Effects of barley flour substitution on glycemic index, compositional, rheological, textural, and sensory characteristics of chickpea flour-based flat bread

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Abstract
The present study investigated the impact of barley flour substitution (10%–40%) on chickpea flour-based flat bread (CFB). The crude fiber content significantly increased on addition of barley flour, whereas a significant decline was observed in protein and fat contents. All chickpea flour doughs with and without addition of barley flour exhibited shear thinning with flow behavior index of less than one. The hardness of CFBs decreased, whereas elasticity increased with the increase in barley flour content suggesting improvement in texture of flat breads. Glycemic index of CFBs containing barley flour was significantly less than control flat bread made without any addition of barley flour. Sensory panelists also gave higher scores to CFBs prepared with barley flour, whereas in terms of flavor and overall acceptability, no significant difference was observed between control bread and CFBs containing up to 30% barley flour content. Thus, the textural, compositional, and digestibility of chickpea flour-based breads can be greatly improved through barley flour substitution without significantly affecting sensory attributes of bread.

KEYWORDS
barley flour, flat bread, glycemic index, rheology, texture

1 | INTRODUCTION

Cereal products, mainly flat breads, contribute significantly to human diet (Krochmal-Marczak et al., 2020). Flat bread is one of the most ancient forms of food and is consumed widely in Pakistan, India, and Middle East countries usually twice or thrice a day and is thus considered a staple part of daily diet. Based upon composition and methods of preparation, there are around 60 different varieties of flat bread around the globe (Salehifar et al., 2010). Flat breads such as chapatti, tandoori roti, puri, paratha, and naan are breads commonly consumed in Pakistan and India; lavash, barbari, taftoon, and sangak are popular breads of Iran, whereas tortillas are consumed in Mexico. Flat breads can be prepared from whole wheat or refined wheat flour, corn flour, or using blends of flours. Composite flours made from wheat and other cereal flours have excellent functional properties that are appropriate for the production of bakery goods (Onoja et al., 2011). With the growing trend toward consumption of functional foods, legumes can play a potentially important role in making healthier breads (Yamsaengsung et al., 2010). Various researches focused on production of cereal-based breads through supplementation of legume flours (Man et al., 2015; Menon et al., 2015; Olojede et al., 2020; Zafar et al., 2015). Blending legume with cereal flours will offer enviable protein pattern that can improve the nutritional needs of people. Legumes consist of peas, beans, lentils, peanuts, and other podded plants that are used as food (Messina, 1999).
Chickpea (Cicer arietinum L.) is the fifth and the cheapest form of legume protein that can be used as a substitute of animal protein (Man et al., 2015; Sofi et al., 2020). It grows both in tropical and subtropical areas of the world (Shirani & Ganesharanee, 2009). Among all pulses, chickpeas have excellent nutritional composition as it contains 50% available carbohydrate, 17%-22% protein, 6.48% fat, and 3.82% crude fiber (Alajai & El-Adawy, 2006). The two main varieties of chickpea are kabuli and desi (Singh et al., 1991). The kabuli and desi varieties of chickpea are not only native to India but also cultivated in many parts of the world. The desi variety of chickpea is mostly grown in Asia and Africa (Pande et al., 2005), whereas the kabuli variety is widely grown in west Asia, North Africa, North America, and Europe (Jukanti et al., 2012). The protein of chickpea is considered a suitable source of dietary protein due to its excellent balance of amino acids composition (Zhang et al., 2007). In terms of mineral content, it is usually higher in zinc, phosphorous, and manganese compared with other legumes (Wang et al., 2010). Due to its higher lysine content, chickpea becomes a tremendous enhancer of protein quality when mixed with cereal grain proteins, which are usually low in lysine but contain higher amount of sulphur-based amino acids (Iqbal et al., 2006).

Chickpea flat bread is a widely consumed unleavened flat bread of South Asia. The bread dough made primarily from chickpea flour, water, and salt is rounded followed by sheeting using a roller pin into 8–10 cm diameter bread. The bread is then cooked on an iron griddle. However, it lacks popularity among masses as it is harder compared with other breads, being devoid of gluten content. Therefore, the aim of the present study was to improve the textural (increased softness and elasticity), rheological, and sensory characteristics of chickpea flour-based flat bread by adding different levels of barley flour. The motive behind preference of barley flour for enriching chickpea-based unleavened flat bread was its health benefits associated with the presence of both soluble and insoluble fiber in barley. Thus, the idea was to make highly nutritious bread with improved organoleptic and textural characteristics.

2 | MATERIALS AND METHODS

Desi variety of chickpea flour with proximate composition of 46.49% total carbohydrate, 25.82% fat, 19.70% protein, 6.25% crude fiber content, and 1.74% ash content and barley flour with proximate composition of 85.52% total carbohydrate, 10.55% protein, 1.77% fat, 1.18% ash, and 0.98% crude fiber content were used to prepare flat breads. Corn oil, red chili, and salt were bought from the local market.

2.1 | Preparation of chickpea flat breads

Five blends of flour were prepared separately by mixing the chickpea flour with barley flour in the ratio of 100:0 (control bread), 90:10, 80:20, 70:30, and 60:40 (w/w), respectively. Based on flour weight, red chili (5%), corn oil (10%), and salt (2%) were added to the flour mixture. The dough was made using Braun Mixer (Model K650, Kornberg/Germany) by kneading for 5 min at room temperature at 3000 rpm while adding 50 g of water per 100 g of flour weight to form a uniform dough.

Dough (50 g) was rounded to make a ball which was then spread out using a wooden roller pin into a thin circular sheet of 3 mm thickness. The dough sheet was subsequently trimmed into an 11.5 cm diameter round sheet using a petri plate. Immediately, after sheeting, the chickpea flour bread was placed on a hot iron griddle at a temperature of approximately 270°C. The bread was then cooked on both sides for 120 s. Before further analysis, breads were cooled and stored in desiccators (containing silica gel beads as desiccant to obtain a dry atmosphere).

2.2 | Proximate analysis of chickpea flat breads

The standard methods of American Association of Cereal Chemists (2000) were adopted to perform proximate analysis of chickpea flour-based breads. For protein (Method 46–13), for ash (Method 8–01), for fat (Method 30–25), and for crude fiber (Method 32–10) were followed. The total carbohydrate content of bread was calculated using the Equation 1:

\[
\text{Total carbohydrate} = 100 - (\% \text{protein} + \% \text{fat} + \% \text{ash} + \% \text{crude fiber})
\]

2.3 | Rheological characteristics of chickpea flat bread dough

The method of Mansoor et al. (2019) was used to determine the rheological properties of dough using controlled stress rheometer (Model Discovery HR-I, TA Instruments, New castle, DE, USA). The rheological characteristics were determined at a temperature of 25°C in terms of frequency sweep measurements within linear viscoelastic region. Power law model was employed using Trios software (V4.1.0.31739, TA Instruments, USA) on curves of both storage and loss moduli (Pa) versus frequency (rad/s).

2.4 | Textural analysis of chickpea flat bread

The textural characteristics of chickpea flour-based bread were performed by using Universal Testing Machine employing the method of Mehfooz et al. (2018). Chapatti was incised into bone type strips from center of bread. The strip was 10 mm long and 5.5 mm wide from edges and 3.5 mm wide at the center. The two clamps of Universal testing machine (Zwick/Roell, GmbH, Germany) were used to hold the strips of flat bread from each side. One clamp was connected to the moving arm, whereas the other was fixed on the platform. The load cell of 1 kilo Newton was used, and grip to grip separation was 50 mm. The upper moving clamp was 50 mm/min in speed, whereas
force shutdown threshold was kept at 30%. The upper clamp stretched the chapatti strip until it broke from the center. The $F_{\text{max}}$ or maximum force required to tear the bread was measured in MPa, and extensibility was measured in mm. Test Xpert software was used to calculate all the parameters.

### 2.5 Sensory analysis of chickpea flat bread

A 16 member untrained panel evaluated chickpea flour bread with and without barley flour addition using a 9-point hedonic scale ranging from 9 (extremely like) to 1 (extremely dislike). The sensory panel included 12 female and four male panelists aged between 22 and 35 years who were faculty members and postgraduate students of the Department of Food Science & Technology, University of Karachi. Sensory booths with provision of white light were used for analysis. The flat breads were randomly coded with a three-digit number so as to carry out a blind trial. One freshly cooked bread of each sample at a temperature of 40–50°C was served to each panelist along with mineral water to clean the palate. The flat breads were rated in terms of appearance, flavor, grittiness, hardness, aroma, and overall acceptability.

### 2.6 Glycemic index of chickpea flat bread

The method of Goñi et al. (1997) was used to determine the predicted glycemic index (pGI) of chickpea flour bread samples. Equation (2) was used to calculate the pGI:

$$\text{pGI} = 39.17 + 0.549 HI$$

### 2.7 Statistical analysis

One-way analysis of variance (ANOVA) followed by Duncan’s multiple range test at $p < .05$ was used to determine significant differences between the means by using SPSS software (version 17, SPSS Inc., USA).

### 3 RESULTS AND DISCUSSION

#### 3.1 Compositional characteristics of chickpea flat bread

It could be observed from the Table 1 that total starch content of chickpea flour-based breads (CFB) increased by increasing level of barley flour into chickpea flour. This increase could be due to the fact that legume flour has low level of total starch content as compared with cereal flour (Gómez et al., 2008). However, a significant decline was observed in protein, fat, and ash content of CFBs showing that barley flour contained lower level of protein, fat, and ash content as compared with chickpea flour (Bai et al., 2018). Rababah et al. (2006) reported increase in protein, fat, and ash content of wheat-chickpea flour composite biscuits showing that cereal flour is a poor source of protein, fat, and ash content as compared with legume flours. Moreover, crude fiber content of CFBs increased with the addition of barley flour as it is a source of both soluble and insoluble fiber. Sharma et al. (2013) reported that biscuit made with 80% barley flour had higher amount of fiber content as compared with wheat and chickpea flour-based biscuits, which are in agreement with the results obtained in the present study. Proximate composition of CFBs showed that addition of barley to chickpea flour significantly reduces fat content, which is a major contributor to the total caloric value. Protein content showed a decline on addition of barley flour, but then it is improving the nutritional profile of protein in breads by providing sulphur containing amino acids present in cereal proteins.

#### 3.2 Dynamic frequency sweep measurements of chickpea flat bread dough

It could be observed from Table 2 that $G'$ and $G''$ increased with the rise in frequency from 1.25365 to 125.367 rad/s. Similar results were also reported by Kahraman et al. (2018). This suggested that both viscous and elastic character simultaneously increased with higher frequency. Therefore, determination of phase angle was necessary to determine the comparative impacts of rising frequency on $G'$ and $G''$. Moreover, Figure 1 showed that values of storage moduli of all the doughs were higher than loss moduli for the entire range of frequency, suggesting elastic nature of dough with solid like properties. Mariotti et al. (2009) also found similar trend for gluten-free bread doughs. The dynamic moduli ($G'$ and $G''$) for doughs prepared from chickpea flour was relatively higher than those for chickpea and barley composite flour-based doughs, which could be due to higher protein content but lower amount of starch in control dough. However, addition of barley flour decreased protein but increased the starch content, which resulted in altered dough network causing softening. Also, barley flour addition means gluten was added leading to the formation of gluten network which can stretch the dough until it breaks.

### Table 1 Effects of barley flour addition on proximate composition of chickpea flat bread

| Barley flour (%) | TS (%)     | Fat (%)     | Ash (%)     | Protein (%) | CFC (%) |
|-----------------|------------|-------------|-------------|-------------|---------|
| Control (0%)    | 46.49 ± 1.22$^a$ | 25.82 ± 1.05$^a$ | 1.74 ± 0.01$^a$ | 19.70 ± 0.14$^a$ | 6.25 ± 0.01$^a$ |
| 10%             | 49.92 ± 0.90$^b$ | 22.83 ± 0.84$^c$ | 1.66 ± 0.01$^c$ | 18.45 ± 0.07$^c$ | 7.14 ± 0.02$^c$ |
| 20%             | 51.99 ± 0.76$^{bc}$ | 21.14 ± 0.71$^{d}$ | 1.61 ± 0.01$^{d}$ | 17.55 ± 0.07$^{d}$ | 7.71 ± 0.03$^{d}$ |
| 30%             | 54.17 ± 0.95$^{c}$ | 18.85 ± 0.86$^{d}$ | 1.59 ± 0.01$^{d}$ | 16.80 ± 0.14$^{d}$ | 8.59 ± 0.04$^{d}$ |
| 40%             | 57.92 ± 0.71$^{d}$ | 16.07 ± 0.76$^{b}$ | 1.54 ± 0.01$^{b}$ | 15.06 ± 0.01$^{b}$ | 9.41 ± 0.06$^{e}$ |

Note: Means with different superscript lowercase letters within a column are significantly different at $p < .05$.
Abbreviations: CFC, crude fiber content; TS, total starch content.
**TABLE 2** Effects of barley flour addition on rheological parameters at 1.25365, 6.28319, and 125.367 rad/s for chickpea flour doughs

| Barley flour (%) | 1.25365 rad/s | 6.28319 rad/s | 125.367 rad/s |
|------------------|---------------|---------------|---------------|
|                  | G’ (Pa)       | G” (Pa)       | Phase angle   | G’ (Pa)       | G” (Pa)       | Phase angle   |
| Control (0%)     | 177939.33c    | 65458.97c     | 20.18a        | 227579.00c    | 86708.07c     | 20.85ab       |
| 10%              | 135347.00bc   | 49440.00bc    | 20.07a        | 167720.67b    | 60743.83b     | 19.91a        |
| 20%              | 119883.67b    | 43545.60b     | 19.96a        | 147479.30b    | 51377.36b     | 19.21a        |
| 30%              | 149002.00bc   | 52265.93b     | 19.14a        | 182078.00bc   | 61300.27b     | 18.50a        |
| 40%              | 55405.40a     | 25768.53a     | 24.95b        | 67153.13a     | 32475.97a     | 25.82a        |

Note: Means with different superscript lowercase letters within a column are significantly different at $p < .05$. 
Abbreviations: G’, storage modulus; G”, loss modulus.

**FIGURE 1** Effect of frequency on storage modulus (G’) and loss modulus (G”) of chickpea and barley flour bread doughs. (a) Chickpea flour without addition of barley flour. (b) Chickpea flour with addition of 10% barley flour. (c) Chickpea flour with addition of 20% barley flour. (d) Chickpea flour with addition of 30% barley flour. (e) Chickpea flour with addition of 40% barley flour.
of soft doughs that were easier to sheet. The dynamic moduli of composite dough decreased due to an increase in water absorption and swelling of starch granule. Both $G'$ and $G''$ decreased with the increased level of barley flour as compared with control. Sozer (2009) reported similar results in their rice pasta dough in which $G'$ and $G''$ decreased by adding gelatinized rice starch in the doughs. The value of phase angle ($\theta$) ranges from 0° to 90°; 0° from 0° to 45° suggest solid like behavior, whereas 45°–90° suggest that material flows like a viscous fluid. Phase angle being ratio of $G''$ to $G'$ suggest the direction of viscoelasticity. It was observed that for all CFB doughs, phase angle increased with frequency, suggesting thinning behavior of doughs with rising frequency. Loss modulus significantly increased with the rise in frequency as compared with control due to which phase angle also increased. Interestingly, phase angle at 1.25365, 6.28319, and 125.367 rad/s showed a significant increase in phase angle of CFB containing 40% barley flour compared with control, suggesting thinning or reduction in dough elasticity. However, at barley flour content, <40%, CFB doughs showed either insignificant or lower phase angle values with respect to control pointing to the fact that the combined effect of rise in starch and crude fiber with decline in fat and protein content on concomitant addition of barley flour can significantly affect the dough network development. This increase in phase angle at 40% barley flour content could also be correlated to sudden drastic decrease in $G'$ values when barley flour content was increased from 30% to 40%. Results presented in Table 3 also reflected thinning behavior of all CFB doughs with and without addition of barley flours as flow behavior indices in terms of both $G'$ and $G''$ were found to be less than one. For all doughs, the consistency coefficient ($k$) values were higher for $G'$ compared with $G''$ suggesting solid behavior of dough. The CFBs containing 40% barley flour showed the lowest values for $G'$ and $G''$, which is in agreement with higher phase angle values. All doughs showed good fitness for power law model.

3.3 | Textural characteristics of chickpea flat bread

It could be observed from Table 4 that chickpea flour bread made without barley flour addition required higher amount of force to rupture or tear compared with barley added breads. The $F_{\text{max}}$ and $\%$ barley addition were negatively correlated ($R^2 = -.992$, $p < .01$). This reduction might be due to the fact that barley flour increased the starch content of CFB, and added gluten protein to doughs due to which breads became softer (Noor Aziah et al., 2012). Extensibility is defined as the distance up to which CFB could be stretched without rupture. The chickpea flatbreads with higher extensibility values indicate more freshness and are a preferred sensory attribute in case of flat bread. It could be observed from Table 4 that control bread was less elastic, whereas extensibility increased significantly with the progressive increase of barley flour content ($R^2 = .964$, $p < .01$). This increase is due to the gluten protein present in barley flour that made breads more elastic as compared with gluten-free control bread. Most of the previous studies (Hefnawy et al., 2012; Pasqualone et al., 2019; Zafar et al., 2020) reported addition of chickpea flour to different types of wheat flour breads. Mohammed et al. (2012) reported a high reduction in elasticity of bread in which wheat flour was supplemented with 30% chickpea flour. This study in contrary reports a different kind of bread made completely with chickpea flour and therefore is very hard, so the aim of this investigation was to increase elasticity and softness of chickpea breads by adding barley flour. The textural characteristics measured objectively using universal testing machine indicated increase in elasticity and reduction in hardness of bread on replacing chickpea with barley flour.

3.4 | Sensory analysis of chickpea flat bread

Sensory attributes of CFBs with and without addition of barley flour are presented in Table 5. Hardness was observed to decrease

TABLE 3 | Effects of barley flour on flow behavior index ($n$) and consistency coefficient ($k$) of chickpea flour bread doughs

| Barley flour (%) | $G'$ | $G''$ |
|------------------|-----|------|
|                  | Slope ($n$) | Consistency coefficient ($k$) | $R^2$ | Slope ($n$) | Consistency coefficient ($k$) | $R^2$ |
| Control (0%)     | 0.17 ± 0.06$^b$ | 5.23 ± 0.06$^c$ | 0.95 | 0.28 ± 0.15$^c$ | 4.73 ± 0.38$^c$ | 0.98 |
| 10%              | 0.14 ± 0.06$^b$ | 5.12 ± 0.26$^k$ | 0.93 | 0.25 ± 0.06$^b$ | 4.60 ± 0.25$^b$ | 0.97 |
| 20%              | 0.11 ± 0.06$^a$ | 5.08 ± 0.03$^k$ | 0.87 | 0.22 ± 0.06$^k$ | 4.55 ± 0.12$^b$ | 0.96 |
| 30%              | 0.12 ± 0.13$^k$ | 5.17 ± 0.67$^k$ | 0.91 | 0.22 ± 0.31$^a$ | 4.62 ± 0.11$^k$ | 0.96 |
| 40%              | 0.15 ± 0.04$^b$ | 4.70 ± 0.12$^a$ | 0.95 | 0.25 ± 0.00$^b$ | 4.32 ± 0.06$^a$ | 0.94 |

Note: Means with different superscript lowercase letters within a column are significantly different at $p < .05$.

TABLE 4 | Effects of barley flour addition on textural characteristics of chickpea flour bread

| Barley flour (%) | $F_{\text{max}}$ (g) | $\varepsilon$-$F_{\text{max}}$ (mm) |
|------------------|----------------------|-------------------------------|
| Control (0%)     | 16.02 ± 0.48$^a$    | 1.73 ± 0.28$^a$              |
| 10%              | 13.51 ± 0.95$^b$    | 1.76 ± 0.40$^b$              |
| 20%              | 11.62 ± 0.33$^c$    | 2.34 ± 0.04$^c$              |
| 30%              | 10.36 ± 0.68$^b$    | 2.62 ± 0.13$^b$              |
| 40%              | 8.75 ± 0.71$^a$     | 3.36 ± 0.17$^c$              |

Note: Means with different lowercase letters within a column are significantly different at $p < .05$.

Abbreviations: $F_{\text{max}}$: force to tear; $\varepsilon$-$F_{\text{max}}$: extensibility.
significantly with the addition of barley flour, suggesting formation of softer breads compared with control due to development of gluten network. These are also in agreement with the results of hardness (Table 4) measured objectively. Mohammed et al. (2014) also reported decrease in hardness of crumb texture for wheat–chickpea composite breads. Results showed that in terms of hardness and appearance, panelists gave higher scores to CFBs prepared with barley flour, whereas in terms of overall acceptability, no significant difference was observed between control bread and CFBs containing up to 30% barley flour content. Flat breads made with 30% and 40% barley flour were perceived for characteristic barley aroma and were given slightly lower scores, whereas flavor of all the CFBs did not show any significant difference as compared with control.

### 3.5 Glycemic index of chickpea flat bread

The maximum hydrolysis extent or equilibrium concentration (C∞) defines the values of starch hydrolysis. It could be observed from Table 6 that control CFB had the highest equilibrium concentration, which decreased significantly with the addition of barley flour up to 40%. This reduction in C∞ was due to the high fiber content in barley flour, which is in agreement with proximate analysis results as mentioned in Table 1. Similar reduction in C∞ was found by Mansoor et al. (2019) in their barley added rotis. In early stage, kinetic constant reflects the hydrolysis rate. However, in the present study, all CFBs showed insignificant difference in kinetic constant values. The hydrolysis index (HI) is another parameter, which was obtained by dividing the area under the hydrolysis curve of each sample by the corresponding area of a reference sample (white bread) over the same period of time (Segura & Rosell, 2011). HI of CFBs with barley flour addition greater than 10% showed significant decrease as compared with control bread. It could be noticed from Table 6 that expected glycemic index decreased with the addition of barley flour into chickpea flour. Almost 8% decline was observed in pGI of CFB made with 40% barley flour addition, suggesting barley as a source of a high fiber content for reducing the glycemic index of foods. Cavallero et al. (2002) and Collar and Armesto (2018) also reported similar results when barley was added to wheat-based breads.

### 4 CONCLUSION

Chickpea flour-based flat breads are usually hard and less elastic, which makes it unpopular for daily consumption. Addition of barley flour increased softness and elasticity of breads besides being low on glycemic load. However, addition of barley addition did not bring any significant change in sensory attributes. Flat breads being staple food are consumed almost with every meal in South Asia. Preparation of healthier flat breads using combination of barley and chickpea flours will not only increase daily fiber uptake values but will also include both cereal and legume proteins in daily diet that can cover all essential amino acids. Development of such flour blends would be beneficial to improve the nutritional value of bread and will reduce the spike of glucose and cholesterol in blood after ingestion. In future, availability of different composite chickpea–barley flour breads in the market will lead to increased barley flour consumption as breads are considered staple food in many countries around the world.

### CONFLICT OF INTEREST

There is no conflict of interest to declare.

### AUTHOR CONTRIBUTIONS

Tahira Mohsin Ali and Remal Mansoor designed this research study. Remal Mansoor conducted the experiments. Tahira Mohsin Ali and Abid Hasnain supervised the work. Remal Mansoor prepared the
original manuscript, and Tahira Moin Ali contributed to the manuscript revision.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon request.

ETHICS STATEMENT
This article does not contain any in vivo studies with human participants (except flat bread sensory test) or animals performed by any of the authors.

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