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Original research

Effect of extraction rate on rheological properties of wheat flour

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ABSTRACT

The effect of different extraction rates (64%, 82% and 90%) of wheat flour on the rheological properties of the wheat flour dough was investigated. A complete study of the rheological behavior of the wheat flour dough was performed by using three different instruments namely alveograph, extensograph, and farinograph. The correlation coefficient among the various parameters of applied methods was also determined and the most suitable method in assessment of flour attributes recognized. The lower bran concentration (extraction rate 64%) in flours showed the better pronounced effect on dough properties yielding strengthened dough. Several expected associations were found among applied methods, 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, 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 and it might be used as the recommended method to assess dough rheology.

Keywords: Rheology, Extraction rate, Wheat flour, Alveograph

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1. Introduction

Among the cereal flours, only wheat flour can form three-dimensional viscoelastic dough when mixed with water. 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 (Phan- Thien et al., 1997). Characterization of rheological properties of dough is effective in predicting the processing behavior and in controlling the quality of food products (Song & Zheng, 2007). Although the production of baking products is considered the most accurate method in quality evaluation (Hoseney, 1994), 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). Gluten is the main base of the wheat dough and is the protein that only exists in wheat and rye and many baking properties in wheat flour are related with this protein. Decreased functional quality of final products such as bread has been ascribed 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 & hoseney, 1999). 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 (Hiruskova & Smejda, 2003). The choice of assessment method is influenced by several factors such as country, wheat class, intended end use, time and cost (Gaines 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). In this study, we focus on dynamic rheological characteristics of wheat flour dough with various extraction rates namely 64%, 82% and 90% by three different assessment methods and influence of extraction

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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.

2. Material and Methods

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 (Buhler, Switzerland) and flours with 64%, 82% and 90% extraction rate were coded as A, B and C respectively.

2.1. 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).

2.2. Dough rheological characteristics

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 R_{50}/E, energy and maximum height. Alveograph test was performed using an alveograph (Chopin (NG), France) following the standard method (AACC, 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).

2.3. 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.

3. Results and Discussion

3.1. Chemical characteristic

Damaged starch in the flours was 6.57%. As expected, 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%. As expected, protein content and ash content were higher in 90% extraction rate flour than the other flours (82% and 64% extraction rate). Sahlstrom et al. (1993) found similar results in whole meal flour (100% extraction rate) compare with white flour (68-73% extraction rate). The sedimentation volume also varied significantly (Table 1) and decreased by increasing the extraction rate of flour.

3.2. Effects of extraction rate on farinograph parameters

The results of farinograph measurements summarized in Table 2 and Fig. 1. 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 sample C was the highest (66.30%) and in sample A, 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). 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 that allow more water interaction through hydrogen bonding than in refined flour (Sudha et al., 2007).

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.

The time required for the dough development or time necessary to reach 500 BU of dough consistency (DDT) was lower in sample A (1.95 min) which contains less bran, than sample B (3.00 min) and sample C (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 fibers 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 (sample A) 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 suchas 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 sample A, with the lowest bran content.

3.3. Effect of extraction rate on extensograph parameters

Extensograph gives information about the viscoelastic behavior of dough (Rosell et al., 2001). This equipment measures dough extensibility and resistance to extension. A combination of good resistance and good extensibility results in desirable dough properties (Walker & Hazelton, 1996). The effect of flour extraction rate on the extensograph measurements throughout 135 min resting time is shown in Table 3 and Fig. 2. 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 period. R_{50} predicts the dough handling properties and the fermentation tolerance (Brabender, 1953). In consequence, the reduction of extraction

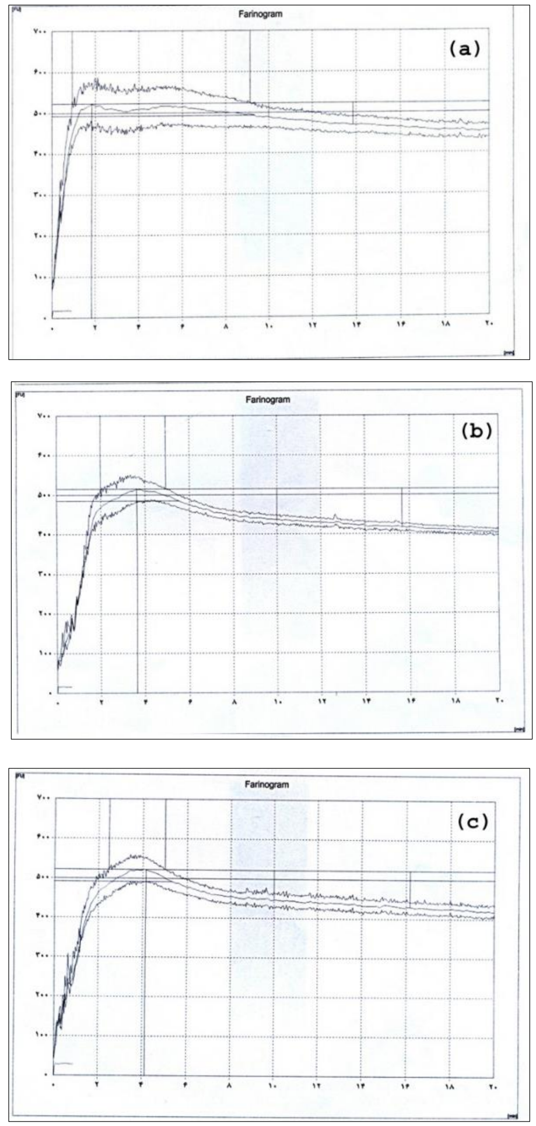

Fig. 1. Farinogram of flour with 64% (a), 82% (b) and 90% (c) extraction rate

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 tolerance index); E (elasticity).

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

Measured Parameter	Flour Sample	Resting time(min)		
		135	90	45
R_{50} (BU)	A	274.0±10.00^{a}	284.0±4.00^{a}	247.0±5.00^{a}
	B	158.0±0.58^{b}	143.0±1.00^{b}	119.0±3.00^{b}
	C	139.0±1.00^{c}	122.0±1.53^{c}	103.0±3.00^{c}
E (mm)	A	122.0±12.00^{b}	135.0±1.53^{b}	140.0±3.00^{a}
	B	155.0±4.00^{a}	161.0±3.00^{a}	150.0±3.51^{a}
	C	119.0±0.58^{b}	138.0±9.50^{b}	151.0±8.50^{a}
Energy (cm^2)	A	48.0±5.00^{a}	64.0±0.58^{a}	68.0±0.58^{a}
	B	27.0±2.00^{b}	35.0±1.53^{b}	38.0±1.53^{b}
	C	18.0±0.71^{c}	25.0±1.00^{c}	31.0±1.00^{c}
Max Height (BU)	A	277.0±3.51^{a}	344.0±1.53^{a}	348.0±4.50^{a}
	B	121.0±4.00^{b}	144.0±1.00^{b}	159.0±0.00^{b}
	C	110.0±3.00^{c}	130.0±3.00^{c}	142.0±0.58^{c}
R_{50}/E (BU/mm)	A	2.3±0.35^{a}	2.5±0.00^{a}	2.5±0.15^{a}
	B	0.80±0.000^{b}	0.90±0.000^{b}	1.1±0.06^{b}
	C	0.90±0.060^{b}	1.0±0.10^{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).

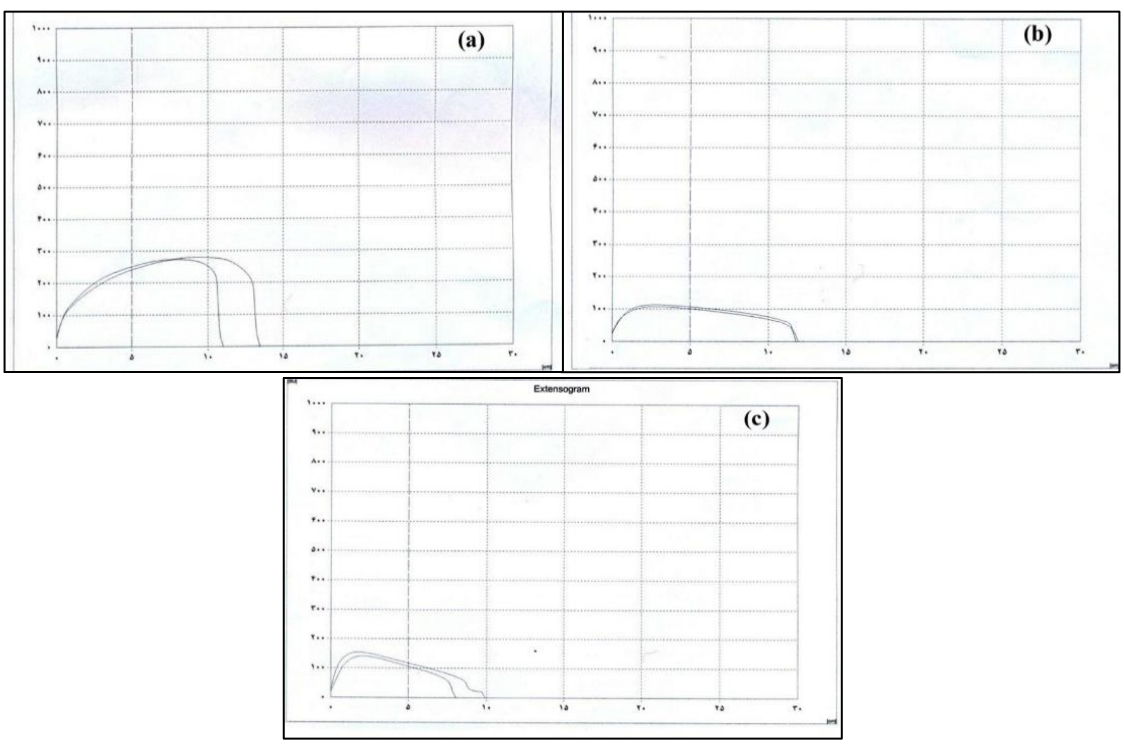

Fig. 2. Extensogram of flour with 64% (a), 82% (b) and 90% (c) extraction rate

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 A and C 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.

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

Flour Sample	P (mmH_2O)	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)

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	12
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).

3.4. *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 (Indrani et al., 2007). This parameter increased by increasing the bran content. In samples A, B and C 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. 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 & Scantos (2007).

3.5. *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.

4. Conclusion

The results showed 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. Combination and comparison of methods might be useful in the evaluation of wheat flour quality. 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. In conclusion these parameters were comparable to each other to assess the dough rheology. Among the applied methods, Alveograph might be considered as the most suitable method in order to predict the flour quality.

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