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Original paper

Bread making potential assessment of wheat-oat composite flours

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Abstract In the recent years, evidence has been accumulated about the beneficial effects on consumers' health of oat in daily diets, respectively: maintaining blood cholesterol, lowering postprandial glucose, cardiovascular risk reduction, reducing oxidative stress and so on. The increase of oat content in bakery products, such as bread was generally associated with a decrease in volume and a worsening of sensorial characteristics, features that are guiding the consumer's decision to buy a particular product. Researchers have aimed to achieve a bakery product that contains a sufficient amount of whole oat flour, without affecting the quality characteristics of bread (volume, porosity, elasticity). Our results have shown that the ideal proportion between the oat flour and wheat flour was 30:70, in order to obtain a functional product attractive to the consumer. We have also analyzed the main rheological changes (by farinographic and alveographic methods) of dough obtained from wheat – oat composite flours (10, 20, 30, 40, 50% oat flour). Our findings have shown that the addition of oat flour significantly increased the water absorption and decreased water retention capacity under mechanical stress. Generally, the rheological parameters in wheat-oat composite flours were affected by a more than 20% oat flour content.

Keywords Bread, functional food, wheat-oat composite flours, whole oat flour, yeast activity

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Introduction

There have been accumulated enough evidences in recent years, related to benefits of eating oat, mainly due to unique nutritional profile of this grain, rich in bioactive compounds. Its bioactive compounds are involved in reducing:the level of cholesterol (β-glucans, tocotrienols), the postprandial glucose level (β-glucans), the oxidative stress (phenolic acids, avenantramides, tocols), the blood pressure (specific protein fractions) or in prevention of breast and colon cancer (dietary fibers, O-methylated flavonoides by tricine-glucosides type or lunazina peptide) (N. GANGOPADHYAY & al. [5]; I. NAKURTE & al. [8]; A. POPA & al. [9]). The main problem for obtaining bread, by using oat derived products, refers to the consumers acceptability towards them.Numerous studies have shown that the use of products derived from oat, in bread composition, caused a drastic decrease of its volume (T. BOJŇANSKÁ & al. [4]; D. LITWINEK & al. [7]; D. BOTAU & al. [2]).

There are a sufficient number of studies that have described baking tests, using either whole oat flour, or various combinations with wheat flour. (E. HÜTTNER et al. [6]) analyzing the bakery performance of oat flours, from different geographical areas (Sweden, Ireland, Finland), obtained for the specific volume of whole oat bread, values ranging from 1.14 ml/g to 1.66 ml/g. A. CZUBASZEK et al. [3] obtained values between 5.63 and 4.74 ml/g for the volume of bread produced from wheat-oat composite flours, in varying proportions (5-20%). The values are comparable to those obtained by D. ZHANG et al. [11], namely 5.8 ml/g for the addition of 10-20% oat flour. D. LITWINEK & al.[6]reported volumes of 3.92-3.96 ml/g for the bread obtained after the addition of 50% oat flour, of various origins, to wheat flour (volumes going down by 50% compared to bread obtained of 100% wheat flour). Finally, L. BLAZEKOVA et al. [1] reported a volume of 2.49 ml/g in the case of bread obtained by addition of 30% oat flour.

The aim of this paper was to obtain bakery products, containing the maximum amount of oat flour, without the quality characteristics (volume, porosity, elasticity) to be affected.

Materials and Methods

To achieve the researches we used two types of flour:

1. wheat flour type 550, from SC Farinsan SA (harvest 2016), having the following quality characteristics: Moisture%=14.5; Protein content%=14.5; Wet gluten content%=34.0; Gluten Index=85; Content of minerals%=0.54; Water absorption (Hydration capacity)%= 57.8; Dough development time (minutes)=2.0; dough Stability time (minutes)=5.9; Softening degree (UF, 12 minutes)=55, Alveographical Mechanical Work W (J/g)=295×10^{-4}/g; alveographical Resistance/Extensibility ratio (P/L)=0.73;

2. whole oat standardized flour, purchased from SC Cope SA Piatra Neamt, having the following characteristics: max. Moisture%=10; max. Ash content%= 1.2; Protein content%=10.0; Fibers content%=4.0; Carbohydrates content%=66.0, Lipid content%=8.0; Granularity was characterized by a particle size mean of less than 500 μ, for 97% of particles and the remaining 3% having sizes between 500 and 1000 μ.

In order to evaluate the impact over farinographical and alveographical parameters, were added successive increasing amounts of whole oat flour to wheat flour, according to the experimental design presented in Table 1. Each variant was performed in triplicates.

Table 1. The amounts of whole oat flour added to wheat flour

Sample No.	Wheat flour (%)	Whole oat flour (%)
Control	100	0
V1	90	10
V2	0	20
V3	70	30
V4	60	40
V5	50	50

To determine farinographical parameters of flours, we used a Brabender Farinograph E. Analyses were performed according to ISO 5530-1 standard [12]. There were determined: Water absorption (WA,%); Development time (DT, min); Stability (ST, min), Softening degree at 12 minutes after max. (DS_{12}, FU). Alveographical parameters were determined according to ISO 27 971: 2008, using a Chopin Alveograph[13]. There were determined: Resistance (P, mm), Extensibility (L, mm), Extensibility of Gluten index (G), Mechanical Work W (10^{-4} J/g), and Index of dough Elasticity (Ie,%).

Other materials used for baking test were: compressed fresh yeast from Pakmaya Romania, iodized salt, water, bread conditioner (Pan Up T- Max from Orkla Foods Romania). Technological parameters and recipes for bread with added oat flour (V1-V5) are seen in Table 2.

Each variant was performed in triplicates. For each variant were determined: the Volume (Fornet device, STAS 91/1983 [14]), Porosity and Elasticity of breads (STAS 91/1983[14]).

Table 2. Recipes and technological parameters of bread made from wheat-oat composite flours

Ingredients	Control	V1	V2	V3	V4	V5
Wheat flour (kg)	100	90	80	70	60	50
Whole oat flour (kg)	0	10	20	30	40	50
Water (l)	56.0	56.5	57.0	60.0	62.5	65.0
Yeast (kg)	3.0					
Salt (kg)	1.5					
Pan Up T-Max (kg)	0.5					
Kneading (min)	3 (slow) + 6 (fast)					
Fermentation (min, 30°C, 70% humidity)	30					
Dividing	600 g					
Rounding						
Final moulding	30 cm long					
Final proof (min, 30°C, 70% humidity)	40					
Baking (tunnel oven, min, 240°C)	25					

In order to compare the activity of yeast, between the wheat and the oat flour, it was used a method derived from the analysis of Falling Number (ISO 3093 [15]). We recall that Falling Number measures the effect of the enzymes on wheat quality. Thus, there were successively weighed in high-viscometer tubes: 7 g of wheat flour, 7 g whole oat flour and 7 g of a wheat-oat composite flour(30% oat flour). To each of these samples were added 0.14 g of yeast, dry matter. It was added 25 ml of water in each tube. The tubes were plugged with rubber stoppers and the content of the tubes was stirred vigorously 22 times. The tubes containing the suspension were introduced in a water bath at 30°C for 10 minutes. Then, the viscometer tubes were stirred again vigorously 22 times and placed in the Falling number device. We measured the time taken for a plunger (25 g weight) to fall to the bottom of the tube and cross the formed gel. High quality sample produced a thicker gel and we recorded a higher Falling Number.

Results and Discussions

a. The effects of whole oat flour addition on rheologycal parameters.

The results of the alveographical and farinographical analyzes are presented in Table 3.

In Table 3 it is observed that wheat-oat composite flours had significant altered properties relative to wheat flour (control). Thus, **water absorption** (hydration capacity) increased on average by about 1.75% for eachamount of 10% whole oat flouradded. There is a strong relationship between water absorptionof composite flours andadded whole oat flour R^2=0.96, Fig. 1). This was due to the contribution of fibers from whole oat flour, and also to the good hydration properties of oat starch, compared to wheat starch.

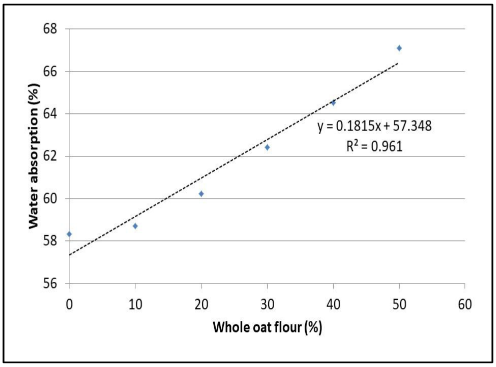

Figure 1. Water absorption variation of composite flours related to added whole oat flour

The **dough development time** had an upward trend in composite flours (from 2 minutes in wheat flour, to 10.5 minutes in composite flours with 50% whole oat flour). This general trend, although obvious, was not perfectly linear, so between the composite flours with 30% and 40% whole oat flour, the differences recorded were statistically insignificant (6.03 minutes and 6.2 minutes, t=-0.39). Theoretically, the dough development time should increase when the whole oat flour is added, due to the increase of the time required for the flour natural ingredients to fill up an additional amount of water. Also, the effect was amplified by the sizes increase of particles in composite

Table 3. Wheat - oat composite flours alveographical and farinographical parameters						
Parameter	**Control**	**V1**	**V2**	**V3**	**V4**	**V5**
			Farinograph			
WA (%)	58.33±0.25	58.70±0.43	60.23±0.40	62.43±0.51	64.53±0.66	67.10±0.80
DT (min)	2.00±0.20	2.13±0.25	7.67±0.31	6.03±0.50	6.20±0.56	10.53±0.61
ST (min)	6.33±0.11	8.60±0.20	9.90±0.46	6.90±0.56	5.20±0.72	4.63±0.55
DS_{12} (UF)	55.33±4.51	66.33±6.51	100.33±4.51	107.67±4.51	91.33±8.08	120.33±5.51
			Alveograph			
P (mm)	84.33±1.53	99.67±1.53	137.00±1.73	159.33±0.58	*	*
L (mm)	114.67±1.53	61.33±1.53	29.00±1.73	14.67±0.58	*	*
G	23.77±0.16	17.38±0.22	11.95±0.36	8.50±0.17	*	*
W(10^{-4} J/g)	295.00±2.64	216.00±2.00	169.00±3.60	97.33±0.58	*	*
P/L	0.73±0.01	1.63±0.06	4.74±0.33	10.90±0.48	*	*
Ie (%)	57.63±0.21	50.50±0.70	0	0	*	*

flours, given that oat flour had a higher granularity than the wheat flour.

The **dough stability** parameter recorded a significant increase in composite flours, by up to 20% whole oat flour (from 6.33 min. in the control sample to 9.9 min. in the composite flour with 20% whole oat flour). Beyond this percentage of oat flour, dough stability dropped significantly to 4.63 min. for dough from composite flour with 50% whole oat flour (Fig. 2).

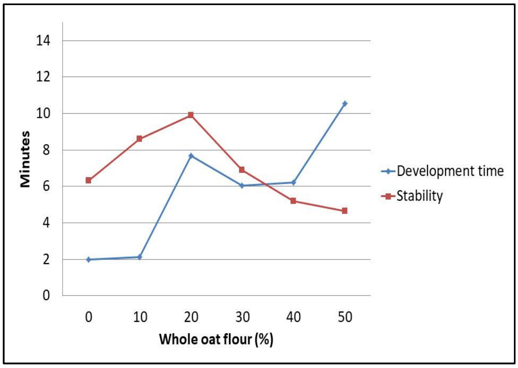

Figure 2. Development time and stability variation of composite flour dough depending on the amount of added whole oat flour

The addition of whole oat flour increased the dough degree of softening.The increase effect was very significant in additions higher than 20% (100.33 to V2 vs. 55.33 to control, t=12.22***). Approximately 76% of the softening degree variation could be explained by the addition of whole oat flour. There was also a significant correlation between the water absorption and the softening degree of composite flours (r=0.82*). This suggests that although the moisture capacity in composite flours increased, as a result of fibers intake and oat starch, the water retention capacity in dough, under mechanical stress conditions, decreased (Fig. 3).

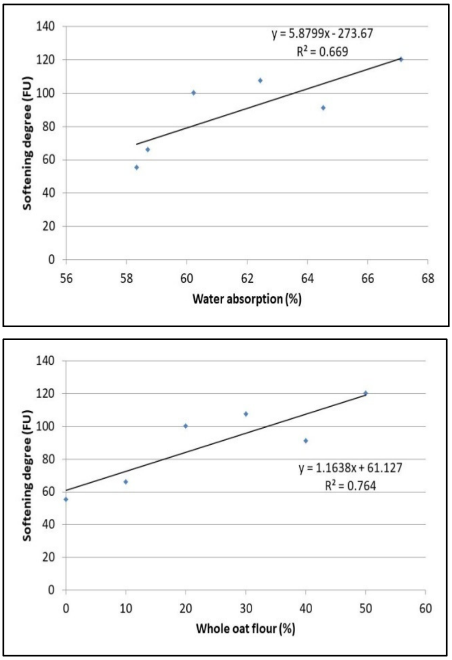

Figure 3. Variation of DS_{12} (up)and WA (%) of composite flours (down)

Alveographic parameters were initially evaluated based on the classic alveographic protocol, at constant hydration, taking into account the moisture content of the composite flours (the results are seen in Table 2). The disadvantage of this protocol was that it did not take into account the additional need for moisture of dough, due to the increase in fibers intake, with the increase of added whole oat flour amount in composite flours. Therefore, alveograms for V4 and V5 (with 40% and 50% whole oat flour, respectively) could not be performed.

The results showed that in composite flours it was noticed a significant increase in dough resistance (P) as the amount of oat flour increased (on average, by about 25 mm/10% whole oat flour added to dough). At the same time it have been registered significant decreases, correlated with the amount of added whole oat flour, of mechanical work (W, on average by about 66x10E^{-4}J/g for each 10% added whole oat flour) and extensibility (L, on average by about 33 mm for each 10% added whole oat flour). These changes were related to the decrease of gluten amount, correlated with the increase of fibers amount, under constant hydration conditions (Fig. 4). These results had the effect of P/L ratio increase from 0.73 to 10.9, as well as the loss of elasticity properties of dough (Ie% for V2 and V3 = 0).

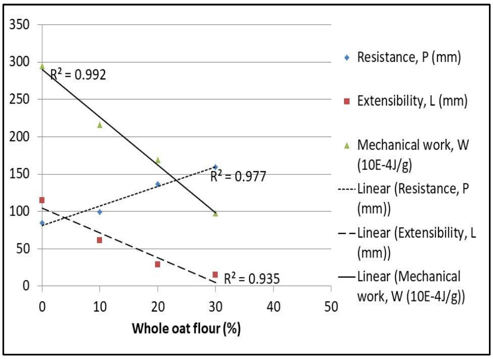

Figure 4. Variation of alveographic resistance, extensibility and mechanical work in composite flours under constant hydration conditions

Table 4 presents the alveographic analysis of composite flours (for hydration conditions, related to farinographically determined water absorption, see Tabel 3). To diminish the effect of sodium chloride (from the hydration solution used by the alveographic method) on the results and considering that it has the role of reducing the hydration capacity of the flours, we opted for an additional of 0.7% solution at each 10% whole oat flour added.

Table 4 shows that additional hydration allowed the alveograms execution also for both V4 and V5. The results obtained were relatively similar to those observed in the case of performing the constant hydration analyzes, with a few differences which were pointed out below:

- alveographic extensibility decreased steadily, as the amount of whole oat flour increased, from 114.67 mm (C) to 9.67 mm in the 50% whole oat flour (V5); dough extensibility rate was, on average, 21 mm for each 10% increase in the amount of oat flour from the recipes;
- mechanical work absorbed by dough decreased very significant from 295.0 x 10^{-4}J/g to 52.67 x 10^{-4}J/g at V5 (t=155.284***); the decrease correlated very significant with the percent of oat flour, beeing on average, 48.5 x 10^{-4}J/g for each 10% added whole oat flour in recipes (Fig. 5);
- alveographic resistance initially recorded an increase, from 84.33 mm (C) to 139.33 mm (V3, 30% whole oat flour), after which its value decreased;
- P/L ratio increased on average, by a rate of 2.19 for each 10% added whole oat flour in composite flours (from 0.73 to 11.68);
- for the addition of more than 10% oat flour, dough elasticity index (Ie, %) dropped to 0.

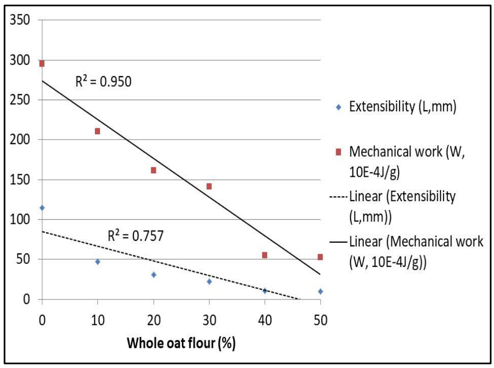

Figure 5. Extensibility and Mechanical Work in composite flours, in terms of variable hydration

Table 4. Alveographic analyzes obtained following the adaptation of the working protocol

Parameter	Control	V1	V2	V3	V4	V5
P (mm)	84.33±1.53	113.00±1.00	126.33±1.53	139.33±0.58	118.67±0.58	112.67±0.58
L (mm)	114.67±1.53	47.00±1.00	31.00±2.00	22.67±0.58	11.00±1.00	9.67±0.58
G	23.77±0.16	15.08±0.16	12.24±0.39	10.47±0.13	7.33±0.34	6.85±0.22
W(10^{-4} J/g)	295.00±2.64	210.33±0.58	161.67±6.51	141.33±2.31	55.00±1.00	52.67±0.58
P/L	0.73±0.01	2.40±0.03	4.09±0.31	6.15±0.18	10.84±0.91	11.68±0.66
Ie (%)	57.63±0.21	51.9±0.11	0	0	0	0

The results of rheological tests suggested that higher amounts than 20% oat flour in composite flours, significantly worsened dough properties, reaching the limit of bakery potential.

b. The effects of whole oat flouraddition on yeast activity

Hydrothermal treatments (in order to inactivate lipolytic complex) to which oat is subjected during preparation for milling process, increase at the same time the amount of simple carbohydrates, due to partial degradation of polyglucides. This provides a more rapid fermentable source for yeast, compared to the source available in wheat flour.

The results achieved by using the method derived from Falling Number analysis are shown in Fig. 6. It was observed that in the case of whole oat flour and 70% wheat-30% oat flour mixture, the time required for the gel liquefaction, in the presence of yeast, was reduced compared to control flour. This time was by 23.9% lower for whole oat flour, compared to the control, without yeast (t=-23.59***). In the case of oat flour and wheat-oat flour mixtures, the time required for the gelliquefaction was about 27% (t=-24.61***). For wheat flour,the time decrease required for gel liquefaction was lower with only 14.5% (t=-11.73**).

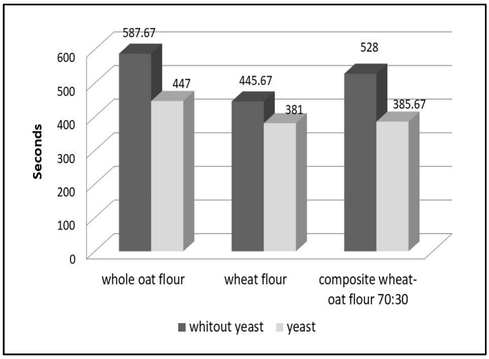

Figure 6. The effect of whole oat flour addition on the activity of yeast

c. The effects of whole oat flour addition on bread quality parameters

The results of the baking tests for the five experimental variants (see Table 1), are shown in Table 5. Results represent the mean values for the three replicates performed for each variant.

The addition of whole oat flour worsened generally the technological characteristics of dough and the quality parameters of finished products, in a proportion that depended on the amount added in recipes. This is due to increased fibers intake, which caused significant degradation of gluten films ability, to retain gases. It was noted that the addition of yeast and bread conditioner (containing enzymes and ascorbic acid) improved the results obtained in the course of baking tests, compared to the rheological analyzes prediction. Fig. 7 shows the general appearance of the obtained loafes and also the core appearance. It is noted that both the general and the core appearance worsened, as the amount of whole oat flour increased.

Table 5. Results obtained for the baking tests

Specification	Specific volume (ml/g)	Porosity (%)	Elasticity (%)
Control	5.58±0.22	88.33±1.53	97.67±0.58
V1	5.32±0.15	87.33±0.58	96.67±1.15
V2	5.22±0.20	85.30±0.58	95.67±0.58
V3	5.05±0.24	84.30±1.53	95.00±1.00
V4	4.51±0.26	80.67±2.52	93.30±0.58
V5	3.73±0.25	75.33±1.15	90.30±1.53

The color of the bread crust was more lighter as the amount of whole oat flour increased, phenomenon which could be related to reduction of Maillard reaction rate and dextrins formation, due to the reduction of the water quantity available for these reactions (R. TAMBA-BEREHOIU [10]). The effect was most visible in the case of V5 (with 50% whole oat flour) at which the color of bread was almost similar to that of the dough from which it came from.

In Fig. 8 it is observed that 87.8% of the loaf volume variation, in experimental variants,was due to the amount (%) of the whole oat flour used in recipes.

It was noted that the best values of the loafes volume were obtained when using a quantity of up to 30% oat flour. Beyond this amount, the volume decreased significant, up to 3.73 ml/g. We considered that the value of 30% whole oat flour is optimal in composite flours, because this was the level from which the loafes volume started to decrease significant, compared with the loafes volume obtained from control flour (t=2.92*).

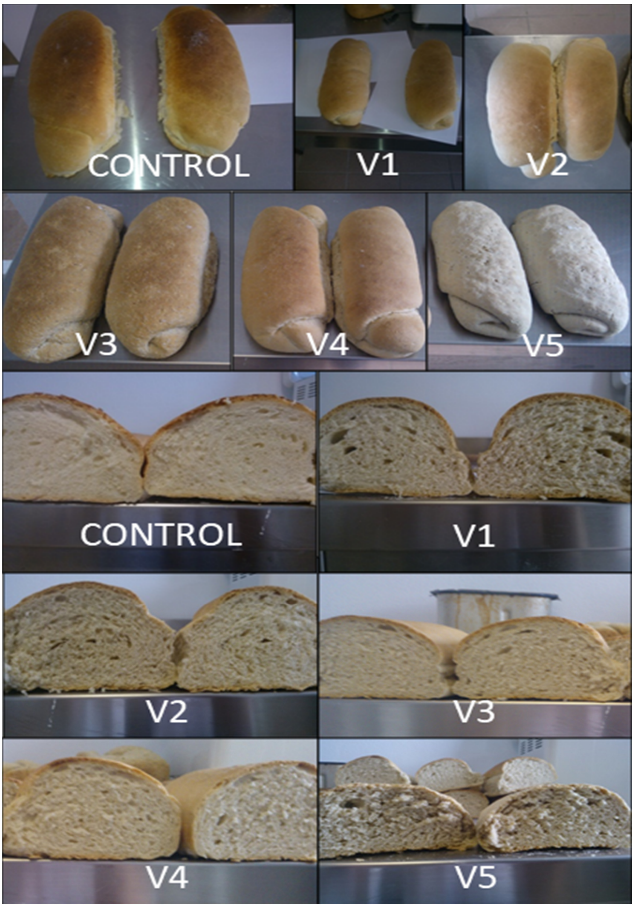

Figure 7. The appearance of the loafes and bread core, obtained by baking tests

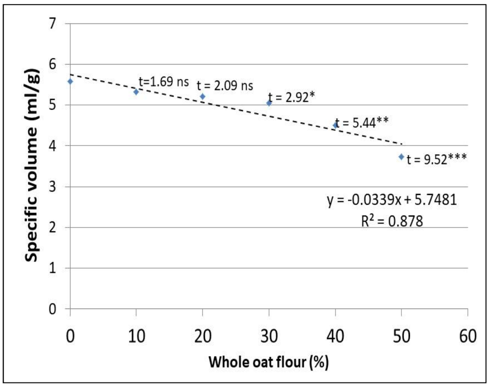

Figure 8. Regression between the bread volume and the amount of added whole oat flour(ns – insignificant; significant levels: *p<0.05, **p<0.01, ***p<0.001)

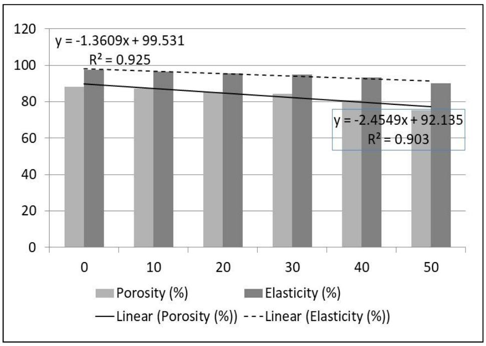

Figure 9. Effect of the oat flour addition on the porosity and elasticity of bread

The same observations could be made in terms of **porosity** and **elasticity** parameters (Fig. 9). About 90% of porosity variation was due to the variation of oat flour in recipes, while about 93% of elasticity variation could be explained due to oat flour. Both porosity and elasticity of bread, significant started to decline compared to control at 20% whole oat flour in composite flour (V2: t=-3.94* for porosity and t=-4.223* for elasticity). However, between V2 and V3,there were no significant differences (V2-V3; t porosity=-1.06 ns, t elasticity=1.00 ns).

Basically, the results suggested that the addition of over 30% whole oat flour significant worsen the quality parameters of products obtained by using conventional technologies. The appearance of final products would be affected, taking into account the major acceptability criteria agreed by the consumers, in accordance with the literature data.

Conclusions

The addition of whole oat flour to wheat flour had a very important role on dough water mobility, with a significant effect on rheological parameters. Thus, **water absorption** (WA, %) of the composite flours increased on average, with 1.75% for each fraction of 10% whole oat flour added in the recipes (R^2=0.96; p <0.001). On the other hand, water retention capacity of dough in conditions of mechanical stress, measured by the farinograph parameter **degree of softening** (DS_{12}, FU), decreased with the increasing of the whole oat amount in composite flours (R^2=0.764; p <0.05). Some rheological parameters tend to worsen significant in composite flours with the addition of higher amounts than 20% of whole oat flour. So, farinographic **stability** (ST, min) and alveographic **resistance** (P, mm) decreased significant beyond the limit of 20% added whole oat flour. Moreover, alveographic parameters namely: **extensibility** (L, mm) and **mechanical work W** (10^{-4} J/g) decreased with the increasing of the whole oat amount in composite flours (R^2=0.95; p<0.01, respectively R^2=0.76; p<0.05).

The addition of whole oat flour significant stimulated the activity of bakery yeast (probably due to the intake of simple carbohydrates brought by whole oat flour in dough). Thus, the time required for the liquefaction of starch gel, in the presence of yeast, was 27.9% lower in the case of composite flour with 30% oat flour. At the same time, the time required for the liquefaction of starch gel, in the presence of yeast, for wheat flour was lower by only 14.5%.

Generally, **bread quality parameters** (volume, porosity and elasticity) worsen, due to the increase of oat flour quantity in recipes. Almost 88% of the bread volume variation and over 90% of the variation in porosity and elasticity could be explained on account of whole oat flour variation in composite flours. It was also noticed a **crust color** variation of finished products, with the amount variation of whole oat flour, suggesting a slowdown in Maillard reactions and dextrins formation, due probably to decrease of water availability.

Our findings suggested that under the addition of enzymes, ascorbic acid and yeast, the maximum amount of whole oat flour, that can be used in preparation of bakery products, is more than 20% (as provided by alveographic analysis). The composite flours with 30% whole oat flour had an optimal bakery potential and were acceptable in terms of bread volume.

Conflict of interest disclosure

There are no known conflicts of interest in the publication of this article. The manuscript was read and approved by all authors.

Compliance with ethical standards

Any aspect of the work covered in this manuscript has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

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