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Formulation, Quality Evaluation, and Antioxidant Potential of Gluten-Free Biscuits Enriched with Rice and Chickpea (*Cicer arietinum* L.) Flours

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ABSTRACT

The aim of this study was to develop and evaluate gluten free biscuits specifically designed for individuals with gluten intolerance or celiac disease. To achieve this, five different biscuit formulations were prepared to investigate the effects of hydrocolloids and blends of rice and chickpea flours on biscuit quality. T0 (control) was made entirely with wheat flour and did not include any gluten-free components. In the T1 to T2 (experimental treatments), wheat flour was replaced with varying combinations of rice flour (70% to 80%) and chickpea flour (18% to 29%). Additionally, natural hydrocolloids gum karaya and gum acacia were incorporated at two levels: 0.5% and 1.0%. The specific formulations were as follows: T1 consisted of 80% rice flour, 19% chickpea flour, and 0.5% of each gum; T2 had the same flour composition but included 1.0% of each gum; T3 contained 70% rice flour, 29% chickpea flour, and 0.5% of each gum; while T4 used 70% rice flour, 28% chickpea flour, and 1.0% of each gum. These formulations were analyzed for their physicochemical properties, antioxidant activity and were also subjected to sensory evaluation. The results indicated that all gluten free treatments significantly improved biscuit quality in comparison to the control sample. Among them, T4 demonstrated the best physical and antioxidant properties, along with improved spread ratio and superior nutritional values in terms of moisture, protein, fat, and ash content. Therefore, T4 was selected as the most effective gluten-free biscuit formulation in this study.

KEYWORDS: Gluten-free biscuits, Rice flour, Chickpea flour, Gum karaya, Gum acacia, Antioxidant, Physicochemical and Nutritional qualities of biscuits

INTRODUCTION

Wheat (*Triticum aestivum*) a staple grain in Pakistan, is rich in carbohydrates, protein, moisture, fat, vitamins, and minerals (Cianferoni, 2016). Its gluten protein, primarily composed of glutenin and gliadin (Shewry & Hey, 2015), is essential for the structure of baked goods such as bread, biscuits, and pasta (Singh *et al.*, 2018). However, gluten consumption can trigger autoimmune responses in individuals with celiac disease, affecting approximately 1.4% of the global population (Lebwohl & Rubio-Tapia, 2021) and around 1% in Europe and the U.S. (Bai *et al.*, 2019). In Pakistan, the exact prevalence is unclear, though undiagnosed cases are reportedly rising, especially among children and adolescents (Rashid *et al.*, 2020). In addition to celiac disease, gluten sensitivity and wheat allergies affect 0.5–6% of the global population (Czaja-Bulsa, 2015), often causing symptoms like bloating, fatigue, and gastrointestinal discomfort. While wheat allergy involves an immune response to wheat proteins (Pieretti & Jarvinen, 2009), celiac disease specifically

damages the small intestinal lining, impairing nutrient absorption (Garmaeva *et al.*, 2021). The only effective treatment is strict gluten elimination, as even 20–50 mg per day can disrupt recovery. Rice (*Oryza sativa*) flour, being gluten-free and rich in carbohydrates, protein, and B vitamins, is commonly used in alternative baked goods (Park *et al.*, 2020). However, it lacks the viscoelastic properties of gluten, reducing product appeal (Jiao *et al.*, 2020). Chickpea (*Cicer arietinum*) flour is often added to enhance protein, fiber, and mineral content (Wu *et al.*, 2019), though it also contains antinutritional factors that may hinder digestion and nutrient absorption (El-Sohaimy *et al.*, 2020). Hydrocolloids such as gum acacia and gum karaya, water-soluble polysaccharides, are used to improve texture, shelf life, and antioxidant activity in gluten-free baked products (Salehi, 2020; Galla & Dubasi, 2010).

Developing gluten-free bakery products remains a challenge for the food industry. This study addresses that gap by formulating gluten-free biscuits using

locally sourced Pakistani rice and chickpea flours, along with gum acacia and gum karaya. The research evaluates the physicochemical, nutritional, sensory, and antioxidant properties of the products, contributing a functional and health-promoting alternative for gluten-sensitive consumers.

MATERIALS AND METHODS

Procurement of raw materials: The study involved purchasing wheat grain, rice kernel, chickpea legume, gum acacia, gum karaya, butter, sugar, salt, baking powder, and egg from local markets in Faisalabad. Analytical grade reagents and chemicals were obtained from the National Institute of Food Science and Technology, University of Agriculture Faisalabad. All raw ingredients were stored at room temperature for analysis.

Preparation of gums powder: Gum karaya and gum acacia powder were prepared by the method described by Hamdani *et al.* (2020). Gum karaya and gum acacia were dissolved in water, centrifuged, oven-dried, ground into powder, sieved through a 125-micrometer sieve, and stored in polypropylene bags at room temperature after detaching unwanted materials and removing moisture.

Preparation of flour: Wheat, rice and chickpea flours were prepared as per method by Lancelot *et al.*, (2021). Wheat rice and chickpea grains were cleaned and sieved to remove foreign materials like iron particles, small pebbles and grains of other cereals. Impurities

were eliminated using a combination of magnetic separators (to remove metallic particles), aspirators (to extract light impurities such as dust and husks), and entoleters (to remove insect-damaged grains and fine debris). Wheat kernels were first tempered by adding a calculated amount of water to raise the moisture content to the desired level (typically 14–16%), which helps to toughen the bran and soften the endosperm, thereby enhancing milling efficiency. After tempering for the required resting period (usually 6–24 hours), the grains were milled into fine flour using a laboratory-scale grinding mill, specifically designed for small batch controlled flour production in research settings. The resulting flour was then stored in clean, food grade polypropylene bags at room temperature to preserve its quality for further analysis

Product formulation: The study evaluated the impact of rice and chickpea flours, hydrocolloids, and gum karaya on gluten-free biscuit quality. Five formulations were developed, replacing wheat flour with rice and chickpea flour, and assessing physicochemical properties and antioxidant potential. The treatments plan given in Table 1. The ingredients were mixed homogeneously in a laboratory mixer bowl for 10 minutes, then resting for 10 to 15 minutes. The dough was then converted into biscuits, baked at 170 °C for 12 to 15 minutes, and cooled before packing in polypropylene bags.

Table: 1: Product formulation

Treatments	Wheat flour	Rice flour	Chickpea flour	Gum karaya	Gum acacia
T ₀	100%	0%	0%	0%	0%
T ₁	0%	80%	19%	0.5%	0.5%
T ₂	0%	80%	18%	1%	1%
T ₃	0%	70%	29%	0.5%	0.5%
T ₄	0%	70%	28%	1%	1%

Physicochemical analysis

Rheology of dough formation: The rheology of dough formation was analyzed using a farinograph, providing detailed information on water absorption, arrival time, dough stability, development time, and mixing tolerance index, using 50g flour, 35-40 mL water American Association of Cereal Chemists (AACC, 2016).

Antioxidant activity of dough of treatments: The antioxidant activity of the dough samples was

evaluated using the method described by Jan *et al.* (2018). In this procedure, 95 microliters of dough extract were analyzed using a spectrophotometer, with absorbance measured at 517 nanometers, which corresponds to the DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging assay. Measurements were recorded at 0 minutes (initial reaction) and after 30 minutes (incubation time) to assess the time dependent antioxidant response of the different dough treatments.

$$\text{DPPH radical scavenging activity} = \frac{\text{Absorbance of Blank} - \text{Absorbance of Sample}}{\text{Absorbance of Blank}} \times 100$$

Proximate Analysis of biscuits: The moisture, crude protein, crude fat, and ash contents of the biscuits were determined according to the standard procedures outlined by the American Association of Cereal Chemists (AACC, 2016). Moisture fat, protein and ash

contents of biscuits ere determined by air oven drying, Soxhlet fat extraction method, Micro Kjeldahl method and muffle furnace respectively. Moisture, crude protein, crude fat and ash contents of biscuits were calculated by the given formula.

$$\text{Moisture \%} = \frac{\text{Sample weight before drying} - \text{sample weight after drying}}{\text{sample weight before drying}} \times 100$$

$$\text{Nitrogen \%} = \frac{\text{Volume of 0.1N H}_2\text{SO}_4 \text{ used} \times \text{Volume of dilution} \times 0.0014}{\text{Weight of sample} \times \text{Volume of diluted sample}} \times 100$$

$$\text{Crude protein \%} = \text{Nitrogen (\%)} \times 5.70$$

$$\text{Crude fat \%} = \frac{\text{Weight of sample before extraction of fat} - \text{Weight of sample after extraction of fat}}{\text{Weight of sample after extraction of fat}} \times 100$$

$$\text{Ash \%} = \frac{\text{weight of sample after ashing}}{\text{weigh of sample before ashing}} \times 100$$

Physical Analysis of Biscuits

Spread ratio of biscuits: The biscuit spread ratio factor was determined by following the protocol described by Man *et al.* (2014). The spread ratio of biscuits was determined by dividing the width (W) by the thickness (T). Six biscuits were randomly selected and their width was measured using a vernier caliper. The average width was calculated by dividing the number six.

$$\text{Spread ratio factor} = \frac{W}{T}$$

W= Width (cm)

T= Thickness (cm)

Antioxidant activity of biscuits

Antioxidant Activity Determination (DPPH Assay):

The antioxidant activity of the biscuit samples was

$$\text{DPPH radical scavenging activity} = \frac{\text{Absorbance of Blank} - \text{Absorbance of Sample}}{\text{Absorbance of Blank}} \times 100$$

Sensory analysis: Sensory evaluation of biscuits was conducted by the trained panel of the National Institute of Food Science and Technology using a 9-point hedonic scale given by Wichchukit and O'Mahony *et al.* (2015).

Statistical analysis: All resulting data was analyzed statistically to test the significance level via the Completely Randomized Design (one- way ANOVA) described by Montgomery *et al.* (2017).

RESULTS AND DISCUSSION

The study aimed to develop and evaluate gluten-free biscuits by analyzing the impact of rice flour, chickpea flour, gum karaya, and gum acacia combinations on their quality. Five combinations were tested by physicochemical analysis of dough, moisture, crude protein, crude fat, ash, spread ratio, antioxidant activity, and sensory evaluation.

Physicochemical analysis: The physicochemical characteristics of food products play a crucial role in determining their overall quality, as processing operations often lead to alterations in their composition and ingredients.

Rheology of dough formation

Farinograph: The dough quality of rice flour and chickpea flour treatments was evaluated using a farinograph for parameters like water absorption, arrival time, stability, development time, and mixing tolerance index.

evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, following a modified version of the standard procedure.

Extract Preparation: Approximately 1 gram of ground biscuit sample was mixed with 10 mL of methanol (or ethanol, depending on solvent choice) and shaken on a mechanical shaker for 30–60 minutes at room temperature. The mixture was then centrifuged at 3000 rpm for 10–15 minutes, and the supernatant (methanolic extract) was collected for further analysis.

DPPH Assay Procedure: A 100 µL aliquot of the biscuit extract was mixed with 2.9 mL of 0.1 mM DPPH solution in methanol. The mixture was incubated in the dark at room temperature, and absorbance was measured at 515 nanometers using a UV–Vis spectrophotometer at 0 minutes (immediate reading) and after 30 minutes to monitor the radical scavenging activity over time.

Water absorption: The water absorption capacity of biscuit formulations varied significantly among treatments. The control sample (T0), made entirely of wheat flour, and showed the lowest water absorption ($54.20 \pm 0.72\%$), likely due to the absence of hydrocolloids and the different hydration properties of wheat flour. Treatments T1 and T2, which incorporated 80% rice flour, around 18–19% chickpea flour, and higher concentrations of gums (gum karaya and gum acacia at 0.5–1.0%), demonstrated the highest water absorption values ($61.16 \pm 0.28\%$ and $61.21 \pm 0.60\%$, respectively). This increase can be attributed to the high water-binding capacity of gums and chickpea flour, which contain more protein and fiber compared to wheat flour. Treatments T3 ($59.03 \pm 0.15\%$) and T4 ($58.50 \pm 0.25\%$) also exhibited significantly higher water absorption than the control, although slightly lower than T1 and T2. This may be due to the lower proportion of rice flour and higher chickpea content, which may affect the matrix structure and its water-binding behavior. Overall, the inclusion of rice and chickpea flours along with hydrocolloids notably enhanced the water absorption capacity of the biscuits, with T1 and T2 showing the most efficient water uptake. This characteristic is beneficial for dough formation, texture development, and product quality in gluten-free biscuit formulations.

Table 3.1: Mean $\pm$ SD % values for water absorption

Treatment	Mean $\pm$ SD %
T0	54.20 $\pm$ 0.72 ^c
T1	61.16 $\pm$ 0.28 ^a
T2	61.21 $\pm$ 0.60 ^a
T3	59.03 $\pm$ 0.15 ^b
T4	58.50 $\pm$ 0.25 ^b

Arrival time: The arrival time, which indicates the time required for dough to reach optimal consistency during mixing, varied significantly across treatments. The control sample (T0), composed entirely of wheat flour, had the shortest arrival time (1.99 $\pm$ 0.00 min), suggesting quicker dough formation due to the presence of gluten, which rapidly develops structure. In contrast, all gluten-free treatments (T1 to T4) showed increased arrival times, reflecting the delayed development of dough consistency in the absence of gluten. Treatment T3 exhibited the longest arrival time (2.93 $\pm$ 0.50 min), likely due to its higher chickpea flour content, which absorbs more water and slows down dough development. T1 (2.63 $\pm$ 0.40 min), T2 (2.56 $\pm$ 0.32 min), and T4 (2.70 $\pm$ 0.11 min) also

demonstrated longer arrival times compared to the control but slightly lower than T3, indicating moderate delays in consistency formation. The addition of hydrocolloids like gum karaya and gum acacia likely contributed to the extended arrival time by increasing water absorption and altering dough hydration dynamics. These changes are typical in gluten-free formulations, where structure must be achieved through alternative binding agents. The results suggest that while gluten-free dough's take longer to reach optimal consistency, the use of chickpea flour and gums helps achieve workable dough properties. Overall, T3 required the most time for structure formation, while T0 remained the fastest due to the inherent properties of gluten.

Table 3.2: Mean $\pm$ SD values for arrival time (min)

Treatment	Mean $\pm$ SD (min)
T0	1.99 $\pm$ 0.00 ^c
T1	2.63 $\pm$ 0.40 ^b
T2	2.56 $\pm$ 0.32 ^b
T3	2.93 $\pm$ 0.50 ^a
T4	2.70 $\pm$ 0.11 ^b

Dough stability: Dough stability, measured in minutes, reflects the dough's ability to maintain its consistency during mixing. Higher stability indicates stronger dough that can withstand mixing without breaking down. The control sample (T0), made from wheat flour, and exhibited the lowest dough stability (3.33 $\pm$ 0.57 min), likely due to the lack of additional binding agents and the nature of wheat gluten under stress. In contrast, all gluten-free treatments (T1–T4) demonstrated significantly higher dough stability. Treatment T3 had the highest stability (5.40 $\pm$ 0.69 min), followed closely by T4 (5.33 $\pm$ 0.28 min), indicating the formation of a more cohesive and resilient dough structure. This improvement can be

attributed to the synergistic effects of higher chickpea flour content and hydrocolloids (gum karaya and gum acacia), which enhance dough strength and water retention. Treatments T1 (4.86 $\pm$ 0.23 min) and T2 (4.56 $\pm$ 0.40 min) also showed improved stability compared to the control, though slightly lower than T3 and T4. These results suggest that the incorporation of chickpea flour and gums effectively compensates for the absence of gluten by forming a stable dough matrix. Overall, the gluten-free formulations, particularly T3 and T4, exhibited superior dough stability, making them more suitable for handling and shaping in biscuit production.

Table 3.3: Mean $\pm$ SD values for dough stability (min)

Treatment	Mean $\pm$ SD (min)
T0	3.33 $\pm$ 0.57 ^c
T1	4.86 $\pm$ 0.23 ^b
T2	4.56 $\pm$ 0.40 ^b
T3	5.40 $\pm$ 0.69 ^a
T4	5.33 $\pm$ 0.28 ^a

Dough development time: Dough development time refers to the time required for dough to reach its optimum consistency during mixing. It is a crucial

parameter indicating the strength and mixing tolerance of the dough. In this study, significant differences were observed among treatments. The control sample (T0),

prepared with 100% wheat flour, had the shortest dough development time (2.13 ± 0.23 min), likely due to the presence of gluten, which forms a quick but less stable network without added hydrocolloids or alternate proteins. In contrast, all gluten-free treatments (T1–T4) required significantly more time to develop, highlighting the role of added chickpea flour and gums in influencing dough structure. Treatment T3 recorded the highest dough development time (5.36 ± 0.23 min), closely followed by T4 (5.23 ± 0.20 min). These longer times are attributed to the higher chickpea flour content and the synergistic action of gum karaya and gum

acacia, which increase water absorption and slow down the hydration and structuring process. T1 (4.73 ± 0.05 min) and T2 (4.53 ± 0.05 min) also exhibited improved development times compared to the control, indicating better dough strength and consistency due to the presence of hydrocolloids and a high percentage of rice flour. Overall, the results suggest that gluten-free formulations, particularly T3 and T4, form stronger, more structured dough's that require longer mixing times to reach optimal development an essential factor for producing quality gluten-free baked products.

Table 3.4: Mean $\pm$ SD values for dough development time (min)

Treatment	Mean $\pm$ SD (min)
T0	2.13 ± 0.23^c
T1	4.73 ± 0.05^b
T2	4.53 ± 0.05^b
T3	5.36 ± 0.23^a
T4	5.23 ± 0.20^a

Mixing tolerance index: Means values of mixing tolerance index are presented in the table 3.5 which shows that value of T0 was 1.60, while it increased in T2, T1, T4, and T3 (1.93, 2.16, 2.57 and 2.63 respectively. The study found that chickpea flour directly stimulated the mixing tolerance index of dough, with an increase in the concentration indicating an increase in mixing tolerance. This effect may be due to increased protein and fiber content in the dough. Similar findings were found in previous studies (Shahzadi *et al.* 2005, Ktenioudaki *et al.*, 2018)

Table 3.5: Mean $\pm$ SD values for mixing tolerance index

Treatment	Mean $\pm$ SD
T0	1.60 ± 0.10^c
T1	2.16 ± 0.28^b
T2	1.93 ± 0.37^c
T3	2.63 ± 0.40^a
T4	2.57 ± 0.37^a

Antioxidant activity of dough of treatments: The antioxidant activity of T0 attained the lowest mean value 9.6, however it increased in T1, followed by T3, T2 and T4 (11.10 %, 11.30 %, 11.93 % and 12.10 % respectively), which is given in table 3.6. The antioxidant activity of dough treatments increased with gum quantity, particularly gum acacia and gum karaya.

This trend was observed in various studies (Hamdani *et al.* 2018, Benkadri *et al.*, 2021, and Gallagher *et al.* (2004), including those on gluten-free biscuits made with rice flour and xanthan gums, which showed antioxidant activity and good nutritional properties. Hydrocolloids and gums are commonly used in gluten-free bakery production

Table 3.6: Mean $\pm$ SD values for antioxidant activity (%) of dough treatments

Treatment	Mean $\pm$ SD %
T0	9.13 ± 0.11^c
T1	11.10 ± 0.26^b
T2	11.93 ± 0.30^a
T3	11.30 ± 0.15^b
T4	12.10 ± 0.28^a

Moisture contents: The study found that the moisture content of gluten-free biscuits significantly impacts its freshness and stability for long-term storage, with values of 9.40 %, 10.40 %, 11.03 %, 10.03 %, and 11.03 % showed in the table 3.7. Gum karaya and gum acacia significantly increase the moisture content of gluten-free biscuits due to their water absorption

properties reported by Hamdani *et al.* (2017). Studies have shown a similar trend of decreasing moisture content with gum concentration water (Xu *et al.*, 2020). Gums and rice flour also slightly increase moisture content in gluten-free bread, as they maintain high moisture levels in cookies (Bolarinwa *et al.*, 2019).

Table 3.7: Mean $\pm$ SD values for moisture % contents of biscuits

Treatment	Mean $\pm$ SD (%)
T0	9.40 $\pm$ 0.52 ^c
T1	10.40 $\pm$ 0.55 ^b
T2	11.03 $\pm$ 0.92 ^a
T3	10.03 $\pm$ 0.20 ^b
T4	11.03 $\pm$ 0.15 ^a

Crude protein: Proteins are crucial for nutritional value and functionality, with T4 having the highest crude protein content, followed by T3, T2, T1, and T0, as shown in table 3.8. The study found that increasing the concentration of chickpea flour in gluten-free biscuits significantly improved their protein content

were reported by Sakr and Hussien (2017). This trend was consistent with previous studies, which also found that supplementing bread, biscuits, and other bakery items with chickpea flour improved the protein content (Durazzo *et al.*, 2013)

Table 3.8. Mean $\pm$ SD values for crude protein % contents of biscuits

Treatment	Mean $\pm$ SD (%)
T0	11.96 $\pm$ 0.25 ^c
T1	13.30 $\pm$ 0.60 ^b
T2	13.13 $\pm$ 0.30 ^b
T3	14.8 $\pm$ 0.26 ^a
T4	15.30 $\pm$ 0.47 ^a

Crude fat: Fat is a vital macronutrient for cell growth, absorption, and energy. T3 has the highest crude fat content (17.97 %), while T4, T2, T1, and T0 have the lowest values which are given in table 3.9. The study found that the fat content of gluten-free biscuits

increased with higher chickpea flour concentration, as chickpea flour contains a high amount of fat (Yadav *et al.*, 2012). However, the fat content decreased with a decrease in chickpea flour concentration and similar findings were (Dandachy *et al.*, 2019)

Table 3.9: Mean $\pm$ SD values for crude fat % contents of biscuits

Treatment	Mean $\pm$ SD (%)
T0	15.16 $\pm$ 0.15 ^c
T1	16.26 $\pm$ 0.15 ^b
T2	16.36 $\pm$ 0.14 ^b
T3	17.97 $\pm$ 0.05 ^a
T4	17.67 $\pm$ 0.36 ^a

Ash contents: The ash contents of T4 attained the highest mean value i.e. 1.52, while decreased in T3 followed by T2, T1 and T0 (1.44 %, 1.10 %, 1.22 % and 1.00 % respectively) as given in table 3.10. The study found that the ash content of gluten-free biscuits increased with increased rice and chickpea flour,

indicating that multigrain ingredients significantly increased the ash content (Chandra *et al.*, 2016). However, there were also reports of decreasing ash content and increased ash percentage in biscuits with high Bengal gram content.

Table 3.10: Mean $\pm$ SD values for ash % contents of biscuits

Treatment	Mean $\pm$ SD (%)
T0	1.00 $\pm$ 0.08 ^c
T1	1.22 $\pm$ 0.14 ^b
T2	1.10 $\pm$ 0.11 ^{bc}
T3	1.44 $\pm$ 0.05 ^a
T4	1.52 $\pm$ 0.06 ^a

Spread ratio of biscuit: The spread ratio is an important quality attribute in biscuits, reflecting the balance between height and diameter during baking. A higher spread ratio generally indicates better dough flow and desirable biscuit texture and appearance.

According to Table 3.11, the control sample (T0), made from 100% wheat flour, showed the lowest spread ratio (3.69 $\pm$ 0.01), which could be due to stronger gluten network formation that limits dough spread during baking. In contrast, all gluten-free

treatments (T1–T4) exhibited significantly higher spread ratios, indicating improved dough flow and biscuit expansion in the absence of gluten. Among the gluten-free formulations, T3 showed the highest spread ratio (3.86 ± 0.02), closely followed by T4 (3.85 ± 0.04). This can be attributed to the optimal combination of chickpea flour and hydrocolloids (gum karaya and gum acacia), which increase water absorption and reduce dough elasticity, allowing better

spreading. T2 (3.79 ± 0.01) and T1 (3.77 ± 0.01) also recorded higher values than the control, though slightly lower than T3 and T4. These results suggest that incorporating rice and chickpea flours along with hydrocolloids enhances biscuit spread ratio, contributing to better appearance and texture. T3 and T4 were particularly effective in achieving desirable spread characteristics, making them promising formulations for gluten-free biscuit production

Table 3.11. Mean $\pm$ SD values for spread ratio of biscuits

Treatment	Mean $\pm$ SD (min)
T0	3.69 ± 0.01^c
T1	3.77 ± 0.01^b
T2	3.79 ± 0.01^{ab}
T3	3.86 ± 0.02^a
T4	3.85 ± 0.04^a

Antioxidant activity of biscuits: Table 3.12 shows biscuits' antioxidant activity increases with gum quantity, with T4 having the highest mean value of 12.00 %, followed by T2, T3, T1, and T0. Gums enhance biscuits' antioxidant activity, with higher concentrations of gum acacia and gum karaya

increasing their value (Daoub *et al.* 2018). This study supports previous research suggesting that gluten-free biscuits' antioxidant activity decreases with lower gum concentration, highlighting the importance of hydrocolloids and gums in bakery production as described by Sakač *et al.* (2016)

Table 3.12. Mean $\pm$ SD values for antioxidant % activity of biscuits

Treatment	Mean $\pm$ SD (%)
T0	9.13 ± 0.02^c
T1	11.10 ± 0.15^b
T2	11.90 ± 0.11^a
T3	11.29 ± 0.15^b
T4	12.00 ± 0.28^a

Sensory analysis: Sensory evaluation involves trained judges assessing food products based on color, flavor, appearance, texture, taste, and overall acceptability using their senses, using a 9-point hedonic scale.

Color: The color quality of T4 was rated highest by judges at 8.23, followed by T2, T3, T1 and T0 (8.10,

7.85, 7.84, and 7.83, respectively) in table 3.13. The addition of gums to gluten-free biscuits, specifically T2 and T4 significantly enhanced their color quality, making them lighter and more attractive. This effect was observed in various studies, including those by Badiu *et al.*, (2014) and Hamdani *et al.*, 2020.

Table 3.13. Mean $\pm$ SD values for color of biscuits

Treatment	Mean $\pm$ SD
T0	7.83 ± 0.28^b
T1	7.84 ± 0.57^b
T2	8.10 ± 0.35^a
T3	7.85 ± 0.29^b
T4	8.23 ± 0.37^a

Flavor: The judges rated the flavor of T4 as the most appealing, with a score of 8.66, outperforming T3, T2, T1, and T0 in table 3.14. The study found that increasing the concentration of chickpea flour in gluten-free biscuits improved their flavor, making

them slightly salty and giving them an intense smell (Jogihalli *et al.*, 2017). This finding was statistically significant among some treatments which was shown in table 2.27.

Table 3.14. Mean $\pm$ SD values for flavor of biscuits

Treatment	Mean $\pm$ SD
T0	7.83 ± 0.28^c
T1	7.66 ± 0.00^c
T2	7.67 ± 0.00^c
T3	8.00 ± 0.00^b
T4	8.66 ± 0.57^a

Taste: The study found that the taste of gluten-free biscuits increased with the increase in chickpea flour concentration, consistent with previous studies

indicating that taste significantly influences food product quality and acceptability as shown in table 3.15. Taste significantly influences food product quality and acceptability (Hamdani *et al.*, 2020)

Table 3.15. Mean $\pm$ SD values for taste of biscuits

Treatment	Mean $\pm$ SD
T0	8.40 $\pm$ 0.00 ^a
T1	7.33 $\pm$ 0.57 ^c
T2	7.66 $\pm$ 0.57 ^b
T3	7.83 $\pm$ 0.28 ^b
T4	8.33 $\pm$ 0.57 ^a

Texture: The study examines the texture of gluten-free biscuits, focusing on sensory evaluation performance. Results show that the texture quality increases with increased gum quantity (1% gum karaya and 1% gum acacia), making the biscuits crispy and less hard which are also given in table 3.16. Similar studies have found

that the texture of gluten-free biscuits made from rice and chickpea flour decreases with decreased gum concentration. Gums also enhance the hardness, thickness, breaking, and fracturability of gluten-free biscuits (Mudgil *et al.*, 2017).

Table 3.16. Mean $\pm$ SD values for texture of biscuits

Treatment	Mean $\pm$ SD
T0	8.40 $\pm$ 0.55 ^a
T1	7.33 $\pm$ 0.50 ^c
T2	7.95 $\pm$ 0.57 ^b
T3	7.53 $\pm$ 0.57 ^c
T4	8.33 $\pm$ 0.55 ^a

Appearance: The judge's recognition of T4 achieved the highest marks (8.00 out of 9 points) on the hedonic scale, while T3 T2 T0 and T0 showed decreases shown in table 3.17. The study found that increasing the concentration of chickpea flour and gums significantly improved the appearance of gluten-free biscuits, with

significant differences observed among some treatments which is presented in the table 2.17. Gonzales *et al.*, (2014) found that gluten-free biscuits' appearance quality decreases with reduced chickpea flour and gum concentration, which enhances their functional properties in bakery items (Salehi, 2020).

Table 3.17. Mean $\pm$ SD values for appearance of biscuits

Treatment	Mean $\pm$ SD
T0	7.11 $\pm$ 0.28 ^b
T1	6.67 $\pm$ 0.57 ^c
T2	7.33 $\pm$ 0.54 ^b
T3	7.66 $\pm$ 0.56 ^a
T4	8.00 $\pm$ 0.00 ^a

Overall acceptability: The study found that gluten-free biscuits' acceptability improved with high chickpea flour and gums, while some treatments

showed decreases. Chickpea flour biscuits also had high protein, fat, ash, and fiber content, enhancing their appearance

Table 3.18. Mean $\pm$ SD values for overall acceptability of biscuits

Treatment	Mean $\pm$ SD
T0	7.90 $\pm$ 0.22 ^b
T1	7.50 $\pm$ 0.44 ^b
T2	7.20 $\pm$ 0.44 ^c
T3	8.20 $\pm$ 0.45 ^a
T4	8.60 $\pm$ 0.54 ^a

CONCLUSION

The study evaluated gluten-free biscuits for gluten intolerant individuals using five different biscuit treatments. Results showed that T2 biscuits had higher

water absorption and arrival times, while T3 biscuits had higher dough stability and development time. The mixing tolerance index increased with protein. T4 biscuits had higher antioxidant activity and moisture

contents, with gums enhancing antioxidant activity. T4 biscuits had high color, flavor, taste, texture, appearance, and overall acceptability. Further research is recommended to better understand the sensory characteristics and consumer acceptance of these products.

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AUTHOR'S CONTRIBUTIONS

The writers of the original manuscript, Nayab Rao, Dr. Muhammad Naeem Zubairi and Muhammad Asif were responsible for conceptualization, evaluating, and editing. Mahnoor Syed, and Ayesha Riaz handled the formal analysis, research. Resources, data validation, data curation. Hafiz Muhammad Irfan Manzoor and Imran Khan.

CONFLICTS OF INTEREST

We declare no competing interests affecting the work reported in this study.

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