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ORIGINAL ARTICLE

Effect of brown rice flour fortification on the quality of wheat-based dough and flat bread

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Abstract The objective of present study was to investigate the impact of Brown Rice flour (BR) incorporation, at three different levels of 5, 10 and 15 % to the Wheat Flour (WF) preparations on rheological properties of wheat-based dough and quality of wheat-based flat bread. The BR flour incorporation mainly affected the chemical properties of flours, the rheological characteristics of dough and, quality and shelf life of bread. The protein-related properties of flours principally experienced reduction; however, the ash content had an increase, along with BR flour incorporation. The rheological properties of dough were affected considerably by BR flour substitution, wherein the sample containing 5 % BR flour was closest to BR flour-free dough (control). Regarding the yielded bread, BR flour addition affirmatively affected sensorial properties and firmness quality evaluation, wherein the bread made from dough with composite flour fortified with 5 % BR flour was scored the best. The findings from instrumental firmness quality assessment were confirmed as the bread containing 5 % BR flour remained softer and demanded lowest force to be compressed over the storage period. Overall, results showed that adding BR flour up to 5 % can be used in baking of flat bread since it meets the required criteria.

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Introduction

Wheat is one of the most appreciated cereals worldwide. China is ranked first to cultivate wheat (115,180,303 MT) and Iran is listed 12th. As a respect to rice paddy, the china is the first (197,212,010 MT), wherein Iran with 2,288,150 MT is not even among top-20 listed countries by FAO (2010). Based on unofficial statistics, wheat is the first highly-produced cereal crop (15,028,800 MT), however in value (1,918,070 Int $1,000) is forth after indigenous chicken meat, tomatoes and cow milk, respectively, in Iran (FAO 2010). Majority of wheat is milled into flour in order to make bread as a staple food for Iranian population (320 g/day per capita) (Anon 2005). In Iran, no official statistics exists on the quantity of bread which is being wasted; however, it is estimated that around 30 % of bread is wasted (Ghanbari and Shahedi 2008), which puts reducing the bread wastes in priority.

Barbary is one of the most popular types of flat breads made from wheat flour in Iran. According to the Institute of Standards and Industrial Research of Iran, Barbary is defined as the traditional flat bread made from wheat flour (locally named Setareh), water, salt and sour-dough or industrial yeast, which is made into variety of shapes and sizes (ISIRI 2002).

There are some attempts available, which have been made to improve the quality of Barbary bread. Sadeghi et al. (2008) evaluated the effect of *Lactobacillus sanfransicencis* (ATCC 14917) and *Lactobacillus plantarum* (ATCC 43332) on shelf life of Barbary bread and, reported that sour-dough containing these lactic acid bacteria had a significant effect on shelf life of bread and, the later bacterium was the best. Pourfarzad et al. (2011) found that propylene glycol could affect greatly the quality of Barbary bread made of composite flour fortified with soy flour. Majzoobi et al. (2011) demonstrated that the wheat-based bread made of blend flour, substituted with tomato pomace powder, had higher moisture content, softer texture and delayed staling when stored for 24–96 h at 25 °C. Finally, Milani et al. (2009) studied the effect of rice bran flour addition on dough rheological and textural properties of Barbary bread. They added different levels of rice bran flour (0, 3, 6 and 9 %) to two types of wheat flour (with 82 % and 88 % extraction rate) and, reported that blending the rice bran flour (6 %) with the wheat flour (82 % extraction rate) received the best scores, in the aspect of sensory evaluation.

Objective of present study was to investigate the effect of adding whole brown rice flour at different levels (5, 10 and 15 %) to wheat flour on the rheological properties (farinograph and extensograph properties) of yielded blend dough and, the quality (Sensory properties) and shelf life (Firmness quality, instrumental and by panelists) of Iranian flat Barbary bread incorporated with brown rice flour to introduce the best ratio of brown rice flour and wheat flour to apply.

Materials and methods

Materials

The commercial *Triticum aestivum* wheat flour (locally named Setareh with an extraction rate of 80 %, according to the manufacturer) was procured from Morshedy milling factory (Tehran, Iran). Brown rice was obtained from a reputable local de-hulling factory (Amole, Iran). The brown rice was milled by using Quadrumate Senior Mill (C. W. Brabender, Duisburg, Germany) and the dried active yeast containing *Saccharomyces cerevisiae* was purchased from local company (Fariman Ltd., Mashhad, Iran). All other applied chemicals were of analytical grade and purchased from local companies.

Dough preparation and flat bread making

Dough for bread making was prepared according to method 5809, described by the Institute of Standards and Industrial Research of Iran (ISIRI 2002). Bread dough was prepared by mixing all the ingredients with the appropriate amount of water, determined by Brabender Farinograph (Brabender Farinograph, C. W. Brabender, Duisburg, Germany), in a laboratory dough mixer (Hobart A200 20 qt, Hobart Corporation, Troy, OH, U.S.A.) at 140 rpm for 15 min. The yielded dough was placed in a proofing cabinet with the relative humidity of 85 % at 30 °C for 1 h, during which the volume of the dough increased due to yeast activity. Then, the dough was divided to 400-g portions, which was followed by hand rounding the portions and placing them in the proofing cabinet for another 10 min. Finally, the dough pieces were shaped using round metallic molds with the thickness of 2±0.2 cm, length of 70 cm and width of 30 cm and, were then baked in a baking oven (Model Karl Welkerkg, Wiesloch, Germany) at 220 °C for 20 min. The baked breads were immediately cooled down to the room temperature (30 °C) for 1 h. The thickness of yielded bread, after cooling period, was around 1±0.2 cm. The flat bread at this stage was referred to as fresh bread.

Determination of chemical properties of the flours

Chemical properties of the plain (BR flour-free) and blend flours including fiber, ash, protein, sedimentation, gluten index, wet gluten and dry gluten content were determined according to approved methods 32–07.01, 08–01.01, 46–14.03, 56–61.02, 38–12.02, respectively (AACCI 2000).

Determination of rheological properties of the dough

Mixing properties were evaluated according to approved method 54–21 (AACCI 2000), using a Brabender Farinograph (C. W. Brabender, Duisburg, Germany) and dough extensograms were evaluated according to approved method 54–10 (AACCI 2000), using a Brabender Extensograph (C. W. Brabender, Duisburg, Germany).

Sensory evaluation

Sensory analysis was performed using a 5-point hedonic scale (Azizi et al. 2003) of excellent (5), very good (4.5–4.99), good (4–4.49), acceptable (3–3.99) and unacceptable (<3). Sensory assessment was carried out by 9 trained panelists (5 males and 4 females with age ranging from 26 to 29). Eight properties of bread (i.e., form and shape, upper surface property, bottom surface property, cavity and porosity, firmness and softness of texture, chewability, odor, flavor and taste, and overall quality score) were selected according to Iranian flat bread evaluation method described by Rajabzadeh (1991). For each of the properties, the mean of panelist scores (n=3) was calculated.

Firmness quality analysis

Firmness quality analysis of the breads, thermo-sealed in the polyethylene bags and stored for 24, 48 and 72 h at ambient temperature (30 °C), was carried out according to approved method 74–30 (AACCI 2000), using a 6-point ranking test (completely soft=6, soft=5, slightly soft=4, slightly firm=3, firm=2 and completely firm=1). Firmness quality evaluation was performed by 9 trained panelists and the calculated values were the average of panelist scores (n=3).

Instrumental firmness quality analysis

The Texture analysis of breads was performed according to approved method 74–09 (AACCI 2000), employing the universal testing machine (Instron, Hounsfield, UK). In order to reach the thickness of 25 mm, two loaves of bread were placed upon each other. The employed compression force by the equipment was 40 % of bread thickness. An aluminum plunger, of 40 mm diameter, was used and, the cross-head and return speed was adjusted to 2 and 5 mm/s, respectively.

Statistical analysis

Statistical analysis of samples was performed according to approved method 78–60 (AACCI 2000). If differences existed in means, multiple comparisons were performed using Duncan's Multiple Range Test (DMRT) (confidence level, α: 0.05). SPSS 16.0.0 statistical software for windows (SPSS Inc., Chicago, USA) was used for data treatment and statistical analysis. The experiments were carried out in three replicates.

Results and discussion

Chemical properties of the flour

All chemical properties of samples were significantly affected by BR flour incorporation (Table 1), except for sedimentation wherein the significant value was obtained by adding BR flour at 15 % level (18.20±0.27). Addition of BR flour to the wheat flour caused reduction in chemical characteristics except for ash content, which rose by increasing the level of BR flour addition (from control: 0.59±0.003 to BR flour 15 %: 0.64±0.008). The increase observed in ash content can be attributed to the higher ash content of brown rice flour (1.40±0.005 %) compared to that of wheat flour (0.59±0.003 %). Some workers have also reported an increase in the ash content of the wheat bread substituted with different levels of various non-wheat flours (Sharma et al. 1999; Dhingra and Jood 2001). The reduction in protein-related chemical properties (Table 1) was expected, since brown rice flour contained lower protein (8.5±0.03 %) than wheat flour (10. 9±0.07 %) and is that of gluten-free type of cereals, as well.

In order to generate good quality bread, gluten protein is considered a key factor in forming the dough structure (Gallagher et al. 2003), Among BR flour-added samples the one prepared by 5 % BR flour incorporation had the closest values to those of the control (Table 1), making it a proper candidate for obtaining a well-defined gluten network in the would-be dough from the blend flour (5 % BR flour: 95 % WF).

Rheological properties of the dough

Farinographic properties of the dough

Water absorption is a parameter by which the appropriate amount of the water, needed to generate gluten network (i.e., to make appropriate dough), is determined. The water absorption for dough samples was affected significantly by BR incorporation and increased along with increase in the amount of BR flour substitution (Table 2). This phenomenon might be associated with higher fiber content of brown rice flour (1.2±0.03 %) than wheat flour (0.82±0.011 %). An increase in water absorption also was reported by other workers previously (Akubor and Badifu 2004; Koca and Anil 2007). However, no statistical difference was observed between the dough fortified with 5 % BR and control (p>0.05) (Table 2), which was in agreement with the study conducted by Sairam et al. (2011) who highlighted that addition of defatted rice bran (CDRB) had marginal effect, except in variation with 15 % CDRB.

The results indicated variations in the samples' dough development time (Table 2). Addition of BR flour beyond 5 % showed considerable effect on dough development time and no significant difference was observed between control and BR flour-fortified dough at 5 % level. However, a number of observations showed an increase and decrease tendency in the dough development time of their samples (Sharma et al. 1999; Bugusu et al. 2001; Abdel-Kader 2000; Yamauchi et al. 2004; Koca and Anil 2007). This farinographic feature is an

Table 1 Chemical and physicochemical properties of the flours

Treatment	Protein (%)	Wet gluten (%)	Dry gluten (%)	Gluten index (%)	Sedimentation (ml)	Ash (%)
Control	10.9±0.07^{c}	29.4±0.16^{c}	8.8±0.11^{c}	54.5±3.59^{d}	20.8±0.30^{a}	0.59±0.003^{c}
BR flour 5 %	10.8±0.05^{b}	27.9±0.12^{b}	8.3±0.08^{b}	44.5±2.50^{c}	20.2±0.31^{a}	0.61±0.005^{c}
BR flour 10 %	10.7±0.05^{b}	27.1±0.06^{ab}	8.1±0.07^{b}	36.0±3.55^{b}	19.3±0.30^{a}	0.62±0.006^{b}
BR flour 15 %	10.6±0.03^{a}	26.8±0.11^{a}	7.8±0.04^{a}	28.0±3.51^{a}	18.2±0.27^{b}	0.64±0.008^{a}

Control: Plain wheat flour

Different letters in the same column indicate significant differences, (P<0.05) (n=3)

BR Brown rice

Table 2 Farinograph properties of the dough

Treatment	Water absorption (%)	Dough development time (min)	Dough stability time (min)	Dough softening after 10 min (BU)	Valorimeter value (BU)
Control	65.9±0.21^{a}	4.6±0.25^{ab}	5.2±0.21^{a}	32±3^{a}	60.0±0.51^{c}
BR flour 5 %	66.1±0.25^{ab}	4.8±0.30^{a}	5.1±0.23^{a}	38±5^{ab}	58.0±0.53^{b}
BR flour 10 %	66.4±0.23^{bc}	4.5±0.21^{b}	4.9±0.20^{ab}	42±5^{b}	55.0±1.22^{a}
BR flour 15 %	66.8±0.22^{c}	4.6±0.26^{ab}	4.8±0.17^{b}	45±4^{b}	53.0±0.52^{a}

Control: Plain wheat flour

Different letters in the same column indicate significant differences, ($P<0.05$) ($n=3$)

BU Brabender Unites

BR Brown rice

index pointing out to the time needed for achieving the appropriate dough (the lower dough development time, the better) (Majzoobi et al. 2011). Therefore, as can be observed in Table 2, the lowest amount was received by dough made of blend flour fortified with 10 % BR flour (4.5±0.21 min), although, Sairam et al. (2011) found incorporation of CDRB at level of 15 % as lowest amount.

Dough stability time is one of the major indices determining the dough strength, which was negatively affected by adding BR flour as compared with the control dough (Table 2). Reduction in the dough stability time was expected because of several studies' reports (Sharma et al. 1999; Yamauchi et al. 2004; Koca and Anil 2007; Muranga et al. 2010). This decrease was related to the dilution of wheat gluten, along with increase in the level of BR flour added to the samples (Table 1), competition between proteins of non-wheat and wheat flour for water to absorb (Deshpande et al. 1983; Rao and Rao 1997), and/or a reverse relationship between farinographic criteria (water absorption and dough stability time), i.e. the release of water to the dough matrix by mixing, which results in lower dough stability time (Majzoobi et al. 2011). Since statistical analysis reached a significant difference by adding BR flour at 15 % level (4.8±0.30 min) (Table 2), supplementation with BR flour ranging from 5 % to 10 % could result in good quality dough, however, Sairam et al. (2011) observed no statistic difference between the samples (containing 5 %, 10 % and 15 % CDRB) and control (CDRB free).

Increase in the degree of BR flour substitution affected dough softening (Table 2), however no significant difference was found between control (32±3 BU) and the dough fortified by BR flour at 5 % level (38±5 BU). As expected from the reduction in dough stability time caused by adding more BR flour, the degree of softening in samples increased and was higher than that of the control. Present paper's results were in agreement with previously conducted studies (Sharma et al. 1999; Coskuner and Karababa 2005; Majzoobi et al. 2011; Muranga et al. 2010).

Replacing wheat flour with different levels of BR flour affected significantly the valorimeter values of samples and was lower than that of the control (Table 2). However, due to minimum acceptable value as described by ICC (2002), valorimeter values of all treatments (ranging from 53.0± 0.52 BU for BR flour 15 % to 58.0±0.53 BU for BR flour 5 %) in the present study remained above 40 BU.

Extensographic properties of the dough

Data given in Table 3 shows that adding BR flour for making dough leads to increase in resistance/extensibility ratio (R/E ratio) and decrease in other extensographic features. This

Table 3 Extensograph properties of the dough after 45 min

Treatment	Resistance to extension (BU)	Extensibility (BU)	R/E Ratio (BU)	Peak viscosity (BU)	Dough energy (BU)
Control	205±5^{c}	317±13^{b}	1.6±0.10^{b}	257±3^{c}	290±5^{c}
BR flour 5 %	200±5^{c}	305±15^{b}	1.5±0.07^{b}	237±7^{c}	279±7^{c}
BR flour 10 %	170±10^{b}	292±4^{a}	1.7±0.11^{a}	192±12^{b}	249±3^{b}
BR flour 15 %	120±5^{a}	270±5^{a}	2.3±0.05^{a}	150±10^{a}	224±6^{a}

Control: Plain wheat flour

Different letters in the same column indicate significant differences, ($P<0.05$) ($n=3$)

BU Brabender Unites

R/E Ratio Resistance/Extensibility Ratio

BR Brown rice

Table 4 Sensory properties of flat breads

Treatment	Form and shape	Bottom surface property	Upper surface property	Cavity and porosity	Chewability	Firmness and softness of texture	Odor, flavor and taste	Overall quality score
Control	3.8±0.81[b]	3.0±0.82[b]	3.2±0.71[b]	2.8±1.21[b]	3.1±1.22[b]	3.6±0.82[ab]	3.2±0.72[a]	3.3±0.93[b]
BR flour 5 %	4.6±0.73[a]	4.4±0.71[a]	4.6±0.71[a]	4.3±0.83[a]	3.8±0.72[a]	4.1±1.01[a]	4.4±1.23[a]	4.2±0.92[a]
BR flour 10 %	4.6±0.61[a]	4.3±0.91[a]	4.5±0.53[a]	3.7±0.71[ab]	3.5±0.53[a]	3.9±0.63[ab]	4.2±1.01[a]	4.0±0.90[a]
BR flour 15 %	4.0±0.62[ab]	3.9±0.63[b]	3.0±0.81[b]	3.6±0.72[ab]	3.1±0.71[b]	3.1±0.61[b]	3.9±0.92[a]	3.7±0.75[ab]

Control: Plain wheat flour.

Different letters in the same column indicate significant differences, (P<0.05) (n=3)

BR Brown rice

decline could be related to the fact that, incorporation of rice proteins and presence of sulphyhydryl groups in rice could weaken and destabilize wheat flour gluten (Sabanis and Tzia 2009). These findings are in accordance with other researchers' observations (Abdel-Kader 2000; Koca and Anil 2007; Sabanis and Tzia 2009; Coskuner and Karababa 2005; Gujral and Pathak 2002). Furthermore, statistical analysis also indicated that this reduction became significantly different when the amount of substitution exceeded 5 % and resulted in weaker dough. Therefore, 5 % BR flour addition can be a limit to fortify, that keeps dough strong and extensible enough.

Sensory evaluation of the flat bread

BR flour incorporation positively affected sensory properties (Table 4). Generally speaking, the trained panelists scored BR flour-added flat bread, regardless of the quantity of BR flour applied, higher in comparison with the control and were all above the acceptable level. However, Sairam et al. (2011) found the control (CDRB free) highly scored acceptable, along with introducing CDRB at 5 % level promising. As can be seen in Table 4, a reduction tendency was found as a result of increase in the amount of BR flour application and the flat bread made from blend flour with 5 % BR flour fortification was highly satisfactory and the highest overall quality score was given to the samples containing 5 % BR flour (4.2 ±0.92) and was found as a threshold for acceptable amount of BR flour being incorporated. However, Rai et al. (2011) indicated that the bread samples made from wheat 25 %: rice 75 % blend flour was given the best acceptability scores by panelists and Kaur et al. (2011) showed that samples incorporated with 50 % rice bran oil was slightly scored higher than others.

Firmness quality assessment of flat bread by trained panelists

Shelf life of bread is strongly affected by firmness, which causes changes including increase in crumb firmness, softening of crust and decrease in bread fragrance (Gallagher et al. 2003). Firmness ranking was not significantly different for BR flour-fortified and control flat bread samples for first 2 days of storage time; however, the BR flour incorporation was able to retard slightly the firmness event, and it is worth noting that the sample fortified with 5 % BR flour was given the highest score (2.6±0.06) at the storage day of 3 (Table 5). The observations seemed to be associated with the higher water absorption of the BR flour-fortified dough (Table 2), as the expectation was that the higher water content would result in slower rate of firming and, thereby, delayed staling (Rogers et al. 1988). The authors also corresponded the low scores, after 72 h storage, received by the flat bread samples made from flours preparations of 15 % BR flour (2.0±0.03)

Table 5 Firmness quality evaluation of flat breads by trained panelists (Scoring)

Treatment	Score after 24 h	Score after 48 h	Score after 72 h
Control	4.7±0.56[a]	2.7±0.95[a]	2.3±0.95[b]
BR flour 5 %	5.0±0.83[a]	3.0±0.83[a]	2.6±0.06[a]
BR flour 10 %	5.0±0.01[a]	3.0±0.81[a]	2.3±0.51[b]
BR flour 15 %	5.0±0.54[a]	3.0±0.08[a]	2.0±0.03[c]

Control: Plain wheat flour

Different letters in the same column indicate significant differences, (P<0.05) (n=3)

BR Brown rice

Table 6 Instrumental firmness quality (Newton) of flat breads

Treatment	Force after 24 h (N)	Force after 48 h (N)	Force after 72 h (N)
Control	10.9±0.62[a]	18.1±0.83[b]	30.6±1.06[b]
BR flour 5 %	10.2±0.95[b]	14.7±0.95[c]	20.3±0.95[c]
BR flour 10 %	11.5±1.36[a]	19.2±0.18[b]	34.0±1.33[b]
BR flour 15 %	11.6±1.92[a]	21.4±0.80[a]	41.3±0.50[a]

Control: Plain wheat flour

Different letters in the same column indicate significant differences, (P<0.05) (n=3)

BR Brown rice

in comparison with control (2.3±0.95) (Table 5) to lower protein and gluten content of it (Table 1).

Instrumental firmness quality analysis of flat bread

BR flour incorporation had significant effect on Instrumental firmness quality analysis of samples (Table 6). The Instrumental firmness quality analysis showed that the flat bread containing 5 % BR flour required lower force for compression and remained softer over the storage time. However, exceeding this quantity (5 % incorporation) resulted in firmer flat bread samples with tougher texture in comparison with control.

Conclusion

The results from this work indicated that it is feasible to incorporate BR flour for baking Barbary flat bread, however the threshold of BR flour ≤5 % flour addition should be considered. Since, dough made from blend flour fortified with 5 % BR flour, due to rheological evaluation, was strong and flat bread baked from dough containing 5 % BR flour was highly ranked acceptable by panelists and remained fresher in comparison with other treatments by the end of storage.

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