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COMPARATIVE ANALYSIS OF MULTIGRAIN AND COMPOSITE FLOURS BASED ON WHEAT, RYE AND HULLED OAT

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Abstract

The chemical composition, functionality and thermo-mechanical properties of the composite flours obtained by blending wheat (80-60%), rye (10-20%) and hulled oat (10-20%) flours were compared with the multigrain flours obtained through milling the equivalent blends of wheat, rye and hulled oat. The flours were obtained using an experimental roller mill. The composite flours had higher ash, fat, crude fiber and protein contents compared to the corresponding multigrain flours. However, the quality of proteins from multigrain flour was better than of the composite flours. Differences in terms of particles size of flours were observed between composite and multigrain flours, the modules ranging from 2.50 to 2.52 and from 2.78 to 2.87, respectively. The Mixolab parameters defining starch gelatinization, gel stability during heating and starch retrogradation were lower for composite flours compared to the multigrain flour. Due to the disruption of gluten network formed by wheat, the specific volume of bread decrease with increasing the level of rye and hulled oat in wheat, from 1.84 to 1.63 cm^3 and from 1.93 to 1.71 cm^3 for composite and multigrain flours, respectively.

Key words: *composite flours, multigrain, roller mill, flours functionality, thermo-mechanical properties.*

INTRODUCTION

Cereals play a key role on food security due to their contribution to the daily energy requirements, ensuring about 19% of the caloric needs (Shiferaw et al., 2013). Moreover, about 21% of the daily dietary protein intake is delivered by wheat, what makes this cereal to be considered the main protein source at the global level.

It is therefore important for the cereal products to accumulate other nutrients in addition to proteins. In this respect, producers permanently provide on the market new products with improved nutritional value. The easiest method to accomplish it is to use whole cereal flours. Other method relies on the preparation of the composite flours in which the wheat flour is substituted with different levels of other cereals, pseudo-cereal, or legume flours.

The most advanced roller milling technology was developed over the years for wheat and rye. The roller milling systems is long-flow or short flow diagrammed, being based on different numbers of break rolls, reduction rolls, middlings divider, bran finisher or purifier machines, and the final flours can be formed by combining various mill streams.

In addition to wheat and rye, oat can be also milled by means of roller mills. Doehlert and Moore (1997) studied the composition of the milled products resulted by milling the oat by using three different mechanisms, namely roller mill, impact mill and pearling mill. They reported similar composition of the brans obtained through roller mill and impact mill, the bran having high amounts of β-glucan arising from the endosperm cell walls. Under the action of break rolls, the endosperm cell walls are ground into larges particles that are further separated into bran by sifting. Moreover, Doehlert and Moore (1997) showed that protein and mineral substances adhere to the cell walls and finally get into the bran. In another study, Aprodu and Banu (2017) reported that hulled oat milling with a roller mill resulted in low flour yields and oat bran containing large and flattened particles.

In this study wheat, rye and hulled oat were milled separately with an experimental roller mill and the resulting flours were blended to get three different composite flours having the wheat flour as base. Additionally, multigrain flours were obtained by milling with the same experimental roller mill the multigrain blends consisting on cereals mixed in the same proportion as in case of the composite flours. All resulting flours were analysed in terms of physical chemical properties, functionality and thermo-mechanical properties.

MATERIALS AND METHODS

Wheat (Boema variety), rye (Suceveana variety) and hulled oat purchased from a specialized local market (Galaţi, Romania) were used in this study.

Flours preparation

In order to obtain wheat (W), rye (R) and hulled oat (O) flours, the cereals were milled with the SK experimental roller mill (Sadkiewicz Instruments, Poland) described by Aprodu and Banu (2017). The obtained flour yields were 61.2%, 59.4% and 57.7% for wheat, rye and hulled oat, respectively. Further composite flours were prepared by mixing wheat, rye and hulled oat flours in the following ratio: 80:10:10, 70:15:15 and 60:20:20.

The multigrain blends were obtained by first blending wheat, rye and hulled oat in the same ratio of 80:10:10, 70:15:15 and 60:20:20, followed by milling the blends with SK experimental roller mill. The yields of the multigrain flours were the following: 58.9%, 54.7% and 50.5% for the blends with different amounts of rye and oat, namely 10%, 15% and 20%, respectively.

Chemical composition

The following methods were used to determine the chemical compositions of the composite and multigrain flours: SR ISO 71:2005 for moisture, SR ISO 2171/2002 for ash, semimicro-Kjeldahl method for protein, Soxhlet extraction with ether for fat, and the Fibretherm Fibre Analyser for crude fiber. For each flour, the module was determined according to Godon and Willm (1994) using sieves with 250, 180, 160, 125 and 90 mm mesh.

Solvent retention capacity tests

Solvent retention capacity (SRC) of the composite and multigrain flours was determined according to the AACC Method 56-11.02. In order to evaluate the flour functionality, the water (W-SRC), sucrose (S-SRC), sodium carbonate (SC-SRC), and lactic acid (LA-SRC) were determined. The gluten performance index (GPI) was calculated according to Kweon et al. (2011). Sodium dodecyl sulphate (SDS) index was determined according to the method described by Seabourn et al. (2012), by using 2.5% (w/w) SDS solution and 0.005 g/ml lactic acid.

Thermo-mechanical properties of multigrain flours

The Chopin+ protocol (AACC Method 54-60) and the Chopin Mixolab device were used to estimate the thermo-mechanical properties of the composite and multigrain flours. The minimum torque C2 (Nm), starch gelatinization C3 (Nm), gel stability during heating C4 (Nm), starch retrogradation C5 (Nm), dough stability S (min) and amplitude A (Nm) were extracted from the Mixolab curve.

The bread-making procedure and bread analysis

The one-stage method for dough preparation described by Banu et al. (2010) was used for preparing the bread samples. Specific volume and crumb firmness were determined for bread samples, as indicated by Banu et al. (2010).

Statistical analysis

The results were reported as mean values together with standard deviation, the experiments being realized in triplicate. The correlation coefficients between different parameters ($p<0.05$) were calculated using Microsoft Excel Soft.

RESULTS AND DISCUSSIONS

The chemical composition of the composite and multigrain flours is presented in Table 1. The results showed that the increase of the substitution level of wheat flour by rye and hulled oat flours resulted in the increase of ash, crude fiber and fat contents in all flour samples. Comparing the chemical composition of the composite flours with the multigrain flours, it appears that for the same level of rye and hulled oat, the ash, fat and crude fiber and protein contents are higher in case of the multigrain flours (Table 1). Moreover, if in case of the composite flours the protein content decreased from 9.77 to 9.44%, with increasing the level of rye and hulled oat flours, in case of the multigrain flours the protein content increased from 7.87 to 8.64%. The decrease of protein content in case of composite flours can be explained by the fact that the wheat flours had higher protein content compared to the rye and hulled oat flours used for substituting the wheat. Thus, according to Aprodu and Banu (2017) the protein content in flours used for obtained the composite flours were: 10.1, 7.4 and 9.5% for wheat, rye and hulled oat flours, respectively.

Table 1. Chemical compositions of composite and multigrain flours

Flours	Ash, %	Protein %	Fat, %	Crude fiber, %	Modu-les	SDS index, ml
Composite						
80W+ 10R+ 10O	0.48	9.77	1.62	1.73	2.50	36
70W+ 15R+ 15O	0.51	9.61	1.88	1.82	2.51	33
60W+ 20R+ 20O	0.54	9.44	2.14	1.90	2.52	31
Multigrain milling						
80W+ 10R+ 10O	0.62	7.87	1.67	1.66	2.78	44
70W+ 15R+ 15O	0.69	8.32	1.81	1.77	2.80	42
60W+ 20R+ 20O	0.71	8.64	2.52	2.89	2.87	38

The low protein content in the multigrain flours can be due to the endosperm breaking in large particles that are refused into bran. This assumption is supported by the values of the modules of multigrain flours that varied from 2.78 to 2.87, being higher than those corresponding to the composite flours that varied from 2.50 to 2.52. Although the multigrain flours contain low protein amounts, the SDS index values suggested that these proteins had higher quality than those from corresponding composite flours (Table 1). Analysing the trend of the SDS index values registered for the multigrain flours, one can see a decrease of this index with increasing level of rye and hulled oat. Similar observation was reported by Tulse et al. (2014) when studying the multigrain milling of blends consisting of wheat, green gram and barley.

The solvent retention capacity tests of composite and multigrain flours were also performed, and the results are presented in Table 2. The W-SRC, S-SRC and SC-SRC values of the composite flours were higher than those of multigrain flours. One explanation for this behaviour could be the higher module values given by the high content of particles with higher dimensions, which can suggest in the same time a low content of damaged starch in the multigrain flours. The LA-SRC values of the multigrain flours were higher than for composite flours, which suggest higher quality of gluten protein in the multigrain flours compared to the composite flours. Moreover, a significant positive correlation (0.93, $p<0.05$) was found between LA-SRC and SDS index. The GPI was calculated in order to estimate the global quality of gluten protein. According to Kweon et al. (2011) GPI describes the overall performance of the gluten. As can be seen from Table 2, the GPI values of multigrain flours varied from 0.52 to 0.45, and were higher than those corresponding to the composite flours, which varied from 0.48 to 0.43. A significant positive correlation (0.87, $p<0.05$) was registered between GPI and SDS index. The increase of the rye and hulled oat addition level resulted in the decrease of LA-SRC. This effect could be a consequence of the gluten dilution effect when reducing the amount of wheat within the blends.

Table 2. Solvent retention capacity profiles of composite and multigrain flours

Flours	W-SRC	S-SRC	SC-SRC	LA-SRC	GPI
Composite					
80W+10R+10O	68.2	79.2	80.7	77.0	0.48
70W+15R+15O	69.0	81.0	84.8	75.5	0.46
60W+20R+20O	70.1	89.7	86.5	75.1	0.43
Multigrain milling					
80W+10R+10O	66.5	79.8	76.1	81.3	0.52
70W+15R+15O	67.6	80.2	79.9	78.3	0.49
60W+20R+20O	68.5	86.4	85.9	76.7	0.45

The thermo-mechanical properties of composite and multigrain flours are presented in Table 3. In addition in Figure 1 are depicted the Mixolab curves for composite and multigrain flours.

The amplitude (A) decreased with increasing the addition level of rye and hulled oat, which means that the dough elasticity decreased (Dubat and Boinot, 2012). Moreover, the dough stability (S) increased, suggesting that the doughs were stronger and develop high resistance to kneading. When increasing the level of rye and hulled oat within wheat, the minimum torque during dough kneading at 30°C (C2) decreased from 0.53 to 0.43 Nm and from 0.51 to 0.48 Nm for composite and multigrain flours, respectively (Table 3). The Mixolab parameters that define starch gelatinization (C3), gel stability during heating (C4) and starch retrogradation (C5) were lower for composite flours compared to the multigrain flour. These results can be a consequence of particles size of flours that most probably induced lower contents of damaged starch in the multigrain flours. The starch was therefore found to be more stable during heating.

Table 3. Thermo-mechanical properties of composite and multigrain flours

Flours	C2, Nm	C3, Nm	C4, Nm	C5, Nm	S, min	A, Nm
Composite						
80W+10R+10O	0.53	2.50	2.44	3.78	7.78	0.11
70W+15R+15O	0.46	2.49	2.44	3.70	7.52	0.09
60W+20R+20O	0.43	2.43	2.34	3.59	10.00	0.07
Multigrain milling						
80W+10R+10O	0.51	2.52	2.60	4.06	5.53	0.19
70W+15R+15O	0.51	2.54	2.58	3.95	9.03	0.08
60W+20R+20O	0.48	2.58	2.50	3.88	9.65	0.07

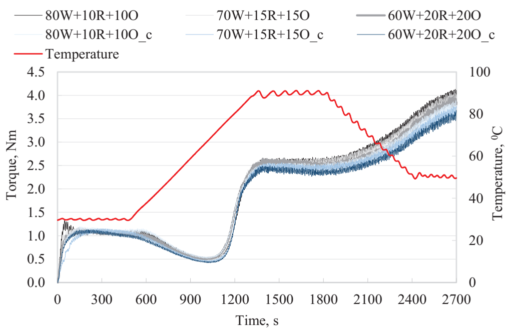

Figure 1. Mixolab curves of composite (80W+10R+10O_c, 70W+15R+15O_c, 60W+20R+20O_c – flours with 80, 70 and, 60% wheat, 10, 15 and 20% rye and 10, 15 and 20% hulled oat, respectively) and multigrain (80W+10R+10O, 70W+15R+15O, 60W+20R+20O – flours with 80, 70 and 60% wheat, 10, 15 and 20% rye and 10, 15 and 20% hulled oat, respectively) flours

The increase of the rye and hulled oat levels resulted in the decrease of the parameters that defined the starch behavior during heating and cooling. In particular, the decrease of C4 value is due the amylase activity of rye which is higher with respect to the wheat (Aprodu and Banu, 2016).

According to Dubat and Boinot (2012) the Mixolab curve of rye indicated high value of C3 followed by a drop of C4 torque due to the low stability of the hot starch. The starch retrogradation also decreased with increasing the level of rye and hulled oat. This observation is in agreement with Dubat and Boinot (2012) that reported lower retrogradation for rye compared to wheat. They explained this behaviour through the different type of starch existent in the two investigated cereals.

The specific volume of bread decreased from 1.84 to 1.63 cm^3, and from 1.93 to 1.71 cm^3 for composite and multigrain flours, respectively, with increasing the level of rye and hulled oat addition to the wheat (Table 4). These results can be explained by the disruption effect caused by rye and hulled oat on the gluten network formed by wheat. In Table 4 are presented the specific volume and texture properties of the bread obtained out of composite and multigrain flours. When comparing the specific volume of the bread samples prepared out of flour samples with the same level of rye and hulled oat, one can see that this is higher in case of the multigrain flours. Significant positive correlations were registered between the specific volume and GPI (0.98, $p<0.05$), as well as between specific volume and LA-SRC (0.85, $p<0.05$).

Regarding the crumb firmness, this property was higher in case of bread samples prepared with multigrain flours than with composite flours. Moreover, a significant positive correlation ($p<0.05$) was established between crumb firmness and C5 value from the Mixolab curve.

Table 4. Specific volume and crumb firmness of breads

Flours	Specific volume, cm^3	Firmness, g force
Composite		
80W+10R+10O	1.84	1423.9
70W+15R+15O	1.77	1708.5
60W+20R+20O	1.63	1854.8
Multigrain milling		
80W+10R+10O	1.93	1502.0
70W+15R+15O	1.85	1811.6
60W+20R+20O	1.71	1936.3

CONCLUSIONS

The result of this study revealed the differences in terms of technological properties between composite and multigrain flours based wheat with different levels of rye and hulled oat.

The ash, fat, crude fiber and protein contents were higher for multigrain flours compared to the composite flours. One major difference between the two types of flours was related to the particle size estimated through module values.

Although the protein contents in the multigrain flours were low, the quality of these proteins appreciated through the SDS index and GPI were higher than in case of composite flours. Additionally, the LA-SRC values of multigrain flours were higher than for composite flours, and the specific volume of breads made with multigrain flours were higher than of breads made with composite flours.

At the same time, significant positive correlations were found between specific volume and SDS index, LA-SRC and GPI.

The increase of the level of rye and hulled oat addition resulted in the decrease of the specific volume of the bread due to gluten dilution when substituting the wheat with other cereals.

Future studies on comparative analysis of composite vs multigrain flours will be realized using a type of experimental roller mill that include break and reduction rolls.

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