Capability of solvent retention capacity to quality of flat bread in three wheat cultivars

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Abstract Variations in levels and properties of flour constituents have an impact on the quality of its end products and a given application. While the solvent retention capacity test has been used to assess flour quality of pan breads and cookies, to date, this test for determination the suitability of flour for flat breads, where extensibility is the most desirable, has not been evaluated. In this study, three bread wheat cultivars were investigated for their major polymeric constituents, the number of disulfide bonds and SRC test values. The attained results revealed that in the gluten network, WRC and SuRC were affected by the gliadin, whereas SCRC and LaRC by gluten as a whole and glutenin content. These observed relationships are respectively owed to the solubility of gliadin in alcoholic solutions, and the solubility of glutenin in either acid or basic solutions. Also, consumers acceptability of flat-bread was observed at higher ratio of arabinose/xylose, which related to structural characteristics of arabinoxylan.

Keywords Flat bread · SRC · Quality · Structural characteristics

Introduction

Wheat flour has wide applicability in the culinary world, being commonly used worldwide as an ingredient in bread, pasta, noodles, breakfast cereals, and fermented drinks, among others. To that end, the balance and interaction between different flour components, such as proteins, starch, lipids, water, pentosans, etc., play a critical role in the final quality of the food prepared, including that of bread, as the most commonly prepared wheat flour foodstuff.

Flat breads have been baked and consumed as a staple food for centuries. Yet, most studies related to bread quality reported to date have primarily focused on the relationship between flour quality and the characteristics of pan bread, in which loaf volume is the most important quality criterion (Quail et al. 1990). While the relationships between loaf volume and dough stability and between dough resistance and extension play a large role in pan bread quality, in flat breads, the extensibility of the dough plays a significantly larger role on its final quality; accordingly, the presence and quality of gluten proteins present in flat bread dough may play a much larger role on the end-product characteristics of flat bread as compared to those of pan breads. For instance, previous findings have indicated that highly elastic dough derived from high quality gluten are not compatible with the rapid expansion of gases that occurs when dough sheets are submitted to the high temperature, short-time conditions typically employed in the baking of flat breads (Faergestad et al. 2000; Faridi 1982). As flat breads are baked from dough sheets consisted of a thickness ranging from 1 to 3 mm, and are only baked for a short length of time, typically between 2 and 3 min, the impact of gluten proteins on the end-product characteristics of flat bread may differ as compared to pan

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breads, thus having sufficient time to expand in comparison to flat breads parameters and flour and dough specifications. Moreover, a new predictive SRC parameter, the gluten performance index, calculated as $GPI = \text{lactic acid} / (\text{sodium carbonate} + \text{sucrose})$ (Zhang et al. 2007), has been found to be an even better indicator of the overall performance of flour glutenin in the environment of other modulating networks of flour polymers (Kweon et al. 2011).

In work by Dexter et al. starch damage was indicated as the predominant factor influencing farinograph water absorption, development time, and stability, whereas protein content was demonstrated to exert moderate influence on farinograph absorption. As protein content was decreased, farinograph development time and stability were shown to decrease, while starch damage was observed to increase. Long bulk fermentation performance was influenced positively by protein content and negatively by starch damage (Dexter et al. 1994). Ram et al. (2005) found a significant positive correlation between LaSRC ($P < 0.001$) and farinograph and mixograph parameters related to gluten strength, such as farinograph peak time and mixing tolerance index, and mixograph peak. Xiao et al. (2006) studied SRC values in relation to hard winter wheat and flour properties and straight-dough bread making quality, revealing that SRC values were greatly affected by wheat and flour protein contents, showing significant linear correlations with 1000-kernel weight and single kernel with respect to weight, size, and hardness of kernels. LaSCR values were shown to yield the highest correlation ($r = 0.83$, $P < 0.0001$) with bread volumes of bread made by North American hard and Argentinean wheat flours, followed by SuRC and WRC values. For Argentinean wheat, bread-specific volume was also shown to be correlated with sodium dodecyl sulfate (SDS) sedimentation and the zeleny index (Colombo et al. 2008). Duyvejonck et al. observed strong linear relationships between European flours, levels of damaged flour starch, WRC values, and SuRC values. Flour proteins, especially glutenin, mainly contributed to LaSRC, while damaged starch was shown to largely impact SuSRC values (Duyvejonck et al. 2011). Kweon et al. concluded that a general pattern of flour SRC values, rather than any single individual SRC value, served as better criterion for successful end-use applications (Kweon et al. 2011). Hammed et al. investigated the relationship between SRC test values and quality assessment results of hard red spring wheat flour in North Dakota. In this work, SRC values were significantly ($P < 0.05$) correlated with flour chemical components (protein, gluten, starch and damaged starch contents), farinograph parameters, and bread-making parameters (water absorption, loaf volume and symmetry) (Hammed et al. 2015). In addition, most SRC studies to date have observed strong linear

relationships between flour WRC, LaSRC, and SuSRC values (Gaines 2000; Ram et al. 2005). For instance, SRC test parameters have been demonstrated to serve as good indicators of the cookie-making performance of soft Argentinean wheat (Colombo et al. 2008), Indian hard and soft (Ram et al. 2005), and Chinese soft (Zhang et al. 2007) wheat flours. Additionally, SRC tests, especially the LaRC test, have been demonstrated as good predictors for the bread making performance of North American hard (Xiao et al. 2006) and Argentinean (Colombo et al. 2008) wheat flours. To the best of our knowledge, no research has been reported to date with respect to the relationship between the technological quality of wheat flour used for making flat breads and SRC values.

Materials and methods

Materials

Three Iranian wheat cultivars, i.e., Morvarid from the North, Chamran from the South, and Sirvan from Centre of Iran, were collected. All solvents/chemicals used were of analytical grade, and obtained from Merck® (Germany).

Methods

Chemical, physicochemical and rheological analysis

Moisture, protein, wet gluten, falling number, zeleny sedimentation value, solvent retention capacity (SRC) values, farinograph, amylograph, and damaged flour starch were determined according to the American Association of Cereal Chemists (AACC 2000).

Wheat milling

Wheat grains were milled by roller Quadrumat senior milling (Brabender, Germany) to obtain flour with 0.95% ash.

Baking Taftoon bread

Taftoon bread was baked according to the straight-dough method (AACC, No. 10-10B). Wheat flours (3000 g), baker's yeast, sodium chloride (1.5%) (on the basis of weight of flour) and optimum amounts of water (calculated from water absorption, measured by farinograph) were mixed. Dough samples were mixed for 8 min in a mixer, then fermented at 30 °C under a relative humidity of 85% for 90 min. After fermentation, the dough was divided and rounded into pieces weighting 250 g. The obtained portions were then flattened and subsequently baked in an

oven at 280–300 °C for 3 min. Breads were cooled at room temperature and packed in polyethylene bags (AACC 2000).

Evaluation of Taftoon bread

The sensory characteristics of the prepared breads were collaboratively determined by 16 trained panelists through the use of a hedonic scale. The textural profile of the breads was also evaluated with the use of a texture analyzer with puncture test (Rochdale 350, England), in accordance with AACC methods (2000). Bread slices of a size corresponding to 5 × 5 cm were punctured at a crosshead speed of 1 mm/s. The resulting peak force of compression was reported as crumb firmness.

Quantification of arabinoxylan

Wheat flour was hydrolysed via the method described by Houben et al. (1997), and arabinose and xylose contents were measured by high-performance anion-exchange chromatography with pulsed amperometric detector (HPAEC-PAD). Glucose contents of samples and standards were determined with an Azura system consisting of a P6.1L (Knauer, Berlin, Germany) gradient pump, a DECADE Elite electrochemical detector with a gold working electrode (E1 = 0.05 V, 0.5 s; E2 = 0.75 V, 0.13 s; E3 = −0.80 V, 0.12 s), and an injection valve Rheodyne 9725i equipped with a 20 µL injection loop (CA, USA). Separations were performed using a CarboPacPA1 (4 × 250 mm) analytical column (Dionex Corp., Sunnyvale, CA) according to a previously established method (Gavilighi et al. 2013).

Evaluation of solvent retention capacity (SRC)

SRC tests for the studied flour samples were performed according to AACC-56-11. Flour (5 g) was weighed in 50 mL centrifuge tubes. Then, 25 mL of the respective media water, 5% (w/w) sodium carbonate in water, 50% (w/w) sucrose in water, and 5% (w/w) lactic acid in water were added. Next, the resulting mixtures were shaken vigorously for 5 s to suspend the flour. Thereafter, the flour suspension was shaken throughout a 20 min period at the 5, 10, 15 and 20 min marks for a 5 s period each time so as to allow the flour to solvate and swell. Immediately after, samples were centrifuged (Duyvejonck et al. 2011) for 15 min at room temperature. Following the decanting of supernatant from tubes, pellets were allowed to drain for 10 min, then weighted. SRC values were calculated according to Eq. (1) (Haynes et al. 2009). All SRC analyses were performed in triplicate.

$$\text{SRC (\%)} = \left(\frac{\text{wet pellet (g)}}{\text{flour (g)}} - 1 \right) \times \left(\frac{86}{100 - \text{moisture (\%)}} \right) \times 100 \quad (1)$$

WRC has been associated with the overall water holding capacity of all flour constituents (Gaines 2000), while SCRC is believed to be related to the damaged starch characteristics of flour, as addition of a 5% (w/w) sodium carbonate solution was previously shown to elevate the pH of the matrix above 11 (Gaines 2000). SuRC solvent has been reported as an indicator of flour gliadin and arabinoxylane characteristics (Gaines 2000). LaRC has been associated with glutenin network formation and the gluten strength of flour (Gaines 2000).

Extraction of gliadin and glutenin

Gliadin and glutenin were extracted from whole meal according to the sequential procedure described by Singh et al. (1991). Wheat cultivars were subjected to three consecutive extraction steps so as to separate the two principal protein sub-fractions, namely gliadin and glutenin. The procedure involved extraction of 1 g of sample with 6 mL of solvent for 30 min at 60°C, with vortexing every 10 min, followed by centrifugation (10,000 g, 10 min). Ground wheat was extracted sequentially with the following solvents: 50% 1-propanol, to extract the gliadin fraction; 50% 1-propanol, containing 4% Dithiothreitol, to extract the glutenin fraction; and 50% 1-propanol containing 4%-DTT and 1% acetic acid, for residual high molecular weight (HMW) and low molecular weight (LMW) glutenin. All fractionation steps were carried out in duplicate.

Determining quantity of gliadin and glutenin by RP-HPLC

Filtered protein fractions extracted from flour as well as different protein standards were analyzed according to the procedure described by Li Vigni (2013) using an Azura HPLC system (Knauer, Berlin, Germany) equipped with a UV–Vis photodiode-array detector (DAD 2. 1L, Knauer) and an LC pump (P 6.1L) (Li Vigni et al. 2013). Gliadin and glutenin separations were performed with a 5 µm ODS3 reversed-phase Prodigy column (250 × 4.6 mm; Phenomenex, USA) using solvent A (water) and solvent B with 0.1% formic acid in both solvents, under gradient conditions at 25 °C (Mejías et al. 2014). The flow rate and injection volume were 1 mL/min and 20 µL, respectively. UV–Vis spectra were recorded in the wavelength range 190–700 nm. Peak identification was carried out via comparisons of retention times and chromatographic areas.

Determining disulfide bond

Free sulfhydryl group (SH) contents were determined via the method described by Beveridge et al. (1974). Flour (80 mg) was suspended in 1 mL TGE buffer (85.9 mM Tris, 91.9 mM glycine, 3.2 mM EDTA, pH = 8) containing 2.5% (W/V) SDS and incubated at room temperature for 60 min. Next, 15 μ L of 5,5 dithiobis, 2-nitrobenzoic acid (DTNB) (10 mM) in dimethylformamide was added to the mixture, which was then kept at room temperature for 30 min to allow for reactions to take place. Following, suspensions were centrifuged at $10,000\times g$ for 10 min, and supernatants were separated and diluted with TGE + SDS (1:10). The absorbance of the diluted supernatants was measured against blank buffer solutions (TGE + SDS) and a blank reagent (TGE + SDS + DTNB) with the use of a UV–VIS spectrophotometer (Cary 60, Agilent, USA) (Beveridge et al. 1974).

$$\text{SH} = (73.53 \times \text{Ab} \times \text{D})\text{C} \quad (2)$$

C, gluten concentration (mg/mL); D, dilution factor; Ab, absorbance.

Disulfide bonds of gluten proteins were determined via the method proposed by Weegels et al. (1994), with some modifications. Flour (80 mg) was suspended in 0.4 mL of 1.5% (W/V) SDS + Tris/HCl at pH = 8, and mixed with 0.4 mL of 6 M NaOH. After 45 min, 0.8 mL of H_3PO_4 and 0.05 mL of 10 mM DTNB (in 0.2 M phosphate buffer, pH = 7) were added to the mixture, which was then held for 1 h to allow for reactions to occur. After centrifugation at $10,000\times g$ for 10 min, the absorbance values of the supernatants were recorded at 412 nm against buffer and blank samples SH and SS were calculated using an extinction coefficient of $13,600 \text{ M}^{-1} \text{ cm}^{-1}$. SS were calculated as the difference between total and free SH contents (Weegels et al. 1994).

$$\text{SH}_{\text{total}} = 2\text{SS} + \text{SH}_{\text{free}}$$

Statistical analysis

Statistical significances of observed differences between the studied wheat cultivars were determined by analysis of variance (ANOVA) with SPSS software. Duncan analysis was performed to differentiate and rank parameters. Statistically significant values at $P < 0.05$ were selected for investigations.

Results and discussion

Analysis of wheat and flat-bread

Of the three tested varieties, the Morvarid cultivar was shown to exhibit the highest protein content, gluten index, stability, and farinograph quality number, whereas the Sirvan cultivar presented the highest wet gluten percentage, zeleny sedimentation value, falling number and dough development time, maximum viscosity of gelation, and damaged starch. According to findings by Barak et al. (2013) and Zhang et al. (2007) and Kaur et al. (2013) dough stability is positively associated with protein content, and negatively correlated with wet and dry gluten. Using this criterion, the assessed Morvarid and Sirvan cultivars thus can be said to be characterized by higher quality factors than Chamran, although the latter seems to be more appropriate for flat-bread making, as according to He et al. (2003), flour quality requirements vary with respect to the employed processing conditions. While medium protein content and medium to strong gluten strength with good extensibility are desirable for mechanized methods, weak to medium gluten strength is preferred for manual methods.

Quantity of arabinoxylan in wheat cultivars

Morvarid, Sirvan, and Chamran cultivars yielded arabinose amounts of 2.27, 2.22 and 2.43 mg/g, respectively, while xylose content of 3.74, 3.54, and 3.53 mg/g, respectively, were observed for the three studied cultivars. Chamran yielded the highest arabinose/xylose ratio (0.69), whereas Morvarid rendered the lowest ratio (0.60). On the other hand, Chamran showed the highest flat-bread quality on the basis of sensory evaluation and required force for puncture (Table 1). To this end, the structural characteristics of arabinoxylane, consisted of a linear backbone of D-xylopyranosyl units to which α -L-arabinofuranosyl substituents are attached (Courtin and Delcour 2002). It can be said, arabinose branches affected Taftoon-bread quality. It was consistent with results of Revanappa et al. (2015), that varieties known for good Chapatti making quality revealed arabinoxylans with higher degree of branching pattern (Revanappa et al. 2015). According to other work suggests that higher than the optimum concentration of arabinose may cause bread with undesirable characteristics (Izydorczyk and Biliaderis 1995).

Solvent retention capacity

The retention capacities of four solvents for the three wheat cultivars under study are presented in Table 2.

Table 1 Chemical and rheological characteristics of Morvarid, Sirvan, and Chamran cultivars and their respective Taftoon breads

Characteristics	Chamran	Sirvan	Morvarid
Water absorption (%)	71.65 ^a ± 0.15	71.3 ^a ± 0.0	56.55 ^b ± 0.15
Dough development time (min)	2.75 ^b ± 0.05	3.75 ^a ± 0.07	1.75 ^c ± 0.05
Dough stability (min)	1.25 ^c ± 0.05	2.25 ^b ± 0.07	5.45 ^a ± 0.05
Farinograph quality number	37 ^c ± 0.0	48 ^b ± 1.41	66 ^a ± 1.0
Begin of gelatinization (°C)	63.4 ^a ± 0.0	61.5 ^b ± 0.0	63.4 ^a ± 0.0
Gelatinization temperature (°C)	83.6 ^b ± 0.0	85.9 ^a ± 0.0	86 ^a ± 0.0
Maximum viscosity of gelation (AU)	696 ^c ± 0.0	1420 ^a ± 0.0	1307 ^b ± 0.0
Damaged starch (farrand)	13.69 ^b ± 0.05	17.96 ^a ± 0.01	6.1 ^c ± 0.0
Protein (%)	12.66 ^b ± 0.16	12.65 ^b ± 0.06	13.21 ^a ± 0.01
Wet gluten (%)	29.05 ^b ± 0.25	31.35 ^a ± 0.50	24 ^c ± 0.50
Gluten index (%)	20.92 ^c ± 0.20	48.68 ^b ± 3.70	80.58 ^a ± 2.28
Zeleny sedimentation (mL)	19 ^b ± 0.0	24.5 ^a ± 0.71	19 ^b ± 0.50
Falling number(s)	527.5 ^b ± 6.5	600 ^a ± 7.07	503 ^b ± 25.0
Required force for puncture (N)	3.18 ^c ± 0.10	4.91 ^a ± 0.10	4.62 ^b ± 0.15
Panelist score (on the basis of 20)	15.49 ^a ± 0.10	13.26 ^c ± 0.10	15.10 ^b ± 0.10

Results are given as mean between triplicate based on measurement of individual sample

Values followed by a different letter in the same row are significantly different ($P < 0.05$)

Table 2 SRCs for Morvarid, Sirvan, and Chamran cultivars

Characteristics	Chamran	Sirvan	Morvarid
Water retention capacity (%)	71.06 ^a ± 0.08	70.50 ^b ± 0.08	68.08 ^c ± 0.50
Sucrose retention capacity (%)	86.63 ^a ± 0.05	84.71 ^b ± 0.03	74.06 ^c ± 0.50
Sodium carbonate retention capacity (%)	70 ^b ± 0.0	90.26 ^a ± 0.37	67 ^c ± 1.50
Lactic acid retention capacity (%)	88.34 ^b ± 0.0	91.10 ^a ± 0.0	71.87 ^c ± 0.0

Results are given as mean between triplicate based on measurement of individual sample

Values followed by a different letter in the same row are significantly different ($P < 0.05$)

According to Table 2, the sodium carbonate retention capacities (SCRC) corresponding to the three cultivars presented the higher variation in values (67–90.26%), while the lower variation was observed for water retention capacities (WRC) (68.08–71.06%). Among the three cultivars, Chamran (intermediate quality) attained the highest WRC and SuRC values, indicating that the pentosan content of wheat flour may play a major role in determining its water absorption capacity. Conversely, Sirvan attained the highest SCRC and LaRC values among the three studied cultivars.

On the basis of results in Tables 1 and 2, positive correlations were found for WRC and SuRC values and protein content, wet gluten and damaged starch, whereas negative correlations were found for WRC and SuRC values with respect to gluten index, stability, and farinograph quality number. Obviously, higher water absorption values will coincide with high levels of gluten and damaged starch. Likewise, according to Barak et al. (2013) findings, positive correlations were found between SCRC values and wet gluten, zeleny sedimentation, dough

development time, and damaged starch. In addition, Katyal et al. (2017) indicated SuRC related to arabinoxylan and was positively correlated with water absorption, also, water absorption had negative correlation with unextractable polymeric protein. The results demonstrated that an increase in protein percentage will result in a decreased starch/protein ratio, as well as a lower degree of grain softness. This was consistent with results of Katyal et al. (2017) that flours from higher hardness index varieties had more protein content, and Kaur et al. (2014), varieties with higher hardness produced more damaged starch. In turn, LaRC values demonstrated to yield a positive correlation with zeleny sedimentation and maximum viscosity of gelation. This was consistent with work previously reported by Kiszona et al. (2013) and Katyal et al. (2018) which indicated that higher protein content may not necessarily yield a higher LaRC, as well as, with Kaur et al. (2014) there is no correlation between LaSRC and wet gluten, it means gliadin contributed more to gluten than the glutenin content. These findings indicated relationship between WRC and SuRC, as well as between SCRC and LaRC.

Indeed, previous work by Moiraghi et al. (2011) and Katyal et al. (2018) revealed a strong correlation between WRC and SuRC. Sensory evaluation of Taftoon bread yielded positive correlations with WRC and SuRC values and a positive correlation was also found between LaRC values and the stiffness of Taftoon bread texture and zeleny sedimentation. So, WRC and SuRC can be concluded to be better indicators of flat-bread quality. This supported previous work by Marchetti et al. (2012) which demonstrated that highly elastic dough derived from high quality gluten was not suitable for the conditions typically employed in the baking of flat breads.

Determining quantity of gliadin and glutenin

Chromatograms of gliadin and glutenin fractions for Morvarid, Sirvan, and Chamran flour are shown in Figs. 1 and 2.

Percent of each fraction, was obtained from sum of under peak area. Gliadin fractions for Morvarid, Sirvan, and Chamran were 45.36, 48.19 and 55.75%, respectively, while glutenin fractions were 54.64, 51.81 and 44.25%, respectively. Larger gliadin values yielded higher WRC and SuRC values. According to Gaines (2000), SuRC can be used as an indicator of flour gliadin characteristics, gliadin was extracted by alcohol, and alcohol has an OH-group, which was also present in water and sucrose molecules.

On the other hand, the Sirvan showed to contain the highest amount of wet gluten $\times$ glutenin ($31.35 \times 51.81\%$); as glutenin dissolves in either acidic (lactic acid) or basic (sodium carbonate) solvents, it is unsurprising that Sirvan yielded the highest LaRC and SCRC values among the studied cultivars.

Disulfide bonds in flour

Absorbances at 412 nm in buffer containing DTNB in Morvarid, Sirvan, and Chamran for SH_{total} were 0.1028, 0.0719, and 0.1994, respectively, while SH_{free} values were measured at -0.0193 , -0.0178 , and 0.0123 , respectively. The number of SS bonds in Morvarid, Sirvan, and Chamran were 5, 8, and 4 per unit protein, respectively. According to Delcour et al. (2012), the SS bond was responsible for the formation of the gluten network, and was therefore main determinant factor in the rheological characteristics of flour and its corresponding baking properties. Disulfide bonds number positively correlated with LaRC (0.997), SCRC (0.731), zeleny sedimentation value (0.771), and stiffness of flat bread texture (0.960). Sirvan showed the greatest number of disulfide bonds, and may be consisted of a compact gluten network, thus yielding the highest hardness index and SCRC value among the studied cultivars. In addition, interchain disulfide bonds between glutenin fractions are also formed in dough; since glutenin absorbs lactic acid, LaRC values correspondingly increase with respect to glutenin content.

Conclusion

Evaluations of flour and bread quality should encompass analyses of different aspects of bread and flour along with an examination of the structural characteristics of wheat flour. To that end, LaRC and zeleny sedimentation values can be used to indicate the quantity and quality of the glutenin fraction present in flour and bread. Since the glutenin fraction can form interchain SS bonds, glutenin polypeptides are able to form a network that entraps lactic acid, which swells and sediments in solution. Accordingly, good quality wheat grains with greater SS bonds will be

Fig. 1 Chromatograms of gliadin fractions in Morvarid, Sirvan, and Chamran flour

Fig. 2 Chromatograms of glutenin fractions in Morvarid, Sirvan, and Chamran flour

characterized by harder endosperm textures, and yield greater damaged starch and SCRC values. As the flour required to prepare flat-bread should have a gluten network that is weaker than that needed for high quality pan-bread, the criteria determined in previous studies with respect to bread and flour quality is not suitable for flat-bread making, as an appropriate flour for flat-bread should yield high WRC and SuRC values, and low LaRC and SCRC values.

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