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Influence of barley flour incorporation on the indicators of bread from a mixture of white wheat and rye flour

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Abstract

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The impact of the addition of barley flour on indicator of wheat-rye bread was tested. The appropriate ratio of wheat and rye flour for control sample was determined. Proportion of 30/70% wheat/rye flour give high values of electrical conductivity and total-dissolved solids. Active acidity is neutral and oxidation potential is high. L (Lab) color component was found to be a good indicator to track color changes in flour, dough and bread from mixture of wheat, rye and barley flours. The active acidity slightly decrease for dough, compared to flour and bread. High positive values of oxidation-reduction potential was found in bread. The addition of up to 25% barley flour provide acceptable bread. These breads have improved nutritional values with acceptable texture and taste. Cooling time, mass losses are near the industrial produced white bread. In addition to improving the nutritional value of bread by adding barley flour, this bread also has potential for industrial production.

Keywords: white wheat flour; rye; barley; sensory analysis; color

Introduction

In recent years, researches increase, centered around creating advanced breads with different additives that have beneficial consequences for the human body and may bring down the danger of different sicknesses (Georgieva et al., 2013; Aly et al., 2018). Barley has been used for the most part to prepare malt and fodder. Barley flour has a high content of dietary fiber and a high degree of soluble fiber, especially β-glucan, which improves the health and utilitarian properties of the bread (Gupta et al., 2009; Zlatev et al., 2019).

The use of barley in bakery blends explores Tsenov et al. (2009). According to the authors, non-traditional use of barley rich in β-glucan in wheat mixtures for bakery purposes is a health concern. In this sense, a suitable mixture to achieve a higher amount of β-glucan is 50% wheat – 50% barley. It states that the presence of barley in various mixtures with wheat leads to a reduction in their technological and baking characteristics, the degree of reduction being dependent on the quality status of the varieties used and the proportion of barley in the mixtures.

Another important problem is related to cooling and storage before commercial distribution of bread. Microbiological safety requirements include the packaging of bread in polyethylene or, in some cases, paper bags. This is possible after cooling the bread. The cooling rate is a critical indicator (Primo-Martín et al., 2008; Lyubenova et al., 2013; Pastuchov, 2015).

The purpose of this study is to investigate the amount of barley flour influence on indicators and cooling rate of bread from a mixture of white wheat and rye flour.

Material and Methods

The material used is White wheat flour, type 500 (Topaz Mel Ltd., Bulgaria), flour type 1750 rye (ET TIT-Tenko Tenev, Kameno, Bulgaria), whole wheat flour from barley (Ecosm Bulgaria Ltd, Stambolovo, Bulgaria).

The bread was made of mixtures of wheat, rye and barley flour. The main technology used is that laid down in an approved Bulgarian white bread standard AS02/2011. The dough is prepared by a single-phase method with one mixing during rising. Yeast Evmaya (Mauri Maya Sanayi AS, Aksakal Bandirma Turkiye) was used; drinking water (according to Bulgarian Ordinance No. 9 of 16.03.2001 on the quality of water intended for drinking and household purposes regulation on requirements for the labeling and presentation of food); iodized salt (according to Bulgarian Decree of the Council of Ministers No 23/2001 on the requirements for the composition and characteristics of the salt for food purposes).

The quantity of raw materials was determined with a scale MH-200 (ZheZhong Weighing Apparatus Factory), a maximum determined mass of 200 g, with a resolution of 0.02 g.

Parameters of flour, dough and bread were measured: Conductivity EC, µS/cm, Conductivity Meter AP-2 (HM Digital, Inc); Active acidity pH, pH meter PH-108 (Hangzhou Lohand Biological Co., Ltd); Total Dissolved Solids TDS, ppm, TDS-3 measuring instrument (HM Digital, Inc.); Oxidation Reduction Potential ORP, mV, Measuring Instrument Model ORP-2069 (Shanghai Longway Optical Instruments Co., Ltd).

Measurements were made at room temperature of 20±2°C and relative humidity of 45% RH.

The preparation of the measurement samples is made according to AACC 02-52.01 methodology. Distilled water is heated to 70°C; the raw material (flour, dough, bread) is dissolved in the distilled water in a ratio of 1/10 (5 g of raw material in 50 ml of distilled water); stirring until a homogeneous solution is obtained; after cooling to ambient room temperature, three consecutive measurements of each indicator were made and their average value was determined.

The color components of the RGB color model (RGB [0 255]) were converted to Lab (L [0 100], a [-86.18 98.23], b [-107.86 94.47]), according to (Baycheva, 2016; Zhelyazkova et al., 2016). The values of chroma C and hue h° were determined by:

$$C = \sqrt{a + b} \qquad h^o = atan\left(\frac{b}{a}\right) \tag{1}$$

Determination of heat losses during cooling of bread. The bread is approximated to a parallelepiped with the dimensions of the sides axbxc. The main parameters for determining heat losses during cooling of bread are the heat losses from convection and radiation, the total heat losses, the average temperature difference.

Thermal convection losses q_{conv}, W:

$$q_{conv} = -hA_{loaf}\left(\theta_{loaf} - \theta_{amb}\right), \tag{2}$$

where h is a convection coefficient w/m^{2}K; A_{loaf} – bread area, m^2; θ_{loaf} – the initial bread temperature, °C; θ_{amb} – ambient temperature, °C.

Thermal losses of radiation q_{rad}, W:

$$q_{rad} = -\varepsilon_{loaf}\sigma A_{loaf}{T_{loaf}}^4 \tag{3}$$

ε_{loaf} – constant; σ – constant? T_{loaf} – initial bread temperature, K.

Total heat losses q_{total}, W:

$$q_{total} = q_{conv} + q_{rad} \tag{4}$$

Temperature difference Δθ, °C

$$c = \frac{\theta_w - \theta_{amb}}{\theta_{loaf} - \theta_{amb}}; \qquad \Delta\theta = \begin{cases} \dfrac{\theta_{loaf} + \theta_w}{2} - \theta_{amb}, & c \geq 0.7 \\ \dfrac{\theta_{loaf} + \theta_w}{ln\left[\dfrac{\theta_{loaf} - \theta_{amb}}{\theta_w - \theta_{amb}}\right]}, & c < 0.7 \end{cases} \tag{5}$$

where c is the criterion for selecting of a difference; θ_w – desired temperature of the bread crumb.

Descriptive statistics of flour, dough and bread parameters were determined by mean-arithmetic mean; SD – standard deviation; CV – coefficient of variation. Data are processed at a level of significance α = 0.05.

Results and Discussion

Determination of parameters of flour mixture of wheat and rye flours

The measured indicators of a mixture of white wheat and rye flour are presented in Table 1. The dependence of these parameters on the amount of rye flour added to the mixture is shown. It is seen that when adding 70–75% rye flour, maximum EC, TDS and ORP values are obtained. High EC and TDS values indicate that the flour mixture can absorb more water than 100% wheat or 100% rye flours. The active acidity is pH = 7.0, indicating that it is neutral. High ORP values indicate that at this ratio of both flours, the mixture has the highest oxidation potential.

Adding rye flour to white wheat results in a significant change in color. In Table 2, the color components of the Lab

Table 1. Parameters of flour from mixturer of white wheat and rye flours

Wheat flour, %	Rye flour, %	EC, µS	TDS, ppm	pH	ORP, mV
100	0	452	137	7.3	139
90	10	465	157	7.2	142
75	25	502	151	7.1	145
50	50	574	187	7.1	148
25	75	654	203	7	152
0	100	393	159	7.3	136

and LCh color models are presented. Clear dependence is seen in the L (Lab) color component, which decreases as the amount of rye flour in the mixture increases. This color component can be used as an indicator of color change because it is not affected by color saturation, it takes into account changes in brightness.

Mixing of wheat and rye flours has impact on the measured EC, pH, ORP parameters. Lower values of L (lab) color component are obtained when the amount of rye flour increase. Impact on these parameters would be the fermentation processes involved in dough (for example, in rising and proofing) with the ratio between rye and wheat flour. A control sample of 30% white wheat and 70% rye flour was determined, because in this ratio the flour mixture have parameters appropriate for preparation of dough.

Determination of parameters of a mixture from wheat, rye and barley flours

Adding barley flour to a mixture of wheat flour and rye flours leads to an increase in its EC, a decrease in pH and a slight change in ORP. According to results, presented in Table 3, high EC and TDS values are obtained by adding 10% and 75% barley flour, indicating that the flour have nutritional potential and, which can improve the dough rising and proofing. At these ratios, higher ORP values are also obtained, indicating that the flour has a high oxidation potential.

Adding barley flour to a mixture of wheat flour and rye flours results in a significant change in color (Table 4). The values of the L (Lab) color component decrease, when increasing the amount of barley flour. Values of a (Lab) and h (LCh) decrease too.

Table 2. Values of color components for wheat and rye flour mixture

Wheat flour, %	Rye flour, %	L			a			b			C			h		
		mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV
100	0	74.62	3.83	0.05	2.4	1.27	0.53	3	2.8	0.92	2.3	0.3	0.11	0.9	0	0
90	10	72.65	4.59	0.06	2.41	1.08	0.45	0.5	1.9	0.69	1.7	0.1	0.04	0.2	0	0.1
75	25	73.43	4.05	0.06	2.29	1.72	0.75	3.1	2.5	0.8	2.3	0	0.01	0.9	0.1	0.1
50	50	71.11	3.99	0.06	3.63	1.21	0.33	1.6	2.6	0.6	2.3	0.2	0.07	0.4	0	0.1
25	75	70.96	3.8	0.05	3.67	1.44	0.39	1.7	2.2	0.32	2.3	0.3	0.12	0.4	0.1	0.2
0	100	80.48	3.22	0.04	2.73	0.7	0.26	2.2	1	0.44	2.2	0.1	0.04	0.7	0	0

Table 3. Parameters of flour from mixtures of wheat, rye and barley flours

Sample	Wheat, %	Rye, %	Barley, %	EC, µS	TDS, ppm	pH	ORP, mV
m1	30	70	0	655	204	7	152
m2	27	63	10	609	188	7.3	191
m3	22.5	52.5	25	410	145	7.3	143
m4	15	35	50	588	181	7.1	159
m5	7.5	17.5	75	676	218	7.1	198
m6	0	0	100	679	225	7	197

Table 4. Values of color components for flour from mixtures of wheat, rye and barley flours

Sample	L			a			b			C			h		
	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV
m1	74.62	2.4	3.03	3.83	1.27	2.78	0.05	0.5	0.9	4.57	1.8	0.4	0.63	0.8	1.2
m2	72.65	2.41	0.52	4.59	1.08	1.92	0.06	0.5	3.7	2.98	1.4	0.5	0.61	0.9	1.1
m3	73.43	2.29	3.06	4.05	1.72	2.45	0.06	0.8	0.8	4.23	2.4	0.6	0.49	0.8	1.7
m4	71.11	3.63	1.62	3.99	1.21	2.6	0.06	0.3	1.6	4.61	1.6	0.4	0.27	0.6	2.2
m5	70.96	3.67	1.67	3.8	1.44	2.19	0.05	0.4	1.3	4.39	2	0.4	0.3	0.4	1.4
m6	80.48	2.73	2.16	3.22	0.7	0.96	0.04	0.3	0.4	3.61	0.7	0.2	0.65	0.3	0.4

Determination of dough parameters from a mixture of wheat, rye and barley flours

An analysis of the dough obtained from a mixture of wheat, rye and barley flour was made after its rising. The addition of barley flour to the mixture increases EC. ORP have not significant change compared to flour, but have high values and oxidation potential of the dough resist. pH decreases, an sour taste of the dough is observed (Table 5).

Significant changes are observed in the color of the prepared dough compared to flour. L (Lab) color component values of dough increase compared to these of flour. There is a clear trend towards decreasing the values of a (Lab) and b (Lab) color components. C (LCh) and h (LCh) also show a tendency to decrease when increasing the amount of barley flour in the dough (Table 6).

Determination of bread parameters from a mixture of wheat, rye and barley flours

The results of determining the basic bread parameters are given in Table 7. As can be seen EC and TDS retain high values compared to flour and dough. The pH is higher than that of the dough and is close to that of the flour. ORP has positive high values indicating that the bread has an oxidation potential and can be a growth medium for the development of fungi and mold during storage. Further research is needed to investigate the changes of resulting bread during storage.

The control sample, compared to other samples has a well-developed porosity and larger bumps to the upper crust. Increasing the amount of barley flour worsens the characteristics of the bread – it does not develop well and results in a small volume and height.

Color of bread crumb have significant change according of the amount of barley flour (Tables 8 and 9). L (Lab) values decrease, but a (Lab) and b (Lab) increase their values. h(LCh) decrease too. Bread crust have different color change tendencies that are opposite to the crumb. a(Lab) and b(Lab) increase their values, C(LCh) and h(LCh) decrease. Most important are color changes of crumb, because color of the crust mostly depend on technological regimes of backing process. Color of the crust is important for external appearance of the bread. With other factors as texture and flavor will affect the choice of consumers.

Table 5. Parameters of dough from mixtures of wheat, rye and barley flours

Sample	Wheat, %	Rye, %	Barley, %	EC, µS	TDS, ppm	pH	ORP, mV
m1	30	70	0	791	195	6.9	185
m2	27	63	10	1192	250	6.9	196
m3	22.5	52.5	25	1086	267	6.8	205
m4	15	35	50	1296	309	6.8	208
m5	7.5	17.5	75	1346	325	6.9	208
m6	0	0	100	1439	354	6.9	212

Table 6. Values of color components for dough from mixtures of wheat, rye and barley flours

Sample	L			a			b			C			h		
	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV
m1	77.68	6.2	21.22	10.17	1.51	1.09	0.13	0.2	0.1	22.2	1.3	0.1	1.29	0.1	0.1
m2	72.09	5.68	21.03	13.66	1.25	1	0.19	0.2	0.1	21.8	1.1	0.1	1.31	0.1	0
m3	78.42	5.49	20.98	9.31	1.39	0.99	0.12	0.3	0.1	21.7	1.2	0.1	1.32	0.1	0
m4	77.51	5.69	21.16	8.54	0.71	0.92	0.11	0.1	0	21.9	1	0.1	1.31	0	0
m5	78.57	6.58	21.26	8.03	0.87	0.78	0.1	0.1	0	22.3	0.8	0	1.27	0	0
m6	85.8	2.74	20.91	5.03	0.81	0.88	0.06	0.3	0	21.1	0.9	0	1.41	0.3	0.2

Table 7. Parameters of bread from mixtures of wheat, rye and barley flours

Sample	Wheat, %	Rye, %	Barley, %	EC, µS	TDS, ppm	pH	ORP, mV
m1	30	70	0	1249	318	7.3	175
m2	27	63	10	1288	338	7.4	185
m3	22.5	52.5	25	1387	357	7.3	198
m4	15	35	50	1293	354	7.3	202
m5	7.5	17.5	75	1271	350	7.4	204
m6	0	0	100	1365	364	7.3	207

Table 8. Values of color components for bread crumb from mixtures of wheat, rye and barley flours

Sample	L			a			b			C			h		
	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV
m1	73.09	7.81	0.11	8.62	1.62	0.94	0.12	0.2	0.1	10.2	1.6	0.2	0.7	0.1	0.1
m2	71.36	10.33	0.14	9.12	1.09	0.93	0.13	0.1	0.2	11.8	1.2	0.1	0.5	0.1	0.1
m3	74.46	14.15	0.19	8.95	1.27	0.5	0.12	0.1	0.1	15.6	1.3	0.1	0.43	0	0.1
m4	69.35	9.47	0.14	10.94	1.17	1.6	0.16	0.1	0.3	10.8	1.4	0.1	0.49	0.1	0.3
m5	76	6.16	0.08	11.77	1.45	0.76	0.15	0.2	0.2	7.66	1.2	0.2	0.64	0.2	0.2
m6	69.99	6.6	0.09	7.65	0.91	0.99	0.11	0.1	0.1	14	1	0.1	1.08	0.1	0.1

Table 9. Values of color components for bread crust from mixtures of wheat, rye and barley flours

Sample	L			a			b			C			h		
	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV	mean	SD	CV
m1	76.76	9.79	6.24	8.38	2.12	0.83	0.11	0.2	0.1	11.6	2.1	0.2	0.58	0.1	0.2
m2	62.8	25.38	13.92	10.7	2.39	1.35	0.17	0.1	0.1	29	2.4	0.1	0.5	0.1	0.1
m3	73.56	18.31	16.43	12.71	6.92	3.5	0.17	0.4	0.2	25.1	5.9	0.2	0.76	0.2	0.3
m4	63.81	13.87	3.41	14.34	3.74	1.64	0.22	0.3	0.5	14.4	3.9	0.3	0.24	0.1	0.4
m5	63.3	17.01	10.26	10.04	2.03	2.44	0.16	0.1	0.2	20.1	1.3	0.1	0.54	0.2	0.3
m6	63.12	10.48	5.19	12.79	3.37	3.87	0.2	0.3	0.8	12	4.3	0.4	0.37	0.3	0.9

Determination of bread parameters on cooling

Figure 1 is a graphical representation of the temperature change data in the bread crumb. It can be seen that this temperature reaches 30°C for 85-95 min, irrespective of the amount of added barley flour. At this temperature the bread can be cut and packaged because it does not stick to the cutting knives of the machines and does not provide a mold and mushroom development environment. The bread is cooled 20-30 min slower than the white wheat flour (Pastukhov, 2015).

Figure 2 is a graphical representation of the bread mass change data. There is a mass loss of 1-3%, the highest (3%) being with the 10% added barley flour. Losses are similar to those for wheat flour (Pastukhov et al., 2011; Zlatev, 2018).

In determining the heat loss of bread, it is approximated to parallelepiped with sides axbxc, m. Convection coefficient h = 10 w/m^{2}K. The bread area A_{loaf}, m^2. The constants σ = 0.121 ε_{loaf} = 0.76. The initial temperature of the bread T_{loaf}, K. The ambient temperature is θamb = 20°C. The desired temperature in the bread medium is θ_w = 30°C. The criterion for selecting a difference of c = 0.1 and the calculations are for the case of c ≥ 0.7. Table 10 gives the results of the calculations made. Mass losses were determined, which is greatest for bread of 100% barley flour.

The results obtained confirm and complement those obtained from (Abou-Raya et al., 2014), which demonstrate

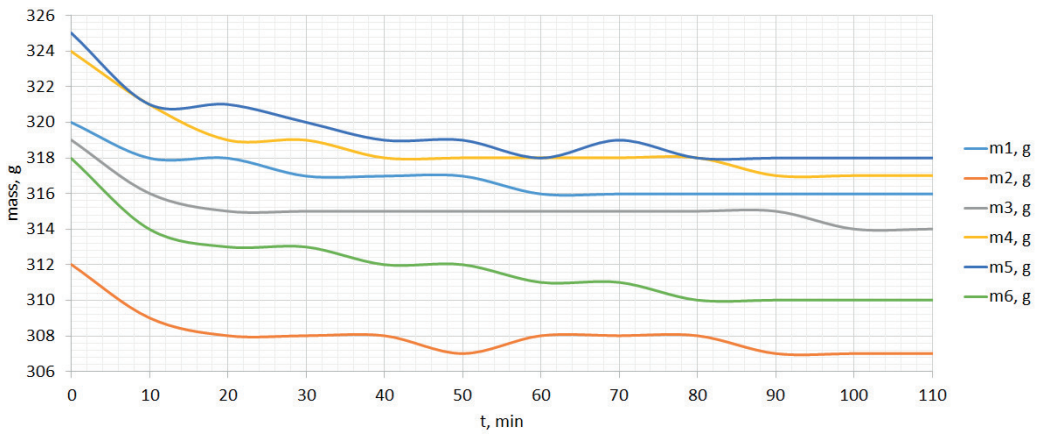

Fig. 1. Changing the temperature in the bread crumb

that the addition of 10-15% barley flour improves the yield of the bread. Results obtained here also confirm those from Kalnina et al. (2015) investigated blends of white wheat, rye and barley flour during paste preparation. Flour of barley has been added 10, 20, 30, 40, 50% to white wheat flour. Good results for a mixture of white wheat and barley flour in a ratio of 50/50% were reported.

The results obtained here show that bread made from a

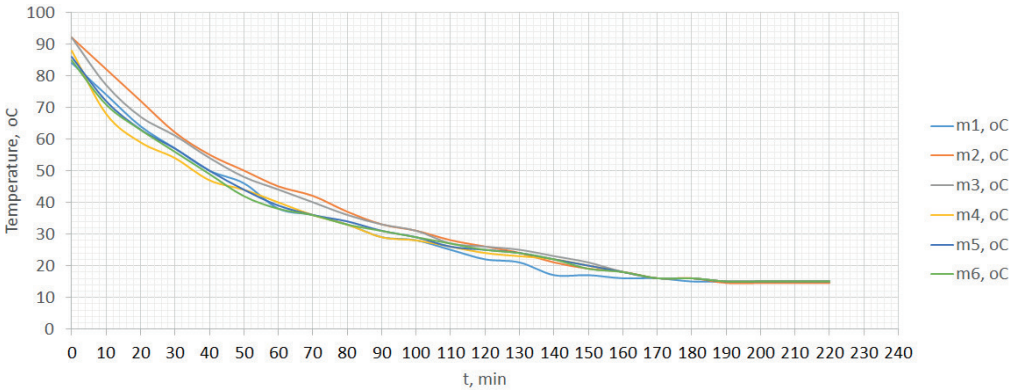

Fig. 2. Changing of the bread mass

Table 10. Results of determining heat losses in bread cooling process

Parameter	Area	Convection losses	Radiation losses	Total losses	Temperature difference	Weight loses
Sample	A, m^2	q_{conv}, W	q_{rad}, W	q_{total}, W	Δθ, °C	%
m1	0.071	-45.63	-50.7	-96.33	29.09	1
m2	0.058	-41.98	-45.3	-87.27	31.41	2
m3	0.054	-38.82	-41.89	-80.72	31.41	2
m4	0.053	-36.09	-39.46	-75.56	30.26	2
m5	0.047	-30.94	-34.09	-65.03	29.68	2
m6	0.042	-27.31	-30.22	-57.53	29.38	3

Table 11. Results of sensory analysis of bread with mixtures of wheat, rye and barley flour

Sample	Indicator	Crust	Taste	Texture	Flavor	Overall
	Descriptive statistics	color				acceptance
m1	mean	8.21	8.1	7.67	8.12	8.51
	SD	0.44	0.65	0.12	1.22	2.12
	CV	0.05	0.08	0.02	0.15	0.25
m2	mean	6.33	6.67	7.67	7.67	7.67
	SD	0.58	0.58	0.58	1.15	0.58
	CV	0.09	0.09	0.08	0.15	0.08
m3	mean	7	7.67	7.33	8	7.67
	SD	0	0.58	1.15	0	0.58
	CV	0	0.08	0.16	0	0.08
m4	mean	8	6.33	5.67	5	4
	SD	0	0.58	0.58	1	0
	CV	0	0.09	0.1	0.2	0
m5	mean	5.34	4.76	5.12	4.41	4.02
	SD	1.34	0.94	0.58	0.18	0.23
	CV	0.25	0.2	0.11	0.04	0.06
m6	mean	4.21	4.12	4.12	3.72	3.14
	SD	0.12	0.14	1.11	0.96	0.02
	CV	0.03	0.03	0.27	0.26	0.01

mixture of rye and wheat flour with the addition of barley flour is obtained with technological characteristics similar to those of the industrially produced wheat and rye-wheat bread. In addition to improving the nutritional value of bread by adding barley flour, this bread also has potential for industrial production.

The results of organoleptic analysis of bread from a mixture of white wheat and rye flour with the addition of barley flour are shown in Table 11. There are similarities between the control sample without the addition of barley flour and the bread with 10% . The high content of 50% and above of barley flour worsens the organoleptic characteristics of the bread obtained and consequently receives lower estimates compared to the other types of bread. The addition of up to 25% barley flour improves the color of the crust and therefore gets the highest score on this indicator.

Conclusion

The characteristics of mixture of rye-wheat flour, dough and bread were modified to some extent by the addition of barley flour. Dough with different percentage of barley flour had pronounced effects on dough properties yielding a higher dough development time, dough stability, extensibility and lower degree of softening as compared to the control rye-wheat flour. The results obtained, indicated the positive effect of lower percentages of barley flour on dough characteristics and the bread porosity. Barley flour addition at levels of 10% and 25% also affected the texture of bread. According to the sensory evaluation, the addition of up to 25% barley flour might provide acceptable bread. Furthermore, these breads have improved nutritional values with acceptable texture and taste.

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