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Research Article

Quality analysis and prospects for the use of lupin seeds of Belarusian selection

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Abstract
The paper investigates technological parameters of the quality of low-alkaloid lupin of five cultivars selected and grown in the Republic of Belarus during the years from 2007 to 2017. Prospects for the use of the obtained seeds have been studied. This study reveals great influence of cultivar and climatic conditions during growth of lupin seeds on correlation of anatomic parts in seeds as well as on their physical properties. Cultivar of lupin seeds Jan is recommended for whole grain flour and graded flour production based on its anatomic composition, uniformity and physical properties. A comparative analysis of chemical composition, quality parameters and technological properties of lupin flour has been done. The chemical composition of lupin flour, of whole grain lupin flour, in particular, has been found to be relatively low in starch, high in protein, food fibers, minerals and organic acids. As a result, whole grain lupin flour has been proved to have higher food value when compared to traditional wheat flour. This paper demonstrates the difference between lupin flour characteristics and those of wheat flour in terms of color, acidity, enzymatic activity and adsorbing properties. This study reveals the possibility of use of lupin flour in bakery products by substituting traditional types of flour with lupin flour at 10-30% levels, as well as by replacing egg products with lupin flour at 25-50% levels. The work highlights the use of lupin flour at the stages of dough kneading, dough preparation, foam and emulsion production mainly by using rapid dough making methods. Practical applications: Recommendations have been made on the usage of lupin flour in the technological process of bakery products manufacturing, macaroni and flour confectionery products production.

Keywords: lupine seeds, lupine flour, flour products, quality of seeds, bakery products, macaroni, bakery confectionery products

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Introduction

In recent years, demand for foodstuffs with a balanced chemical composition and improved nutritional value tends to increase among Belarusian population. The use of new types of food raw materials becomes one of the prospective fields, with further research being done on technological procedures and methods of processing. Scientists and specialists in food industries take greater interest in valuable chemical composition of lupin seeds, protein of which is similar to the animal proteins in terms of amino acid composition. However, despite its high nutritional value lupin seeds have not been used as a raw material in food production. Its unpopularity was due to low yields which inhibited large-scale cultivation. On the other hand, specific bitter taste of beans caused by the presence of alkaloids (Vovnyanko 1991; Sizenko 2004) also contributed to the lack of interest. At present the breeders from Belarus have selected new high-yielding cultivars with low-alkaloid content, with nutritional properties being highly appreciated (Grin 2003; Belarusian agriculture 2006). At the same time, physical, chemical and technological parameters inherent in new cultivars are not fully understood. Unfortunately, physical, chemical, and technological properties of these new species have not been fully studied. It explains the necessity for further investigation. The present paper studies the anatomical and chemical composition, organoleptic, physical, chemical and technological properties of lupin seeds of Belarusian selection, as well as their future prospects of the use in food industry.

Materials and Methods

Lupin seeds of Belarusian selection of following cultivars: Pershatsvet, Pryvabny, Dziuny, Myrtan, Jan have been chosen as material for this study. These seeds were grown at the experimental farms of the SPC NAS of Belarus for agriculture (Zhodino) in the period from 2007 till 2017. The research was done both in laboratory and production conditions. Actual standard methods approved by the Republic of Belarus were used for quality assessment of lupin seeds and flour. For example, the odor level evaluation and color of lupin seeds was performed according to GOST 10967; mass fraction of moisture – according to GOST 13586.5; size – according to GOST 30843; test value – according to GOST 10840; the weight of 1000 grains – according to GOST 10842. Analysis of the quality of lupin flour was done using the following methods: taste, smell, color – according to GOST 27558; mass fraction of moisture – according to GOST 9404; whiteness – according to GOST 26361, grinding fineness – according to GOST 27560, total titrated acidity – according to GOST 27493; ash content – according to GOST 27494; the content of metal-magnetic impurity – according to GOST 20239; quantity and quality of gluten – according to GOST 17839, the number of falling – according to GOST 27676, baking properties were defined based on the results the results of the laboratory baking test according to GOST 27669. The mass fraction of fat in flour was analyzed using the Soxhlet method; the mass fraction of starch in flour – using the method of Evers; the mass fraction of fiber in flour – according to Kiurnner and Ganek; the mass fraction of protein in flour – according to Kjeldahl. Analysis of the quality of semi-finished products and flour products was carried out using current standard methods.

Results and Discussion

Quality of lupine seeds. The choice of the best cultivars of lupin seeds can be made only on the basis of complete information about their qualities, including physical and chemical characteristics of the grain, its technological properties. When assessing the organoleptic properties of lupin seeds, it was noted, that there are differences in the color of seeds due to unequal degrees of physiological maturity, seed coat thickness and other reasons regardless of the cultivar and a year of harvesting. In the course of studying, the anatomical composition of lupin seeds variations of the number of roots were determined, seminal membranes and cotyledons were found out, which correspond to 1.8±1.2%; 25.5±3,4% and 72.5±3.5 %, respectively. It has been noted that cultivar Jan has the largest number of cotyledons (from 73.8% to 76.9%), while the cultivar Pryvabny has the lowest ones (from 71.2% to 72.7%). Table 1 shows data on the amount of anatomic parts in cultivar Pershatsvet.

Table 1. Anatomic parts of seed of lupine of sort Perschatcvet

Anatomic parts of seed	Year of harvest				Limit of variation, %
	2007	2010	2014	2017	
Cotyledons, %	78.7±2.2	78.2±2.2	74.4±2.1	74.3±2.2	76.5±2.2
Seed shells, %	19.0±2.2	19.2±2.2	23.0±2.3	2.6±2.3	21.3±2.3
Root, %	2.3±0.2	2.6±0.2	2.6±0.2	2.2±0.2	2.4±0.2

The greatest variation patterns are characteristic for the lupin seeds harvested in 2007 which was characterized by higher temperatures during the maturation of the seeds, and it is likely that not every lupin cultivar has become drought-resistant. The ratio of the mass fraction of cotyledons to the mass fraction of seed coat with the root of the lupin seeds harvested in 2007 has been found to be in the range from 2.7 to 3.7; for the yield of 2010 and for those grains harvested in 2014 – from 2.5 to 3.6 and for those harvested in 2017 – from 2.2 to 3.2, respectively. At this point, cultivar Jan turned out to be the best one among other lupin seeds with an average vegetation period within 94 days and average yield of 0.329 kg/m^2, characterized by fairly good seed ripening. It was also found, that within one cultivar the ratio of the anatomical parts of the lupin seeds depended on the year of harvesting. For example, the ratio of seed coat increased 1.2 times and the ratio of cotyledons decreased 1.1 times in 2014 and 2017. Probably, this fact is due to an annual increase in the average daily temperature of the environment during the ripening season. The variation value found for the cotyledons and seed coat in lupin during the investigated period was practically the same (on average ±2.24 %). The thickness of seed coat of all investigated lupin cultivars was found to be within the range from 0.019 to 0.024 mm. At the same time the lower coat thickness values are typical for lupin seeds harvested in 2007 and 2010, and higher coat thickness were found in seeds harvested in 2014 and 2017. However, the regularity of these changes could not be identified because of negligibility of the obtained values. Indicators of physical properties and variation patterns of the investigated lupin seeds are presented in Table 2.

Table 2. Quality of lupine seed

Sort of lupine	Nature, g.dm^{-3}	Wight 1000 grains, g	Volume, mm^3	Closeness, g.cm^{-3}
Perschatcvet	710±79	124±13	89±17	1.274±0.030
Pryvabny	756±27	138±17	102±27	1.309±0.030
Dziuny	760±30	126±14	90±19	1.311±0.090
Myrtan	711±51	134±16	80±17	1.335±0.070
Jan	822±59	125±14	95±24	1.304±0.090
All sorts	752±49	129±15	91±21	1.307±0.060

The moisture content of all studied species changed insignificantly within the following range 11.5±0.3%. The limits and patterns of variation of the quality parameters vary and depend on a cultivar. Moreover, these parameters depend on the year of harvesting. Cultivar Jan, grown in 2011, among other studied lupin cultivars had the highest test values and the mass of 1000 grains. Regardless of the year of harvesting, Pershatsvet, Dziuny and Jan species were more equal in size by the sum of gatherings from two successive sieves with a hole diameter of 5.5 and 5.0 mm. Pryvabny and Myrtan seeds have the sum of the withdrawals from two successive sieves with aperture diameter of 6.0 and 5.5 mm (Fig. 1).

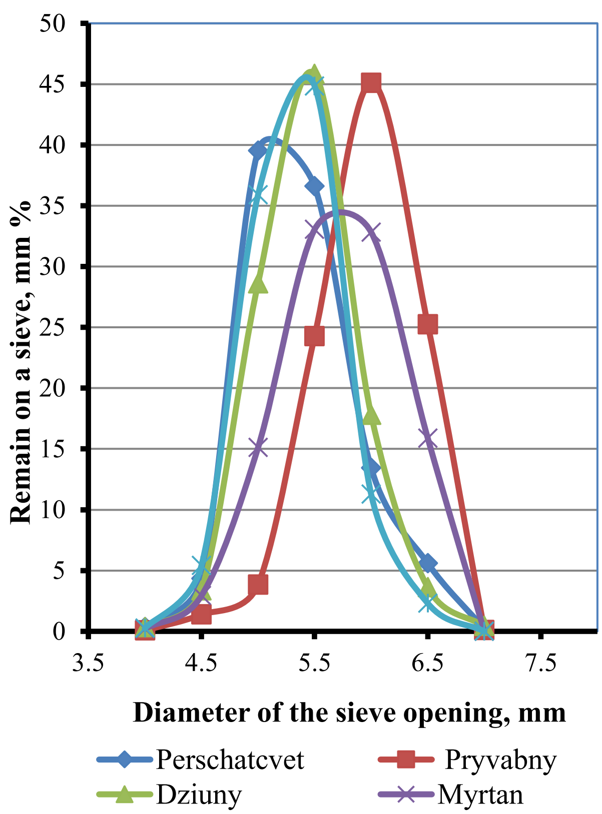

Figure 1. Curves of largeness of seed of lupine of different sorts

Pershatsvet cultivar has smaller seeds, while Pryvabny has larger seeds compared with other species of lupin, which is in good agreement with the results of analysis of the mass of 1000 grains (Table 2). The fractional composition varies considerably depending on the year of harvesting and a cultivar. Especially it is typical for fractions obtained by withdrawing from sieves with a diameter of 5.0 mm; 5.5 mm; 6.0 and 6.5 mm. In this case, the lupin seeds of Jan and Dziuny species were more uniform. Thus, cultivar characteristics of lupin seeds and climatic conditions while growing significantly affect the ratio of anatomical parts and physical properties. This should be taken into account when accepting seeds and preparing seed batches which are sent for storage and processing. A comparative analysis of lupin seed quality has revealed cultivar Jan to be the most promising technological species among all investigated cultivars.

When determining the chemical composition of the investigated lupin species, it was found that the following cultivars were sufficiently high in protein content (in percent) such as Myrtan cultivar – 30,5; Pryvabny – 29.0; Pershatsvet – 27.0; Dziuny – 26.2 and Jan – 29.5.

The evaluation of the amino acid composition of various lupin species showed a significant variation in the content of identical amino acids. Thus, the leucine variation is 1.36±0.76 %, for isoleucine 0.70±0.46 %, for threonine 1.65±0.23 %, for arginine 1.87±0.75%, for phenylalanine – 0.86±0.48 %. In comparison with the other amino acids that have been determined, the greatest content of them have been found in arginine and leucine. All investigated species of lupin seeds are low in lysine and histidine, the variation of their values are 0.62±0.24 % and 0.53±0.14 %, respectively.

The fat content in the lupin seeds have been found to range from 4.9 to 5.7 %, starch content range from 6.2 to 9.5 % and sugar content range from 7.3 to 8.6 % depending on a cultivar and the year of harvesting Lupin seeds are rich in iron compounds (54.8±2.5 mg/kg), calcium (1145±35 mg/kg), sodium (53.3±3.8 mg/kg).

The content of alkaloids in the lupin seeds of all the studied species does not exceed 0.012 %. The energy value of the investigated lupin cultivars varies from 216 to 243 kcal.

Quality of lupine flour. At the next stage of the research, organoleptic, physical, chemical and technological properties of whole grain lupin flour and lupin flour First grade were investigated. The methods of obtaining lupin flour First grade were described in detail in the earlier publication (Rukshan et al. 2008). Thus, granulometric composition of whole grain lupin flour First grade (Fig. 2) is characterised by the fact that about 50 % of the particles have size 220 µm, which exceeds the maximum particle size of wheat flour grain of the Highest and First grades (from 180 to 190 µm) and correspond to the size of the flour particles of the flour Second grade and whole-meal flour.

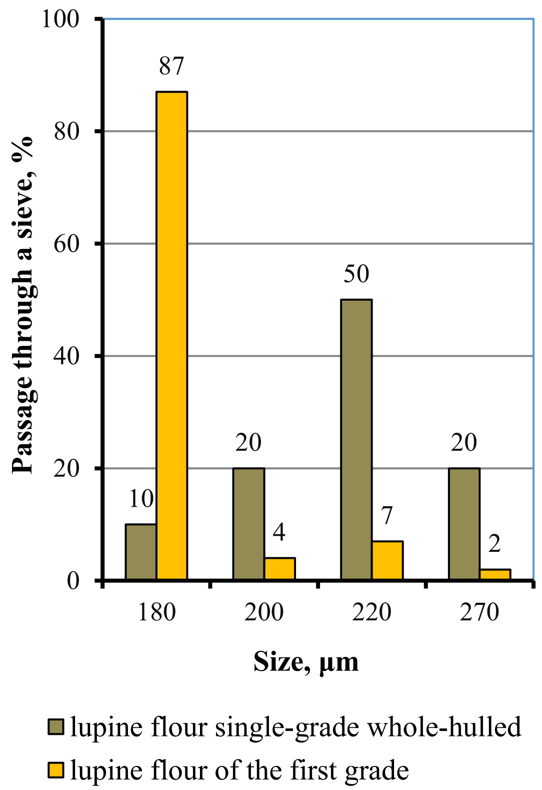

Figure 2. Particle-size of lupine flour

At the same time the granulometric composition of the lupin flour First grade, also represented in Figure 2, is close to the granulometric composition of wheat flour First grade. Taking into account the effect of flour particle size on dough and flour products quality, in terms of granulometric composition, whole grain lupin flour is recommended for confectionery and bakery production, and graded flour is recommended for bakery, macaroni and confectionery production.

Organoleptic indices of the lupin flour differ significantly from those of wheat flour. In particular, lupin flour has a bright yellow color due to the carotene content. Whole grain lupin flour has a bright yellow color due to the presence of yellow-colored peripheral (bran) seed particles. As a result, the lupin flour seems appropriate either in recipes of flour products with intensive coloring of the surface. The crumb gets golden yellow due to the high content of such components as sugar, molasses, honey, butter, egg products, etc. Also, it may be used in recipes for low-calorie flour products. The yellow color of lupin flour can simulate the presence of the above mentioned ingredients. The characteristic for all legumes taste and smell of whole grain lupin flour as well as those of graded lupin flour are much less pronounced due to the special pre-treatment processing before grinding.

The chemical composition of lupin flour (Fig. 3, Fig. 4) also differs from that of wheat flour.

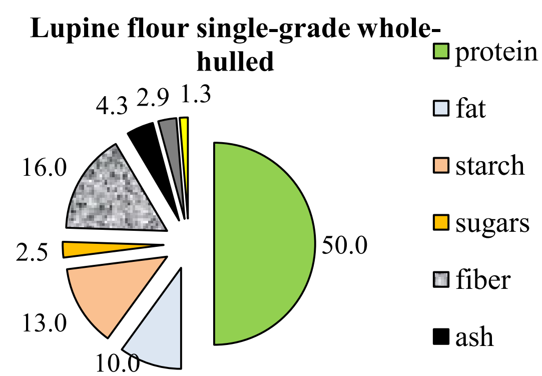

Figure 3. Chemical composition of dry substances of lupine flour single-grade whole-hulled (in percents

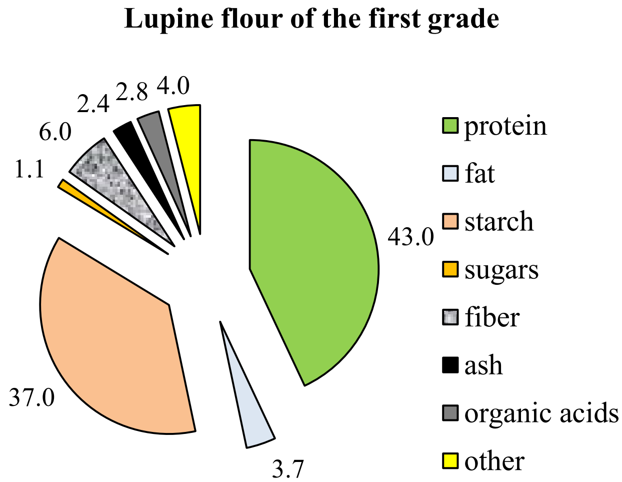

Figure 4. Chemical composition of dry substances of lupine flour of the first grade (in percents)

The dry substances of lupin flour, especially of single-graded flour and whole grain lupin flour are characterized by a relatively low content of starch, significant amount of protein, dietary fibers, minerals and organic acids. In general, lupin flour has been found to be a raw material with higher nutritional value tin comparison to wheat flour. It should be noted, that lupin flour is rich in fat content, which must be taken into consideration when grinding, storing and using it in flour products. Both single-grade whole grain lipin flour and graded lupin flour have approximately the same energy value (383 and 370 kcal per 100 g).

Prospects fot the use of lupin flour based on some physical and chemical parameters are given (Table 3).

Table 3. Physicochemical parameters of wheat and lupine flour

Name of indicators	Type of flour		
	wheat flour M 54-28	**lupine flour single-grade whole-hulled**	**lupine flour of the first grade**
Mass fraction of moisture, %	12.2±0.2	4.9±0.2	9.6±0.2
Ash content in terms of dry substance, %	0.52±0.03	4.30±0.03	2.41±0.03
Whiteness, standard units. device P3-BPL	55±1	12±1	14±1
The amount of raw gluten, %	29±1	is not washed	is not washed
Of raw gluten, standard units. device IDK (group)	85 (II)	is not determined	is not determined
Number of incidence, seconds	190±5	115±5	160±5
Metallomagnetic admixture, mg.kg^{-1}	0.2±0.1	2.7±0.3	1.3±0.3
Acidity, degree	3,0±0,2	31.6±0.2	16.1±0.2
Sedimentation sediment, cm^3	52±2	16±2	14±2
Alkali-holding capacity, %	129±5	323±6	136±5

Lower moisture content and increased ash content of lupin flour compared with those of wheat flour are associated with its chemical composition and crushing of lupin seeds. High acidity of lupin flour is 5 to 10 times higher than the value of that of wheat flour of highest grade, and it is due to high amount of amino acids, organic acids, acid salts. Despite the fact that the protein content in lupin flour is 3.5 to 4 times higher, gluten is not washed away from it, unlike it occurs in wheat flour. However, lupin seed flour contains more water-soluble proteins, which results in an increased alkalinity and a lower sedimentation value. The lupin flour is significantly superior to wheat flour in terms of its enzymatic activity. The falling number value of lupin flour corresponds to that of rye peeled flour. The greatest activity is characteristic for proteolytic enzymes of lupin flour.

The use of lupine in flour products. The use of lupin flour in the production of flour products reduces gluten strength in dough and increases acidity in semi-finished products. In bread production, therefore, introduction of lupin flour into semi-finished products requires the use of special technological methods (use of starter cultures, accelerated methods of preparation) to obtain dough with required organoleptic, physical, chemical and rheological properties. In pasta production, the gluten-free lupin flour enrichesassortment of products used in the gluten-free diet. In the confectionery industry, the use of lupin flour is more appropriate for the production of plastic and viscous-plastic dough products (gingerbread, sugar and biscuit cookies, wafers, biscuit and shortbread products, etc.), with the obligatory adjustment of the chemical baking powders and fat according to the recipe (Rukshan et al. 2008; Rukshan et al. 2012; Rukshan et al. 2017). In the course of studies undertaken in the period from 2007 to 2014 the optimal quantity of lupin flour and methods of its introduction into flour products were being determined when assessing prospects for using lupin flour. It has been established that lupin flour as a high-protein raw material is reasonable to use in recipes of flour products as a substitute for a part of wheat flour as well as a substitute for egg products (Rukshan et al. 2008; Rukshan et al. 2012; Rukshan et al. 2017). The optimum quantity data on lupin flour as a partial substitute of wheat flour in dough production for bread, confectionery and macaroni are given in Figure 5.

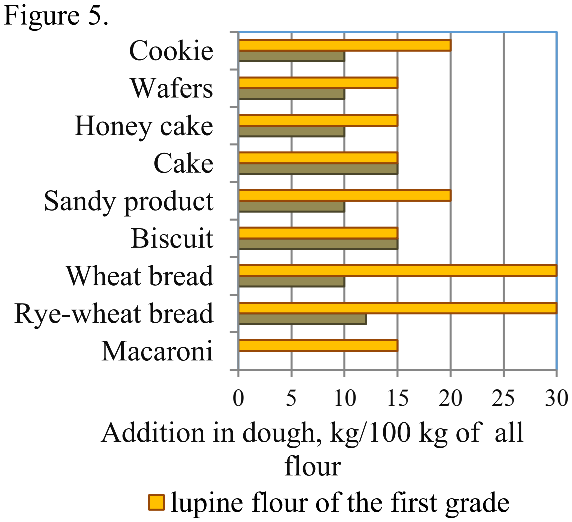

Figure 5. Addition of lupine flour to dough in food products

Figure 5 shows that the amount of lupin flour as a substitute of wheat flour in recipes varies from 10 to 30 %, whereas the use of graded lupin flour is possible in higher dosages (by 5−20 %) in comparison to whole grain lupin flour. Rapid dough making methods are recommended when taking into account the increased acidity and enzymatic activity of lupin flour. For example, the use of intensive «cold» technology, the process of batter preparation on a liquid dispersed phase, and an accelerated method without fermentation in bulk with a paste and a brief dough patch guarantee the best quality of wheat bread products.

When producing rye-wheat bread, it is preferable to use technologies with the use of acid-forming semi-finished products (for example, starter cultures) with the introduction of lupin flour at the kneading stage or in brewed bread varieties instead of rye flour at the stage of dough kneading. The quality of short-cut pasta produced using high-temperature kneading and dough processing is improved when introducing lupin flour. In flour confectionery products, lupin flour is preferable to add at the kneading stage. In brewed gingerbread and honey cake production lupin flour is better introduced during preparation of dough kneading. In addition, due to the relatively high content of proteins as surface active substances, lupin seeds can be used in the preparation of confectionery foams and emulsions. It has been established that the use of lupin flour is also possible in preparation of biscuit semi-finished products, muffins and butter biscuits as a substitute of a part of egg products at the stage of sugar-egg foam or emulsion frothing. The amount of whole grain lupin flour is 25 % and that of graded flour accounts for up to 50 % vs the amount of egg solids used. As a result of the present research unified recipes and technological process charts have been worked out for production of bread, vermicelli, gingerbread, biscuits, muffin, sponge cake, short semi-finished products, wafer sheet using lupin flour. Improvement of the chemical composition and nutritional value of the developed products in terms of protein content, minerals, carotene, dietary fiber has been found.

Conclusions

Based on the results of the studies, the following conclusions can be drawn:
– lupin seeds of cultivar Jan of Belarusian selection have been found to be technologically prospective according to anatomical composition, uniformity, and physical properties;
–lupin seeds can be processed both into whole grain flour and graded flour;
– whole grain lupin flour can replace from 10 to 15% of traditional wheat flour in the production of bakery products, flour confectionery products or replace up to 25 % of egg solids in flour confectionery products;
– based on its organoleptic, physical, chemical and technological properties graded lupin flour can replace from 15 to 30 % of traditional wheat flour in the production of bakery products, macaroni and flour confectionery products or replace up to 50 % of egg solids in flour confectionery products;
– using of lupin flour in flour products instead of wheat flour is advisable at the stage of preparation of dough kneading, dough and other semi-finished products while using rapid dough processing methods, with adjusting of shortening and fat products being necessary;
– using of lupin flour in flour products instead of egg products is appropriate at the stage of preparation of foams and emulsions.

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