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EFFECT OF THE ADDITION OF WHEAT BRAN STREAM ON DOUGH RHEOLOGY AND BREAD QUALITY

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The milling by-products have high nutritional value and can be incorporated into white flour. This study was aimed at comparatively examining the rheological behaviour of the doughs made from wheat white flour with different levels (3-30%) of bran streams incorporated and from wholewheat. The results indicated significant correlations between the ash content of the wheat bran streams incorporated into flour and Alveograph, Rheofermentograph and Mixolab parameters. The white flour sample with 25% wheat bran streams had the ash content similar to wholewheat, but the dough rheology was improved. The quality of the white flour bread with 25% wheat bran streams was improved compared to the wholemeal bread.

Keywords: wheat bran stream, Alveograph, Rheofermentometer, Mixolab, bread

Introduction

From the bread making point of view, wheat (*Triticum aestivum*) is the most important crop. The wheat kernel consists of germ, pericarp layers (outer and inner), seed coat, aleurone layer and starchy endosperm. The objective of milling is to separate the starchy endosperm from the kernel, and to ground it into flour. The aleurone layer, pericarp layer and seed coat form the bran. Flours differ in their extraction rate, chemical and nutritional compositions. White flour is produced when the extraction rate is 75% or less, and whole meal flour is generated when the extraction approaches 100%. When white flour is produced, many important nutrients and fibres are removed, because these components are mainly located in bran and germ. Therefore the wholemeal flour provides good bread in terms of nutritional value and health benefits (Dewettinck *et al.*, 2008). Since the market of

white flour bread is better than the wholemeal flour one, there is much interest in developing white breads rich in dietary fibres content (Peressini and Sensidoni 2009) and/or with high vitamins and minerals contents (Hansen *et al.*, 2005).
Current technologies for producing bread enriched in dietary fibres (soluble or insoluble), account for fibres from different cereals or fruits and vegetables (Sudha *et al.*, 2007; Zhang and Moore, 1997); gums, such as guar gum and modified celluloses (Gomez *et al.*, 2003), or inulin-type fructans (Peressini and Sensidoni, 2009; Wang *et al.*, 2002). Although researchers and breadmaking industry worked together for improving the quality of these products, often their acceptance is quite limited due to the reduced loaf volume, hard crumb, and particular flavors of the crumb (Rosell *et al.*, 2010; Wang *et al.*, 2002).
Different milling by-products that often are discarded and end up as feed are rich in proteins, fats, vitamins, antioxidant compounds and minerals (Dewettinck *et al.*, 2008). These milling fractions could be used to increase the nutritional value of the bread products without affecting sensory quality (Bonnand-Ducasse *et al.*, 2010).
The aim of this study was to compare the rheological behaviour of the doughs made from white wheat flour with different levels of bran incorporated and from wholewheat.

Material and methods

Materials

Romanian common wheat, Dropia cultivar (harvest 2011 from Eastern Romania), was milled to an extraction rate of 77%, with an industrial roller mill (Buhler, Uzwil, Switzerland) having a capacity of 3300 kg/hr. The wheat was tempered prior to milling up to final moisture of 15%. The industrial roller mill consisted of four break rolls, nine reduction rolls, one coarse middlings divider, three bran finishers, and one turbostar sifter. The characteristics of the roller mill and the milling diagram ensure an efficient particle size separation that compensates for the absence of the purifier machines. The mill streams, tailing and second sieve, from nine reduction passage were selected to be incorporated into white wheat flour. These mill streams were ground in a laboratory mill to diminish the particle size to pass a 125 mesh sieve and then stored in plastic bags at 4-5ºC until testing. The product resulted is referred to as wheat bran streams (WBS).

Evaluation of chemical properties

The chemical properties were determined using the following methods: the moisture content using the AACC 44-51 method; the ash content using the SR ISO 2171:2002 method; the protein content using semimicro-Kjeldahl method; the fat content by extraction with ether through Soxhlet method; the gluten index and wet gluten content using the SR ISO 21415-2:2007 method; the falling number value and liquefaction number using the AACC 56-81B method; total pentosans content and soluble pentosans content using Hashimoto method (Hashimoto *et al.*, 1987); water absorption of wheat bran fiber using the method described by Bonnand-Ducasse *et al.* (2010).

Evaluation of rheological properties

The rheological characteristics were tested by means of: the NG Chopin Alveograph using the AACC 54-30 method, the F3 Chopin Rheofermentometer using the Chopin protocol and the Chopin Mixolab. The running parameters of the Mixolab device during the tests are: mixing rate 80 rpm, dough weight 75 g, tank temperature 30ºC, temperature of the first plateau 30ºC, duration of the first plateau 8 min, temperature of the second plateau 90ºC, first temperature gradient 4ºC/min, duration of the second plateau 7 min, second temperature gradient 4ºC/min, temperature of the third plateau 50ºC and duration of the third plateau 5 min.

The baking test

The one-stage method was used to prepare the dough using a laboratory mixer. The dough was prepared at 29-30ºC by mixing flour (100%), water (according to the water absorption capacity indicated by the Mixolab), salt (1.5%) and yeast (3%). The dough was fermented at 30ºC for 150 min in a laboratory proofer. Two re-kneadings of 30 s each were afterwards performed at 60 and 120 min. The dough was then divided in two pieces which were molded and placed in baking tins. After a final leavening of 30 min, the trays were introduced into the oven. The samples were baked at 230ºC for 30 min (when placing them into the oven, a steam tap was turned on for 10-15 s). After a 2 hour cooling, each sample was weighed and analysed in terms of specific volume (ml/100 g), porosity and elasticity of the crumb (SR 91:2007). The porosity of the bread was also estimated by analyzing the scanned images of the vertically halved breads by means of the Image J software (Datta *et al.*, 2007) that uses the contrast between the two phases (pores and solid part) in the image. The scanned color images were first converted to gray scale. Using bars of known lengths, pixel values were converted into distance units. The largest possible rectangular cross-section of the bread halves was cropped. After adjusting the threshold, the pores areas as fraction of total area were determined using the software.

Statistical analysis

Statistical analysis was carried out using the Microsoft Excel software. All experiments were carried out in triplicate and the average values are reported together with standard deviations. Analysis of variance (ANOVA) was used to test the statistical differences among results.

Results and discussions

Influence of wheat bran stream incorporation on physico-chemical characteristics of flour

The proximate composition of the WBS incorporation into white flour is: moisture content 11.2%, ash content 5.8%; protein content 17.6%, lipid content 6.5%, total pentosans 24.2%, water soluble pentosans 6.5%. Water absorption of WBS was 5.5%. Bonnand-Ducasse *et al.* (2010) reported for wheat fibres obtained from aleurnone layer and for the wheat fractions obtained after abrasion from outer bran

the total arabinoxylans contents of 35 and 32% of fraction, respectively. The water absorption of these fractions was 8 and 7 ml/g, respectively. The proximate composition of the commercial wheat aleurone fraction, manufactured by Bühler is: protein 21%, total dietary fibre 43%, ash 12% and fat 7%. Given these results, we can state that the WBS contains an important part of aleurone layer.
WBS was incorporated in different percentages (3, 5, 10, 15, 20, 25 and 30%) into white wheat flour and its impact on a wide range of quality characteristics was evaluated. The physico-chemical characteristics of the samples are reported in Table 1.

Table 1. Physico-chemical characteristics of flour with WBS

Samples[a]	Moisture content [b] (%)	Ash content (%)	Wet gluten content (%)	Gluten index (%)	Falling number values (s)	Liquefaction number value
P0	11.3± 0.03	0.53± 0.02	25.0±0.15	96±0.7	315 ± 2.8	22.6
P1	11.4± 0.06	0.65± 0.06	24.4±0.19	95±1.4	278± 4.2	26.3
P2	11.4± 0.06	0.74± 0.06	24.2±0.19	94±1.4	274± 4.2	26.8
P3	11.5± 0.05	0.95± 0.04	24.1±0.17	93±1.4	270± 2.8	27.3
P4	11.5± 0.05	1.17± 0.04	22.9±0.16	93±0.7	262± 2.8	28.3
P5	11.6±0.04	1.38± 0.05	21.0±0.15	92±0.7	256± 2.8	29.1
P6	11.5±0.04	1.61± 0.03	19.9±0.15	91±0.7	248± 2.1	30.3
P7	11.0±0.03	1.80± 0.03	18.4±0.14	90±0.7	238± 2.1	31.9
P8	11.0±0.03	1.62± 0.02	25.3±0.15	86±0.7	294± 2.8	22.6

[a]P0 - white flour, control sample, without WBS; P1 - sample with 3% WBS; P2 - sample with 5% WBS; P3 - sample with 10% WBS; P4 - sample with 15%; P5 - sample with 20% WBS; P6 - sample with 25% WBS, P7 - sample with 30% WBS; P8 - wholewheat flour.
[b]Expressed on 14% moisture basis.

The addition of 3 to 30% WBS to the white flour increased the ash content and decreased the falling number value of the samples. The ash content and liquefaction number increased from 0.65% to 1.80% and from 22.6 to 31.9, respectively, whereas the falling number value decreased from 278 s to 238 s. It is well known that there is a linear relation between liquefaction number and alpha-amylase content (Perten 1964; Tara and Bains 1975). Our results indicate a significant correlation of 0.94 ($p < 0.05$) between percentage of WBS incorporated into white wheat flour and liquefaction number. WBS is a mill stream that arises from the last reduction passage, and is expected to have alpha-amylase activity.

Kruger and Tipples (1980) and Rani *et al.* (2001) reported that the mill streams from the final break and reduction passages contain relatively high levels of alpha-amylase activity.

Gluten index decreased from 96% to 90% with the increase of WBS incorporated into the white wheat flour, but the gluten index of all blends is higher than the index of the whole grain (86%). This parameter provides information on both quantity and quality of gluten, and is based on the ratio high/low molecular weight proteins. High gluten index implies greater proportion of high molecular weight proteins present in gluten (Collar *et al.*, 2007). Gluten index depends on the amount of wet gluten that passes through a sieve under centrifugal force, and a higher proportion of gluten that remains on the sieve after centrifugation indicated stronger gluten (Dowell *et al.*, 2008).

Influence of wheat bran stream on Alveograph parameters

Addition of WBS into white wheat flour had a significant impact on dough rheology properties measured by Alveograph (Table 2).

Table 2. Alveograph parameters of flour with WBS

Samples	P (mm)	L (mm)	P/L	G	Wx10^{-4} J
P0	89 ± 2	73 ± 2	1.22	19.0 ± 0.8	232 ± 10
P1	91 ± 5	64 ± 2	1.42	17.8 ± 0.8	204 ± 8
P2	91 ± 3	67 ± 2	1.36	18.2 ± 0.7	211 ± 7
P3	96 ± 3	51 ± 1	1.88	15.9 ± 0.6	181 ± 6
P4	108 ± 4	36 ± 1	3.00	13.4 ± 0.5	152 ± 5
P5	126 ± 5	24 ± 1	5.25	10.9 ± 0.4	131 ± 4
P6	134 ± 5	18 ± 1	7.44	9.4 ± 0.4	105 ± 2
P7	134 ± 5	12 ± 1	11.16	7.7 ± 0.4	75 ± 2
P8	139 ± 5	10 ± 1	13.90	7.0 ± 0.5	66 ± 2

The dough resistance to deformation (P) is an indicator of the dough ability to retain gas; a high value of P indicates that the dough resists to deformation, while a low value of P indicates that the dough is less elastic. The extensibility of the dough (L) gives information about the processing characteristics of the dough, its capacity of extending without breaking down; a high value of the L indicates that the dough exhibits high extensibility and is easily stretchable. The index of swelling (G) can be interpreted in the same way as L. Alveograph P/L represents the balance of elasticity and extensibility; the high P/L values result in lower spread owing to the elastic nature of the dough. The W index is used to estimate the dough behaviour during the baking process; W is the most widely used characteristic because it summarises all Alveograph parameters.

Doughs made from wheat flour with strong protein have a high elasticity and a low extensibility (Bordes *et al.*, 2008). For very good quality flours, P value ranges from 80 to 100 mm, W is above 170 and P/L value is between 0.50 and 0.90 (Bordes *et al.*, 2008).

Gomez *et al.* (2003) and Wang *et al.* (2002) reported that the dietary fibres additions had pronounced effects on Alveograph parameters of wheat flour dough. According to Gomez *et al.* (2003) the addition of some purified dietary fibres from different origins (orange, pea, cocoa, coffee, wheat and microcrystalline cellulose) increases the dough tenacity (P) and reduces the dough extensibility (L). In general, all the fibres tested by Gomez *et al.* (2003) led to a moderate increase (up to 18%) in the deformation energy (W), with the exceptions of the wheat fibres with an average length of 0.035 mm and the cocoa fibres that decreased the dough strength by 23% and 10%, respectively. Wang *et al.* (2002) reported the increase of P by the addition of inulin, carob and pea fibres due to the interactions between fibres (polysaccharides) and wheat proteins, and a reduction of about 42% in the extensibility of the wheat flour.

Addition of WBS into white wheat flour increased the dough tenacity (P) and reduced the dough extensibility (L), and as a result, the P/L value increased. Compared to the control, the samples with 3, 5 and 10% had slightly higher P values (about 8%) and moderately lower W and L (about 21% and 30%, respectively). When 25 and 30% WBS were added, the dough tenacity and extensibility were comparable. When 15, 20, 25 and 30% WBS were added, the P/L reached very high values, probably due to the high content of cellulose present in these fibres (Wang *et al.*, 2002). In this case, improving the handling characteristics of dough by using additives would be necessary. The sample with 25% WBS (P6) had ash content similar to whole wheat (P8), but the dough rheology was different. Gan *et al.* (1989) found that the addition of nonendosperm components from the wheat to dough promoted a physical disruption of the gluten protein matrix, and the epicarp hairs appear responsible for deteriorating the baking performance of flour.

Sullivan *et al.* (2011) observed that the addition of barley middlings in wheat standard flour increases the resistance to deformation, producing more firm dough, and also decreases the extensibility of the dough. They consider that the increases of the dough firmness may be due to the barley middlings causing a change in the gluten matrix of the dough. The addition of fibres decreases the gluten concentration of the dough and increases the level of beta-glucan or arabinoxylans that have a high affinity for water and compromise the ability of the dough to form the gluten network (Brennan and Cleary, 2007; Courtin and Delcour, 2002). Sullivan *et al.* (2011) in agreement with Skendi *et al.* (2010) showed that the inclusion of beta-glucan into a dough system weakened the gluten network of the dough by disrupting intermolecular associations of gluten proteins. Angioloni and Collar (2009) suggested that the enrichment of wheat flour with high levels of fibres decreases the extension and resistance to fracture of dough. The authors considered that the inclusion of fibres lead to gluten dilution and to the disruption of the starch-gluten matrix. Moreover, Skendi *et al.* (2010) and Wang *et al.* (2002) suggested that addition of high levels of fibres could result in a reduction of gas retention capacity in the dough and a possible deterioration in the gluten network structure during proofing.

According to Indrani *et al.* (2007), the ash content is significant by negatively correlated to Alveograph G, W, and P/L. Wheat flour with higher ash content had lower values for Alveograph P and L as a consequence of the formation of smaller volume dough bubbles (Indrani *et al.*, 2007). The dough resistance to deformation (P) depends on the polypeptide chains present in the gluten that develop a viscoelastic matrix able to support the pressure from the gas produced by the fermentation process (Doxastakis *et al.*, 2002). The better viscoelasticity of dough and improving stability of gluten matrix is due to the intra/inter chain rearrangements resulted from disulphide bound formation (Morel *et al.*, 2002).

According to Grosch and Wieser (1999) the reduced level of endogenous glutathione (GHS) increases strongly with the ash content because GSH is mainly located in the germ and aleurone cells. Junqueira *et al.* (2007) reported that the dough elasticity is significantly increased in the presence of a mixture of lipoxygenase enzymes, benzoyl peroxide and ascorbic acid. They showed that GSH reacts almost exclusively with intermolecular S-S bonds, which are responsible for aggregative properties of glutenin low molecular weight subunits.

Our results indicated a significantly negative correlation between ash content resulted by WBS incorporating into white flours and Alveograph parameters: L (-0.97, $p \leq 0.001$), G (-0.98, $p \leq 0.001$), W (-0.98, $p \leq 0.001$). Similar results were reported by Indrani *et al.* (2007): L (-0.712, $p \leq 0.001$), G (-0.838, $p \leq 0.001$), W (-0.821, $p \leq 0.001$).

Influence of wheat bran stream on Rheofermentograph parameters

The increase of dough height during fermentation, gas production and gas retention were registered with the Rheofermentometer. The influence of WBS addition on the Rheofermentograph parameters is shown in Table 3.

Addition of WBS decreases the maximum height reached during fermentation (Hm), compared to the control sample (P0), in agreement with the increase of dough resistance to deformation and decrease in extensibility (Table 2). This behaviour is caused by the poor quality of the gluten matrix because of its dilution and water competition (Angioloni and Collar, 2009; Skendi *et al.*, 2010; Wang *et al.*, 2002). The time required for the maximum dough development (T1) was reduced by the addition of WBS. The time of maximum gas formation (T'1) and the time at which gas starts to escape from dough (Tx) were decreased with the addition of WBS, indicating a better dough permeability to carbon dioxide. The percentage of gas retention (Table 3) was found to decrease when the WBS was added, and this observation is in agreement with Wang *et al.* (2002).

Our results indicated a significantly negative correlation between ash content resulted by WBS incorporated and Rheofermentograph parameters: Hm (-0.82, $p \leq 0.001$), T1 (-0.94, $p \leq 0.001$), Tx (-0.51, $p \leq 0.001$), T'1 (-0.87, $p \leq 0.001$) and gas retention (-0.86, $p \leq 0.001$).

Table 3. Rheofermentograph parameters of flour with WBS

Samples	Dough development			Gas behaviour		
	Hm (mm)	T1 (min)	Gas loss (ml)	Tx (min)	T'1 (min)	Gas retention (%)
P0	56.3±0.14	139±1.41	38±0.14	76±0.35	102±0.71	97.6±0.71
P1	50.4±0.14	128±1.41	65±0.49	75±0.42	93±0.71	96.3±0.42
P2	35.2±0.28	118±1.41	73±0.42	76±0.37	80±0.71	96.2±0.28
P3	30.0±0.28	106±2.12	91±0.28	75±0.35	80±1.41	95.2±0.42
P4	29.8±0.14	94±1.41	98±1.41	67±0.21	67±0.71	95.0±0.71
P5	27.1±0.28	96±1.41	110±0.71	67±0.35	60±0.71	94.3±0.42
P6	24.0±0.28	84±0.71	125±2.12	66±0.21	59±0.71	93.8±0.42
P7	14.9±0.14	68±0.71	135±0.42	62±0.14	59±0.71	93.6±0.42
P8	28.5±0.28	70±0.71	120±1.41	67±0.14	57±0.71	92.3±0.42

Influence of wheat bran stream on Mixolab parameters

Addition of WBS into white wheat flour changed significantly the thermo-mechanical behavior of dough measured with Mixolab. Parameters obtained from the Mixolab curve are detailed in Table 4, and they describe the following stages: dough development, overmixing, cooking and cooling.

The dough development (DT) represents the time required to increase the dough consistency up to 1.1 Nm, after the suitable hydration of flour compounds. Dough consistency and stability are mainly due to the aggregates formation as a consequence of hydrogen bonding or proteins linking through disulfide or di-tyrosine bonds. Addition of WBS into white wheat flour increased dough consistency at a given amount of added water. However, from Table 4a, one can see that, in the case of WBS levels of 3 and 5% the development time is similar to the control sample (P0). Dough development times of the samples P6 (WBS level of 30%) and P8 (whole wheat flour) were comparable. Water absorption (WA) increased with the percentage of WBS incorporated into white wheat flour, due to the hydroxyl groups of the fibres which allow water bonding. These results are in agreement with the observation of other authors when studying different kinds of fibres (Gomez *et al.*, 2003; Zhang and Moore, 1997).

Regarding dough stability (ST) one can see from Table 4a that WBS incorporation caused the increase of this parameter. The investigations of Zhang and Moore (1997) revealed that the addition of wheat bran into bread dough systems decreased the mixing stability, as a consequence of gluten networks disruption by wheat bran particles. In case of WBS addition, the increase in dough stability is due to the increased interactions through hydrogen bounding involving the hydroxyl groups present in fibres molecules most probably (Rosell *et al.*, 2010).

Table 4. Mixolab parameters of flour with WBS

a.

Samples	Primary parameters									
	WA (%)	DT (min)	ST (min)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	α, (Nm/ min)	β, (Nm/ min)	γ, (Nm/ min)
P0	57.1± 0.20	1.35± 0.04	8.7± 0.52	0.40± 0.02	1.62± 0.06	1.94± 0.08	3.04± 0.12	-0.028 ±0.001	0.328 ±0.01	0.006 ±0.0001
P1	58.1± 0.40	1.50± 0.05	9.52± 0.63	0.39± 0.02	1.58± 0.06	1.88± 0.08	2.84± 0.10	-0.028 ±0.001	0.302 ±0.01	0.020 ±0.002
P2	58.4± 0.40	1.35± 0.05	9.55± 0.55	0.38± 0.02	1.62± 0.06	1.85± 0.08	2.82± 0.11	-0.028 ±0.001	0.322 ±0.01	0.022 ±0.002
P3	60.2± 0.20	3.97± 0.11	9.9± 0.68	0.41± 0.02	1.81± 0.08	1.75± 0.06	2.61± 0.08	-0.036 ±0.002	0.410 ±0.02	-0.020 ±0.002
P4	61.6± 0.40	4.70± 0.15	10.32± 0.71	0.44± 0.03	1.78± 0.07	1.65± 0.06	2.48± 0.10	-0.036 ±0.001	0.524 ±0.04	-0.038 ±0.001
P5	64.2± 0.40	6.32± 0.24	10.17± 0.64	0.44± 0.02	1.76± 0.07	1.49± 0.06	2.15± 0.10	-0.024 ±0.001	0.480 ±0.03	-0.050 ±0.002
P6	65.6± 0.60	5.67± 0.19	9.23± 0.79	0.45± 0.03	1.76± 0.07	1.41± 0.06	2.04± 0.09	-0.022 ±0.001	0.514 ±0.02	-0.056 ±0.002
P7	68.2± 0.60	5.87± 0.12	9.98± 0.82	0.46± 0.03	1.75± 0.07	1.32± 0.05	1.83± 0.08	-0.058 ±0.004	0.492 ±0.02	-0.050 ±0.002
P8	61.4± 0.40	5.70± 0.11	9.18± 0.77	0.44± 0.02	2.06± 0.11	1.91± 0.08	2.89± 0.11	-0.078 ±0.004	0.706 ±0.04	-0.032 ±0.001

b.

Samples	Secondary parameters			
	C1-C2 (Nm)	C3-C2 (Nm)	C4-C3 (Nm)	C5-C4 (Nm)
P0	0.75±0.04	1.22±0.04	0.32±0.03	1.10±0.02
P1	0.72±0.04	1.19±0.05	0.30±0.03	0.96±0.02
P2	0.72±0.04	1.24±0.04	0.23±0.02	0.97±0.01
P3	0.69±0.03	1.40±0.06	-0.06±0.01	0.86±0.02
P4	0.70±0.03	1.34±0.04	-0.13±0.03	0.83±0.01
P5	0.65±0.03	1.32±0.04	-0.27±0.02	0.66±0.01
P6	0.65±0.04	1.29±0.04	-0.35±0.03	0.63±0.02
P7	0.64±0.03	1.28±0.04	-0.43±0.03	0.51±0.01
P8	0.65±0.04	1.62±0.05	-0.15±0.02	0.98±0.02

c.

Samples	Mixolab Profiler index					
	Water absorption	Mixing	Gluten+	Viscosity	Amylase	Retrogra dation
P0	3	2	2	4	8	7
P1	5	5	1	4	8	7
P2	5	4	1	4	8	7
P3	7	6	2	5	8	6
P4	8	6	2	4	7	6
P5	8	6	2	4	5	4
P6	8	6	3	4	4	4
P7	9	5	4	4	2	3
P8	8	4	2	8	7	7

During overmixing stage, the dual mechanical shear and temperature constraint cause protein weakening and torque decrease to the minimum value C2 (Rosell *et al.*, 2010). The value of C2 (Table 4a) and protein weakening range (C2-C1) (Table 4b) decrease with the addition of WBS. Taking into account that by incorporating the WBS into white wheat flour some gliadin and glutenin are replaced with the albumin and globulin fractions from the outer layer, these decreases of the C2 and (C2-C1) were expected. According to Collar *et al.* (2007) the rate of flour extraction (white/wholemeal) is an important factor influencing the rheological behaviour of the dough. Compared to the white flour, in case of WBS addition the protein weakening is delayed, and the reduction is higher while the breakdown (α) is slower.

Cooking stage describes starch behaviour and is characterized by starch pasting ability (C3), amylase activity (C4), gelatinization rate (β) and cooking stability rate (γ). The C3 and β values increase with WBS addition into white wheat flour (Table 5a), while C4 and γ values decrease. (C3-C4) value is lower in the case of the samples with WBS compared to P0. (C3-C4) of dough made of whole wheat (P8) is higher than doughs that contain levels of WBS from 20 to 30%. WBS is a fraction from the outer layer and probably contains α-amylases causing the decrease of the C4 and (C3-C4) values and the increase of the β value.

The cooling setback (C5-C4) indicates the retrogradation ability of the starch and decreases with the WBS addition into white wheat flour (Table 4b). This behaviour can be explained by the higher lipid contents of WBS compared to white flour and lipid-amylase complex forming ability (Sedej *et al.*, 2011). The high lipid content causes changes in the reassociation and recristallization of the amylose molecules.

In Table 4c one can see the scores of the index defined by Mixolab Profiler: absorption potential (Water absorption index), behaviour of the dough during mixing at 30°C (Mixing index), behaviour of the gluten when heating the dough (Gluten+ index), maximum viscosity during heating that depends on both amylase activity and starch quality (viscosity index), starch ability to withstand amylolysis (amylolysis index) and starch retrogradation (retrogradation index). The higher value of the Mixing index and Gluten+ index corresponds to the high dough stability in mixing and to high gluten resistance to heating, respectively. The high value of Viscosity index corresponds to high dough viscosity during heating, while the high values of the Amylolysis index and Retrogradation index corresponds to low amylase activity and to a low shelf life of the end product (Chopin Applicatios Laboratory, 2009).

Comparing the sample P6 (with 30% of WBS) and P8 (wholewheat) one can see from Table 4c that the Mixing index and Gluten+ index are higher in the case of P6, while the Viscosity index, Amylase index and Retrogradation index are higher in the case of P8. Sample P4 (with 15% of WBS) had for all Mixolab profiler index higher values compared to P8.

Influence of wheat bran stream on bread quality evaluation

The effect of the WBS additions on bread quality characteristics is summarized in Table 5. Bread with WBS had smaller loaf volumes than the control sample (P0).

Up to 25% WBS (P1 to P6), the bread quality was better compared to the wholewheat bread (P8), but inferior to the white flour (P0). A similar result was reported by Gomez *et al.*, (2003) and Sullivan *et al.* (2011) that utilized wheat fibres and barley middlings. The gluten dilution resulted by adding the fibres, coupled with poor retention of gas during proofing, led to a decrease in baking quality (Sharma and Chauhan, 2000).

Table 5. Influence of WBS on the physical parameters of breads

Samples	Specific volume (ml/100 g)	Cell-to-total area ratio	Porosity (%)	Elasticity (%)
P0	347.2±6	0.565	77.8±0.8	96.7±0.8
P1	342.1±6	0.560	75.3±0.7	95.0±0.8
P2	320.3±5	0.526	75.3±0.7	91.7±0.8
P3	308.1±4	0.527	74.1±0.6	91.7±0.7
P4	257.9±6	0.476	65.5±1.8	91.7±0.6
P5	236.4±6	0.471	64.0±1.8	86.7±0.8
P6	212.1±5	0.459	63.2±0.7	83.3±0.7
P7	200.0±6	0.440	58.7±0.9	77.3±1.1
P8	205.1±5	0.436	60.2±0.6	78.3±1.2

The number of cells in a bread slice gives an indication of the amount of gas bubbles captured during proofing. For quality bread usually a large number of small sized cells are desirable. Cell-to-total area ratio was significantly ($p \leq 0.001$) affected by increased incorporation of WBS. The cell-to-total area ratio decreased when the level of WBS increased (Table 5) from 0.565, in P0, to 0.440, in the case of sample with 30% WBS. These results indicate that the incorporation of WBS into the white flour leads to a more coarse structure of bread. Sullivan *et al.* (2011) explained the low number of cells by gas escaping during proofing, suggesting a disruption of the gluten matrix in the dough. These would also support the decreased loaf volume and slice area in WBS containing breads.

According to the results in Table 5, the bread that contains 25% WBS had good quality compared to the wholewheat bread (P8).
Our results indicated a significantly negative correlation between ash content resulted by WBS incorporated and physical parameters of bread: specific volume (-0.98, $p \leq 0.001$), cell-to-total area ratio (-0.94, $p \leq 0.001$), porosity (-0.94, $p \leq 0.001$) and elasticity (-0.91, $p \leq 0.001$).

Conclusions

The wheat bran streams incorporated at different levels (3-30%) into white flour significantly change the rheological parameters of doughs, as showed by the Alveograph, Rheofermentograph and Mixolab curves. The results indicated that the white flour with 25% wheat bran streams had the ash content similar to wholewheat, but the dough rheology was improved. The level of 25% wheat bran steams incorporated into white flour can be used to increase the nutritional value of the bread products with less damage on the bread quality compared to wholemeal flour.

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