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Rheological properties of wheat flour with different extraction rate

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Abstract

A study of the rheological behavior of the wheat flour dough with different extraction rates (64%, 82% and 90%) was conducted by using three different instruments namely alveograph, extensograph, and farinograph. The lower bran concentration (with high extraction rate 64%) in flours showed a better pronounced effect on dough properties. In spite of the fact that no significant correlation among all parameters of the methods was observed, some parameters of the measuring methods had very strong correlation (P<0.01) that included farinograph water absorption (WA), tenacity (P), extensibility (L), P/L, swelling index (G) of alveograph, energy and the resistance to constant deformation after 50 mm stretching (R_{50}) of extensograph. Among the applied methods, most of the alveograph parameters had significant correlation (r=1, P<0.01) together. So choosing a suitable extraction rate can develop the quality of final product because of the effect of extraction rate on wheat's properties.

Introduction

Among the cereal flours, only wheat flour can form three-dimensional viscoelastic dough when mixed with water (Pecivova *et al.*, 2010). The microstructure of wheat kernel has been well understood, consisting of an embryo or germ (2-3%), bran (13-17%), and an endosperm packed with starch granules in a protein matrix (about 75-80%). After milling and sieving, wheat grains are separated into flour, bran and germ, with flour consisting mainly of endosperm (Goesaert *et al*., 2005). Characterization of rheological properties of dough is effective in processing behavior predicting and in controlling the quality of food products (Song and Zheng, 2007; Abbasi *et al.*, 2011). Although the production of baking products need the most accurate method in quality evaluation, in order to assess flour-quality attributes, several predictive tests which are closely related to wheat flour quality are frequently used in wheat industry (Colombo *et al*., 2008). When wheat flour is mixed with water, a complex protein called gluten is formed (Aboaba and Obakpolor, 2010). Gluten is the main base of the wheat dough and is the protein that only exists in wheat and rye; meanwhile many baking properties in wheat flour are related with this protein. Functional quality loss in final products such as bread has been related to a dilution of functional gluten proteins (Pomeranz *et al*., 1977). Farinograph, extensograph and alveograph are the most common empirical instruments used for characterizing dough rheology. Tests based on these instruments are useful for providing practical information for the baking industries while they are not sufficient for interpreting the rheological testing, especially in the linear viscoelastic region (Janssen *et al*., 1996; Miller and Hoseney, 1999; Diosi *et al*., 2015). Thus it is necessary to look for the suitable methods of evaluating gluten quality and dough rheology which can help us to select the proper flour for our aimed purpose.

The choice of assessment method is influenced by several factors such as country, wheat class, intended end use, time and cost (Gains *et al*., 2006). Today, dynamic rheological tests have become a powerful and preferred approach for examining the structure and the fundamental properties of wheat flour dough and proteins because of its characteristic and sensitive response to the structure variation of wheat flour dough and proteins (Song and Zheng, 2007).

The aim of this study is focus on dynamic rheological characteristics of wheat flour dough with various extraction rates (64%, 82% and 90%) by three different assessment methods and influence of

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extraction rate on the rheological behaviors of flour dough is outlined. Moreover, the correlation among the parameters of applied methods through statistical analysis, were determined in order to judge about the quality of the flour more accurately.

Materials and Methods

Materials

Commercially available soft white wheat flours were procured from the Tak flour factory (Karaj, Iran), and were stored in sealed containers, in a cold room (5-7°C), until use. samples were prepared on a roller mill (Industrial Buhler, Switzerland) and flours with 64%, 82% and 90% extraction rate were coded as A, B and C, respectively.

Flour analysis

In order to determine the main characteristics of flours, some important quality tests such as protein content (AACC 46-12), moisture (AACC 44-16), ash (AACC, 08-01) and zeleny sedimentation (AACC 56-60) were performed (AACC, 2000). Also the content of damaged starch and falling number were determined according to approved methods 76-30A, 56-81B, respectively (AACC, 2000).

Rheological characteristics

Dough rheological analysis which was consisted of flour (100 g), salt (1.8 g) and water (achived by farinograph test), are described below. Farinograph and extensograph characteristics were determined according to the AACC 54-21 and AACC 54-10 methods, respectively (AACC, 2000). The following parameters were determined in a Brabender farinograph: water absorption percentage of water required to yield dough consistency of 500 BU (Brabender Units), dough development time (DDT, time to reach maximum consistency), stability (time during dough consistency is at 500 BU), mixing tolerance index (MTI, consistency difference between height at peak and to that 5 min later) and elasticity (band width of the curve at the maximum consistency). Brabender extensograph gave the resistance to constant deformation after 50 mm stretching (R_{50}), the extensibility (E), the ratio R50/E, energy and maximum height.

Alveograph test was performed using an alveograph (Chopin (NG), France) following the AACC method (54-30A) (AACC, 2000). The following alveograph parameters were automatically recorded by a computer software program: tenacity or resistance to extension (P), dough extensibility (L), curve configuration ratio (P/L ratio), the deformation energy (W), swelling index (G) and elasticity (P200/P ratio).

Statistical analysis

The results were expressed as the mean of three replicates ± SD. The data were statistically analyzed using the statistical analysis system software package. Analyses of variance were performed by application of ANOVA procedure. Significant differences between the means were determined using Duncan multiple range test. Also the correlation coefficients were determined and tested for their significance.

Results and Discussions

Chemical characteristic

Damaged starch in the flours was 6.57%. This result was the same as those found in soft wheat flours (Gaines, 2000); the falling number value on 14% moisture basis was 456 s. Other chemical characteristics of flours (Table 1) indicated a wide variation in the quality characteristics of flours by different extraction rates. There was a significant difference (P<0.05) among all the flours in moisture, ash, protein and zeleny sedimentation. The values for ash varied from 0.46% to 1.40%, moisture 10.68% to 13.97% and protein 11.60% to 13.21%. Protein content and ash content were higher in 90% extraction rate flour than the other flours (82% and 64% extraction rate). Result was similar to Mueen-ud-Din *et al.* (2010) investigation. The sedimentation volume also varied significantly (Table 1) and decreased by increasing the extraction rate of flour.

Effects of extraction rate on farinograph parameters

The results of farinograph measurements summarized in Table 2. There was a significant difference (P<0.05) among the flours in water absorption and DDT. Concerning water absorption, the higher bran concentration individually promoted the higher increase in water absorption; water absorption in 90% extraction rate was the highest (66.30%) and in 64% extraction rate, it was the lowest (53.20%). This means by increasing the flour extraction rate, the bran content of flour is higher and water absorption will be increased (Sliwinski *et al*., 2004; Mueen-ud-Din *et al.*, 2010).

The inclusion of a higher amount of bran in the dough formulation usually resulted in increased dough water absorption due to the higher levels of pentosans present in bran (Sanz Penella *et al.*, 2008). Sudha *et al.* (2007) suggested that the differences in water absorption are mainly caused by the greater number of hydroxyl groups in the fiber structure

Table 1. The chemical composition of flour samples

Flour sample	Extraction rate (%)	Ash (%)	Moisture (%)	Protein (%)	Zeleny sedimentation(ml)
A	64	0.46± 0.030^{c}	13.9±0.03^{a}	11.6±0.00^{c}	30.0±0.00^{a}
B	82	0.82±0.010^{b}	12.3±0.01^{b}	12.0±0.00^{b}	19.0 ±0.00^{b}
C	90	1.2±0.51^{a}	10.7±0.51^{c}	12.1±0.00^{a}	14.0 ±0.00^{c}

Values followed by different letters are significantly different *(P < 0.05)*.
Values are means± SD of three replicates.

Table 2. The quantity of the farinograph analysis of flour samples

Flour sample	WA(%)	DDT (min)	S(min)	MTI(BU)	E (BU)
A	53.2±0.35^{c}	1.9±0.05^{c}	7.8±0.35^{a}	38.0±0.00^{c}	89.0±4.00^{a}
B	58.9±0.20^{b}	3.0±0.28^{b}	2.8±0.15^{b}	93.0±5.51^{a}	45.0±3.51^{c}
C	66.3±0.30^{a}	4.3±0.06^{a}	2.9±0.35^{b}	74.0±1.53^{b}	55.0±2.00^{b}

Values followed by different letters are significantly different *(P < 0.05)*.
Values are means± SD of three replicates.
WA (water absorption); DDT (dough development time); S (stability); MTI (mixing toleranceindex); E (elasticity)

that allow more water interaction through hydrogen bonding than in refined flour.

The time required for the dough development or time necessary to reach 500 BU of dough consistency (DDT) was lower in 64% extraction rate (1.95 min) which contains less bran, than sample 82% extraction rate (3.00 min) and sample 90% extraction rate (4.27 min). Bran concentration had a positive significant linear effect in the time to reach maximum consistency, which is in agreement with previous findings (Laurikainen *et al.*, 1998). In addition, the increase in development time was attributed to the effect of the interaction between fibres and gluten that prevents the hydration of the proteins, affecting the aggregation and disaggregation of the high molecular weight proteins in wheat (Sanz Penella *et al.*, 2008). The stability value is an indication of the flour strength, with higher values suggesting stronger dough (Rosell *et al.*, 2001). Dough containing less bran (64%) exhibited more stability than the other samples. Conversely, mixing tolerance index (MTI) values were significantly increased at higher bran concentration. Bran has softening effect in dough and by increasing the bran content in flour, there is an increase in the farinographic properties such as water absorption and MTI and in contrast, DDT and stability of the dough decrease (Goesaert *et al.*, 2005). There was a significant difference (P<0.05) among the flours in elasticity and the elasticity of dough was reduced by increasing bran and the highest elasticity was observed in 64% extraction rate, with the lowest bran content.

Effect of extraction rate on extensograph parameters

Extensograph gives information about the viscoelastic behavior of dough (Rasell and Rajan, 2001). This equipment measures dough extensibility and resistance to extension. A combination of good resistance and good extensibility results in desirable dough properties (Walker and Hazelton, 1996). The effect of flour extraction rate on the extensograph measurements throughout 135 min resting time is shown in Table 3. Regarding the behavior during the assay, all the parameters decreased by increasing the resting time. The initial resistance to deformation (R_{50}), i.e. at 45, 90 and 135 min resting time, decreased by increasing extraction rate and there was a significant difference (P<0.05) among them. In comparison, dough containing lower bran exhibited greater stability to changes with time, showing the highest resistance after 90 min resting time with a slightly decrease at the end of the repose

Table 3. The quantity of the extensograph analysis of flour samples

Flour sample	R_{50} (BU)			E(mm)			energy(cm^2)			max height(BU)			R_{50}/E (BU/mm)		
	Resting time(min)														
	45	90	135	45	90	135	45	90	135	45	90	135	45	90	135
A	274.0± 10.00^a	284.0±4 .00^a	247.0±5 .00^a	140.0±3 .00^a	135.0±1 .53^b	122.0±12 .00^b	68.0± 0.58^a	64.0±0 .58^a	48.0±5 .00^a	348.0±4 .50^a	344.0±1 .53^a	277.0±3 .51^a	2.5±0.1 5^a	2.5±0.0 0^a	2.3±0.3 5^a
B	158.0± 0.58^b	143.0±1 .00^b	119.0±3 .00^b	150.0±3 .51^a	161.0±3 .00^a	155.0±4. 00^a	38.0± 1.53^b	35.0±1 .53^b	27.0±2 .00^b	159.0±0 .00^b	144.0±1 .00^b	121.0±4 .00^b	1.1±0.0 6^b	0.90±0. 000^b	0.80±0. 000^b
C	139.0± 1.00^c	122.0±1 .53^c	103.0±3 .00^c	151.0±8 .50^a	138.0±9 .50^b	119.0±0. 58^b	31.0± 1.00^c	25.0±1 .00^c	18.0±0 .71^c	142.0±0 .58^c	130.0±3 .00^c	110.0±3 .00^c	0.90±0. 060^b	1.0±0.1 0^b	0.90±0. 060^b

Values followed by different letters are significantly different *(P < 0.05)*.
Values are means± SD of three replicates.
R_{50} (the resistance to constant deformation after 50 mm stretching); E (extensibility)

Table 4. The quantity of the alveograph analysis of flour samples

Flour sample	P (mmH2O)	L(mm)	E(%)	G(mm)	W($\times 10^{-4}$j)	P/ L
A	53.6±1.53^b	84.0±2.64^a	46.2±0.87^a	20.4±0. 32^a	136.6±2.52^a	0.64±0.040 ^{b}
B	54.3±0.05^b	63.0±7.00^b	28.6±1.34^b	17.6±1.02^b	89.6±7.64^b	0.87±0.120^b
C	66.6±3.05^a	43.0±1.00^c	22.8±0.62^c	14.6±0.20^c	88.6±4.72^b	1.55±0.11^a

Values followed by different letters are significantly different (P < 0.05).
Values are means± SD of three replicates.
P (tenacity); L(dough extensibility); E (elasticity); G (swelling index); W (deformation energy)

period. R_{50} predicts the dough handling properties and the fermentation tolerance. In consequence, the reduction of extraction rate suggests a good handling comportment and a large dough tolerance in the fermentation stage. Higher bran yielded an increase of dough extensibility. However, the extensibility was practically not modified as resting time increased; only sample 64% and 90% extraction rate originated a clear decrease of this parameter. The overall effect of bran resulted in a decreased R_{50}/E, but the analysis through the time showed better stability of the dough containing lower bran. There was a significant difference (P<0.05) among the flours in the energy necessary for the deformation and maximum height. These factors were reduced by increasing bran and resting time.

Effect of extraction rate on alveograph parameters

The effect of flour samples with different extraction rate on the alveograph parameters is shown in Table 4. There was a significant difference (P<0.05) in flour samples among the most parameters of alveograph. Dough resistance to deformation or tenacity (P) is a predictor of the ability of the dough to retain gas and this parameter increased by increasing the bran content (Indrani *et al*., 2007). In samples 64%, 82% and 90% extraction rate which the extraction rate increases respectively, P factor increases consequently. It is worthy to remark that the resistance results from the extensograph are not comparable to the resistance obtained with the alveograph because of the differences in principles involved in the measurements (Rosell *et al*., 2001).

Likewise, the extensibility of dough (L), an indicator of the handling characteristics of dough, was greatly reduced by increasing bran content , dropping to almost half of sample A extensibility with increasing bran content in sample C (from 84 mm for sample A to 43 mm for sample C). As a result of the bran increase on both dough resistance and dough extensibility, the P/L ratio (which gives information about the elastic resistance and extensibility balance of a flour dough) was augmented in dough containing higher bran content which is agrees with the results

Table 5. Correlation coefficients (r) [a] for farinograph, extensograph and alveograph with fundamental rheological parameters

Parameter	1	2	3	4	5	6	7	8	9	10	11
1											
2	1**										
3	1**	1**									
4	0.2	0.2	0.2								
5	1**	1**	1**	0.2							
6	1**	1**	1**	0.2	1**						
7	1**	1**	1**	0.2	1**	1**					
8	1**	1**	1**	0.2	1**	1**	1**				
9	0.8	0.8	0.8	0.4	0.8	0.8	0.8	0.8			
10	1**	1**	1**	0.2	1**	1**	1**	1**	0.8		
11	1**	1**	1**	0.2	1**	1**	1**	1**	0.8	1**	
12	0.8	0.8	0.8	0.4	0.8	0.8	0.8	0.8	0.6	0.8	0.8

Level of significance: [a] r=1, p=0.01 (**).
1- P (tenacity or resistance to extension); 2- L(dough extensibility); 3- G (swelling index); 4-W(deformation energy) 5-P /L; 6- water absorption; 7- energy (45 min); 8- energy (90 min);9- energy (135 min); 10- R_{50} (45min); 11- R_{50} (90 min);12-R_{50} (135 min).

of Hruskova and Smejda, 2003. Sample C yielded dough with the highest P/L ratio (1.55 vs. 0.64 in sample A and 0.87 in sample B).The deformation energy (W), swelling index (G) and elasticity from sample A to sample C reduced significantly. The observed effect, agrees with reduction of rheological properties of flour by increasing bran content found by Collar and Scantos (2007).

Correlation coefficients among rheological parameters of applied methods

Statistical tests were performed to look for relationships among rheological parameters of farinograph, extensograph and alveogragh methods in three flours by different extraction rates (Table 5). Regarding the results of rheological tests, for each method some parameters were considered as the most important parameters to assess the dough rheology. Water absorption parameter in farinograph method, energy (45, 90 and 135 min) and R_{50} (45, 90 and 135 min) in extensograph and also P, L, G, W and P/L parameters of alveograph were considered as the fundamental rheological parameters.

The results showed some significant correlations with the current rheological results. Alveograph parameters such as P, L, G and P/L had very strong correlation (r =1, P<0.01), and among the extensograph parameters, energy (45 and 90 min) and R_{50} (45 and 90 min) had significant correlation (r =1, P<0.01) together. The comparison of methods revealed high correlation (r =1, P<0.01) among farinograph water absorption, extensograph R_{50} and energy (45 and 90 min) as well as P, L, G, P/L of alveograph.

Conclusion

A study of the rheological behavior of the wheat flour dough was performed by using alveograph, extensograph, and farinograph. Results show that, rheological characteristics of wheat flour dough were affected by the flour extraction rate and increasing the extraction rate had negative effect on the dough rheology. Parameters such as farinograph water absorption, alveograph P, L, G, P/L ratio and also extensograph energy and resistance to extension (R_{50}) after 45 and 90 min resting time had significant correlation together. So choosing a suitable extraction rate can develop the quality of final product because of the effect of extraction rate on wheat's properties. It should be mentioned that combination and comparison of methods might be useful in the evaluation of wheat flour quality and alveograph among the applied methods might be considered as the most suitable method in order to predict the flour quality.

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