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Changes in Rheology and Sensory Properties of Wheat Bread with the Addition of Oat Flour

Gh. Peymanpour[1], K. Rezaei[1*], B. Sorkhilalehloo[2], B. Pirayeshfar[2], and G. Najafian[2]

ABSTRACT

Among cereals, oats are unique for their benefiting from high protein as well as lipid content. However, insufficient gluten content creates a big challenge to making breads out of this kind of cereals. Flour made of one type of bread wheat cultivar plus two types of improved oat lines were employed in this study to make composite oat-wheat flour bread. According to the data obtained from farinograph readings, water absorption capacity and the duration of the dough development increased with an increase in the dough's proportion of oat. The data obtained from the extensograph readings showed that the dough energy increased but extensibility property decreased with increase in the proportion of oat in the dough. Breads with 10% oat flour were ranked highest by the panelists. However, from a sensory point of view, the 10% formula was found to be inferior to control (bread baked from 100% wheat flour). Overall, considering the substantial nutritional benefits of oat, a certain level of compromise in the sensory properties can be made by offering breads with 20-30% rate of oat content.

Keywords: Bread properties, Oat-wheat flour bread, Sensory evaluation.

INTRODUCTION

Oat belongs to the family *Poaceae* and genus *Avena*. *Avena sativa* L. is the species that is currently cultivated (McMullen, 2000). Oats are harvested with their hulls on them (Hoseney, 1994). Among cereals, oats are unique for their high protein as well as lipid contents.

Oat is a perfect source of soluble dietary fiber *ß*-glucan, a non-starchy polysachcaride available in the cell walls of the aleurone layer in bran. The most important beneficial effects of ß-glucan are their contribution to a lowering of serum blood cholesterol and as well moderating blood glucose in diabetics (McMullen, 2000; Webster, 1996). Considering the progressive demand for products having lower calories and higher levels of dietary fibers, the developing and offer of dietary breads is an important step forward in meeting these demands.

Breads containing oat maintain their pleasant flavor and retain a fair level of moisture content during storage. However, due to lower levels of gluten in oat, it is used in combination with wheat flour (as the major component) to make bread of desirable texture and acceptable volume (Webster, 1996). D'Appolonia and Youngs (1978) studied the effect of oat bran and high protein concentrates on the dough and bread characteristics. They reported that breads made of wheat flour mixed with 10 or 20% of oat bran were favorably better than those made of wheat flour together with their corresponding levels (10 or 20%) of wheat bran.

Also, Oomah (1983) studied the bread- and cookie-making properties of oat and wheat flour mixtures. Bread and dough qualities of

[1] Department of Food Science, Engineering and Technology, University of Tehran, P. O. Box: 31587-77871, Karaj, Islamic Republic of Iran.
[*] Corresponding author, e-mail: krezaee@ut.ac.ir
[2] Cereals Research Department, Seed and Plant Improvement Institute, Karaj, Islamic Republic of Iran.

10 and 15% oat-bran breads were studied by Krishnan *et al.* (1987). They found that bread made of flour with 10% oat bran content yielded a more desirable bread volume and texture than that with 15% of oat bran. Flander *et al.* (2007) used breads with 51% whole-oat flour and then optimized the ingredients as well as baking conditions to achieve a reasonably good texture and flavor bread. The aim of this study was to investigate the effect of oat flour addition to bread flour on the rheological properties of the dough and the sensory characteristics of wheat bread.

MATERIALS AND METHODS

Materials

Bread wheat cultivar (Pishtaz) along with two oat lines (Oat D921 and Hulless oat) were supplied by "Seed and Plant Improvement Institute" (SPII, Karaj, Iran) in year 2007. Active instant dry yeast (*Saccharomyces cerevisiae*) was purchased from Dez Maye Co. (Tehran, Iran). Bread improver containing emulsifier, gluten, ascorbic acid, and enzyme was obtained from Golnan Puratos (Belgium and Iran). Tetrazolium (2, 3, 5- triphenyl tetrazolium chloride, microbiology grade, was purchased from Merck KGaA Chemical (Darmstadt, Germany).

Dough Characteristics

The effects of oat flour on the rheological properties of wheat dough were evaluated using a farinograph and an extensograph (both from Brabender, Duisburg, Germany), following the ICC standard methods (1972). Changes in water absorption capacity, developmental time and dough energy were investigated.

Flour Preparation

To inactivate the lipolytic enzymes, oat grains (before being milled) were heated at 110ºC for 50 minutes (in accordance with Zhang *et al.,* 1998) in a baking oven in aluminum trays of 50×50 cm dimensions and to a depth of 1 cm (Karl Welker KG.6908, Wiesloch, Germany). To assure the proper inactivation of lipolytic enzymes, Tetrazolium Test (ISTA, 2003) was performed.

A hammer mill (Laboratory Mill 3100, Falling Number, Huddinge, Sweden) was employed to grind oat grains. The hulls were removed from the oat flours using an electrical sieve (mesh no. 30). Wheat grains were milled by use of a roller mill (Brabender, Duisburg, Germany, NA/13 Nr. 12086).

Bread Making

Bread baking was performed according to the "Rapid Mix Test" method (ICC, 1980). Basic dough formula on a 100-g flour basis consisted of dry yeast (1.80 g), salt (1.50 g), sucrose (1.86 g), bread improver (0.30 g) and water. The volume of water was determined using the data obtained through farinograph. Two different oat breads (using each of oat-line flours plus wheat flour) were prepared by replacing 10, 20, 30, 40 and 50% of wheat flour with oat flours. The dough was mixed and 90-g pieces were then taken, hand-molded and fermented for 30 minutes (at 30ºC and 75% of humidity). The dough was degassed through hand-molding, baked (after a final proofing stage for 50 minutes) at 230ºC for 20 minutes and cooled at room temperature. Bread volume was measured by use of the rapeseed displacement test (Datta *et al.*, 2007). All the experiments were performed in three riplicates.

Organoleptic (Sensory) Tests

Bread sensory evaluation was performed by six panelists, using a nine-point hedonic scale (0, 1, 2, 3, 4, 5, 6, 7, 8) to rate the crust and crumb colors, odor, texture, taste, chewiness, bitterness as well as the overall acceptance of the bread samples. This was done through parametric statistics. A wider scale (such as the one employed in this study) can result in a more accurate rating as reported by the panelists.

Randomly coded samples were served with water (at room temperature). Each of the above-mentioned quality criteria was scored 0 (for the poorest product) and 8 (for the most appropriate and acceptable one). However, in order to avoid misunderstanding among the panelists, a reverse scale was adopted for evaluation of the bread bitterness (that is, 0 dedicated to a lack of bitterness *vs.* 8 for bitterness at its highest level). This was taken into account during the statistical rating process.

Statistical Analysis of the Data

All experiments were performed in triplicate. Comparison among the means were carried out using Least Significant Differences (LSD) at 95% confidence level from Statistical Analysis System (SAS) release 9.1 (SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION

Dough Physical Properties

The data obtained from the farinograph analysis of oat-wheat flour blends are presented in Table 1. Water absorption capacity ranged from 64.0±0.0 to 69.3±2.4%. For both types of oats, water absorption capacity of dough (with 50% oat flour) was significantly ($P< 0.05$) higher than those for 0% (control), 10% and 20% doughs. Development times for doughs of 40 and 50% D921 oat were lengthier than those for the other mix type doughs. Development time for the dough with 50% hulless oat was significantly longer than those for doughs with 0, 10, 20 and 30%. There exist several rheological tests to evaluate dough characteristics during mixing and fermentation processes. Among them, water absorption capacity of the flour is important to obtain acceptable dough consistency during the mixing time. Since bran particles in the flour prevent a perfect development of gluten matrix, it is also important to evaluate the development time of the flour by a farinograph (Bloksma and Bushuk, 1988). A

Table 1. The effect of oat percentage on the rheological properties of the dough as by farinograph analysis.

Oat type	Oat (%) [a]	Water absorption capacity (%) [b]	Development time (Min) [b]
D921	0 (Control)	64.0±0.0 [c]	1.9±0.2 [c]
	10	64.7±1.0 [c]	2.4±0.1 [b]
	20	65.7±0.4 [bc]	2.7±0.0 [b]
	30	67.1±1.3 [abc]	2.6±0.1 [b]
	40	68.6±2.0 [ab]	3.2±0.1 [a]
	50	69.3±2.4 [a]	3.2±0.2 [a]
Hulless	0 (Control)	64.0±0.0 [c]	1.9±0.2 [c]
	10	64.3±0.4 [bc]	2.6±0.1 [bc]
	20	64.8±0.8 [bc]	2.9±0.1 [bc]
	30	66.2±1.1 [abc]	2.5±0.4 [bc]
	40	68.1±2.7 [ab]	3.3±0.9 [ab]
	50	69.3±2.4 [a]	4.2±0.4 [a]

[a] Percent oat used in the bread formula. Control bread is made of 100% wheat flour.
[b] Values are mean±SD of three independent determinations. In each column, means with the same letter are not significantly different ($P>0.05$).

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farinograph evaluates the mixing properties of dough when gluten develops. Gluten proteins (gliadin and glutenin) form a strong, cohesive and elastic dough that could retain gasses and make a good leavened product (Hoseney, 1994; Adsule and Kadam, 1985; Mailhot and Patton, 1988). In this study, as the oat level in the flour increased, the time needed for the preparation of a good dough was also increased, due to a weaker formation of gluten matrix. Since pentosans and *ß*-glucans benefit from high water binding capacities, their presence in the oat flour caused slightly higher water absorption capacities, for doughs made of oat as part of the formula, in comparison with control. Similar results have been reported by Sudha *et al.* (2007) when studying the effect of adding fiber of different sources (wheat, rice, oat and barley) to wheat flour on the rheological properties of the dough. The above data were all in good agreement with those obtained by D'Appolonia and Youngs (1978) and as well by Krishnan *et al.* (1987).

An extensographic analysis of oat-wheat flour blends is presented in Table 2. Among all the flour blends, only those with 30, 40 and 50% oat content showed the capability for three times of extension and relaxation. Doughs of the other blends (those with 10 and 20% oat content) and that of the control indicated one time of extension and relaxation only as observed from the low curve area, extensibility and resistance to

Table 2. The effect of oat level on the rheological properties of dough as obtained through extensograph analysis.

Oat type	Oat (%) [a]	Dough energy [b]	Dough extensibility [b]
	0 (Control)	2.0 ± 1.4^{e}	
D921	10	1.5 ± 0.7^{e}	
	20	2.5 ± 0.7^{de}	
	30	5.0 ± 1.4^{cde}	65.0 ± 0.0^{a}
	30	7.5 ± 0.7^{bcd}	65.0 ± 0.0^{a}
	30	8.0 ± 0.0^{bc}	57.5 ± 10.6^{a}
	40	7.5 ± 0.7^{bcd}	52.5 ± 3.5^{a}
	40	10.0 ± 1.4^{abc}	60.0 ± 7.1^{a}
	40	12.0 ± 1.4^{ab}	60.0 ± 7.1^{a}
	50	9.0 ± 2.8^{bc}	$65.0\pm0.^{a}$
	50	12.5 ± 4.9^{ab}	52.5 ± 3.5^{a}
	50	14.5 ± 4.9^{a}	56.0 ± 8.5^{a}
	0 (Control)	2.0 ± 1.4^{d}	
Hulless	10	2.5 ± 0.7^{cd}	
	20	3.5 ± 0.7^{bcd}	
	30	5.5 ± 2.1^{abcd}	
	30	7.0 ± 2.8^{abcd}	
	30	8.5 ± 2.1^{ab}	55 ± 0^{a}
	40	7.5 ± 2.1^{abc}	55 ± 0^{a}
	40	7.0 ± 2.8^{abcd}	50 ± 0^{b}
	40	9.5 ± 2.1^{a}	55 ± 0^{a}
	50	5.5 ± 4.9^{abcd}	56 ± 2^{a}
	50	7.0 ± 2.8^{abcd}	50 ± 0^{b}
	50	9.5 ± 2.1^{a}	50 ± 0^{b}

Doughs containing 30, 40 and 50% oat had the ability to undergo three times of extension and relaxation. Doughs of 10 and 20% oat content as well as that of control passed only one time of extension and relaxation.

[a] Percent oat used in the bread formula. Control bread is made of 100% wheat flour.

[b] Values are mean±SD of three independent determinations. In each column, means with the same letter are not significantly different (P>0.05).

stretch. According to extensibility data obtained in this study, it is important to mention that the decrease in the gluten content of the dough and the increase of bran proportion (ending up with weaker formation of gluten matrix) could not maintain the dough extensibility. Dough energy increased as the oat proportion in the flour increased (Table 2). Energy for the 50% D921 oat dough was significantly higher than those for 0, 10, 20, and 30% doughs. For hulless oat, dough energy for the 50% formula was significantly ($P< 0.05$) higher than those for the 0, 10 and 20% dough formulas. Extensograph is employed to predict the dough characteristics during the fermentation process. Flours with high protein contents and high gluten strength result in doughs with a nearly perfect gluten matrix. The breads made of such doughs could benefit from near to perfect texture and bread volume (Bloksma and Bushuk 1988). In the current study, increasing the energy level of dough through an increase in the oat level could be associated with a corresponding increase in the water absorption capacity of the dough, resulting in higher enthalpy values for an extension of the dough.

Sensory Evaluation

Eight sensory characteristics of the bread (crust and crumb colors, odor, texture, taste, chewiness, bitterness, and overall acceptance) were evaluated by panelists. Oat contains a large proportion of unsaturated fatty acids, nutritionally beneficient for humans. Lipase activity is strongly influenced by water in the dough which can cause rapid release of free fatty acids leading to rancidity (Youngs, 1978). Although it was tried to inactivate the lipolytic enzymes, there was still some bitterness evident, associated with the breads made of a high level of oat flour. Therefore, it was important to consider this bitter taste in regards to consumer acceptance. Oat bran affects the chewiness of the bread. Chewiness was another sensory characteristic of the bread extensively influencing consumer acceptance. Table 3 shows the results of sensory evaluation of breads made of dough with different levels of oat content. For D921 oat, the best crust color score was respectively given to those with 0, 10 and 20% of oat (7±1, 6±1, and 5±1, respectively). The best crumb color, after the 0 and 10% oat content (both at 7±1 levels) was registered for the 20% formula (6±1). Other blends scored at similar levels with no significant differences ($P> 0.05$). The highest scores for the odor went to the breads with 0, 10 and 20% oat content levels (6±2, 7±1 and 6±1, respectively). The lowest levels of texture score belonged to the breads made of flour with 40 and 50% oat content (both at 4±2 level). This was significantly different from the records of the breads made of flour with 0-30% oat content. The highest taste score was obtained for 0 and 10% bread formulas (7±1). The 0 and 10% breads also indicated the highest chewiness level records (8±0 and 7±1, respectively). The highest score for the bitterness was obtained for the 50% bread flour formula (4±3), which was significantly higher than those for the 0, 10 and 20% bread formulas (0±0, 0±1 and 1±1, respectively). The overall acceptance levels of the breads were recorded as: 0 and 10%> 20 and 30%> 40 and 50%. As for the breads made of hulless oat, the highest crust color score went to those with 0 and 10% oat (7±1 and 6±1, respectively). The highest levels of crumb color record were obtained for the 0 and 10% oat containing breads (8±1 and 7±1, respectively). Odor score obtained for the 50% bread formula (4±1) was significantly below those for the 0 and 10% bread formulas (6±3 and 6±2, respectively). The lowest levels of texture score were obtained for the 30, 40 and 50% breads (4±1, 4±2 and 4±2, respectively). The top two taste scores were given to the 0 and 10% breads (7±1 and 6±1, respectively). Also, the 0 and 10% oat containing breads showed the highest chewiness score levels (7±1). Higher levels of bitterness scores were given to the 50 and 40% bread formulas (5±2 and 4±2, respectively), which were significantly

Table 3. Sensory evaluation of breads with different oat levels.

Oat type	Oat (%) [a]	Crust color [b]	Crumb color [b]	Odor [b]	Texture [b]	Taste [b]	Chewiness [b]	Bitterness [b]	Acceptance [b]
D921 oat	0 (Control)	7±1 a	7±1 a	6±2 ab	8±1 a	7±1 a	8±0 a	0±0 d	7±1 a
	10	6±1 b	7±1 a	7±1 a	7±1 b	7±1 a	7±1 ab	0±1 d	7±1 a
	20	5±1 b	6±1 b	6±1 ab	6±1 bc	6±1 b	6±1 bc	1±1 cd	6±1 b
	30	4±1 c	5±1 c	6±1 bc	5±2 cd	5±1 bc	5±1 cd	2±2 bc	5±2 b
	40	4±2 cd	4±1 c	5±1 cd	4±2 de	4±2 cd	5±2 d	3±2 b	4±2 c
	50	3±2 d	4±2 c	4±2 d	4±2 e	4±2 d	4±2 d	4±3 a	3±2 c
Hulless oat	0 (Control)	7±1 a	8±1 a	6±3 ab	7±1 a	7±1 a	7±1 a	0±0 d	7±1 a
	10	6±1 a	7±1 a	6±2 a	6±1 b	6±1 a	7±1 a	1±1 d	7±1 a
	20	5±2 b	5±1 b	5±2 abc	5±1 c	5±1 b	6±1 b	2±2 c	5±1 b
	30	4±1 bc	5±1 bc	5±1 abc	4±1 d	4±2 bc	5±1 c	3±2 b	4±1 bc
	40	3±2 cd	4±2 cd	5±1 bc	4±2 d	4±2 cd	4±2 c	4±2 ab	4±1 cd
	50	3±2 d	3±2 d	4±1 c	4±2 d	3±2 d	4±2 c	5±2 a	3±2 d

[a] Percent oat used in the bread formula. Control bread is made of 100% wheat flour.
[b] Values are Mean±SD of three independent determinations. In each column, means represented with the same letter are not significantly different ($P > 0.05$).

Table 4. Sensory evaluation as obtained throygh the rank analysis of the data.

Oat (%) [a]	D921 oat		Hulless oat	
	Mean Score	Mean Rank	Mean Score	Mean Rank
0 (Control)	7.3±2.7	2.7±2.7	7.1±2.7	2.9±2.7
10%	6.9±2.3	3.1±2.3	6.7±2.2	3.3±2.2
20%	6.2±2.0	3.8±2.0	5.8±1.6	4.2±1.6
30%	5.5±1.6	4.5±1.6	5.3±1.2	4.7±1.2
40%	5.1±1.5	4.9±1.5	5.0±1.2	5.0±1.2
50%	4.7±1.3	5.3±1.3	4.6±1.4	5.4±1.4

[a] Percent oat flour mixed in the bread formula. Control bread is made of 100% wheat flour.

higher than those of the 0 and 10% bread formulas (0±0 and 1±1, respectively). No bitterness was detected for the breads with 0 and 10% oat levels. Similar results have been reported by D'Appolonia and Youngs (1978) for breads with 10 and 20% oat bran. The highest acceptance level was 7±1, which was given to the 0 and 10% bread formulas. Sensory panelists scored lower crust and crumb color ratings with increase in the oat percentage in the dough. Similar results were obtained for the texture of the breads. Oat bran content can adversely impact the formation of gluten matrix (Bloksma and Bushuk, 1988). It also adversely affects the bitterness of the bread.

Table 4 shows the results of sensory evaluation obtained through a rank analysis of the data. The mean score and mean ranks of different oat-wheat flour blends were compared with each other. The bread samples made of D921 oat were ranked in the order of: 0> 10> 20> 30> 40> 50%, respectively. Similar results were obtained for the breads made of flours with different proportions of "hulless" oat.

Bread Volume

General outside views of the breads made of different combinations of oat and wheat flours are depicted in Figure 1. Also, the volumes of the bread and containing "hulless" D921 oats are presented in Table 5. Higher volumes of breads from either one of oat types were obtained by those made of 0, 10, and 20% oat levels (in the same order). Increasing the oat level in the bread formula resulted in a lower gluten level in the dough and consequently in a lower volume of the breads. The inside view of the breads for each of the formulas is shown in Figure 2 (for D921 oat breads) and Figure 3 (for hulless oat breads). The control bread indicated the best crumb grain as well as volume. Through an increase in the level of oat flour in the dough, the bread volume decreased and the crumb grain became further compressed. Similar results have been reported by D'Appolonia and Youngs (1978) and as well by Krishnan *et al.* (1987) for breads with 10, 15 and 20% oat bran, but no data were found for the composite oat-wheat breads.

Table 5. Effect of oat level (%, w/w) on the bread volume.

Oat (%) [a]	Bread volume (ml)	
	D921 oat [b]	Hulless oat [b]
0 (Control)	290±10 [a]	293±6 [a]
10%	210±10 [b]	203±12 [b]
20%	187±12 [c]	183±6 [c]
30%	157±12 [d]	158±8 [d]
40%	148±14 [de]	152±8 [de]
50%	133±6 [e]	143±6 [e]

[a] Percent oat flour used in the bread formula. Control bread is made of 100% wheat flour.
[b] The letters values are Means±SD of three independent recordings. In each column, means with the same letter are not significantly different (P> 0.05).

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Figure 1. Photos of D921 (a), and hulless (b) oat breads made throughout the study. On each image, bread loaves from left to right indicate breads with 0 (control), 10, 20, 30, 40 and 50% (w/w) of oat flour content.

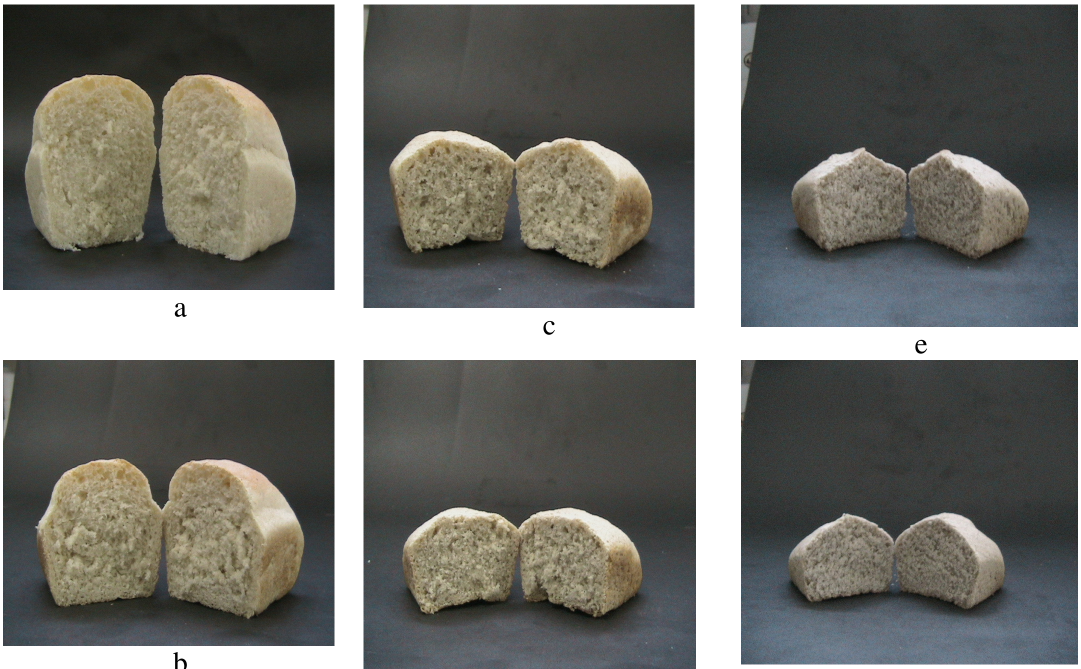

Figure 2. Photographs of D921 oat breads baked throughout the study. (a) Control bread (100% wheat flour), (b) 10%, (d) 20%, (c) 30%, (d) 40% and (e) 50% (w/w) D921 oat flour containing bread.

CONCLUSIONS

Dietary fibers have recently been incorporated in many food formulations. Fortification of bread with dietary fibers is one way of achieving its further health beneficial effects. According to the data obtained from the farinograph, water absorption capacity and the length of developmen time were both increased as the oat proportion was increased in the dough, which was consistent with the dough energy as obtained by use of the extensograph. Based on the results of the study, breads with lower levels of oat flour (10, 20 and 30%) in the formula are suggested so that, not only the technological aspects of bread baking along with consumer acceptance are

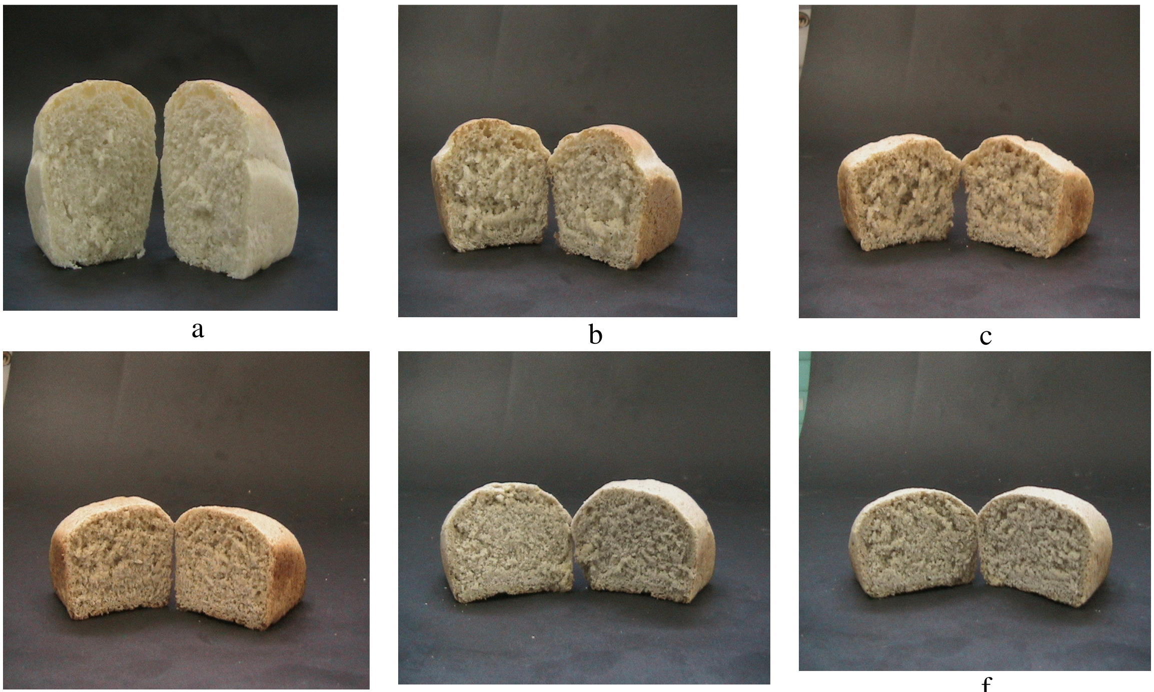

Figure 3. The photographs of hulless oat breads made in this study. Control bread (100% wheat flour), (b) 10%, (c) 20%, (d) 30%, (e) 40% and (f) 50% hulless oat bread.

paid attention to, but health promotion measures are also taken care of.

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تغییرات خواص رئولوژیکی و حسی نان گندم با افزودن آرد یولاف

غ. پیمان پور، ک. رضایی، ب. سرخی اله لو، ب. پیرایش فر و گ. نجفیان

چکیده

در میان غلات، یولاف به دلیل داشتن مقادیر زیاد پروتئین و چربی، منحصر به فرد می باشد. با این وجود، مقدار کم گلوتن یولاف مشکلاتی را در تهیه نان آن در مقایسه با دیگر غلات ایجاد می کند. در این مطالعه، یک رقم گندم نان و دو لاین یولاف برای تهیه نان ترکیبی گندم-یولاف استفاده شدند. نتایج فارینوگراف نشان داد که با افزایش درصد آرد یولاف در فرمول پخت نان، درصد جذب آب و زمان گسترش خمیر افزایش یافت. نتایج اکستنسوگراف نشان داد که با افزایش درصد آرد یولاف، انرژی خمیر نیز افزایش ولی کشش پذیری آن کاهش می یابد. نتایج آنالیز آزمون های حسی نان، نان ۱۰٪ را بهتر از نان شاهد (۱۰۰٪ گندم) نشان داد. به طور کلی، با در نظر گرفتن خواص تغذیه ای و سلامت بخش یولاف، نان های با درصد های یولاف ۲۰ و ۳۰ نیز می توانند در تهیه نان های رژیمی (درمانی) مورد استفاده قرار گیرند.