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THE INFLUENCE OF LUPIN FLOUR ADDITION ON BREAD QUALITY

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Abstract: *In recent years there has been an increased interest in using lupine for human nutrition due to its nutritional properties and health benefits. It was used in bakery, pasta, dairy cheese, ice cream, meat products, for different purposes, and especially for its high protein content. This paper aims to identify the optimum dose of lupine that can be used in wheat bread with a high technological quality so that the customer can benefit from a quality product from all points of view. For this purpose we studied the physical changes of bread, that occur by substituting wheat flour by lupin flour in proportions of 5%,10%, 15%, 20%. The results obtained showed that with the addition of lupin, the mass of products increased the volume and porosity decreased and the textural and color parameters changed significantly. A substitution of up to 10% lupin addition leads to bread with higher mass, lower volume, firm, lower cohesiveness and elasticity as compared to the control sample and high gumminess and chewiness values as well. By using ANOVA, the parameter values such as physical, color, crumb cell, textural and sensory characteristics did not vary significantly and therefore the changes in bread quality were not substantial.*

The sensorial analysis performed showed that the most appreciated bread was the one with 5% and 10% lupin addition. The most appreciated characteristics were taste, aroma, color, odor, overall appearance and overall acceptability of bread.

Key words: *lupin, wheat flour type, bread quality*

1. Introduction

Lupin, a legume known for over 4000 years, has aroused interest not only for its nutritional composition, but also for its high adaptability on poor soils, competing with soy and other legumes [1-2]. Due to high protein content, lupin was used initially as green manure and in time it became an important element in human diet [3].
Studies have shown that lupin has twice more proteins as compared with other legumes consumed by humans. Protein intake ranges from 28% to 48%, depending on lupin species, growing conditions and soil type [4]. Globulins (α-conglutin, β-conglutin, γ-conglutin) are the major storage proteins found in proportions of 80-90% in lupin seeds and prolamins and gluteins are found in smaller quantities as compared to other legumes [5]. Albumins rich in amino acids are found in proportions of 15% in lupin seeds. Lupin seeds have a smaller content of globulin (80%) compared with soy seeds (90%) but a much higher albumin content (20%) unlike soy seeds (10) [6].
Lupin seeds are a good source of fibers, 40% are found in nucleus mass and a good source of essential amino acids. They

contain a high amount of lysine and are generally low in sulfur amino acids (methionine, cysteine) and threonine [7].

Although lupin beans are not considered oilseeds, they have a considerable amount of oil, about 5-20% raw oil. In general, lupin oil is characterized by a balanced composition of fatty acids with a total of 10% of saturated fatty acids and 90% unsaturated ones, including: (18:1) 30-50% oleic, (18:2) 17-47% linoleic, (18:3) linoleic 3-11% [8].

Lupin seeds are an important source of minerals. The mineral content varies depending on the variety and can reach values between 3.2 and 4.6 g/100g. The minerals present are: potassium (66-90 mg/g), calcium (15-29 mg/g), magnesium (11-20 mg/g), sodium (3-11 mg/g) [9].

Lupin and lupin derivatives can be found in a wide range of foods such as meat products, fish, bread, pasta, tofu cheese or ice cream [10-16]. In bakery, they are used both as lupin protein concentrates and lupin flour to enhance the nutritional quality of the finished product [17-19]. The use of lupin flour in large quantities can affect adversely the quality of bread. This is due to the fact that it reduces the elasticity of wheat dough and weakens the gluten matrix due to its high fiber content, obtaining a product with unpleasant texture and small volume [20].

Generally the addition of legume flours is associated with decreased loaf volume, the same case in lupin addition, when the proportion of lupin increases, the volume of bread decreases [21]. This is due to the decrease of gluten content, to the decrease of viscous-elastic properties of dough and to the impossibility of dough to retain gas during baking [22-23]. Studies show that the volume decreases in a proportion that depends on the lupin species used, white lupin having less influence on the volume as compared to the blue lupin. The color of loaf is also influenced depending on the amount of lupin flour added. The crumb gets yellow with higher values by the increased percentage of lupin flour added, and the crust becomes darker due to Maillard reaction between sugars and amino acids.

Research shows that substitution of wheat flour by lupin flour in amounts exceeding 10% influences negatively the quality of dough and thus affects adversely the quality of the finished product. To obtain high quality bread, several parameters must be considered such as dough kneading, dough fermentation and baking. The control of these parameters is critical to the achievement of loaves with outstanding features, specific volume and suitable textural properties.

Lupin-based foods draw increasingly consumers' attention due to their possible role in preventing cardiovascular diseases and reduce blood glucose and cholesterol levels [24-29]. In recent years it has been noticed an increase in allergy cases caused by lupin, therefore, in November 2007, the labeling of lupin as potential allergen became mandatory [30]. It has been discovered that the cause of allergy is β-conglutin, a major allergen contained by *L. albus* and *L. angustifolius*, types of lupin mostly used in human food. Processing methods like boiling or heat treatment combined with pressure drop can completely remove allergens.

This paper aims to study the influence of lupin flour addition in doses of 5%, 10%, 15% and 20% in wheat flour of 650 and 1350 types on bread quality. Volume, textural parameters, color and sensory characteristics of bread from wheat-lupin composite flour were analyzed.

2. Materials and methods

2.1.Materials

To obtain the bread samples with addition of lupin flour, the following materials were used: sweet lupin flour, 650 wheat flour type, 1350 wheat flour type, water, yeast, salt. The 650 flour used in this study presents the following characteristics: moisture content 14.5%, ash content 0.65%, wet gluten content 28%, gluten deformation index 8 mm and titratable acidity 2.3 degree of acidity. The 1350 flour used presents the following characteristics: moisture content 14.1%, ash content1.35% wet gluten content 28%, gluten deformation index 5 mm and titratable acidity 3.0 degree of acidity. The flour chemical composition was determined according to the Romanian standard methods: moisture (SR EN ISO 712:2010), ash content (SR EN ISO2171:2010), wet gluten content and gluten deformation index (SR 90:2007), acidity (SR 90:2007).

2.2. Preparation of composite lupin-wheat flour bread

Bread samples with 5%, 10%, 15%, 20% lupin flour was obtained from each type of wheat flour and two control samples as well. The quantity of yeast used was 3% of flour mass and the salt of 1.5% of flour mass.

Dry ingredients were blended with water with a temperature of 29-30°C for 10-15 minutes to obtain homogeneous dough. The shaped loaves were placed in trays and left to rise for 15 minutes. After rising they were placed in pre-heated oven at 130° C and steamed for 1 minute. After steaming, the temperature was raised to 180° C. Baking time was of 35 minutes.

2.3. Composite lupin-wheat flour bread evaluation

The bread physical properties: volume, loaf volume (loaves were determined using the rapeseed displacement method), porosity, elasticity were determined according to SR 91:2007.

The crumb cells were analyzed with the MoticSMZ–140 stereo microscope with a 20x objective to a resolution of 2048 x 1536 pixels.

Textural properties of bread were determined using a texture analyzer Mark-10-ESM301, displacement of 10 mm/min, were: hardness, cohesiveness, elasticity, gumminess, chewiness (table 1).

Texture analysis refers mainly to the mechanical properties of the product, mostly often food products. It is associated with the sensory properties detected by humans. Intense research developed a set of definitions regarding the sensory properties of products and instrumental properties that can be calculated using two cycle tests of textural profile analysis (fig. 1). Texture analyzers perform those tests by applying controlled forces on the product and record its response in the form of force, deformation and time.

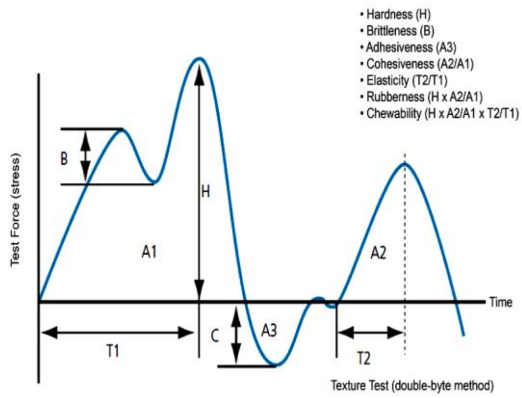

Figure 1. Load diagram in two cycles used for texture profile analysis

Tabe1 1.
Primary and secondary parameters

Textural parameters	Notation (Fig.3.4.)
Hardness	H
Cohesiveness	(A_2/A_1)
Viscosity	C
Elasticity	T_2/T_1
Adhesiveness	A_3
Fracturability	B
Gumminess	$H \cdot A_2/A_1$
Chewiness	$H \cdot A_2/A_1 \cdot D_2/D_1$

Colors of bread were analyzed by Konica Minolta CR–700 colorimeter. This method analyzes color by recreating human color vision [32]. System CIE L* a* b* is one of the most common color measurement systems. It describes a three dimensional color space coordinates based on brightness coordinates L* and color coordinates a*, b* (Fig.2). The values of L* vary from 0 - pure black to 100 - pure white. Axis color is divided into green (-a*) and red (+a*). Axis b* is divided into yellow (+b*) and blue (-b*). Knowing these three values L*, a*, b* can accurately describe the color in the space of color. By increasing a* and b* values and the distance from the point of interaction staining increased. The intersection of the axes is neutral gray, L*=50, a*=0, b*=0.

Color analysis was made using a portable colorimeter by measuring L* (brightness), a* (red/green), b* (yellow/blue), ΔL (difference in brightness), Δa (difference red/green), Δb (difference yellow/ blue), ΔE (color difference).

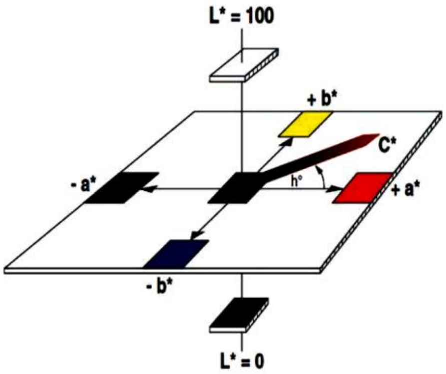

Figure 2. CIE L*, a*, b* system [32]

Evaluation of ***sensory characteristics of bread samples*** was performed in a tasting session. Tasters, numbering 20, were students of 4th year of the Faculty of Food Engineering, University Stefan cel Mare, Suceava, Romania. They were presented the products and given for evaluation every sample starting with the control sample, followed by the samples with 5%, 10%, 15%, 20% lupine flour added. Participants were asked to rate a set of features such as general appearance, color, taste, odor, flavor, texture and overall acceptability. The assessment was based on hedonic test. Hedonic test allows not only choosing the best product but also determining the degree of preference. Hedonic scale includes nine points, the first four referring to negative perceptions and the other four to positive perceptions.

Statistical analysis was performed using Microsoft Excel 2007 where we applied ANOVA, in order to highlight the extent to which the bread quality is influenced by the addition of lupin flour. The influence of lupin flour on volume, texture parameters, color and sensory acceptability of the bread was studied.

3. Results and discussion

3.1. Effect of lupin addition on bread volume

Studies show that the substitution of wheat flour by lupin flours reduces the volume of bread. This negative effect is associated with the obtaining of poor quality products [33].By analyzing the results obtained, it has been found that the bread volume decreased with the increase of lupin flour addition at levels higher than 10% addition in the case of wheat flour type 650 substitutions and for all levels in the case of 1350 wheat flour substitution (fig. 3 and fig. 4).

The decreased values of the bread volume may be due to the reduced amount of gluten from lupin-wheat composite dough which may reduce its viscous-elastic properties and the dough capacity of gas retention during baking [34]. This effect of reduced volume of composite flour bread has been reported by other researchers, too [35-38].

Although volume changes occur, they are not statistically significant. Regarding P value over 5% and $F = 0.3453 < F_{critic} = 6.3882$, it can be concluded that lupin flour percentage added does not influence significantly the bread volume. Also, loaf volume values do not significantly vary ($F = 0.4882$, $P = 0.747752283 > 5\%$).

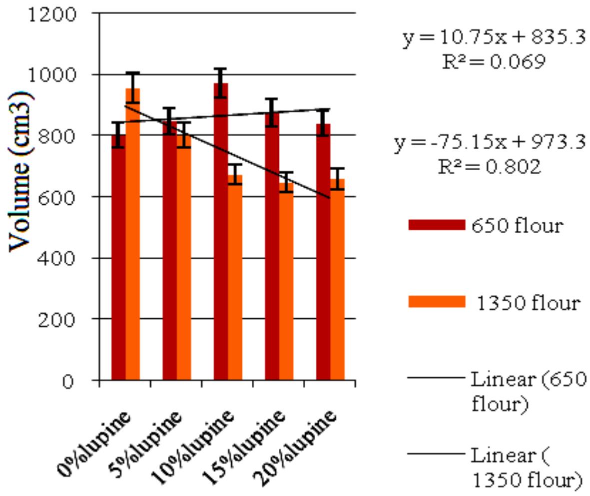

Figure 3. Bread volume variation

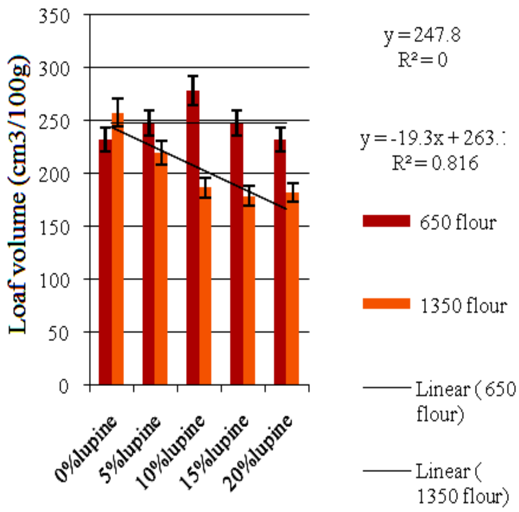

Figure 4. Bread loaf volume variation

3.2. The influence of lupin flour addition on bread porosity

Regarding porosity, the values obtained were slightly lower as compared to the control samples. Porosity did not exceed 97%, the lowest porosity obtained being for the 1350 flour type with 10% lupin flour addition (figure 5, 6 and 7).

By applying ANOVA, it can be said that the percentage of lupin does not affect significantly porosity (P = 0.683, $F < F_{critic}$). According to the test, porosity is influenced by the type of wheat flour (P = 0.0342, $F > F_{critic}$). Other studies have concluded that porosity decreases with the addition of legume flour, the lower porosity may be an effect of low gluten content in lupin-wheat flour composite dough [39].

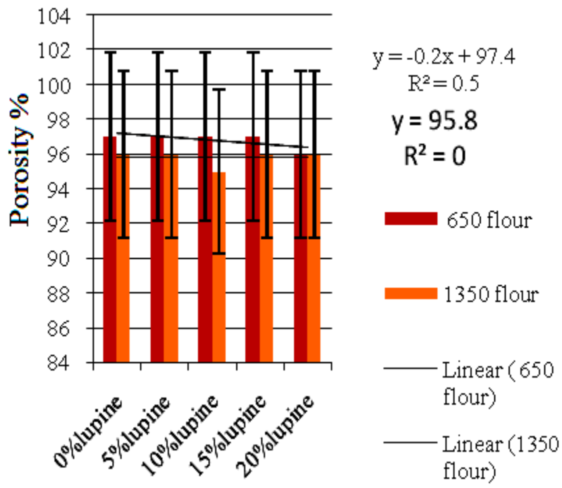

Figure 5. Porosity values of bread samples

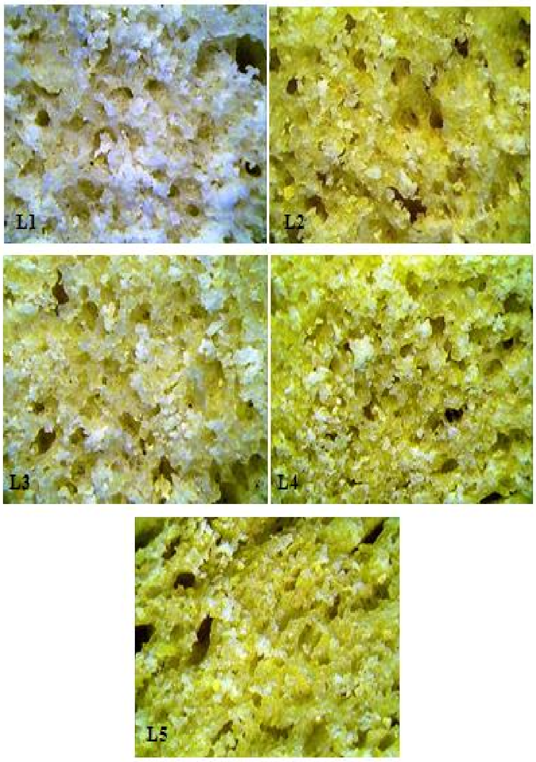

Figure 6. Crumb microstructure of bread samples from 650 wheat flour type with lupin addition
L1 - control, L2 - 5% lupin, L3 - 10% lupin, L4 - 15% lupin, L5 - 20% lupin

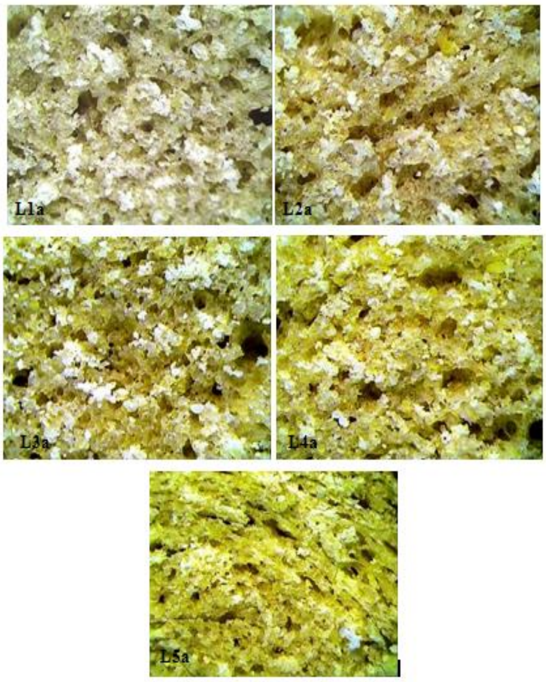

Figure 7. Crumb microstructure of bread samples from 1350 wheat flour type with lupine addition
L1a - control, L2a - 5% lupine, L3a - 10% lupine, L4a - 15% lupine, L5a - 20% lupine

3.3.Effect of lupine flour added on elasticity of bread

Elasticity decreases by increasing the percentage of lupine added (Fig. 8). Elasticity decreased is not significant and is may be due to the low gluten content of the analyzed bread with high levels of lupine addition. In this study, the elasticity was determined after 48 h from the bread samples obtained. Similar results were obtained and by other researchers [40].

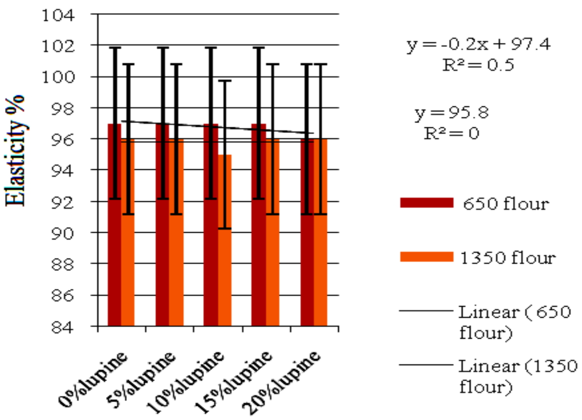

Fig. 8. Elasticity values of bread samples

3.4. Texture profile analyses

Table 3 shows the texture parameter values obtained. There are correlations between the percentages of lupin and texture parameter values, these correlations highlighting connections between the addition of lupin and texture parameters. Following the Pearson's correlation a number of binary values of the correlation coefficient were obtained which highlights the extent to which substitution of lupin is connected to the texture parameters (Table 4 and table 5). It is noticed that in the case of 650 flour bread, the correlations between the percentage of lupin and texture parameters are not very high the correlation coefficient obtained being low (table 6). Strong correlation is observed between firmness, chewiness and gumminess of 1350 four bread, the regression coefficient being higher than 0.8. Regarding firmness, its increase is observed with the increasing of the lupin content.

Cohesiveness shows a slight decrease with the increase of lupin flour addition and gumminess and chewiness increase. The results show that a substitution of wheat flour with lupin flour over 20% does not have a high influence on the textural characteristics of the finished products. Other studies have found that the substitution between 5% and 10% may lead to valuable products regarding the nutritive composition without changing their textural qualities. Statistically the textural parameters were not influenced by lupin flour percentage, therefore it can be concluded that bread with lupin addition is similar to wheat bread in terms of texture. Values closest to control sample were recorded for both 650 and 1350 flour with a substitution of 5% and 10%.

3.5. Color analysis

Table 8 shows the results of color analysis. Statistically, by studying color parameters it has been observed that L* varies significantly depending on the lupin flour percentage added (P = 0.00708) and the type of wheat flour (P = 0.0001). a* parameter varies significantly, being influenced by the type of wheat flour used not by the lupin flour percentage (P = 9.9762). Significant variation is observed in the case of ΔL and ΔE parameters, these parameters being influenced by the type of wheat flour and the lupin flour percentage (Table 2).

Table 2.
ANOVA test results regarding color parameters

Parameters	F	P-value	$F_{critical}$
L	19.24293	0.00708	6.388233
a	0.790479	0.587364161	6.388233
b	4.733412	0.080651217	6.388233
ΔL	19.26507	0.007064765	6.388233
Δa	1.140303	0.450906	6.388233
Δb	4.640253	0.083156	6.388233
ΔE	15.73804	0.010282	6.388233

Table 3.
Bread texture parameter values

Wheat flour	650 flour					1350 flour				
Samples	Control	5% lupine	10% lupine	15% lupine	20% lupine	Control	5% lupine	10% lupine	15% lupine	20% lupine
Primary texture parameters										
Firmness	35.62	66.04	44	44	45.1	31.14	43.6	51.28	64.44	74.86
Cohesivity	0.627	0.596	0.724	0.725	0.675	0.700	0.699	0.668	0.542	0.606
Elasticity	0.837	0.746	0.802	0.826	0.765	0.820	0.779	0.818	0.750	0.788
Secondary texture parameters										
Gumminess	22.328	39.352	31.865	31.892	30.436	21.784	30.476	34.254	34.929	45.399
Chewiness	18.686	29.360	25.556	26.354	23.272	17.856	23.748	28.016	26.199	35.763

Table 4.
Pearson's correlation for bread from 650 wheat flour type

	Lupine percentage	Firmness	Cohesiveness	Viscosity	Elasticity	Adhesiveness	Gumminess	Chewiness
Lupin percentage	1							
Firmness	-0.04298	1						
Cohesiveness	0.616352	-0.48038	1					
Elasticity	-0.26026	-0.8277	0.417912	-0.56933	1			
Gumminess	0.228624	**0.923789**	-0.10811	**0.800001**	-0.76198	**0.816702**	1	
Chewiness	0.2449	**0.844356**	0.04797	**0.826583**	-0.60886	**0.83695**	**0.976461211**	1

Table 5.
Pearson's correlation for bread from 1350 wheat flour type

	Lupine percentage	Firmness	Cohesiveness	Viscosity	Elasticity	Adhesiveness	Gumminess	Chewiness
Lupin percentage	1							
Firmness	**0.99769**	1						
Cohesiveness	-0.79815	-0.80569	1					
Elasticity	-0.50682	-0.55311	**0.746002**	0.780538	1			
Gumminess	**0.958875**	**0.956862**	-0.60081	-0.11675	-0.38136	-0.10237	1	
Chewiness	**0.927189**	**0.918327**	-0.51468	-0.00452	-0.2542	0.010091	**0.990856**	1

Table 6.

The correlation coefficients and regression equations based on lupine percentage

Parameters	650 flour		1350 flour	
	Regression equations	Correlation coefficients	Regression equations	Correlation coefficients
Firmness	y = -6.6x+47.56	0.001	y = 216.5x+31.40	0.995
Cohesiveness	y = 0.449x+0.624	0.379	y = -0.686x+0.711	0.637
Elasticity	y = 0.128+0.808	0.067	y = -0.186x+0.890	0.256
Gumminess	y = 17.51x+29.42	0.052	y = 103.3x+23.03	0.919
Chewiness	y = 12.33+23.41	0.06	y = 76.52x+18.66	0.859

Table 7.

ANOVA test results

Texture parameters	F	P-value	F_{critic}
Firmness	0.997903	0.500787	6.388233
Cohesiveness	0.184572	0.934732	6.388233
Elasticity	1.393935	0.377698	6.388233
Gumminess	1.975612	0.262909	6.388233
Chewiness	1.591818	0.331721	6.388233

Table 8.

Bread color values

Wheat flour	650 flour					1350 flour				
Parameters	0% lupine	5% lupine	10% lupine	15% lupine	20% lupine	0% lupine	5% lupine	10% lupine	15% lupine	20% lupine
L	67.6	66.75	68.13	68.89	70.39	63.06	62.74	65.32	64.72	66.4
a	-1.27	-2.32	-1.81	-2.15	-2.13	1.57	0.67	0.13	0.34	-0.01
b	14.88	23.13	19.66	24.21	26.74	17.43	18.21	19.62	21.05	23.16
ΔL	31.78	30.93	32.31	33.06	34.56	27.24	26.92	29.5	28.9	30.58
Δa	-14.63	-15.67	-15.16	-15.5	-15.48	11.79	-12.68	-13.22	-13.01	-13.36
Δb	0.66	8.9	5.44	9.9	12.52	3.21	3.98	5.39	6.62	8.94
ΔE	34.99	35.79	36.1	37.86	39.89	29.85	30.02	32.77	32.42	34.54

3.6. Sensory characteristics evaluation

Following statistical analysis of the responses of the participants in the tasting session, it was found that in the case of 650 flour bread, the percentage of lupin flour is statistically significant (P = 0.002), the interaction between the percentage of lupin and analyzed characteristics did not influence scores (P = 0.996). Regarding the 1350 flour bread, the lupin flour percentage was statistically insignificant (P = 0.697).

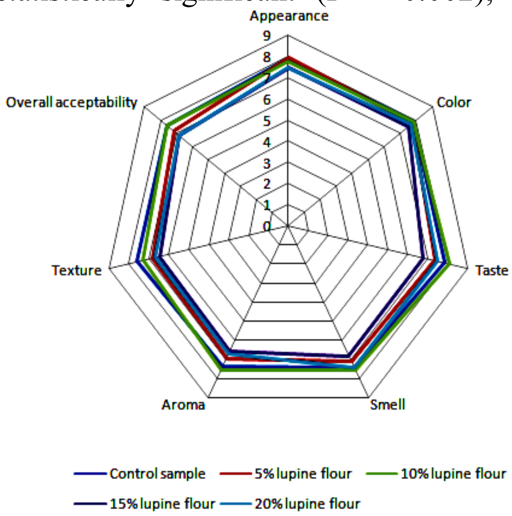

Figure 9. Sensory characteristics of bread samples from 650 wheat flour type with lupin addition

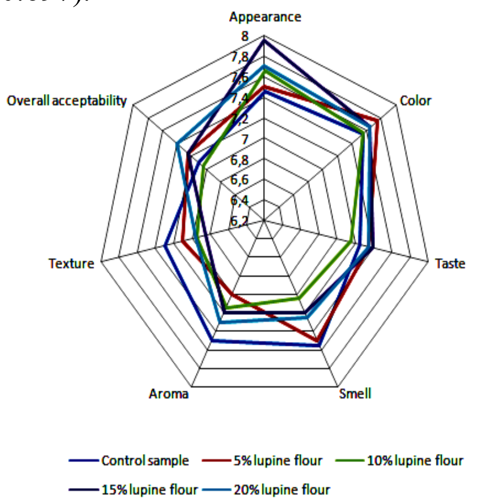

Figure 10. Sensory characteristics of bread samples from 1350 wheat flour type with lupin addition

According to the responses the most appreciated feature of the 650 flour bread was the overall appearance of the sample with 5% lupin flour addition. Generally, the most appreciated 650 flour bread was the one with 10% lupin flour addition (Figure 9).

By analyzing the 1350 flour bread (Figure 10) respondents considered as the most appreciated bread the one with 20% lupin flour addition. Regarding color, overall appearance and taste, the most appreciated was the bread with 15% lupin flour addition.

The consistence of samples was underappreciated as compared with control samples for both types of wheat flour used. The observations made by participants in the tasting session were related to taste, smell and aroma. They pointed out that the samples with over 10% lupin flour addition had a slight bitter taste, more pronounced in samples with 20% lupin flour, smell and flavor of cheese in samples with over 15% lupin flour.

4. Conclusions

Lupin, a legume with a particular chemical composition, turns out to be a product with many uses in food industry. In bakery it can be primarily used as a fortifier due to its high protein content. The use of lupin flour can bring a series of changes to bread as finished product, changes that influence its quality. Volume and specific volume values of the product can decrease by increasing the percentage of lupin flour addition. The textural proprieties can also be influenced, firmness increases by increasing the amounts of lupin flour addition, cohesiveness, and elasticity slightly decrease as compared with control samples and gumminess and chewiness increase. It has been shown that lupin flour can also change the color of the product obtained bread with lupin addition, leading to a more yellow crumb and brown crust.

Having in view all the parameters studied, it can be concluded that products with 5% and 10% lupin flour addition are the closest to the quality of the control samples. As compared to other studies, the results obtained are similar.

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