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Research Article

Effect of Soaked Barley Flour Incorporation in Whole Wheat Flour on the Nutritional Characteristics and Acceptability of Flat Bread (Chapatti)

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ABSTRACT

Pre-cleaned wheat grains were milled to produce whole wheat flour. Cleaned barley grains were soaked in water overnight which were dried till the desirable moisture of 9.0 % and milled to produce barley flour. After this, composite flour of wheat and soaked barley was made at a combination of 0, 5, 10, 15, 20, and 25% barley in the whole wheat flour. The composition and rheology of composite flour were tested and then the chapatti was made from different combinations of flour blend. A sensory evaluation of wheat barley chapatti was also done to know product acceptability. It was observed that protein, ash, beta-glucan, energy value, mineral digestibility (20.28%), and protein digestibility rate (47.96%) increased significantly while the gluten, carbohydrates, and phytates decreased in a significant manner. Dough rheology depicted a significant increase in water absorption and dough development time while dough stability was reduced. Moreover, chapatti developed from 20% soaked barley flour had a significant increase in protein, ash, beta-glucan, and calorie value but carbohydrates were momentously reduced. To summarize, chapatti made from a blend of 20% soaked barley flour in whole wheat flour had increased nutritional value (more mineral and protein digestibility) and good acceptability.

Keywords: Soaked barley, Whole wheat flour, protein digestibility, nutritive chapatti

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INTRODUCTION

Wheat can be incorporated with different grains to enhance the nutritional benefits of the different developed foodstuffs. Milled barley blended with whole wheat flour has been shown to increase its nutritive advantages upon consumption (Narwal *et al.*, 2017). Barley grain is considered to be rich in several nutritional components (Abdullah *et al.*, 2023). Its consumption as food by humans, however, is restricted while this grain can be added into other cereals to develop a variety of value-added foodstuffs (Narwal *et al.*, 2017). Previously, it has been shown that barley incorporation in the whole wheat flour substantially increased the nutritive quality of finished products such as antioxidative potential, polyphenols and beta-glucan level (Abdullah *et al.*, 2021). Additionally, barley addition in whole wheat flour at the domestic scale is easy and by doing so health of the consuming population can be improved. Natural wheat carries meager beta-glucan contents (0.5%) (Gebruers *et al.*, 2008). On the other hand, barley is a good reservoir of beta-glucan and with the blending of barley flour in the whole wheat flour resultant wheat product could exhibit itself as a very good source of beta-glucan. Previously, we (Abdullah *et al.*, 2023) have shown that chapatti prepared from wheat (70%) and barley (25%) flour blends carried beta-glucan content of 2.5%. Likewise, the raw blended flour also exhibited a significant rise in its bet-glucan contents. Based on the recommendation of the Food and Drug Administration, USA, the beta-glucan should be ingested each day by an individual either through barley or by oats. Moreover, the International Food Safety Organization has also recommended the same daily dose of beta-glucan. This is recommended that beta-glucan and phenolic compounds (avenanthramides) should be added to everyday food baskets like FPIs (Gao *et al.*, 2015).

Soaking of grains and their products is a useful technique for the elimination of various undesirable anti-nutritional factors. Besides this, it also decreases culinary duration. Various enzymatic reactions involved in the discharge of phytase are increased in the food grains and other seeds because of soaking. It also helps supply necessary moisture content to different food grains and seeds that facilitate the sprouting process and decrease the enzyme inhibiting agents along with other undesirable anti-nutritional factors to improve their digestion and nutritive quality (Kumari 2018).

It was investigated during a study that soaked grains and beans have increased levels and bioavailability of microelements and possessed more protein digestibility and absorbability in addition to reduced levels of phytates (Coulibaly *et al.*, 2011). Similarly, in grams, phytates reduction increased from 48-56% upon enhancing the soaked interval from 1.5-11.5 hours (Ertaş and Turker 2014). Simple food handling techniques are highly acceptable and beneficial for common populations as compared to large-scale food management approaches due to less availability of centralized formed food for the rural communities. Hence, (Hotz 2000) targeted to reduce the phytate content of chapatti using a simple home-scale technique (soaking).

Wheat flour is used in making chapatti, leavened bread, and other baked foodstuffs. Intake of whole cereal grains in food products is beneficial for human health. However, they might contain anti-nutritional ingredients that can impede nutrient bioavailability and absorption. By applying soaking techniques, protein and minerals digestibility rate is significantly improved and anti-nutritional factors such as phytates and polyphenols are noticeably decreased (Afify *et al.*, 2012). Furthermore, soaking has been reported to promptly reduce ~ 85% of anti-nutritive agents (Baranwal *et al.*, 2014). In ancient eras, grains were soaked that improve digestibility, taste, and nutrient bioavailability and to reduce cooking time.

Based on the health benefits of the barley, we prepared chapatti developed from soaked barley and whole wheat flour with an aim to enhance the overall nutritive properties. Dough rheology, mineral digestibility, protein digestibility, nutrient composition, and acceptability of the functional chapatti were tested so as to identify the chapatti treatment with good dietary quality and acceptability.

MATERIALS AND METHODS

Materials

We procured grains of the barley variety “Jau-17” and wheat variety “Anaj-17” from the Wheat Research Institute, Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan. The grains of both crops were hand-threshed and cleaned by removing dirt, dust, and stones. Furthermore, defective food grains and grains of other crops such as oats and impurities including weed seeds were removed.

Soaking of barley grains and production of barley flour

Cleaned barley grains were soaked in water following the method adopted by Hotz with modifications. Grains were kept in a plastic jar and dipped in water about four times the weight of the immersed barley grains and left for overnight intervals. Then the grains were shifted to steel trays and air-dried in the oven until the kernel moisture reached 9±0.5%.

The dried grains were then milled in the Lab mill (LM-130, Perten, Sweden) and packed in air-tight plastic jars, and stored at room temperature (25 °C) for further use. Likewise, cleaned wheat grains of Anaj-17 were milled, and the resulting whole wheat flour was packed in an airtight plastic jar and stored at a temperature of 25 °C for further utility. Soaked barley flour was added at the rate of 0-25% (hereby termed as S0, S1, S2, S3, S4, and S5 with 100-0%, 95-5%, 90-10%, 85-15%, 80-20%, and 75-25% wheat-barley blend, correspondingly) in the whole wheat flour to develop the functional chapatti according to Table 1.

Quality composition of the composite blend

Proximate components of the blend were analyzed following the relevant AOAC (Chemists 1995) procedures. Moisture, starch, protein, and gluten were estimated in ISO-17025:2017 accredited lab through the calibrated Instrument Kernelyzer (Model No. 21G802699, Bruins, Germany). The calorific content of the blend was assessed by using the Combustion Calorimeter (CAL3K, DDS, South Africa). Estimation of beta-glucan was carried out according to Hussein *et al.*, (2006) while phytic acid was appraised through the method of (Haug and Lantzsch 1983). To estimate mineral and protein digestibility in vitro, 1 g sample was incubated in pepsin solution (containing one liter hydrochloric acid and two g pepsin) at 38 °C for 90 minutes and filtered through ash-free filter paper. Residues along with filter paper were ignited in the Muffle furnace and ash content was recorded. Mineral and protein digestibility rates were calculated according to the formula:

$$\text{Mineral digestibility rate ((\%)} = \frac{\text{Digestible content of minerals}}{\text{Total minerals}} \text{ x } 100$$

$$\text{Protein digestibilty rate (\%)} = \frac{\text{Nitrogen of super natatant} - \text{Nitrogen of pepsin}}{\text{Total nitrogen in the sample}} \text{ x } 100$$

Table 1. Six different samples (one control and 5 blends) of whole wheat (raw)-barley (soaked) flour

Samples	Whole wheat flour (%)	Soaked barley flour (%)
S0	100	0
S1	95	5
S2	90	10
S3	85	15
S4	80	20
S5	75	25

Rheological Properties of Flour Blend

The dough rheological properties of the five treatments were analyzed using the AACC method No. 54-20 (AACC, 2010a) with a calibrated Farinograph-E (Model No. 1923040, Brabender, Germany). Additionally, the falling number was determined following AACC method No. 56-81.04 (AACC, 2010b).

Production of chapatti from soaked barley flour-whole wheat flour blend

Composite chapatti of all five treatments of soaked barley-wheat flour blend was prepared employing the procedure established by (Haridas Rao *et al.* 1986). Briefly, in 200 g flour, 65-70% water was added, and both ingredients were uniformly mixed for ~ 90 seconds in a Hobert mixer to develop the dough for each treatment. Then the dough was given a resting period of 60 minutes at room conditions.

Then a piece of 80 g dough was taken and shaped into a ball and then spread to make chapatti on a specific dais structure using a roller pin. Each chapatti was prepared (2 mm thick) from all five treatments using PDS-380C (sheeting machine). Chapatti baking was performed at 210-215 °C on a controlled temperature griddle (DB-2, Germany) for 90 seconds. The hot chapattis after baking were cooled at 25 °C to perform the sensorial evaluation and then stored in bi-oriented polypropylene bags (BOPP) at 18-20 °C for other testing.

Composition of composite chapatti

Baked chapattis of all five treatments were analyzed for different proximate parameters following the recommended methods (AACC 2010a). The calorific value and beta-glucan content of the stored product were assessed by following the methods described previously.

Sensory Quality of Chapatti

Sensorial attributes of the chapattis were evaluated by six well-trained sensory judges who employed a 9-point hedonic scale according to Meilgaard technique (2007). Prepared chapattis kept at 25 °C for 20 min were sent to the concerned lab and presented before the judges along with necessary “Evaluation Performa” for evaluation of sensory characteristics.

Statistical analysis

All the observations were recorded in triplicates. The outcomes discussed in the present trial were articulated as mean values ±standard error of mean values. The significance of the results through the application of statistical tools was assessed using the analysis of variance technique (ANOVA) while Tukey’s test (comparing the mean values of different variables) was performed in R environment version 3.6.3. The investigated means derived from the collected data had $p \leq 0.05$ as the significance level.

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RESULTS

Composition of the flour blend

Quality characteristics of the flour blend increased significantly while gluten, carbohydrates and phytates followed a significant decrease in all soaked barley flour treatments than the control (Table 2). Mean beta-glucan content was lowest in S0 (0.91 %) which increased to the maximum (2.21%) in S5 (Table 2). Likewise, the mean protein content of composite flour was the lowest in S0 (11.29%) and the highest in S5 (13.19%). Ash content was also the lowest in S0 (1.67%) and highest in S5 (2.12%). Moreover, the energy content of the composite flour was also lowest in S0 (340.12 kcal) and highest in S5 (345.22 kcal). On the contrary, mean values of gluten (29.63%), carbohydrates (72.4%) and phytates (1910 mg/100g) were highest (Table 2) in S0 and decreased significantly to 18.21%, 71.6% and 1559.22 mg/100g, respectively in S4 and further in S5.

Table 2. Moisture, protein, gluten, fat, carbohydrates, ash, energy contents, falling number, beta-glucan phytates concentration (on dry weight basis), Protein and Mineral digestibility (%) in the samples.

Samples	S0	S1	S2	S3	S4	S5
Moisture(%)	11.5±0.03^{c*}	11.6±0.06^{c}	11.8±0.06^{b}	11.8±0.06^{b}	11.9±0.06^{ab}	12±0.06^{a}
Protein (%)	11.29±0.02^{f}	11.82±0.01^{e}	12.47±0.01^{d}	12.81±0.01^{c}	12.92±0.01^{b}	13.19±0.01^{a}
Gluten (%)	29.63±0.01^{a}	29.17±0.01^{b}	24.23±0.01^{c}	22.9±0.06^{d}	18.21±0.01^{e}	13.56±0.01^{f}
Fat (%)	1.16±0.01^{b}	1.17±0.01^{ab}	1.18±0.01^{ab}	1.19±0.01^{a}	1.19±0.01^{a}	1.17±0.01^{ab}
CH_2O (%)	72.4±0.06^{a}	71.6±0.03^{b}	71.4±0.06^{bc}	71.2±0.12^{bcd}	71±0.29^{cd}	70.9±0.06^{d}
Ash (%)	1.67±0.01^{d}	1.68±0.01^{d}	1.69±0.01^{d}	1.72±0.01^{c}	2.09±0.01^{b}	2.12±0.01^{a}
Energy (kcal)	340.12±0.01^{f}	340.83±0.03^{e}	341.5±0.01^{d}	342.33±0.01^{c}	343.44±0.01^{b}	345.22±0.01^{a}
FN (sec)	464±0.58^{b}	442±0.29^{d}	466±0.29^{a}	467±0.29^{a}	452±0.29^{c}	435±0.29^{e}
Beta-glucan (%)	0.91±0.01^{f}	1.09±0.01^{e}	1.59±0.01^{d}	1.77±0.01^{c}	1.99±0.01^{b}	2.21±0.01^{a}
Phyt(mg/100g)	1910±0.97^{a}	1852.5±0.29^{b}	1759.3±0.17^{c}	1655.8±0.12^{d}	1559.2±0.01^{e}	1431.4±0.03^{f}
PD (%)	60.67±0.09f	64.75±0.05e	68.72±0.01d	76.45±0.02c	82.34±0.02b	89.77±0.03a
MD (%)	45.32±0.17f	47.23±0.01e	49.89±0.01d	50.34±0.01c	52.77±0.02b	54.51±0.01a

*Letters in superscript indicate that the values are significantly different from each other. CH_2O (Carbohydrates), FN (Falling number value), Phyt (Phytates), PD (Protein digestibility) and MD (Mineral digestibility).

The mean value of mineral digestibility was found to be lowest (45.32%) in the control treatment (S0) which showed a significant increase in all soaked barley treatments where the highest value was recorded in in S4 (52.77 %) and S5 treatments. A similar trend was observed in protein digestibility rate which was lowest (60.66%) in control treatment (S0) that showed an increasing trend till S5 (89.77 %) (Table 2).

Rheological behavior of flour blend and nutrient content of soaked barley composite chapatti

The analysis of variance (ANOVA) indicated that rheological properties of the soaked barley-wheat flour blend also exhibited significant changes in water adsorption capacity (60.51±0.01f-68.22±0.01a), dough development time (1.55±0.01f-2.95±0.01a) and dough stability time (4.17±0.01a-1.44±0.01f). Our analysis of the proximate composition of chapatti revealed that the quality characteristics of the soaked barley and whole wheat composite chapatti (moisture contents, protein, ash, energy and beta-glucan contents) increased considerably from S1 to S5 whereas the fat and carbohydrate contents decreased from S1 to S5. For instance, a significant increase was evident in protein contents that improved from 10.9% in S0 to 12.89 in S5. Ash contents also increased significantly from S0 (1.47%) to S5 (1.92%). An increase in energy content was also witnessed from S0 (330.22 kcal) to S5 (334.99 kcal). Remarkably the beta-glucan contents almost tripled from S0 (0.64%) to S5 (1.92%). On the contrary, the carbohydrate contents decreased from S0 (54.62%) to S5 (51.53%) whereas the increase in fat contents from S0 to S5 was inconsistent (Table 3).

Sensory evaluation of chapatti

According to ANOVA, sensory evaluation of soaked barley-based developed chapatti (S1-S5) showed significant variation in comparison to the control chapatti S0. Sensory attributes of the control chapatti S0 were highest and as the incorporation level of soaked barley increased in the flour, chapatti acceptability quality was affected. Although the incorporation of soaked barley in the whole wheat flour has a good impact on chapatti and even at 20% addition of soaked barley flour into the whole wheat flour, color, texture, taste, chewability, aroma, flavor and overall acceptability score of developed chapatti varied from 9.0-7.0, 9.0-7.1, 9.0-7.2, 9.0-7.5, 9.0-7.0, 9.0-7.5 and 9.0-7.4, correspondingly. All the sensory attributes of the control chapatti showed excellent product acceptability while soaked barley chapatti formulated to S4 level depicted good acceptability too while the product acceptability at 25% barley incorporation level (S5) was highly compromised (Table 4).

Table 3. Moisture, protein, fat, carbohydrates, ash, energy and beta-glucan contents of chapatti prepared from various flour blends (on dry weight basis).

Samples	S0	S1	S2	S3	S4	S5
Moisture (%)	29.51±0.01^{f*}	29.55±0.01^{e}	29.76±0.01^{d}	30.22±0.01^{c}	30.29±0.01^{b}	30.41±0.01a
Protein (%)	10.9±0.06^{f}	11.23±0.01^{e}	11.69±0.01^{d}	12.48±0.01^{c}	12.69±0.01^{b}	12.89±0.01a
Fat (%)	1.03±0.01^{c}	1.04±0.01b^{c}	1.05±0.01^{ab}	1.04±0.01b^{c}	1.06±0.01^{a}	1.05±0.01^{ab}
CH_2O (%)	54.62±0.01^{a}	53.68±0.01^{b}	52.77±0.01^{c}	52.45±0.01^{d}	52.01±0.01e	51.53±0.01^{f}
Ash (%)	1.47±0.01^{e}	1.48±0.01d^{e}	1.49±0.01^{d}	1.52±0.01^{c}	1.89±0.01^{b}	1.92±0.01^{a}
Energy (kcal)	330.22±0.01^{f}	331.85±0.01e	332.27±0.01^{d}	333.31±0.01^{c}	334.18±0.01^{b}	334.99±0.01^{a}
Beta-glucan (%)	0.64±0.01^{f}	0.76±0.01^{e}	1.28±0.01^{d}	1.79±0.01^{c}	1.87±0.01^{b}	1.9±0.01^{a}

*Letters in superscript indicate that the values are significantly different from each other. CH_2O (Carbohydrates).

Table 4. Sensory evaluation of chapatti prepared from wheat flour and soaked barley flour

Variable	S0	S1	S2	S3	S4	S5
Color	9±0.00^{a*}	8.8±0.06^{b}	8.5±0.06^{c}	8±0.06^{d}	7±0.06^{e}	5.5±0.06^{f}
Texture	9±0.00^{a}	8.7±0.06^{b}	8.2±0.06^{c}	8±0.06^{d}	7.1±0.06^{e}	5.5±0.06^{f}
Taste	9±0.00^{a}	8.5±0.06^{b}	8.2±0.06^{c}	8.1±0.06^{c}	7.2±0.06^{d}	5±0.06^{e}
Chewability	9±0.00^{a}	8.5±0.06^{b}	8.1±0.06^{c}	8±0.06^{c}	7.5±0.06^{d}	6±0.06^{e}
Aroma	9±0.00^{a}	8.5±0.06^{b}	8±0.06^{c}	7.9±0.06^{c}	7±0.06^{d}	5±0.06^{e}
Flavor	9±0.00^{a}	8.5±0.06^{b}	8.1±0.06^{c}	7.8±0.06^{d}	7.5±0.06^{e}	6±0.06^{f}
OA	9±0.00^{a}	8.5±0.06^{b}	8.2±0.06^{c}	8±0.06^{d}	7.4±0.06^{e}	5.8±0.06^{f}

*****Different letters in superscript indicate that the values are significantly different from each other, OA=overall acceptability.

DISCUSSION

A significantly large proportion of wheat in South Asian countries is consumed as chapatti and its synonymous forms, for instance, roti, naan paratha, etc. Despite carrying good nutritional ingredients, wheat flour also contains certain elements that hinder the incorporation of minerals. This can be mitigated by incorporating barley flour during the making of dough (Lukinac and Jukic 2022). This practice has been evidenced to reduce the phytate contents in the resulting bread.

To withstand conventional wheat-related dietary systems, this is necessary to maintain a steadiness between modern approaches and ethnic practices. Approaches to use conventional awareness along with modern practices may help overcome food security issues in the masses (Boukid 2025). The effect of barley supplementation on cookie quality was estimated previously by (Masoodi 2017) who concluded that 25% barley incorporation in wheat flour significantly enhanced moisture (10.6-12.0%), crude protein (11.7-13.9%), crude fat (1.3-3.3%), ash content (0.54-1.09%) and calorific value (361.0-363.9 kcal per 100g) of the flour blend. However, carbohydrates (76.00-69.80%) were significantly reduced as the level of barley flour fortification was higher. The moisture content of barley is more than that of wheat because it is high in fiber so when barley is added to the wheat flour, the moisture and ash content of the composite flour are enhanced. Moreover, barley contains low phytates and as a result, ash content increased in the flour blend with progressive addition of its flour in the wheat flour. Barley also contains a higher protein content and hence addition of barley has increased the protein content of the wheat barley composite flour. The carbohydrate content of the flour blend was decreased which might be from the barley that activates starch hydrolyzing amylase enzymes and consequently, the protein content is enhanced. As barley has somewhat more fat than wheat so barley fortified flour has increased fat than the control and due to the increase in protein and fat of the composite flour, its calorific value is also raised. Our results are in close agreement with (Abdullah *et al.*, 2021) who developed chapatti from the supplementation of germinated barley flour into whole wheat flour. Likewise, since we used soaked barley in our investigation, our moisture contents in S4 (11.9%) and S5 (12%) were considerably higher than those reported by [S4 (10.6%) and S5 (10.58%) where raw barley flour was incorporated in wheat flour. The International Codex Organization (2016) specified the limits of flour blends' moisture contents to be < 15.6% for composite flour. Additionally, (El-Yamlahi and Ouhssine 2013) found the maximum moisture percentage of ≤ 12.0%

in composite flour blends. Thus, our results are also in line with (El-Yamlahi and Ouhssine 2013) and International Codex Organization (2016). Furthermore, this moisture % also had an increasing effect on the falling number in the same treatments accordingly. For instance, a study reported the falling number as 398 ±0.29 and 389 ± 0.87 in S4 and S5, correspondingly. On the other hand, the falling number in the current investigation was 452 ±0.29 and 435 ±0.29, respectively, in S4 and S5. In the current study of soaked barley chapatti, in vitro mineral and protein digestibility increased significantly at 20% supplementation of soaked barley (Table 2). This may be attributed to the protein solubility which increased during the soaking process. In addition to that, phytase enzymes were activated which break down the phytates resulting in enhanced mineral and protein digestibility. A significant increase in mineral digestibility and a decrease in anti-nutritional factors (phytates and polyphenols) due to soaking have been reported in wheat, supporting our findings. The authors further highlighted a negative correlation between mineral bioavailability and anti-nutritional factors during the soaking process of cereal grains (Arif *et al.*, 2011; Sorour *et al.*, 2021).

Additionally, Afify *et al.* (2012) further corroborated our results which explored those bioprocesses increased protein digestibility of sorghum and barley from 60-65 and 60-80% when the grains were soaked at 20 °C for a period of 72-120h. Moreover, the said treatment increased protein digestibility of pearl millet from 30-57% at 16-20°C after an interval of 96h. A previous report has reported that the water absorption capacity of blend amplified to 66.3 and 71.1% of flour incorporated with 20 and 40% barley meal, respectively, whereas the water absorption capacity was 60.6% for the placebo sample of whole wheat flour. This could be attributed to the fact that blend is supplemented with fiber fraction which in turn increases the water absorption capacity of dough. It is also proven (Sharma and Gujral 2014) that a high quantity of water was needed for optimum dough kneading containing barley. They described further that the composite flour blend of wheat and barley has increased water absorption capacity as compared to the control treatment of whole wheat flour.

Fiber has hydroxyl linkages which are the reason for the interrelation of H2O molecules with the H2 bonds and as a result affinity of the blend to absorb water is enhanced. Similarly, dough development followed the same trend during a study and jumped up to 3.1 minutes when the supplementation level of barley flour in the wheat flour was 40% while it was only 1.6 minutes for the placebo treatment of whole wheat flour. However, dough stability did not follow the same drift and was less in the 40% barley flour supplementation due to the reason that fiber portion distracts linkages between starch and gluten and thus reduces the blend stability span, but the dough stability time increased to peak value at 20% barley incorporation than the placebo treatment. It is well established that blend stability is more acceptable if it remains for a longer period (Mehfooz *et al.*, 2018). More recently, another study has reported that the addition of β-glucan-rich flour has been found to influence the rheological properties of the dough, resulting in longer development times and decreased stability compared to control samples (Kovac and Bregar, 2024), which is concurrent with our findings also.

Phytate is the chief stored type of important mineral “phosphorus (P)” found in food grains that binds microelements and averts their duodenal assimilation. Some preliminary practices of drenching, sprouting, fermentation, and use of phytases are available that are effective in reducing the prevalent phytates in cereals and other seeds (Gupta *et al.*, 2015). Phenolic compounds also have the property to bind proteinaceous matter, amino compounds, and microelements like Fe, Zn, and Ca of various dietary items (Gilani *et al.*, 2005). Therefore, these interfere with bio-accessibility of indispensable microelements, and a decline in these phenolic compounds might improve the bioavailability of these essential dietary ingredients. It has been realized that the soaking of grains helps in the discharge of phytase. It also helps supply necessary moisture content to different food grains and seeds, thus facilitating the sprouting process and decreasing the enzyme-inhibiting agents, along with other undesirable anti-nutritional factors to improve their digestion and nutritive quality (Kumari 2018). When we incorporated the soaked barley flour into the wheat, we also witnessed a significant reduction in the phytate contents of the resulting blended flour, thus supporting the findings of Kumari (2018). Moreover, our phytate contents were also considerably less in the corresponding treatments (1910 ±0.97 to 1431 ±0.03 mg/100g) than in our previous report (Abdullah *et al.*, 2023) where phytate contents ranged from 1920.3 ±0.92 to 1535 ±0.01 mg/100g because of the use of soaked barley in the current investigation.

Soaking is an important processing technique that is being used on commercial and home levels. Soaked cereal grains for the development of value-added products pass through spontaneous acidic fermentation, which improves dietary nutritional value. Similarly, soaking maize flour at ambient conditions (23-25 °C) for one hour removes the phytates by > 50% (Hotz 2001). Cereals and other grains soaked for at least 12 h have considerable removal of phytates followed by enhanced bioavailability of microelements. Because the activity it of phytases is optimum at somewhat warm and slightly acidic conditions, it is good to use slightly hot water, and citrus extract should be preferred during soaking. During a study, whole wheat milled in the lab mill had an extraction rate of more than 94% while it contained 9.3% protein and 1.87% mineral matter (Wang *et al.*, 1998). The whole wheat flour's water absorption capacity was 61.5%. The water absorption capacity of the dough increased due to whole wheat flour, protein, and ash content, but incorporating barley flour significantly contributed in this regard. The water absorption capacity of the blend rose to 65.6% at 20% barley incorporation. The decrease in the extensible property of stored chapatti was also less due to the added barley flour signifying that soluble fiber beta-glucan present in the barley might be the reason to retard the chapatti firmness (Wang *et al.*, 1998). Soluble fibers like glucans increase the extensible property by arranging a high quantity of water during dough formation, refining the mechanized power of the watery film, and connecting through a constant proteinous phase in the kneaded flour (Wang *et al.*, 1998). Beta-glucans prevent recrystallized starch production due to the absorption of more water content, leaving less starch for the recrystallization phenomenon. Additionally, it is also reported that 20% supplementation of germinated barley flour into whole wheat flour for developing functional chapatti intensified the nutrient ingredients of chapatti (protein, ash, beta-glucan, fat, and energy) and pacified the carbohydrate contents (Abdullah *et al.*, 2023).

In further reports related to barley flour-supplemented chapatti, ash was found to be lowest in the placebo treatment of whole wheat flour but was highest in the treatment containing 30% barley flour. A comparable verdict was also given in a related investigation. The reason was that barley flour has a noticeable quantity of fiber and consequently appears blacker and is rich in minerals matter as compared to wheat.

In the above study, the protein content of the barley-supplemented flour was found in the range of 11.55-13.2%, which was less in wheat flour and highest in the 30% barley-supplemented flour. A study of bajra (pearl millets)-based supplemented wheat flour depicted the same values of protein at 10-30% incorporation level (Beswa 2008). The findings of our study are also supported by the results of Ejaz (2014). Elsewhere, protein content was recorded more in barley cultivars than wheat and described the core cause of high protein levels examined in barley varieties during his study. This could be attributed to the use of nitrogenous fertilizers that enhance the storage form of proteins that are concentrated more in barley in comparison to wheat.

Previously, chapatti was made from whole wheat flour incorporated with barley flour at a level of 5 to 30%, and quality scoring (physico-chemical, culinary, and sensorial attributes) was performed (Sharma and Gujral 2014). The authors found that composite flour chapatti revealed altered taste perception even at a level of only 5% addition of barley flour. On the flip side, the acceptability score of chapatti made from 30% barley flour incorporation reduced from 8.7 to 7.24 which was attributable to minor variations in product appearance and palatability. Hence at 30% level of barley incorporation, the reduction in chapatti quality scored < 16% and the product had sufficient acceptability. Later investigation reported a sensorial score of 4.55-8.91 about the overall acceptability of barley-supplemented chapatti (Arshid *et al.*, 2018). Chapatti prepared from 30% supplemented barley flour (with 4% additional blend) got a maximum sensory score of 8.91 and had a good appearance, better taste perception, better foldability, fine texture, and least score of 4.55 was noticed in the chapatti developed from 10% barley flour supplementation (with 6% additional blend).

Chapatti prepared from the treatment having 30% supplemented barley flour (with 4% additional blend) had greater sensory and nutritional quality (Arshid *et al.*, 2018). In the current work, we also report that the sensory acceptability score of supplemented flour chapatti was greatly influenced due to the difference in sensory acceptability of barley and other supplemented functional ingredients, which is also in line with the conclusions drawn in a previous study (Ejaz 2014; Koksel *et al.*, 2024).

CONCLUSION

In summary, we found that the addition of 20% soaked barley flour into wheat flour considerably enhanced the proximate quality parameters, beta-glucan, energy value, and mineral and protein digestibility of the blend. On the flip side, gluten, phytates, and carbohydrates revealed a significant reduction at this substitution level. Rheological properties revealed a reduction in stability but an increase in water absorption and developing time of kneaded flour. Likewise, chapatti developed from 20% incorporation of soaked barley flour had an increase in protein, ash, energy, and beta-glucan content while decrement in carbohydrates. Additionally, chapatti made from composite flour (80% wheat and 20% barley) had an acceptable range of quality scores. When compared to our previous report where we used raw barley flour, the chapatties prepared from 20% soaked barley flour blend in this investigation carried less phytate and carbohydrate contents, more ash contents, and had better acceptable scores.

AUTHOR CONTRIBUTIONS

MA Conceived the idea, designed the study, and wrote up the manuscript. JA Supervisor of the study, MARA Contributed to technical guidance, TT & MZ Helped in write-up and Review, MIK, AK Compiled data, SS & AM Conducted proof reading, AJ & AA Collected literature review, MN Helped in data collection, AH Conducted statistical analysis.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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