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Effect of multigrain flour mixes on the physicochemical, nutritional, textural, and sensory quality of cake rusks

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Abstract

This work involves blending wheat flour with various proportions of millet, gram, and maize flours to check the effects on cake rusk with respect to important parameters such as moisture; protein; fat; ash; fiber; α-amylase activity; gluten content; and rheological, physical, textural, and proximate characteristics. Five flour blends were used in the study, which included T0 (wheat flour), T1 (400 g wheat flour and 100 g millet flour), T2 (400 g wheat flour and 100 g gram flour), T3 (400 g wheat flour and 100 g corn flour, and T4 (200 g wheat flour, 100 g millet flour, 100 g gram flour, and 100 g corn flour). Rheological study of flours revealed that gluten content was high for T1, amylase activity was high for T2, water absorption was high for T3, dough development time was high for T4, and dough stability was high for T2. Proximate analysis of cake rusks showed that T1 had the highest moisture and protein contents, T2 had the highest fat, T4 had the highest ash and fiber, and T3 had the highest calorie contents. Textural analysis showed that cake rusks in T3 had significantly high hardness and crispness, whereas physical parameters showed that T0 had high weight, width, and thickness. T1 had the highest antioxidant activity of 86.78 TE/100 g among all treatments. Finally, consumers preferred T1 by providing the highest sensory scores for various parameters studied. Finally, it could be concluded that T1 turned out to be the top performer in terms of taste and overall quality when compared to the others. Meanwhile, T2, T3, and T4 also showed enhancements in several aspects of physicochemical parameters. From the research outcomes of the present study, it can be concluded that formulating multigrain flour blends could enhance the nutritional value of cake rusk without compromising its sensory attributes.

Keywords: Bakery product; malnutrition; sustainability; textural analysis; physicochemical analysis

Introduction

A variety of grains are combined to create multigrain flour mixes, and each one has a unique flavor and nutritional value. Whole grains like wheat, barley, oats, rye, corn, and rice are frequently included in these mixtures. Addition of a few grains to the flour provides numerous nutritional advantages and changes the nutritional composition of the final product (Olagunju *et al.*, 2021; Rohi *et al.*, 2022). In order to combat malnutrition, multigrain flours can be added to a variety of meals including cake rusks, to facilitate the availability of a nutritious and healthy diet. A range of nutrients, including proteins, fibers, vitamins, and minerals, can be obtained by using blended flours made from wheat, barley, corn, gram, millet, and oats. This method can help in improving general fitness and well-being by addressing nutrient deficiencies that are frequently observed in a malnourished population (Habib *et al.*, 2024; Rajagopal *et al.*, 2024; Ihsan *et al.*, 2024). However, these are relatively difficult conditions, and multigrain flour blends provide certain qualities that can enhance the nutritional value of cake rusks. These combinations are higher in antioxidants, nutrients, minerals, and nutritional fiber than single grain flours. However, the rheological, physical, and textural properties of the composite flours and the resulting baked goods may vary if multigrain flour mixtures are added to cake rusk compositions (Garcia *et al.*, 2018; Rajiv and Soumya 2015). Therefore, the selection of grains, their level of incorporation in the flours, and further impacts on the flours and products are crucial to consider before developing such products.

The most important cereal produced globally is maize, which is also utilized extensively in supplemental foods. Corn is essential for nutrition and food security. With its high nutritional content, high resistant starch content, and low glycemic index, maize flour has useful qualities that can be used to make nutritious foods that need to be more soluble in water, have a higher capacity for emulsification, and retain water longer than traditional flours (Mejía-Terán *et al.*, 2024). In order to meet the dietary needs of the growing global population, millets, a significant source of food for humans, have seen a steady increase in production in recent decades. All of the important nutrients, including protein, carbs, fat, minerals, vitamins, and bioactive substances, are abundant in millets. On the other hand, adding millet flour to wheat flour can improve the nutritional and bioactive qualities of composite flours and their derivatives (Dekka *et al.*, 2023; Yousaf *et al.*, 2021). In addition to grains, pulses are a common source of protein and other nutrients. The oldest and most widely grown pulse crop in the subcontinent is the chickpea, often known as the gram. In addition to micronutrients and bioactive components, it is a rich source of minerals, dietary fiber, protein, and carbs. Numerous research studies have noted its significance and application in a variety of medical conditions as well as in baked goods (Kaur and Prasad, 2021; Kumar *et al.*, 2021). Wheat, corn, and millet are all rich resources of carbohydrates. Carbohydrates function as the primary source of strength for the body, offering strength for numerous physical capabilities and bodily activities (Mir *et al.*, 2019). Gram is in particular excessive in protein, and these kinds of grains make a contribution of some quantity of protein to cake rusks. Protein is crucial for the growth, repair of tissues, immune function, and the manufacturing of enzymes and hormones (Vijayakumar, 2021). Millet and wheat are terrific sources of nutritional fiber, which promotes digestive health by means of aiding in bowel regularity and stopping constipation. Fiber also facilitates to regulate blood sugar tiers, lowers levels of cholesterol, and can lessen the danger of heart failure and varieties of most cancers (Grdeń and Jakubczyk, 2023; Kaur and Prasad, 2021; Kauser *et al.*, 2024).

Cake rusk, one of the most well-liked baked goods, has gained a lot of recognition because of its distinct flavor and texture (Punia *et al.*, 2020). Originally from the Mediterranean region, cake rusks have changed with time and are now enjoyed by people all over the world. Cake rusks are traditionally created by placing batter in an oven, slicing it thinly, and then toasting or dehydrating it until it becomes crunchy. Cake rusks are a popular snack, and this technique gives them a crispy texture (Rafique *et al.*, 2023; Smith *et al.*, 2019). However, changes in the physical and textural characteristics of the multigrain flour-based cake rusks will define the ultimate marketability and acceptability of the product. Therefore, this study aims to deal with this gap by investigating the impact of multigrain flour mixes on the physicochemical, textural, nutritional, and sensory characteristics of cake rusks. For this purpose, different blends of wheat flour with gram, millet, and corn flours were created to assess their suitability for the development of cake rusks. This study gives valuable insights into the cake rusk optimization process through enrichment of nutritional contents. For more detailed analysis and to correlate the process parameters with product quality, rheological behaviors of these composite flours were also studied in this research.

Materials and Methods

Experiments conducted in this study involving plants/plant materials/seeds adhere to international/national/institutional protocols/guidelines. Furthermore, plant material used in this study were cultivated. Therefore, no permissions or licenses were required for their use.

Procurement of raw materials

Cereals like wheat, gram, corn, and millet flours were procured from the local market of Sargodha, Pakistan. Other ingredients comprising sugar, butter, egg, and baking powder were obtained from the resident marketplace of Sargodha. The present research work was conducted at the Institute of Food Science and Nutrition, University of Sargodha and Ayoub Agricultural Research Institute, Faisalabad during the years 2023 and 2024.

Reagents and chemicals

Analytical grade reagents and chemicals of the same brand were used for all analysis throughout this work and were acquired from Sigma Aldrich, Germany and Aladdin Chemicals, China.

Development of multigrain flours

Five different variations of multigrain flour mixes were developed using flours of wheat, millet, corn, and gram at different levels of incorporation as mentioned below.

T0 with 100% wheat flour served as the control
T1 wheat and millet in the ratio (80:20)
T2 wheat and gram flour in the ratio (80:20)
T3 wheat and corn flour in the ratio (80:20)
T4 wheat, millet, corn, and gram flour in a ratio (40:20:20:20), respectively.

Physicochemical analysis of multigrain flours

Amylase rest

The degree of alpha-amylase activity in multigrain flour was determined according to the *approved method of the American Association of Cereal Chemists* (AACC) Method No. 22-08.01 (AACC, 2011). A falling number instrument was used to measure the alpha amylase activity in the flour samples. A 7 g sample was weighed and combined with 25 mL of distilled water in a glass falling number tube and shaken to form a slurry. The slurry was then heated in a water bath at 100°C and constantly stirred until the starch gelatinized and formed a thick paste. The time it took for the stirrer to drop through the paste was recorded as the Falling Number value.

Gluten test

The gluten content was determined in accordance with AACC Method No. 38-12.02 (AACC, 2011). Gluten was washed from samples taken from each treatment using an automatic gluten washing apparatus known as the Glutomatic. The gluten was then centrifuged on a specially constructed sieve under standardized conditions. The weight of the gluten forced through the sieve was measured, and the total gluten was expressed as a percentage of the sample. The gluten index was calculated as the percentage of gluten remaining on the sieve after centrifugation.

Gluten and gluten index were measured according to the following formulas:

$$\text{Gluten \% (14\% moisture basis)} = \frac{\text{total glutan (g)} \times 860}{100 - \text{\% Sample Moisture}}$$

$$\text{Gluten Index} = \frac{\text{gluten sieve (g)} \times 100}{\text{total gluten (g)}}$$

Rheological properties of multigrain dough

The rheological properties of multigrain dough were assessed in accordance with AACC Method No. 54-21.02 (AACC, 2011). A farinograph was used to evaluate the dough mixing characteristics, with slight modifications as needed. Following the addition of hot water to the flour, the farinograph was observed. Various parameters, including water absorption, dough development time, dough stability, weakening, and mixing tolerance index, were analyzed for multigrain dough.

Development of multigrain flour cake rusk

By following the procedure adopted by Rafique *et al.* (2023), the multigrain flour-based cake rusk was prepared by using five different batters; the one with 100% wheat flour was considered as control (T0), and the other four were of different ratios of flour mixes as mentioned in the treatment plan (Section 2.3). Other ingredients like icing sugar (250 g), butter (250 g), eggs (300 g), and baking powder (12.5 g) were added in each 312 g of flour mix from each treatment. To briefly describe the baking process, butter and sugar were first creamed, then eggs were added and well combined until a foamy mass was formed, and finally composite flour was added till a homogenous consistency was achieved. The developed batter samples were filled into the pans, with butter paper lining the inside surface. The mix was baked for almost 20 min at 170 to 180°C. The cakes were then allowed to cool before being cut with a mechanical slicer and baked again for 20 min at 150 to 160°C. Following baking, cake rusks were kept aside for cooling before being placed in plastic bags. In total, five types of cake batter were prepared, as mentioned in Table 1.

Table 1. Cake rusk formulations and ingredients.

Treatments	Wheat/Multigrain flour (g)	Butter (g)	Icing sugar (g)	Eggs (g)	Baking powder (g)	Salt (g)
T0	312	250	250	300	12.5	10
T1	312	250	250	300	12.5	10
T2	312	250	250	300	12.5	10
T3	312	250	250	300	12.5	10
T4	312	250	250	300	12.5	10

Proximate analysis of developed cake rusks

The multigrain flour cake rusk samples were processed into a fine powder for analysis. The samples were analyzed for moisture, protein, ash, fat, crude fiber, and nitrogen-free extract (NFE) according to their standard methods described in AACC, (2011). The proximate analysis was conducted in the laboratory of Food Science and Nutrition Institute in the University of Sargodha, Sargodha, Pakistan, and each analysis was done in triplicate. By following the process adopted by Hussain *et al.* (2021), the gross value of energy (Kcal/100 g) of cake rusks was calculated using the following factors: for fat with 9 Kcal/g, carbohydrate with 4 Kcal/g, and protein with 4 Kcal/g by using the below equation:

$$\text{Calorie count} = (\%\ \text{protein} \times 4) + (\%\ \text{fat} \times 9) + (\%\ \text{carbohydrate} \times 4)$$

Measurement of antioxidant activity

The Trolox Equivalents (TE) method, by following the procedure adopted by Hussain *et al*. (2021), was applied for quantifying the antioxidant activity of multigrain cake rusk, which compares the antioxidant activity of the sample to that of Trolox, a water-soluble analogue of vitamin E. Firstly, cake rusk samples were ground into a fine powder to increase the surface area for extraction. A specific amount of the powdered sample (20 mg) was extracted using 80% ethanol at a sample to solvent ratio of 20:80 (w:v). This solvent was chosen for its ability to dissolve antioxidant compounds present in the sample. The extract was filtered through Whatman filter paper to remove any undissolved particles and obtain a clear solution. Then, 2 mL from every one of our DPPH (2,2-diphenyl-1picrylhydrazyl) solutions was taken and mixed with our antioxidant extract. The mixture was incubated in darkness at 25°C for approximately 30 min. The dark environment prevents degradation of DPPH by light, and the temperature ensures a consistent reaction rate. The absorbance of the mixture was measured at 517 nm using a UV-Vis spectrophotometer. The decrease in absorbance indicates the scavenging of DPPH radicals by the antioxidants in the sample. The antioxidant capacity was expressed as TE per 100 g of cake rusk. This involves comparing the antioxidant activity of the sample to that of Trolox, using standard curves derived from Trolox solutions.

Textural analysis

The textural consistency of the cake rusk was assessed using a texture analyzer 24 h after baking, according to Method No. 74-10.01 from AACC (2011). Using a compression platen probe, the greatest peak compression force was measured to determine the hardness or breaking strength of the cake rusk.

Physical characteristics of cake rusk

Physical characteristics of the cake rusk includes its width, thickness, and weight. They were calculated corresponding to the methods discussed in AACC (2011), with required modifications.

Weight

Weight of cake rusks was calculated by placing the cake rusk on a digital weight machine, with triplicate readings being measured (AACC, 2011).

Width

To measure the width of the control cake rusk and cake rusk made with various multigrain flours, the standard method described in AACC (2011) was modified. Six cake rusks were lined up side by side and their width was measured using a scale. After rotating each slice at a 90° angle, the width was once more measured, and the average width was computed.

Thickness

The thickness of the cake rusk sample was determined using the technique provided in AACC (2011). Each treatment's cake rusk was stacked on top of one another, and readings were recorded in millimeters. Cake rusks were rearranged in random configurations, and the thickness was observed once more. Then, the average value was determined.

Sensory evaluation of the cake rusk

The multigrain flour cake rusks were evaluated for their organoleptic properties including color, crispiness, texture, aroma, flavor, mouthfeel, appearance, and overall acceptability, following the method described by Rafique *et al*. (2023). Forty evaluators of both genders with an average age of 30 years from the University of Sargodha, in Sargodha, carried out the assessment. The sensory qualities of the cake rusks were evaluated using a rating scale ranging from 1, representing "disliked extremely," to 9, indicating "liked extremely." The judges were presented with cake rusks, on coded plates along with their descriptions. They evaluated each aspect and provided scores on the given sheets.

Statistical analysis

The study procedures were conducted thrice. The results were presented as mean values, with deviations indicated. The treatments underwent analysis of variance (ANOVA) and both significant and nonsignificant outcomes were assessed for each treatment group (Steel *et al*., 1998).

Table 2. Effect of treatments on falling no. (sec) of multigrain flour.

Treatments	Mean± Std. Deviation
T0	379.67±5.69[b]
T1	260.33±2.52[e]
T2	386.67±4.93[a]
T3	340.00±4.58[c]
T4	264.67±10.97[d]

Means that do not share a letter [a b c d e] in column is significantly different at level ($P < 0.05$).
T0 = Control: wheat flour 500 g
T1 = 400 g wheat flour and 100 g millet flour
T2 = 400 g wheat flour and 100 g gram flour
T3 = 400 g wheat flour and 100 g corn flour
T4 = 200 g wheat flour, millet flour 100 g, gram flour 100 g, and Corn flour 100 g

Results and Discussion

Physiochemical properties of the multigrain flours

Falling number (amylase activity)

The activity of amylase plays a role in understanding how enzymes in the flour work during the baking process, while this impact on the texture and quality of the goods are enjoyed later on by the consumers. The falling number is considered an indicator of amylase activity; the higher the falling number, the lower the amylase activity (Zeng *et al*., 2024). The outcomes presented in Table 2 show that there were differences in the falling numbers across the multigrain flour combinations tested in the study. In particular, T2 had significantly high falling number and thus low amylase activity. After T2, the control group (T0) also showed comparatively high falling number (low amylase activity) as compared to other treatments. The heightened falling number of T3 also indicates that gram flours rich in enzyme content may have an impact on speeding up the breakdown of starch into sugars through the alpha amylase action (Silvestre-De-León *et al*., 2020). The breakdown of enzymes plays a role in determining the texture and tenderness of the cake rusk because increased sugar levels encourage fermentation and the release of gas while baking. This observation suggests that gram flour plays a role in boosting activity while the presence of millet and corn flours seems to have an inhibitory effect on it. These results are in line with the findings of Olagunju *et al*. (2021), when a similar trend of falling number and amylase activity was observed during the development of multigrain flour bread. The low falling number (high amylase activity) seen in T1 and T4 may not be desirable, as it may create an undesirable crumb in the texture of end products. Alpha amylase works to break down starch into dextrin and maltose sugars, which can result in more gas being produced during fermentation leading to a softer texture. Although these qualities can improve the taste and aroma of the cake rusk, they may affect the texture. So, it is important to control amylase levels with caution (Silvestre-De-León *et al*., 2020). When there is amylase activity in the dough, it can make the dough overly sticky and cause issues during processing like struggling with handling and getting an uneven texture in the end product. An aspect to watch out for with increased amylase activity in cake rusk making could be the risk of disrupting the texture of cakes if the breakdown of starch by enzymes isn't balanced well with flour elements (Das and Kayastha, 2023). For example, a softer crumb might be nice to have in a cake rusk recipe; however, if the gluten network weakens much because of enzymatic activity, it might result in the final product lacking the necessary crunch and sturdiness that quality rusks are known for. So, it's suggested to do testing, on the texture of the product, to really grasp how amylase activity affects its overall quality. This information could help in making changes to the flour mix or the baking method settings to improve both the fluffiness and firmness of the cake rusk. The gram flour can boost enzyme performance effectively, in a manner indicated by Rohi *et al*. (2022) in their research on grain flour used in muffins with added functionality.

Gluten content

Gluten levels play a key role in determining the quality of flour since they impact the flexibility of the dough and its texture during baking (Silvestre-De-León *et al*., 2020). Table 3 presents mean values of the results of the gluten levels in the multigrain flour treatments. Based on the analysis, it appears that T0 had the highest gluten content at 6.75%. In contrast, T4, which includes a blend of wheat, millet, gram, and corn flours, had the lowest gluten content with a mean of 6.60%. Furthermore, among the treatments, a descending order of T0>T1>T2>T3>T4 was discovered for gluten content. The presence of additional flours, such as millet, gram, and corn, appears to decrease the gluten content of the multigrain flour mix. In this study, it was found that by adding either gram flour, millet flour, or corn flour, individually or combined, there was a declining trend in gluten content of flour as also described earlier by Shipra *et al.* (2017) during the development of multigrain flour. Comparative outcomes were also provided Rohi *et al.* (2022), in the study conducted upon multigrain flour prepared for the development of functional muffins. Similar results have also been confirmed by the earlier studies of Hussain *et al.* (2024) and Rafique *et al.* (2023), when they used non-wheat flours to create composite flours, and there was an obvious decrease in gluten contents.

Rheological characteristics of the multigrain dough

Because wheat grain goes through a number of conditions during the milling process, including the removal of high-fiber bran and the addition of some water to increase the water activity, there is an increase in the intentional or unintentional loss of nutritional value as processing increases (Yousaf *et al*., 2021). Water absorption is an important rheological parameter of the multigrain flour, while dough development time and dough stability along with the Farinograph Quality Number (FQN) are important rheological parameters of the multigrain dough, and all these parameters have high impact on the quality of the end products (Hussain *et al*., 2023). The findings presented in Table 4 reveal differences in these attributes among treatments; notably, T4 stands out for its exceptional qualities. This indicates that T4 might be the right mix for baking top notch cake rusks. Water absorption plays a role in determining the consistency of dough and subsequently impacts the texture and overall quality of the final baked goods. According to a recent study, it was found that water absorption rates varied significantly among different flour combinations (Hussain *et al*., 2023). In our work, T3 demonstrated the highest water absorption rate at 63.4% (Table 4). This higher absorption is linked to the texture and excellent moisture retention ability of the corn flour. Such findings are seen in composite flour blends commonly used in the baking processes (Kaur *et al*., 2024). T0 showed the lowest water absorption value at 52.1%. T3 showed increased water absorption because of the texture and elevated starch content of corn flour; this aspect improves the ability of the dough to retain moisture effectively for making cake rusk and assists in achieving the desired consistency and texture of the final product. The variations in water absorption emphasize the significance of fine-tuning flour combinations to customize baking properties for the products (Kaur *et al*., 2024; Rafique *et al*., 2023).

Table 3. Gluten content in different multigrain flour treatments.

Treatment	Flour composition (%)	Gluten content (%)
T0	100% Wheat	6.75±0.03[a]
T1	80% Wheat, 20% Millet	6.68±0.03[b]
T2	80% Wheat, 20% Gram	6.65±0.02[c]
T3	80% Wheat, 20% Corn	6.60±0.01[d]
T4	40% Wheat, 20% Millet, 20% Gram, 20% Corn	6.60±0.01[d]

*Means that do not share a letter [a b c d] in column is significantly different at level (*P* < *0.05*).

The development time for dough refers to the duration required to mix the dough to its optimal consistency. This time is indicative of the protein quality in the flour blend, as stronger flours typically require more time to develop (Hussain *et al*., 2023). As shown in Table 4, the mean dough development time across treatments varied significantly, ranging from 2.3 min to 4.5 min. T4 exhibited the longest dough development time (4.5 min). The longer duration is probably because of the mix of flours that need time for the proteins to combine and create a consistent structure together (Rafique *et al*., 2023). On the hand, T0 made from wheat flour had the lowest dough development time showcasing the uniformity of gluten formation, in wheat flour. Similar findings were also reported in a recent work by Olagunju *et al.* (2021), when multigrain flour was used to develop bread. The prolonged dough development process noted for T4 suggests that the complex interactions among proteins from grains necessitates time to establish a unified structure successfully. This prolonged process could impact the effectiveness of baking procedures in baking industries where timing plays a key role. Conversely, a prolonged fermentation period might lead to inconsistency of the dough, which potentially can elevate the overall texture of the ultimate product (Aslam *et al*., 2023).

Dough stability is the measure of how well the dough maintains its structure before it begins to break down. This parameter is crucial for understanding the dough's capacity to withstand mechanical mixing and its resilience during proofing. Typically, stronger doughs, which have a higher protein content, exhibit greater stability (Hussain *et al*., 2023). The mean values of dough stability (Table 4)

Table 4. Rheological characteristics of multigrain flours.

Treatment	Water absorption (%)	Dough development time (min)	Dough stability (min)	Farinograph Quality Number (FQN)
T0	52.1±0.10[e]	2.3±0.10[e]	3.5±0.10[e]	75±0.10[e]
T1	55.3±0.10[d]	3.0±0.10[d]	5.0±0.10[d]	80±0.10[d]
T2	58.2±0.10[c]	3.8±0.10[c]	8.2±0.10[a]	83±0.10[c]
T3	63.4±0.10[a]	4.0±0.10[b]	6.0±0.10[c]	85±0.10[b]
T4	60.8±0.10[b]	4.5±0.10[a]	7.5±0.10[b]	93±0.10[a]

*Means that do not share a letter [a b c d e] in column is significantly different at level ($P < 0.05$).
T0 = Control: wheat flour 500 g
T1 = 400 g wheat flour and 100 g millet flour
T2 = 400 g wheat flour and 100 g gram flour
T3 = 400 g wheat flour and 100 g corn flour
T4 = 200 g wheat flour, 100 g millet flour, 100 g gram flour, and 100 g Corn flour 100 g

were found to be ranging from 3.5 min for T0 to 8.2 min for T2, which showed that the dough stability was the highest for T2. This indicates that adding gram flour notably boosts the strength of the dough. The improved dough stability in T1 is probably because of the protein network created by the gram flour, which might have helped the dough endure mixing pressures. However, T0 made only with wheat flour exhibited the lowest dough stability highlighting how beneficial it is to include different grains to enhance this aspect. The improved dough stability noticed in T2 can be credited to the protein present in the gram flour. This protein boosts the gluten network and assists the dough in retaining its form and texture during mixing (Li *et al.*, 2024). Enhanced stability proves advantageous for upholding the quality of the dough in production phases like proofing and baking, which eventually leads to a better-quality cake rusk. The results suggest that adding gram flour to the flour mixture can greatly improve the stability of the dough, which is an important factor in achieving the desired texture and crumb structure in the end product (Aslam *et al.*, 2023). Present findings were in line with the earlier results presented by Olagunju *et al.* (2021), when multigrain flours were used in different ratios to develop the bread.

The FQN also plays an important role in assessing the quality of dough by considering factors like water absorption capability and dough consistency over time during mixing and baking processes for ensuring good-quality baked goods. The FQN is a measure of how the dough performs, showcasing its quality and behavior across treatments (Wang *et al.*, 2022). The findings, as shown in Table 4, reveal that the FQN score of T4 was 93. This indicates that this specific mixture offers the most favorable dough quality and baking attributes, out of all the variations tested. The elevated FQN value signifies excellent water absorption, dough consistency, and stability, all of which contribute to creating well-formed cake rusks. The FQN value of 93 for T4 indicates that this mix of grains can handle the strain during processing while still keeping the texture intact in the final product (Olagunju *et al.*, 2021). The ability of the dough to endure mixing and baking pressures and its positive textural attributes make it well suited for creating cake rusks with an enticing texture. On the other hand, the lower FQN values of 75 for T0 and also for other treatments imply that these mixes may not deliver the level of dough quality and performance. T0, which contains only wheat flour, had the lowest FQN, emphasizing the advantages of including different types of grains to improve the quality of the dough. The analysis of FQN reveals that mixing different types of flours in the dough mix can significantly enhance its quality and performance. The combination of grains including 40%t wheat flour and 20% each of millet flour, gram flour, and corn flour (referred to as T4) delivers favorable outcomes in terms of FQN. This indicates a well-balanced and superior quality dough, ideal for creating excellent cake rusks. This discovery supports the goal of refining flour mixtures to attain desirable dough characteristics, while similar findings have also been confirmed by Shipra *et al.* (2017) and Rohi *et al.* (2022), during the development of muffins from multigrain flours.

Proximate analysis and energy value of cake rusks

Proximate composition results of multigrain flour–based cake rusks are shown in Table 5. The moisture level plays a significant role in the baked goods as the increased water activity attracts microbial growth. That's why the final moisture has to be within the optimal range to ensure the shelf stability of the final product (Aslam *et al.*, 2023). In Table 5, the results of the moisture level in different baked cake rusk treatments are shown as T0 (9.32), T1 (9.53), T2 (9.11), T3 (9.23), and T4 (9.43) g/100 g. Meanwhile, the highest moisture level was discovered

Table 5. Proximate analysis and energy value of cake rusks.

Treatments	Proximate composition of cake rusks (g/100 g)					Energy (Kcal/100 g)
	Moisture content	Protein content	Fat content	Fiber content	Ash content	
T0	9.32±0.021[c]	5.85±0.036[e]	12.74±0.247[e]	1.05±0.015[d]	0.89±0.010[e]	409.4±5.2[b]
T1	9.53±0.031[a]	7.63±0.021[a]	13.99±0.060[b]	1.24±0.020[b]	1.33±0.015[d]	401.2±4.8[e]
T2	9.11±0.021[e]	6.75±0.026[c]	14.61±0.348[a]	1.15±0.020[c]	1.52±0.031[b]	408.3±5.0[c]
T3	9.23±0.030[d]	6.30±0.030[d]	12.96±0.083[d]	1.21±0.020[b]	1.40±0.021[c]	413.5±5.4[a]
T4	9.43±0.038[b]	7.19±0.015[b]	13.37±0.231[c]	1.40±0.021[a]	1.69±0.026[a]	404.1±4.9[d]

*Means that do not share a letter [a b c d e] in column is significantly different at level ($P < 0.05$).
T0 = Control cake rusks: wheat flour 500 g
T1 = Cake rusks having 400 g wheat flour and 100 g millet flour
T2 = Cake rusks having 400 g wheat flour and 100 g gram flour
T3 = Cake rusks having 400 g wheat flour and 100 g corn flour
T4 = Cake rusks having 200 g wheat flour, 100 g millet flour, 100 g gram flour, and 100 g corn flour

in T1 and the minimum moisture level was discovered in T2. In this study, it was found that because of the combined effect of all three flours (T4), there was an incline trend in the moisture level during the development of cake rusks, while on the other hand by adding only gram (T2) and corn (T3), a decline in the moisture level was found, which is a good indicator for the extended shelf-life stability. Similar findings have also been reported in an earlier work conducted by Shipra *et al.* (2017) during the development of multigrain flour muffins. The improvement of the nutritional quality of food products to meet consumers' needs have remained the focus of various studies worldwide (Staichok *et al.*, 2016). Protein does not work well under a hot environment, especially in baked items, where the heat is intense and causes protein loss during production (Li *et al.*, 2024). In this study, multigrain flour having higher amounts of gram flour as well as corn and millet flour was developed, and these individual flours are significantly higher in nutrients such as fiber and protein, to increase the nutritional contents of the final cake rusk. From the findings presented in Table 5, the highest protein level was observed in T1 (7.65 g/100 g) and the minimum protein level was discovered in T0 (5.88 g/100 g). In this study, it was found that by adding millet flour, corn flour, and gram flour individually or in combination, an increase in the protein content was found during the development of cake rusks. On the other hand, by adding only corn flour (T3), there was minimal increase in the protein level. These findings show that the millet protein along with wheat protein could play its part in the development of good quality cake rusk (Yousaf *et al.*, 2021). Further, these outcomes were found in complete agreement with the earlier findings of Shipra *et al.* (2017). The results of the level of fat in different baked cake rusk treatments are shown in Table 5, from where it can be seen that the highest level of fat was discovered in T2 (14.98 g/100 g), which has 400 g wheat flour and 100 g gram flour, while in comparison the minimum level of fat was discovered in T0 (12.53 g/100 g), which comprises only wheat flour and no other constituent. These results show that multigrain flours can add to the fat content of the baked items, as these flours contain sufficient amount of fat along with protein (Rohi *et al.*, 2022). Also, high fat content in the gram flour was responsible for high fat content in T2.

Dietary fibers are resistant to digestion in the human body. They are nonstarch polysaccharides and are present in cell wall compounds. Dietary fiber mainly contains pectic substances, cellulose, hemicellulose, and lignin. In addition, legume and pulse flours, particularly gram flour, are considered as excellent sources of fiber (Zhu *et al.*, 2022). From the results presented in Table 5, the lowest level of fiber was discovered in T1 (1.05 g/100 g) having only wheat flour, while in comparison the maximum level of fiber was discovered in T4 (1.40 g/100 g). This increment in fiber contents of bakery products through incorporation of nonwheat flours has also been witnessed in the works conducted by Hussain *et al.* (2023), Rohi *et al.* (2022), and Rafique *et al.* (2023). Legumes such as green or black gram, chickpea, and particularly gram are reported to exhibit a rich fiber content (Silvestre-De-León *et al.*, 2020). Because of the high fiber contents of gram, corn, and millet, these flours are considered as potential constituents for the development of functional food products (Etiosa *et al.*, 2018). In Table 5, the analysis of the level of ash in different baked cake rusk treatments was also analyzed, which shows that the maximum level of ash was discovered in T4 (1.72 g/100 g), whereas the minimum level of ash was discovered in T0 (0.88 g/100 g), which comprises only wheat flour. This increment in ash content was because of the high level of ash in the millet and gram flours, while these results are in line with the earlier findings of Shipra *et al.* (2017), who also reported that multigrain flour–based bakery items present high ash contents.

The energy content plays a role in determining the value of food products since it encompasses the protein levels as well as the fat and carbohydrate content in each treatment of multigrain food products (Olagunju *et al*., 2021). In Table 5, the energy content of the cake rusk formulations were found to be ranging from 401.2 to 413.5 Kcal/100 g. T3 had the highest energy content because of its higher fat percentage, while T1 had the lowest energy content, possibly because of its low fat content. These analyses revealed significant differences in the energy content among treatments ($P < 0.05$), indicating that the variations in multigrain flour composition directly influence the caloric value of the final product. These findings suggest that the energy density of cake rusk can be tailored by adjusting the proportions of ingredients. This is particularly relevant for developing products aimed at specific dietary needs, such as energy-dense snacks or low-calorie options (Rafique *et al*., 2023). A similar variation in the energy levels of the baked products was also reported by Aslam *et al*. (2023), when a variety of flours were used to develop bread.

Textural analysis of cake rusks

Texture analysis evaluated the key quality attributes such as hardness, crispness, and cohesiveness in the developed multigrain cake rusks, which are crucial factors for consumer acceptance. Results presented in Table 6 show that T4 exhibited the highest hardness value as 58.6 N, which is significantly higher than that of the control treatment (T0), which had the lowest hardness value at 45.2 N. The coarse texture and lower moisture retention capacity of corn flour contribute to this increase in the hardness, resulting in a firmer and crisper texture (Mejía-Terán *et al*., 2024). It has been noted that the inclusion of corn flour tends to result in baked goods with a more brittle consistency. The hardness of cake rusks can be a quality factor that is often gauged by how much force it takes to compress the sample to the peak hardness level. As shown in Table 6, the findings indicate that adding corn flour and millet as a part of T3 and T4, respectively, notably enhanced the hardness of the rusks, while this improvement makes them better suited for achieving the desired texture in the cake rusk keeping and transporting process. A similar increase in hardness of the muffins was also noted by Din *et al*. (2024), as they replaced wheat flour with lotus rhizome powder having high starch contents, just as corn flour contains. Crispness, measured by the number of peaks in the texture profile analysis, reflects the product's brittleness and fracturability (Rajiv and Soumya, 2015). Table 6 shows the crispness values for each treatment, where T3 exhibited the highest crispness with a value of 14.0 peaks, followed closely by T4 with a value of 13.8 peaks, indicating that corn and millet flours significantly enhanced the crisp and brittle texture of the cake rusks. In contrast, T0 had the lowest crispness value of 8.5 peaks, which is an indication of a softer texture with less fracturability. This crispiness was noticeably less as compared to the other mixtures such as T3 and T4. This outcome supports the idea that the fragile quality of corn flour enhances the breakability and crispness of the goods (Mejía-Terán *et al*., 2024). These results align with the previous research results of Patel *et al*. (2013), which has demonstrated that nongluten flours like corn and millet enhance the brittleness of baked products. Cohesiveness is a key textural parameter that reflects the ability of cake rusk to withstand deformation and retain its structure upon chewing. Higher cohesiveness indicates a product that maintains its integrity when subjected to a second compression relative to the first. This attribute contributes significantly to the mouthfeel of the product, as more cohesive rusks tend to maintain their form better when bitten into (Rajiv and Soumya, 2015). As shown in Table 6, T0 exhibited the highest cohesiveness value of 0.62, which can be attributed to the strong gluten network formed by wheat flour. Gluten is essential for developing a cohesive structure, and its abundance in wheat flour contributes to better resilience during mastication (Hussain *et al*., 2023). In contrast, T3 exhibited the lowest cohesiveness value of 0.54, likely because of the lower gluten content and the coarser granulation of the corn flour (Mejía-Terán *et al*., 2024), which disrupts the gluten matrix and weakens the structural integrity of the cake rusk. The reduction in cohesiveness for multigrain blends (T1, T2, T3, and T4) can be explained by the substitution of wheat flour with nongluten-forming flours, such as millet, gram, and corn. These flours do not develop the same cohesive gluten structure, leading to a weaker product matrix (Rohi *et al*., 2022). Despite these reductions, the differences between the multigrain treatments were relatively minor, with all values remaining within a narrow range of 0.54 to 0.58. This suggests that the inclusion of multigrain flours primarily affects cohesiveness to a small extent while still maintaining the fundamental structure of the cake rusks. Adding corn flour to T3 has resulted in a decrease in cohesiveness because these flours do not have gluten proteins, which are essential for maintaining structural integrity (Lee *et al*., 2020), as seen in T0. This aligns with research findings where products with corn flour showed lower levels of cohesiveness (Kaur *et al*., 2024).

Fractureability refers to how a product breaks when pressure is applied to it. It also indicates whether a cake rusk's texture leans toward being brittle or flexible. This aspect plays a role in pleasing consumers since cake rusks are expected to offer a break without crumbling too much. It serves as a measure of product excellence in the baked goods such as cake rusks, where achieving the right balance between brittleness and flexibility enhances the overall eating experience (Rajiv and Soumya, 2015).

Table 6. Textural analysis of cake rusks.

Treatment	Hardness (N)	Crispness (Peaks)	Cohesiveness	Fractur ability (N)	Chewiness
T0	45.2±1.5[e]	8.5±0.5[e]	0.62±0.02[a]	10.4±0.3[e]	0.25 0.03[d]
T1	50.3±1.8[d]	10.2±0.6[d]	0.58±0.02[b]	12.3±0.4[d]	0.31±0.04[c]
T2	55.4±2.0[c]	12.1±0.7[c]	0.56±0.03[c]	14.6±0.5[a]	0.27±0.02[d]
T3	60.8±1.7[a]	14.0±0.8[a]	0.54±0.03[c]	13.1±0.4[c]	0.35±0.05[b]
T4	58.6±1.9[b]	13.8±0.7[b]	0.55±0.02[c]	13.8±0.5[b]	0.40±0.06[a]

*Means that do not share a letter [a b c d e] in column is significantly different at level ($P < 0.05$).
T0 = Control cake rusks: wheat flour 500 g
T1 = Cake rusks having 400 g wheat flour and 100 g millet flour
T2 = Cake rusks having 400 g wheat flour and 100 g gram flour
T3 = Cake rusks having 400 g wheat flour and 100 g corn flour
T4 = Cake rusks having 200 g wheat flour, 100 g millet flour, 100 g gram flour, and 100 g corn flour

In Table 6, T2 demonstrated fractureability as 14.6 N. This observation implies that gram flour contributes to a texture likely because of its unique blend of proteins and starches that forms a less cohesive dough structure (Silvestre-De-León *et al.*, 2020). The lower gluten content in gram flour when compared to wheat flour leads to a robust dough structure upon baking, resulting in increased fragility according to research by Miñarro *et al.* (2012). On the other hand, the control group (T0) showed the breaking force at 10.4 N, indicating a more flexible and less fragile composition. This variation is likely because of the robust gluten framework in wheat flour that improves dough flexibility and diminishes the chances of breakage when pressure is applied (Hussain *et al.*, 2023). These findings show that using multigrain flours generally led to fracture resistance compared to the control group. For example, the mixtures T1 and T3 showed resistance values of 12.3 N and 13.1 N, respectively, which were notably higher than those of T0. These findings suggest that swapping out wheat flour with protein options like millet, gram, and corn increases the brittleness of cake rusks. The reason behind this could be linked to the amount of gluten present in the dough. This leads to a poor structure overall and produces a final product that is more fragile (Sharma *et al.*, 2018). These observations correspond to the earlier study results as to how nonwheat cereals–based flours behave when incorporated into baked products (Yousif *et al.*, 2012).

Chewiness is a vital textural attribute that reflects the energy required to chew baked product until it is ready to be swallowed. It is closely associated with the resistance of the cake rusk to the deformation during mastication, and higher chewiness values indicate a denser and tougher texture. This characteristic directly affects consumer perception, with chewier products being perceived as more substantial and requiring more effort to break down in the mouth (Rafique *et al.*, 2023; Yousif *et al.*, 2012). As shown in Table 6, T4 exhibited the highest chewiness value of 0.40, indicating a significant increase in chewiness compared to the control (T0) and other treatments. This elevated chewiness can be attributed to the inclusion of multigrain flours, particularly corn flour, which is known for imparting a denser structure to the baked goods (Mejía-Terán *et al.*, 2024). In contrast, T0 showed the lowest chewiness value of 0.25, reflecting the softer texture typically associated with products made solely from wheat flour, which forms a strong but more elastic gluten network (Hussain *et al.*, 2023). The data indicate that the substitution of wheat flour with multigrain flours (T1, T2, T3, T4) increases chewiness. Treatments T3 and T4, which contain a proportion of multigrain flours, showed significantly higher chewiness values compared to the control. These findings are in line with the previous results reported by Miñarro *et al.* (2012), as they observed that legume flours significantly affect the textural properties of bakery products. Corn flour, in particular, is known to contribute to a firmer and chewier texture, possibly because of its coarse granulation and higher starch content, which reduces the flexibility of the gluten network in the dough (Kaur *et al.*, 2024). The greater chewiness values for treatments containing a proportion of multigrain flour (specifically T3 and T4) were also possibly because of the uneven distribution of coarse non-wheat flours within them. Despite this variation in chewiness among treatments with multigrain flour additions being noticeable, the overall range of values across all treatments stayed within reasonable levels primarily because of the presence of these multigrain flours, which have been successfully incorporated in the development of baked products (Lee *et al.*, 2020).

Physical characteristics of cake rusks

Physical parameters of the baked products play a key role in the acceptance of the product, and these are greatly affected by the selection of flours used (Rafique *et al.*, 2023). The analysis of width, thickness, and weight in different baked cake rusk treatments is shown in Table 7, which shows that weight values of cake rusks as T0 (11.57), T1 (10.59), T2 (11.23), T3 (10.26), and T4 (9.61) g, and these were found to be significantly different. In addition, the average values of width in T0 (37.61), T1 (32.02), T2 (34.01), T3 (30.02), and T4 (27.02) mm, were also found to be significantly different among all treatments. Similarly, the results of thickness were found to be T0 (10.07), T1 (7.09), T2 (9.05), T3 (8.03), and T4 (5.05) mm. The highest value of weight as 11.65 g of T0, width 37.62 mm of T0, and thickness 10.12 mm of T0 were noted. These results indicated that by adding millet flour, corn flour, and gram flour individually or in combination, there was a decreasing trend in physical attributes such as thickness, width, and weight during the development of cake rusks, while on the other hand by adding only gram flour, the least incline in these physical parameters was investigated. These results were found to be in coherence with the findings provided earlier by Shipra *et al.* (2017) and Rohi *et al.* (2022), as they also observed an increase in weight and thickness of the baked products having nonwheat flours. Current study results were also supported by the findings of Hussain *et al.* (2023) and Din *et al.* (2024), as they also observed that addition of nonwheat flours to an extent adversely affects the physical properties of the baked items, possibly because of the disturbance of the gluten ratio and network. Therefore, selection of their appropriate level is necessary to minimize these quality changes (Fan *et al.*, 2024).

Antioxidant activity of cake rusks

The demand for baked products with high antioxidant activity is high as such products having antioxidant compounds from nonwheat flours are capable of improving human health (Maqbool *et al.*, 2024). In Figure 1, the analysis of antioxidant activity of different baked cake rusk treatments is given, which shows results as T0 (82.79), T1 (86.27), T2 (84.72), T3 (83.76), and T4 (83.10) TE/100 g. These data show that the maximum antioxidant activity was observed in T1, while in comparison the minimum antioxidant activity was observed in T0. This highest antioxidant activity of T1 could be attributed to the antioxidant compounds present in the millet flour (Kaur *et al.*, 2024). From these results, it was noted that by adding millet flour, corn flour, and gram flour individually or in combination, there was a significant increase in the antioxidant activity of cake rusks. These results were found to be in sync with the findings provided by Shipra *et al.* (2017), when multigrain muffins showed high antioxidant activity as compared to the control. In another similar work, increased antioxidant activity of biscuits was noted when nonwheat flour was used by Hussain *et al.* (2022b). This increment in the antioxidant activity of cake rusks could be attributed to the different bioactive components present in nonwheat flours (Hussain *et al*, 2022a; Subbuvel *et al.*, 2024). A similar increase in the antioxidant activity of multigrain flour–based bread was also witnessed by Olagunju *et al.* (2021), validating the current findings that these flours could enhance the functional characteristics of the baked products. Present results were also validated when barley flour was used to replace wheat flour for the development of cake rusks by Punia *et al.* (2020), and they observed a significant increase in the antioxidant status of these formulated cake rusks.

Table 7. Physical characteristics of cake rusks.

Treatment	Weight (g)	Width (mm)	Thickness (mm)
T0	11.57±0.08[a]	37.61±0.01[a]	10.07±0.06[a]
T1	10.59±0.10[c]	32.02±0.02[b]	7.09±0.08[d]
T2	11.23±0.27[b]	34.01±0.02[b]	9.05±0.05[b]
T3	10.26±0.28[d]	30.02±0.02[c]	8.03±0.03[c]
T4	9.61±0.13[e]	27.02±0.03[d]	5.05±0.05[e]

*Means that do not share a letter [a b c d e] in column is significantly different at level ($P < 0.05$).
T0 = Control cake rusks: wheat flour 500 g
T1 = Cake rusks having 400 g wheat flour and 100 g millet flour
T2 = Cake rusks having 400 g wheat flour and 100 g gram flour
T3 = Cake rusks having 400 g wheat flour and 100 g corn flour
T4 = Cake rusks having 200 g wheat flour, 100 g millet flour, 100 g gram flour, and 100 g corn flour

Sensory analysis of cake rusks

Sensory acceptance of any baked product is crucial toward its market acceptability and durability. Therefore, whenever new flours are tried with wheat flour to develop bakery products, their sensory analyses are performed to check the reaction of consumers toward these products (Din *et al.*, 2024). In Table 8, the analysis of the sensory attributes of cake rusks made with different multigrain flour treatments is presented. Data show the mean values for each sensory attribute, including aroma, color, flavor, texture, crispiness, mouthfeel, appearance, and overall acceptability. The analysis reveals that the highest aroma score was observed for T1 (8.10), which contained 400 g of wheat flour and 100 g of millet flour. On the other hand, the lowest aroma score was found in T0 (7.20), which consisted entirely of wheat flour. For the color attribute, the maximum color score was found for T1 (7.50), indicating that the addition of millet flour improved the visual appeal of the cake rusk (Kaur *et al.*, 2024). T0 also had a good color rating, which indicates that the control sample was also perceived as visually

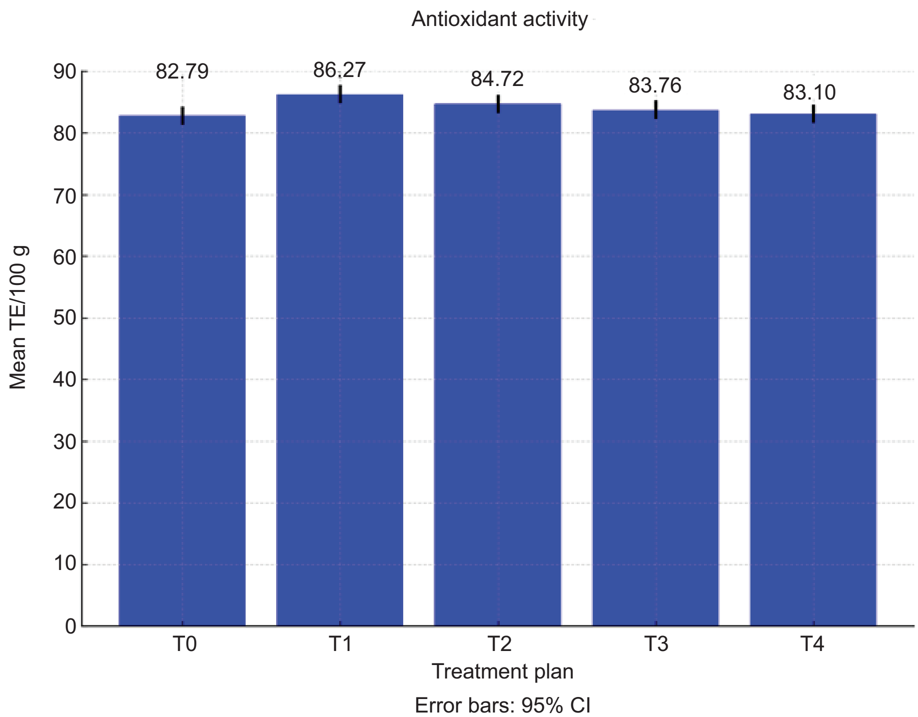

Figure 1. Antioxidant activity of cake rusks (TE = Trolox equivalent).

Table 8. Sensory analysis of cake rusks.

Treatment	Aroma	Color	Flavor	Texture	Crispiness	Mouthfeel	Appearance	Overall acceptability
T0	7.20±0.45$_e$	6.80±0.30^e	7.00±0.35^e	6.70±0.40^e	6.60±0.30^e	6.80±0.40^e	7.00±0.35^e	7.10±0.30^e
T1	8.10±0.60^a	7.50±0.40^a	8.30±0.55^a	8.00±0.55^a	7.90±0.50^a	8.10±0.55^a	8.20±0.50^a	8.30±0.45^a
T2	7.50±0.55^b	7.10±0.45^b	7.60±0.50^b	7.40±0.45^b	7.30±0.45^b	7.50±0.50^b	7.60±0.45^b	7.70±0.50^b
T3	7.30±0.30^c	6.90±0.50^c	7.40±0.45^c	7.20±0.35^c	7.10±0.40^c	7.30±0.35^c	7.40±0.40^c	7.50±0.40^c
T4	7.60±0.40^d	7.20±0.35^d	7.50±0.40^d	7.10±0.30^d	7.20±0.35^d	7.40±0.45^d	7.50±0.35^d	7.40±0.35^d

*Means that do not share a letter $^{a\,b\,c\,d\,e}$ in column is significantly different at level ($P < 0.05$).
T0 = Control cake rusks: wheat flour 500 g
T1 = Cake rusks having 400 g wheat flour and 100 g millet flour
T2 = Cake rusks having 400 g wheat flour and 100 g gram flour
T3 = Cake rusks having 400 g wheat flour and 100 g corn flour
T4 = Cake rusks having 200 g wheat flour, 100 g millet flour, 100 g gram flour, and 100 g corn flour

attractive as compared to the other treatments. The taste scores of the cake rusks also showed a difference between T1 and T0 variants. T1 was the most favored with a rating of 8.30 while T0 received a score of 7.00. Further, Table 2 shows the sensory appearance of different cake rusk treatments. The introduction of millet flour in T0 possibly enriched the flavor profile contributing to its reception by the judges, as the millet flour is not only nutritional but also imparts functional features to the products (Yousaf *et al.*, 2021). Similarly, the ratings for texture, crispness, and mouthfeel exhibited a trend, with T1 consistently outperforming T0 in these aspects. The overall acceptability scores of T1 (8.30) were also found to be significantly high than all other treatments. On the other hand, when all these treatments are compared for all sensory parameters, it could be observed that use of multigrain flours for the development of cake rusks was not disliked by the consumers, instead they preferred these cake rusks over the control giving these comparatively high scores. Acceptability of muffins added with corn flour has also been witnessed by recent research by Kaur *et al.* (2024). Similarly, Rohi *et al.* (2022) have also validated the current results, as muffins developed by multigrain flours were preferred by the evaluators as

Figure 2. Sensory appearance of different cake rusk formulations based upon multigrain flours used.

compared to the control muffins developed from simple wheat flour. Present findings were also in line with the results reported by Shipra *et al.* (2017), when flours from different grains were used to develop muffins, and consumers appreciated this product at an optimum level. Cake rusks supplemented with 30% barley flours were also found to be acceptable when Punia *et al.* (2020) evaluated different replacement levels of barley and wheat flours in a similar fashion conducted in the present study. Therefore, the choice and selection of the right level of combination of multigrain flours could be important in developing acceptable bakery products.

Conclusion

This study on how multigrain flour blends impact the quality features of cake rusks has given us information on boosting nutrition and enhancing the functionality of this treat. When multigrain flours like millet, gram, and corn were added to the cake rusk recipe, there were enhancements in its nutritional value, especially protein, fat, fiber, and ash content. Addition of millet flour raised fiber content and antioxidant activity, addition of gram flour raised the protein content, whereas combination of all flours significantly raised the ash contents of the cake rusks. Although variations in physical and textural properties of different treatments were noted, these were found to be within acceptable range, thus encouraging the use of multigrain flours for the development of cake rusks. These improvements were made with minor effects on the sensory aspects of the cake rusk, where sensory panel members provided the highest scores to the cake rusks having millet flour, whereas other treatments also got appreciable scores. The research showed that using combinations of multigrain flours had effects on the texture and nutritional content of the end product, suggesting that incorporating these mixes into making cake rusks could improve the health benefits of baked goods and fuel innovation in the bakery sector to meet consumer preferences for healthier food choices. Further research could delve into enhancing multigrain blends to improve aspects like bioactive compounds, in vitro and in vivo analysis, and shelf-life stability, in order to maximize the benefits of foods based on multigrain.

Ethical Statement

The sensory evaluation was conducted in accordance with the guidelines for sensory studies as outlined by the Ethics committee of Institute of Food Science and Human Nutrition, University of Sargodha, with the approval number (UOS/IFSN/2023/06). Informed consent was obtained from all individual participants included in the study.

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Authors Contributions

All authors contributed equally to this work.

Conflict of Interest

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