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THE USE OF LUPIN FLOUR AS NUTRITIONAL ADDITIVE TO ORGANIC WHEAT SOURDOUGH BREAD

Summary

As is the case of other legumes lupins are characterized by several potential advantages, such as high-protein, dietary fiber and others valuable nutritional components content. The aim of this work was to assess the possibility of organic sourdough bread obtaining, made from lupin species, available in Poland, in terms of its physico-chemical properties and nutritional value. The lupin flours prepared from whole seeds of yellow lupin (Lupinus luteus) cultivar Bursztyn and narrow-leaved lupin (Lupinus angustifolius) cultivar Kurant were used. The rheological properties of the dough obtained from mixed wheat-lupin flour were determined; organoleptic evaluation of obtained breads was performed. The evaluation of dough with lupin flours addition using a farinograph revealed that it had positive effect on water binding and rheological properties,– increases a water absorption, dough development time and stability. It has been found that the quality of the tested breads was high and the content of protein and dietary fiber was significantly higher than in wheat bread. It has been demonstrated that the lupine flour obtained from whole grain can be used to obtain sourdough bread. Lupin flour gives to bread functional features due to increased content of proteins and dietary fiber. Such bread can be recommended in a vegetarian diet as a source of protein.
***Key words**: lupin whole-seeds flour, bread, rheology, nutritional value, dietary fiber*

WYKORZYSTANIE MĄCZKI Z ŁUBINU JAKO DODATKU ODŻYWCZEGO (*NUTRITIONAL ADDITIVE*) DO EKOLOGICZNEGO PIECZYWA PSZENNEGO NA ZAKWASIE

Streszczenie

Podobnie jak w przypadku innych roślin strączkowych do zalet łubinu należy m.in. wysoka zawartość białka, błonnika pokarmowego i innych cennych składników pokarmowych. Celem pracy była ocena możliwości otrzymywania ekologicznego chleba wyprodukowanego z udziałem mączki z dwóch gatunków łubinu dostępnych w Polsce, na zakwasie pszennym, oraz ocena pieczywa pod względem jakości (właściwości fizyko-chemicznych i organoleptycznych) i wartości odżywczych. Wykorzystywano mączki przygotowane z całych nasion łubinu żółtego (Lupinus luteus) odmiana Bursztyn i łubinu wąskolistnego (Lupinus angustifolius) odmiana Kurant. Określono właściwości reologiczne ciasta otrzymanego z mieszanki mąki pszennej i mączki łubinowej; przeprowadzono ocenę organoleptyczną otrzymanych chlebów. Ocena farinograficzna ciasta z dodatkiem mączki łubinowej wykazała, że ma ona pozytywny wpływ na wodochłonność i właściwości reologiczne to znaczy zwiększa absorpcję wody, czas rozwoju i stałość ciasta. Stwierdzono, że jakość badanych chlebów była wysoka, a zawartość białka i błonnika pokarmowego była znacznie wyższa niż w chlebie pszennym. Wykazano, że mączka z łubinu otrzymana z całego ziarna może być stosowana do otrzymywania chleba na zakwasie. Nadaje ona pieczywu cechy funkcjonalne poprzez podwyższenie zawartości białka i błonnika pokarmowego w stosunku do pieczywa pszennego. Pieczywo takie może być polecane w diecie wegetariańskiej jako źródło białka.
***Słowa kluczowe**: mączka z całych nasion łubinu , chleb, reologia, wartość odżywcza , błonnik pokarmowy*

1. Introduction

Legumes are an important source of protein, including essential amino acids, vitamins, minerals, dietary fiber, oligosaccharides, bioactive phenolic compounds and minerals [1, 2, 3, 4]. The protein content in legumes seeds is around 17-40%, for comparison, the range of their contents in meat is 18-25%) [1, 5]. Among the legumes, lupins distinguish themselves by a high protein content (at the level of its content in soybeans) and dietary fiber [2]. Lupins offer several potential advantages over soybeans [16]. In particular, the digestibility of lupin protein and oil is superior to that of soybean. In addition, lupin seeds are characterized by a high level of unsaturated fatty acids (over 80% of fatty acids) [6, 7]. In Europe, white, yellow and narrow-leaved lupin (*Lupinus albus*, *Lupinus luteus* and *Lupinus angustifolius*) are grown, that could become plants protein source comparable to soya bean in food production [16]. In recent years, sweet lupin seeds (*Lupinus albus L.*) was often the object of research, in which its nutritional values were confirmed. Frequent consumption of legumes, which is an important element of the Mediterranean diet, as well as the basis of diet in many Asian countries, it reduces the risk of civilization diseases. A significant relationship was found between the diet rich in legumes and the lower risk of coronary heart disease (CHD) [2, 8, 9, 10, 11, 12], type 2 diabetes [14], obesity [15], the intake of legumes is also associated with a lower risk of osteoporosis [15]. The high dietary fiber content of lupin is typically associated with cholesterol-lowering activity [16]. To use lupin as food ingredient because of alkaloid content must be maintained as low as possible [3].

At present, the increase in the consumption of leguminous plants through their incorporating in the new, convenient and healthy food products is promoted [13, 27]. Thanks to the content of bioactive ingredients, bread with the addition of legumes enriches the vegetarian diet, it can also be included in the dietetic prevention of civilization diseases [2, 3]. Attempts were made to use legumes for obtaining gluten-free bread, as well as other bakery products (cookies, crackers). As raw material, for example, lupin flour, soy flour, lentils, chickpeas and concentrates of pea or soy protein [18, 14, 17, 18, 28] were used; most often by replacing part of the wheat flour with mixtures of various raw materials.

Previous studies mostly have concerned development of gluten-free bread technology containing only small amounts of lupin flour in a mixture of other ingredients, e.g. starch, other legumes or buckwheat flour [6, 20]. It was observed, that the content of raw materials derived from legumes in several percent in the recipe have a positive effect on the technological and sensory characteristics of the products obtained, among others humidity, volume, otherwise increase its nutritional value [6, 27]. Villarino et al. [25] optimized the composition of bread with more than 20% of Australian sweet lupin flour, obtaining good quality bread, however, the moisture and volume of bread deterioration was observed [30, 31]. Therefore it is advantageous to use in the production of bread technology based on sourdoughs because fermentation of the dough with addition of lactic bacteria positively affects the nutritional value and improves the sensory properties of the bread [27].

2. Aim of the study

The aim of this work was to determine optimal proportion of organic lupin flour in mixed, wheat-lupin bread, in terms of quality, including organoleptic properties and achieving a high nutrient content. The adjustment of several process parameters was carried out.

3. Materials and methods

The lupin organic flours were obtained from the Institute of Soil Science and Plant Cultivation-State Research Institute in Puławy. Lupin flours were prepared from yellow lupin (cultivar Bursztyn - LFB) and from narrow-leaved lupin (cultivar Kurant - LFK) by grinding whole seeds to fine flour using a laboratory mill the WZ1. The produced flour was added to lupin flour-enriched bread at 10, 15, 20 and 25% substitution levels of wheat flour. Organic wheat flour type 550 (BIO Planet) was purchased in local market. Wheat flour has a good baking properties (i.e. content of gluten 28.8%, gluten index 98, falling number 430 s). The chemical composition of wheat flour (WF), yellow lupin flour cultivar Bursztyn (LFB) and narrow-leaved lupin flour cultivar Kurant (LFK) were shown in Table 1.

Chemical analyses (protein and ash content) were performed according to standard methods. Protein content was determined according to PN-EN ISO 20483:2014-02E, a conversion factor of 5.7 for wheat flour and 6.25 for lupin flour was used to convert nitrogen to protein content, in the case of bread, the contribution of particular flours were taken into account in the calculations. Determinations of total ash and dry matter of the samples were made according to PN-EN ISO 2171:2010 and to PN-EN ISO 712:2012, respectively. Fat content was determined by extraction method according to PN-EN ISO 11085: 2015-10. The content of total dietary fiber was determined by the enzymatic hydrolysis method according to the official methods AOAC 991.43, AACC 32-07, the dietary fiber test (Megazyme production) was used as described by the manufacturer.

All the determinations, such as fat, protein, and moisture, were expressed on a dry matter basis.

In order to assess the rheological properties of the two-component flour mixtures dough, during mixing and kneading, farinograph test was performed. Water absorption of mixtures of wheat flour with various substitution (10, 15, 20 and 25%) of lupin flours as well as rheological parameters of the dough: dough development time, stability, dough softening, farinograph quality number were determined, using the Brabender farinograph according to PN-EN ISO 5530-1: 2015-01 (procedure of constant flour mass).

The dough development time was defined as peak time from the beginning of the addition of water to point on the curve immediately before the first sign of the decrease of maximum consistency. Stability is the difference in time between the point where the top part of the curve intercepts, for the first time, the line 500 FU and the last point where leaves this line. The degree of softening is the difference between the center of the curve at the point where it begins to decline and the centre of the curve 12 minutes after that point.

Technological parameters of the bread doughs during fermentation process

The determination of the physical and chemical properties of sourdough, bread doughs were performed according to PN-A-74100:1992 and they included: the determination of pH and total titratable acidity, expressed in degrees (ml 0,1mol NaOH/10g). Performance and dough fermentation time were established.

The breads were prepared with wheat and lupin flours (LFB, LFK) replacing wheat flour at levels 10, 15, 20 and 25% using sourdough method. Wheat sourdough was inoculated with bacterial starter culture (containing *Lactobacillus plantarum* ZFB107, *Lactobacillus brevis* ZFB 134, *Lactobacillus plantarum* SFR), the addition of bacterial biomass - 0,5% of flour, dough yield 200 (the flour and water proportions 1: 1). Fermentation was carried out for 24 hours at room temperature. The sourdough was used as 20% of the total wheat flour amount provided for in the recipe. The dough was fermented at 30°C and 75% relative humidity for 30 min. Then the dough was divided into 250 g baking pieces, which were molded by hand, put into forms and placed in a fermentation chamber at 35°C. Breads were baked for 35 minutes at 230°C in a Piccolo Wachtel Winkler deck oven in an atmosphere of steam. The bread test was carried out 20 ± 4 h after baking. Baking test was carried out on three loaves from each bread type (including control bread - sourdough wheat only). The quality of bread, including the organoleptic assessment, was evaluated according to the Polish standard (PN-A-74108: 1996). Hardness of the bread crumb, was measured using an Instron 1140 analyzer, according to the manufactures procedure, expressed as the force (N) needed to achieve the assumed bread deformation.

The data was statistically analyzed using Statistica 8, StatSoft INC. An analysis of variance and post hoc test (Tukey) were performed with a level of significance $\alpha = 0.05$.

4. Results and discussion

The chemical composition of wheat and lupin flours were shown in Table 1.

Table 1. Chemical composition of wheat and lupin flours
Tab. 1. Skład chemiczny mąki pszennej i mączek z łubinów

Quality factors, Content	WF	LFB	LFK
Moisture, %	14.6 ± 0.2a	7.8± 0.2b	8.2± 0,2b
Ash , g/100 g DM	0.6 ± 0.1a	3.7 ± 0.1b	3.5± 0,1b
Total protein, g/100 g DM	12.3± 0.2a	34.6± 0.6 c	25.2± 0,7b
Dietary fiber, g/100 g DM	1.9± 0.2a	46.5± 2,6b	47.6± 2,2b
Fat, g/100 g DM	1.1 ± 0.a	5.0 ± 1,2b	6.1± 0.3b

DM - based on dry matter, WF- wheat flour, LFB - yellow lupin flour cultivar Bursztyn, LFK - narrow-leaved lupin flour cultivar Kurant, values are averages of three repetitions, ± sd – standard deviation for three independent determinations, means with different letters within a row are significantly different (P<0.05).

Source: own work / Źródło: opracowanie własne

In order to increase the nutrient content of the bread in the present research, the lupin flours prepared from yellow lupin (*Lupinus luteus*) and narrow-leaved lupin (*Lupinus angustifolius*) by grinding whole seeds (with hulls) were used in the production. Flour of both lupin species seeds were characterized by high protein content as well as dietary fiber content in comparison to the values given in literature [2, 13, 14, 31, 32]. Especially high was the content of protein in flour made of yellow lupin cultivar Bursztyn, (34.6 g/100g DM). The total dietary fiber content in both lupin flours was also high (46.5, 47.6 g /100g DM) [2]. Tested flours are hardly comparable to that used in other works due to the grinding of whole seeds (with hull), which increased the fiber content (in order to increase their nutritional value).

The addition of lupin flour to wheat flour increased the water absorption of the mixture and modified the rheological properties of the dough (Table 2). Narrow-leaved lupin flour LK (in range from 10 to 25% replacement) increased the water absorption to a greater extent than the yellow lupin LB flour. After adding the lupin flours, the dough development time increased, which indicates the need to extend the time of mixing the dough during the production of bread. This is the opposite effect than observed by Pollard et. al. [20], however, these researches concerned replacing wheat flour with lupin at 5%. Increase in water absorptionof flour is usually the result of high fiber and protein content [27]. Positive influence on water absorption, dough development time and dough stability in wheat flour substitution higher than 10-15% was observed both in the study of mixtures of wheat flour with lupin and other legumes [7, 14, 28].

The substitution of wheat flour by flour of both lupin species tested increased the stability of the dough when their share in the flour mixture was up to 15%. A particularly high increase in dough stability, more than two fold, was observed in the case of the use of the narrow-leaven lupin cultivar Kurant (LK), stability at this level is characteristic for strong gluten wheat flours with a high content of gluten protein. The softening of dough made with the yellow lupin cultivar Bursztyn LB (10%) and narrow-leaved lupin Kurant LK (10 and 15%) was lower compared to the control wheat dough, which is typical for dough prepared of good wheat flours. When replacing wheat flour with 20 and 25% of lupin, the dough softening after 12 min increased slightly, which means that in the process of producing bread dough with such mixing proportion shows a slightly lower tolerance to fermentation. Evaluation of water absorption of the mixture of wheat flour and lupin flour allowed to determine the optimal dough performance. Previous studies indicate a large variation in the impact of the addition of lupin flour on the rheology of mixed dough depending on the species, as well as the variety of lupin [7, 20]. In Table 3 were shows technological parameters of dough prepared with mixed flour. For the preparation of all the tested dough, wheat sourdough was used, with which 20% of the wheat flour provided by the recipe was added. The acidity of sourdough after 24 hours of fermentation was: titrable acidity 13.7, pH 3.6.

The use of lupin in mixed flour increased dough yield, well above yield of wheat dough and reached 180.4 in the case of 25% of LFK. With a higher share of lupine flour up to 15% LFB and up to 20% LFK, the increased acidity of dough was observed. This effect is probably related to the high proportion of dietary fiber in the raw material. In addition, lupin proteins show emulsifying properties [13, 16]. The properties of bread obtained after dough baking are presented in Table 4.

Table 2. Effect of thelupin flours addition on water absorption of flours mixtures and rheological properties of dough
Tab. 2. Wpływ dodatku mączek z łubinu na wodochłonność mieszanek mąk i parametry reologiczne ciast

Type of flour/ share of lupin flour		Farinographic parameters				
		Water absorption, cm^3/100 g	Dough development time, min	Stability, min	Degree of softening, FU	Quality number
WF	0%	56.4±1.0	2.5±1.2	7.3±3.8	53±13	93
LFB	10%	58.6 ±0.6	8.0±2.0	11.5±2.5	41±7	185
	15%	59.5 ±1.0	6.7±1.0	7.6 ±3.0	55±4	128
	20%	60.7 ±1.0	6.3±2.0	4.0 ±1.0	77±10	93
	25%	60.7±2.0	6.2±2.0	3.1 ±1.0	89±14	86
LFK	10%	61.3±1.0	7.9±2.5	16.6 ±5.0	19±3	218
	15%	64.4±1.0	8.3±3.0	11.0 ±3.5	52±17	171
	20%	67.6±1.0	8.0±2.4	6.8 ±1.0	75±8	119
	25%	70.5±1.5	5.9±1.2	3.3 ±1.5	93±11	86

WF - wheat flour, LFB - yellow lupin flour cultivar Bursztyn, LFK - narrow-leaved lupin flour cultivar Kurant, values are averages of three repetitions, ± sd – standard deviation for three independent determinations

Source: own work / Źródło: opracowanie własne

Table 3. Technological parameters of bread dough with the substitution of lupin flours
Tab. 3. Parametry technologiczne ciast z udziałem mączek z łubinów

Type of flour/ share of lupin flour		Titrable acidity, degree	pH	Yield of dough (flour + water)	Final development of dough pieces
WF	0%	6.8±0.1	4.6±0.1	166.1±2.1	48
LFB	10%	6.5±0.1	4.8±0.1	168.5±0.8	52
	15%	7.6±0.2	4.9±0.1	169.5±0.5	50
	20%	7.9±0.1	4.9±0.1	170.6± 1.2	46
	25%	8.2±0.2	5.1±0.2	170.7± 1.5	44
LFK	10%	5.8±0.2	5.1±0.1	171.2 ±0.6	45
	15%	6.1±0.1	5.2±0.1	175.3 ±2.5	45
	20%	8.2±0.2	5.2±0.1	177.5 ±1.7	37
	25%	7.9±0.2	5.2±0.1	180.4± 2.1	36

WF - wheat flour, LFB - yellow lupin flour cultivar Bursztyn, LFK - narrow-leaved lupin flour cultivar Kurant, values are averages of three repetitions, ± sd – standard deviation for three independent determinations

Source: own work / Źródło: opracowanie własne

Table 4. The characteristic of wheat with varius addition of lupin flour bread quality
Tab. 4. Cechy chleba pszennego z różnym udziałem mączek z nasion łubinu

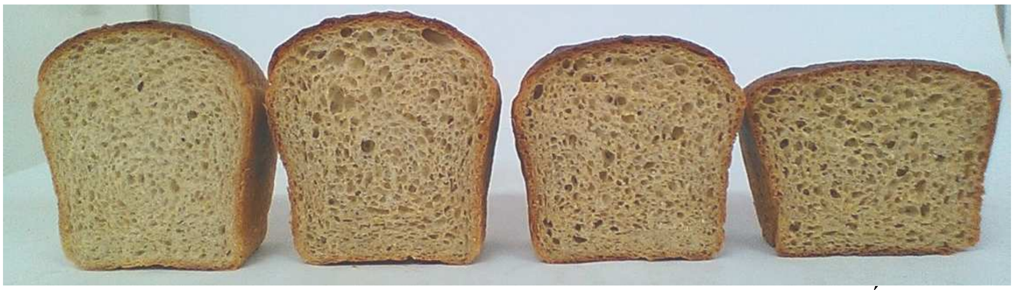
Type of flour/ Share of lupin flour		Yield of bread made with 100g flour	Volume of bread, cm^3		Hardness of crumb, N	Crumb moistu-re content, %	Crumb titrable acidty, degree	Organoleptic evaluation, points
			100g	made of 00g flour				
WF	0%	138.2 ±0.2a	336.3 ±6.8a	465.0 ±8.8	14.7 ±0.9	42.9 ±0.6	3.2 ±0.06a	38.7 ±0.7 b
LFB	10%	144.6 ±0.4b	301.0 ±6.6b	436.0 ±8.5	14.2 0.5±	45.3 ±0.2	4.4 ±0.1c	38.0 ±0.0 b
	15%	144.8 ±0.6b	277.0 ±4.6c	401.3 ±5.1	18.4 ±0.6	44,3 ±0,2	4,4 ±0,1c	36,3 ±0,6c
	20%	142.8 ±1.0b	239.0 ±8.2d	341.0 ±10.0	32.3 ±1.4	44.3 ±0.3	4.5 ±0.1c	34.0 ±0.0d
	25%	142.3 ±0.9b	213.7 ±2.3e	303.6 ±3.5	41.0 ±1.0	45.2 ±0.4	4.1 ±0.1b	33.0 ±0.2d
LFK	10%	145.7 ±0.8c	310.3 ±2.5b	452.3 ±5.8	14.1 ±0.4	43.4 ±0.2	3.1 ±0.1a	39.3 ±0.4 a
	15%	149.6 ±0.7d	307.0 ±6.0b	459.0 ±7.0	13.8 ±0.6	45.1 ±0.2	3.3 ±0.0a	36.8 ±0.3c
	20%	150.6 ±1.3d	264.3 ±4.0c	397.6 ±9.1	24.7 ±0.8	46.3 ±0.1	3.3 ±0.1a	33.7 ±0.6d
	25%	153.4 ±0.3d	250.0 ±6.1d	383.6 ±8.0	23.6 ±0.8	48.3 ±0.1	3.6 ±0.0a	32.7 ±0.6d

WF - wheat flour, LFB - yellow lupin flour cultivar Bursztyn, LFK - narrow-leaved lupin flour cultivar Kurant, data are the mean of two independent experiments, a–d means within a column with different superscript letters are significantly different, ($P \geq 0.05$).

Source: own work / Źródło: opracowanie własne

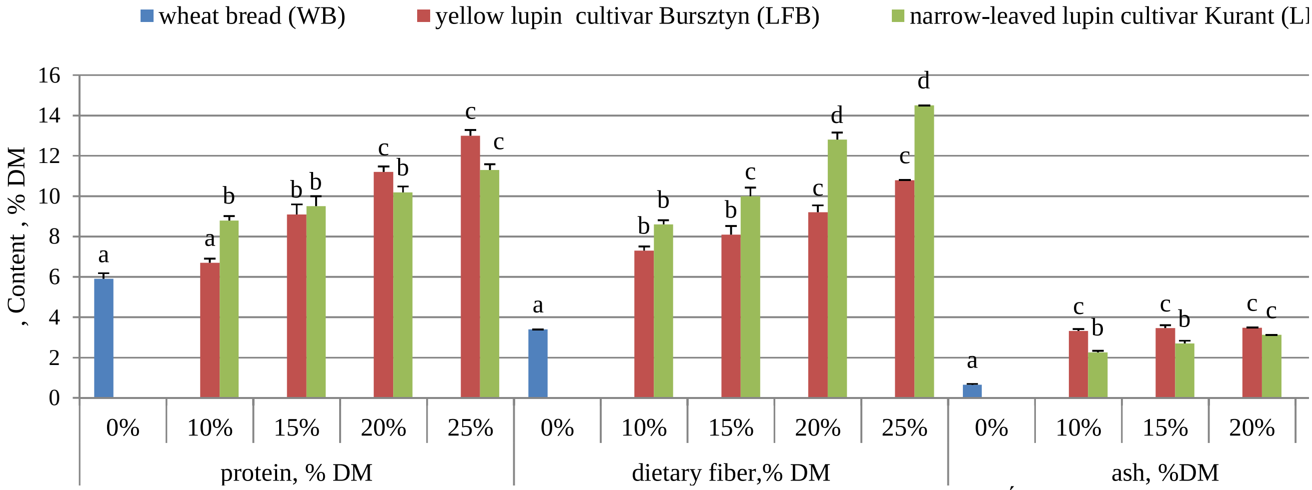
The use of lupin flour for the production of wheat bread had a positive effect on its quality when the share of tested flours was up to 15%, while at higher levels of substitution the quality of the bread deteriorated. Along with the increase in the share of lupin flour in the bread, the bread volume decreased. This tendency was observed in other studies [7, 20]. Hardness of the crumb of bread with a 10% share of legumes was less than for the control sample, and in the case of the narrow-leaven lupin cultivar Kurant, also with 15% share, the crumb of bread was softer than the crumb of wheat bread. The higher share of legumes in wheat bread resulted in a significant increase in crumb hardness, which was particularly evident in the case of the use of yellow lupin cultivar Bursztyn. The substitution of wheat flour by flour of both lupin species significantly influenced the moisture content of the bread crumb, which was related to the high water absorption of mixed lupin-wheat flours and was preferably received in the assessment of organoleptic quality. The replacement of wheat flour by lupin flour up to 20% did not cause a distinct change in the taste and aroma of the bread, only a slight bitter taste was noted with a 25% share of lupin. The influence of yellow lupin on increase in the acidity of the crumb was also noticed, which gave also pungent flavor.

Sourdough bread obtained with the share of lupin flour from whole seeds was characterized by both high sensory quality and nutritional value. Compared to wheat bread, the level of protein and dietary fiber was significantly higher (Fig. 2).The high content of dietary fiber and protein, which mainly consists of albumins and globulins, is beneficial in terms of nutritional value. Legume proteins are rich in lysine and deficient in sulfur containing amino acids contrary to wheat flour [13, 27]. The positive effect of lupine flour on the quality of bread could be also related to its emulsifing properties [20]. The highest fiber content was found in bread with 25% of narrow-leafed wheat flour, however the deterioration of the quality of bread was observed (bitter aftertaste was most noticeable). The share of 15% of each of tested lupin flours could be recommend in mixed wheat-lupin bread recipe. In the case of all breads, the share of 25% of lupin flours adversely affected the bread volume, whereas the high moisture content of the crumb increased the organoleptic assessment.



Source: own work / Źródło: opracowanie własne

Fig. 1. Wheat bread slices with the share of 10, 15, 20, 25% of narrow-leaved lupin flour (LFK) - from left
Rys. 1. Przekroje chleba pszennego z udziałem mączki z łubinu wąskolistnego 10, 15, 20, 25% (od lewej)



Source: own work / Źródło: opracowanie własne

Fig. 2. The content of chosen components in bread with the lupine flour, based on dry matter (DM)
Rys. 2. Zawartość wybranych składników w pieczywie z udziałem mąk z łubinu, na podstawie suchej masy

5. Summary

The optimal proportion of lupine in wheat bread was selected due to the physicochemical properties of the dough and the quality of the bread. In conclusion, sourdough bread obtained with the share of flour made from seeds of both species is an attractive offer for consumers taking into account both nutritional value and organoleptic attributes. Bread producers should be interested in such bread because it allows to increase the range and variety of the assortment, moreover its production does not create technological problems. Therefore, the yellow and narrow-leaved lupin can become a plant providing adequate protein supply for vegans [2, 16]. The present experiments have shown that it is also possible to obtain bread with the share of lupin flour with a high content of dietary fiber and attractive organoleptic qualities.

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