42% in A4 (100:0) whereas A2 (50:50), A3 (75:25) and A4 (100:0) were statically at par with each other and differ from C (0:100) and A1 (25:75). This increased in total solid was primarily due to the higher concentration of protein, fat, dietary fibre and minerals in *Rajgara* than *Maida*. As the *Rajgara* concentration increases, the proportion of dry matter also increases. Further, frying reduces moisture content, thereby contributed to the increased in total solid. The findings of this study aligned closely with previous research on *Chhana jhilli*. [17] reported total solid values ranging from 58.95% to 60.07% and [18] observed similar ranges between 57.93% and 59.88%. However, the total solid content in this study was generally lower than values typically reported for *Gulabjamun*. For instance, [19] found that *Amaranthus*-based *Gulabjamun* ranged from 66.15% to 71.29%, while [14] reported 66.26% to 71.85% for pearl millet variations.

Table 1. Effect of Rate of Addition of *Rajgara* on the Chemical Composition of *Chhana jhilli*

Treatment	Fat (%)	Protein (%)	Ash (%)	Total solid (%)	Total carbohydrate (%)
C (0:100)	9.78 ^c ±0.09	8.07 ^c ±0.06	1.68 ^c ±0.01	58.45 ^c ±0.78	38.92 ^b ±0.76
A1 (25:75)	9.87 ^c ±0.04	8.13 ^{bc} ±0.05	1.72 ^d ±0.01	59.78 ^b ±0.48	40.06 ^a ±0.49
A2 (50:50)	9.93 ^{bc} ±0.05	8.24 ^b ±0.05	1.75 ^c ±0.01	60.39 ^a ±0.12	40.47 ^a ±0.13
A3 (75:25)	10.02 ^{ab} ±0.5	8.33 ^a ±0.04	1.79 ^b ±0.01	60.89 ^a ±0.09	40.74 ^a ±0.11
A4 (100:00)	10.12 ^a ±0.03	8.42 ^a ±0.05	1.84 ^a ±0.01	61.42 ^a ±0.09	41.04 ^a ±0.12
SE(m)	0.06	0.05	0.01	0.42	0.42
CD (0.05)	0.17	0.15	0.03	1.26	1.26
CV (%)	1.12	1.23	2.31	1.38	2.02

Means sharing common superscript letters were statistically not significant. Each observation is a mean ± SD (n=4). The total carbohydrate was determined by difference.

The fat% for the different treatment groups: C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) were

found 9.78, 9.87, 9.93, 10.02, 10.12% respectively. The fat% of *Chhana jhilli* increased significantly from 9.78 in C

(0:100) to 10.12% in A4 (100:0) whereas C (0:100) and A1 (25:75) are statically at par with each other. This increased in fat% was primarily due to the higher concentration of lipid content of *Rajgara*. *Rajgara* contains approximately 5-8% fat [20], while *Maida* contains only 1-2% fat. As the *Rajgara* concentration increases, the proportion of fat content also increases. Fat content ranged from 9.78 to 10.12% are closely related as mentioned by [17] ranging from 9.43% to 10.28% and [18] observed similar ranges between 9.41% to 10.23%.

The samples showed a protein range between 8.07% and 8.42% across five different treatments. Specifically, the protein values for the different treatment groups: C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) were 8.07%, 8.13%, 8.24%, 8.33% and 8.42%, respectively. The highest protein content was recorded in the A4 (100:00) 8.42%, while the C (00:100) exhibited the lowest 8.07%. Statistical results indicated that the incorporation of *Rajgara* had a highly significant effect ($P < 0.01$) on the nutritional composition of *Chhana jhilli*. This shows a clear increased in protein levels as the amount of *Rajgara* increases. This elevated protein content in *Rajgara* based *Chhana jhilli* is due to the higher protein concentration of *Rajgara*. *Rajgara* typically contains 14-16% protein [21], whereas *Maida* generally provides around 10% or less. Substituting *Maida* with *Rajgara* consequently raises the protein density of *Rajgara* and *Rajgara* based *Chhana jhilli*. Results of the protein levels in this study were slightly lower than those reported by [17] at 8.98% and [18] at 8.94% of *Chhana jhilli*.

The carbohydrate levels of *Chhana jhilli* ranged from 38.92% to 41.04%. Specifically, the carbohydrate percentages for the different ratios of *Rajgara* to *Maida* are C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) were recorded at 38.92%, 40.06%, 40.47%, 40.74% and 41.04% respectively. Statistical analysis confirms that the addition of *Rajgara* had a significant impact ($P < 0.05$) on the total carbohydrate content, with the highest concentration observed in the A4 (100:00). A clear trend shows that the carbohydrate content increased significantly as the concentration of *Rajgara* increases. These results aligned closely with the findings of [17], who reported carbohydrate of 38.51% for *Chhana jhilli* and [18], who noted 38.39%.

The ash content of *Chhana jhilli* ranging from 1.68% to 1.84%. Specifically, as the substitution level of *Rajgara* for *Maida* increased, the values were recorded as 1.68% for the control C (00:100), 1.72% for A1 (25:75), 1.75% for A2 (50:50), 1.79% for A3 (75:25) and 1.84% for A4 (100:00). *Rajgara* is rich in calcium, iron, magnesium, potassium and phosphorous which contribute about 2-3% [21]. Due to greater mineral density of *Rajgara*, the ash content *Rajgara* incorporated *Chhana jhilli* was higher compared to control *Chhana jhilli*. Statistical analysis indicates that the inclusion of *Rajgara* had a highly significant impact ($P < 0.01$) on the mineral content of the product. Furthermore, no two treatments were found to be statistically identical. The results of this study are higher with those reported by [17] and [18], who observed ash contents in *chhana jhilli* ranging from 0.55% and 0.56% respectively.

3.2 Effect of Rate of Addition of *Rajgara* on the Physical Properties of *Chhana jhilli*: The physico-chemical characteristics of *Chhana jhilli* such as pH, acidity levels

and sugar syrup absorption, were evaluated as the concentration of *Rajgara* increases in *Chhana jhilli*. The resulting data regarding are presented in Table 2.

The average values for the acidity of the *Chhana jhilli* samples are summarized in Table 2. The acidity levels for the various formulations are C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) were measured at 0.290%, 0.280%, 0.281%, 0.277% and 0.280%, respectively.

Statistical analysis of these results indicates a significant difference ($P < 0.05$) in acidity across the experimental treatments. However, unlike the protein or ash content, there was no discernible trend or linear correlation observed between the addition of *Rajgara* and the acidity of the *Chhana jhilli* samples. These findings are broadly consistent with previous research on similar products. For instance, [19] reported acidity levels in *Amaranthus Gulabjamun* ranging from 0.32% to 0.33% LA, while [22] observed values between 0.31% and 0.35% LA in WPC incorporated versions.

For the different ratios of *Rajgara* to *Maida* are C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) the pH levels were recorded as 6.22, 6.19, 6.18, 6.20 and 6.19, respectively. These values fluctuated within a very narrow margin, ranging from 6.22 to 6.18. Statistical analysis of the data revealed significant difference ($P < 0.05$) in the pH levels as the concentration of *Rajgara* increases. A1 (25:75), A3 (75:25) and A4 (100:00) are statically at par with each other. Control showed the highest pH value at 6.22. This may be due buffering action of protein & mineral which resist the pH change. When compared with previous studies the observed values were slightly higher than those reported by [17] and [18], who recorded pH values of 6.17 and 6.11 for *Chhana jhilli*, respectively.

Table 2: Effect of *Rajgara* on the Physical Properties of *Chhana jhilli*

Treatments	Acidity (%LA)	pH	Sugar Syrup Absorption (g/100g)
C (0:100)	0.290 ^a ±0.002	6.22 ^a ±0.01	113.59 ^b ±0.31
A1 (25:75)	0.280 ^b ±0.001	6.19 ^b ± 0.00	114.72 ^{ab} ±0.66
A2 (50:50)	0.281 ^b ±0.001	6.18 ^c ±0.01	116.0 ^a ± 0.57
A3 (75:25)	0.277 ^c ±0.004	6.20 ^b ±0.01	116.45 ^a ±0.88
A4 (100:00)	0.280 ^b ±0.004	6.19 ^b ±0.01	116.96 ^a ±0.73
SE(m)	0.003	0.01	0.66
CD (0.05)	0.008	0.02	2.00
CV (%)	1.91	0.24	1.14
Means sharing common superscript letters were statistically not significant. Each observation is a mean ± SD (n=4).			

The absorption values ranged from 113.59 to 116.96 g/100 g. For specific formulations: C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) as the absorption rates were 113.59, 114.72, 116.00, 116.54 and 116.96 g/100 g, respectively. Statistical analysis indicates that the concentration of *Rajgara* had a significant influence ($P < 0.05$) on the syrup absorption. The results showed that as the level of *Rajgara* increased the sugar syrup absorption increases accordingly. As a result of, the A4 (100:00) formulation recorded the highest absorption among all treatments. The results were comparable with *Amaranthus* based *Gulabjamun* as reported by [19].

3.3 Effect of Rate of Addition of *Rajgara* on the Sensory Attributes of *Chhana jhilli*: Consumer acceptability of the

product was evaluated using sensory parameters. To evaluate the most acceptable level of *Rajgara*, sensory evaluations was carried out by a panel of semi-trained judges. The findings in this section shows how different levels of *Rajgara* substitution affects the sensory characteristics of the *Chhana jhilli*. All sensory scores are compared in Table 3.

Flavour is an important sensory property that influencing the overall consumer acceptability of a food product. The scores assigned to the flavour profile of the *Chhana jhilli* samples are detailed in Table 3. For the various formulations a C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) the flavour scores were 8.36, 7.84, 7.64, 7.79 and 8.10 respectively. The flavour scores for the experimental samples (excluding the control) ranged from 8.10 to 7.84, with the A4 (100:00) achieving the highest score of 8.10. Statistical analysis revealed that the different rates of *Rajgara* addition have a highly significant ($p < 0.01$) impact on the flavour scores of the *Chhana jhilli*. The higher flavour score of *Rajgara* based *Chhana jhilli* may be due to the natural nutty flavour of *Rajgara* and the pleasant aroma developed during frying. These characteristics blended well with the flavour of *Chhana* and improved the overall flavour compared with *Maida*.

"Body" refers to the structural integrity and physical substance of a food product, while "texture" describes the sensory characteristics perceived through touch and mouthfeel during consumption. The quantitative assessments for the body and texture of the *Chhana jhilli* samples are detailed in Table 3. The body and texture scores for the experimental formulations ranged from 8.11 (A1) to 7.86 (A4). Specifically, the scores for the various *Rajgara* to *Maida* ratios are C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) were 8.30, 8.11, 7.92, 7.89 and 7.86 respectively. Statistical analysis revealed that the differences in these scores across the various samples were statistically significant ($P < 0.05$) as the *Rajgara* incorporated. The body and texture score slightly decreased with the addition of *Rajgara* flour because it is gluten-free and contains more fibre than *Maida*. These properties reduced the smoothness and firmness of *Chhana jhilli*, resulting in a slightly lower body and texture score.

Table 3: Effect of different rate of *Rajgara* on sensory attributes of *Chhana jhilli*

Treatments	Flavour	Body & Texture	Colour & Appearance	Overall Acceptability
C (0:100)	8.36 ^a ±0.12	8.30 ^a ±0.13	7.66 ^c ±0.11	8.10 ^a ±0.12
A1 (25:75)	7.84 ^c ±0.16	8.11 ^{ab} ±0.12	7.79 ^c ±0.18	7.89 ^{bc} ±0.17
A2 (50:50)	7.64 ^d ±0.11	7.92 ^{bc} ±0.12	7.84 ^c ±0.18	7.80 ^c ±0.13
A3 (75:25)	7.79 ^c ±0.14	7.89 ^c ±0.15	8.08 ^b ±0.12	7.85 ^c ±0.12
A4 (100:00)	8.10 ^b ±0.09	7.86 ^c ±0.14	8.27 ^a ±0.11	8.01 ^{ab} ±0.16
SE(m)	0.05	0.07	0.06	0.04
CD (0.05)	0.14	0.20	0.17	0.13
CV (%)	1.18	1.65	1.44	1.11
Means sharing common superscript letters were statistically not significant. Each observation is a mean ± SD (n=4).				

Visual appeal is a primary factor in the consumer acceptance of any food product and it plays a significant role in the perception of *Chhana jhilli*. The scores for colour and appearance are detailed in Table 3. The average ratings for colour and appearance ranged from 7.66 to 8.27 across

the various samples. For the specific ratios of *Rajgara* to *Maida*: C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) as the scores were recorded as 7.66, 7.79, 7.84, 8.08 and 8.27 respectively. Statistical evaluation confirmed that there was highly significant difference ($P < 0.05$) in these scores among the different experimental treatments, indicating that the substitution of *Rajgara* increases the visual appeal of the product. The addition of *Rajgara* flour improved the colour and appearance of *Chhana jhilli* by producing a uniform golden-brown colour during frying. This enhanced the overall appearance and increased its sensory acceptability.

The overall sensory ratings for the different *Rajgara* to *Maida* formulations are C (00:100), A1 (25:75), A2 (50:50), A3 (75:25) and A4 (100:00) were 8.10, 7.89, 7.80, 7.85 and 8.01 respectively. Statistical analysis indicated that the variations in overall acceptability across the different treatment levels were statistically significant ($P < 0.05$).

After assessing the nutritional, physico-chemical and sensory data, the A4 (100:00) was identified as the optimal choice for subsequent shelf-life analysis. Although the C (00:100) sample received marginally higher sensory ratings, these differences lacked statistical significance, confirming that the A4 (100:00) sample delivers a similar consumer experience alongside enhanced nutritional value. A4 (100:00) distinguished itself by reaching the highest protein (8.42%) and ash (1.84%) concentrations, marking a substantial nutritional improvement over traditional *Maida*-based recipe. Additionally, its superior syrup uptake of 116.96 g/100 g suggests a highly effective porous matrix, which is essential for maintaining the signature juiciness and texture of *Chhana jhilli*. Sensory analysis shows that the A4 (100:00) samples show similar overall acceptability with the control, confirming that the complete substitution of *Maida* with *Rajgara* does not negatively impact the product's flavour and other sensory score.

3.4 Effect of *Rajgara* on the Textural Properties of *Chhana jhilli*

Textural properties describe how a food feels when it is handled, chewed and swallowed and they are a key determinant of consumer acceptability and eating quality. In dairy and processed foods, texture depends mainly on the interaction among proteins, fats, carbohydrate and water, which together determines hardness, cohesiveness, chewiness, gumminess, springiness and mouthfeel characteristics. These properties are evaluated by Texture Profile Analyzer (TPA) which help quantifying changes caused by processing, storage or ingredient modification. The texture hardness of *Chhana jhilli* changes notably during processing stages.

Hardness values for control and optimized *Chhana jhilli* presented in Table 4. Hardness values of control *Chhana jhilli* is 2037.75 g and optimized *Chhana jhilli* is 2344.75 g. Addition of *Rajgara* had a significant ($p < 0.05$) impact on the hardness of the product as shown in Table 4. The increase in this hardness was due to the higher starch content in *Rajgara* which during frying these undergo gelatinization, creating a denser and more rigid structural network [19]. Reported the incorporation of *Amaranthus* flour in *Gulabjamun* (3.33 N to 16.51 N) had significantly ($p < 0.05$) influences the structural hardness of the product.

Table 4: Effect of *Rajgara* on the Textural Properties of *Chhana jhilli*

Treatment	Hardness (g)	Cohesiveness	Gumminess (g)	Springiness (mm)	Chewiness (g mm)
C (0:100)	2037.35 ^b ±18.98	0.40 ^a ±0.01	1188 ^a ±15.25	8.09 ^a ± 0.16	9609.63 ^a ±140.79
A4 (100:0)	2344.75 ^a ±30.83	0.41 ^a ±0.02	1200 ^a ±10.80	7.81 ^b ± 0.17	9366.6 ^a ±240.89
Se(m)	11.10	0.01	6.61	0.08	98.65
CD	33.30	0.03	19.22	0.25	295.95
CV (%)	1.02	4.49	1.11	2.03	2.08

Means sharing common superscript letters were statistically not significant. Each observation is a mean ± SD (n=7)

Cohesiveness represents the internal bond strength of the product, describing the extent to which the material can be deformed before it ruptures. The results indicates that the cohesiveness of the sample remained non-significant by the addition of *Rajgara*. Cohesiveness values of control *Chhana jhilli* is 0.40 and optimized *Chhana jhilli* is 0.41. Addition of *Rajgara* had a non-significant impact on the cohesiveness of the product as shown in Table 4.

Gumminess is defined as the amount of energy required to disintegrate a semi-solid food product to a state ready for swallowing. Experimental data regarding the gumminess of *Chhana jhilli* is summarized in Table 4. Gumminess values of control *Chhana jhilli* is 1188 g and optimized *Chhana jhilli* is 1200 g. Statical analysis revealed that the addition of *Rajgara* remains non-significant with the gumminess of *Chhana jhilli*. In the context of texture profile analysis (TPA) this parameter measures the extent of height recovery exhibited by the sample between the first and second compression cycles. The findings of this study regarding gumminess of *Amaranthus Chhana jhilli* are in close agreement with result reported by [19], who states that gumminess of *Amaranthus Gulabjamun* varies from 0.60 N to 5.80 N.

The average springiness data is affected by different concentration of *Rajgara* in the product are presented in Table 4. Statical evaluation reveals that the inclusion of *Rajgara* in the *Chhana jhilli* formulation significantly influenced ($p<0.05$) on the springiness of sample. Springiness value of controlled samples was recorded as 8.09 mm while optimized sample exhibited a springiness of 7.81 mm. The observed variation suggests that concentration of *Rajgara* played a crucial role in maintaining the elastic structure of the product.

Chewiness is defined as the energy required to masticate a solid food product until it reaches a consistency suitable for swallowing. The mean chewiness value of *Chhana jhilli* by the as influenced by the integration *Rajgara* summarised in Table 4. Chewiness value of controlled samples was recorded as 9609.63 g mm while optimized sample exhibited a springiness of 9366.6 g mm. Statical evaluation of chewiness demonstrated that the level of *Rajgara* incorporation remains non-significant with the chewiness of the final product [19]. found that the chewiness value of *Amaranthus Gulabjamun* ranged from 3.92 to 50.42 N mm.

4. Conclusion

The present study demonstrated that *Rajgara* (*Amaranthus hypochondriacus* L.) flour can effectively replace *Maida* as a binder in the preparation of *Chhana jhilli* without compromising its quality characteristics. Incorporation of *Rajgara* significantly improved the nutritional composition of the product while maintaining desirable physicochemical, textural and sensory attributes. Among the formulations evaluated, *Chhana jhilli* prepared with 100% *Rajgara* flour exhibited overall acceptability comparable to the control and

was identified as the optimum formulation. The findings suggest that *Rajgara* is a promising gluten-free alternative to *Maida* for the development of nutritionally enhanced traditional dairy products with good consumer acceptability.

5. Acknowledgments

The authors are grateful to the Head, Department of Dairy Technology, G.N Patel College of Dairy Science, Kamdhenu University, Sardarkrushinagar, Gujarat, India, for providing the necessary facilities to conduct this research. The authors also thank the laboratory staff and sensory panel members for their support. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The authors declare that they have no conflict of interest.

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