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Original Research

Nutrient Contents in Yellow Lupine (*Lupinus luteus* L.) and Blue Lupine (*Lupinus angustifolius* L.) Cultivars Depending on Habitat Conditions

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Abstract

The objective of the study was to determine the effects of habitat conditions on the content of nutrients in the seeds of different cultivars of blue and yellow lupine. Experiments were located in different parts of Poland. Sixteen cultivars of blue lupine and eight cultivars of yellow lupine were used in these experiments. The study showed that yellow lupine seeds had a higher protein content then blue lupine, and the contents of this component were varied between both cultivars of this species depending on examined factors, while the fiber content was little varied between species and cultivars. The average fat content in the seeds of blue lupine was slightly higher, the amount of starch was a much higher, and the water-soluble sugars slightly lower than in the seeds of yellow lupine. Significant differences between cultivars of blue lupine were found in the contents of crude fat, water-soluble carbohydrates and alkaloids, and between cultivars of yellow lupine in the amounts of crude fat. The cultivation region did not significantly affect only starch accumulation by the tested lupine cultivars as well as alkaloids in yellow lupine. The contents of the other components were varied depending on the area of cultivation.

Keywords: yellow lupine, blue lupine, cultivar, regions, crude protein, crude fibre, crude fat, sugars, alkaloids

Introduction

Covering requirements for high-quality protein in animal feed and human food is becoming more and more important in EU countries, including Poland. Over the past 30 years, around 70% of plant protein requirements in Poland have been covered by imported extracted soybean meal. Population growth, changing weather conditions, and a decrease in arable lands have forced farmers to grow other species that provide feed and food and constitute plant proteins [1]. Legume seeds may play such a role. Lupines are a species particularly well adapted to climatic conditions of Poland. They have a number of nutritional and agronomic advantages [2]. They can be grown on different soils (including light) and under various habitat conditions, at the same time increasing the fertility and

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culture of the soil [3-6]. The nutritional value of lupine seeds depends on the quantity and quality of amino acid composition of protein, fat, carbohydrates, and anti-nutritional substances. There are variations in the protein content between species and cultivars as a result of the characteristics of the growing conditions and soil types, from 28% to 48% of the dry weight of the whole seed [7]. As has been shown in numerous studies, lupine seeds can be a substitute for extracted soybean meal in the feeding of pigs, poultry, and young cattle [8-11]. According to Chalupa et al. [12], lupine seeds are an important source of protein in the feeding of ruminants and allow for preparing a balanced ration, especially for dairy cattle.

Flour from lupine seeds is used for producing functional foods and increasing the nutritional value of different products [13-14]. The digestibility of lupine protein is comparable with the digestibility of soybean protein [15]. Lupine flour improves the nutritional value of bread, pasta, and biscuits [16-18]. The interest in lupine as a source of feed and a food additive has been steadily increasing together with growing awareness of its nutritional and pro-health properties [19, 20]. Bähr et al. [21] believe that lupines are an alternative to soybeans, as they contain comparable amounts of proteins of a similar amino acid profile, but more fiber content, which is favorable from the dietary point of view, compared to beans.

The aim of our study was to determine the effect of habitat conditions (agroecological) on the content of nutrients in the seeds of different varieties of yellow and blue lupine.

Material and Methods

The impact of agroecological conditions (region, precipitation, pH) on the content of nutrients in lupine seeds was evaluated on the basis of an analysis of material obtained from experiments carried out in 2010-2012. Experiments located in different parts of Poland took into account 16 registered cultivars of blue lupine (*Lupinus angustifolius* L.): Baron, Bojar, Boruta, Dalbor, Graf, Heros, Kadryl, Kalif, Karo, Mirela, Neptun, Oskar, Regent, Sonet, Tango, and Zeus – each tested at 11 sites: Bobrowniki, Cicibór Duży, Głodowo, Kawęczyn, Kościelec, Marianowo, Nowy Lubliniec, Rarwino, Ruska Wieś, Wrócikowo,Wyczechy; and eight of yellow lupine (*Lupinus luteus* L.): Baryt, Dukat, Lord, Mister, Parys, Perkoz, Talar, Taper, each tested in 11 sites: Bobrowniki, Cicibór Duży, Głodowo, Marianowo, Nowa Wieś Ujska, Nowy Lubliniec, Ruska Wieś, Sulejów, Świebodzin, Tomaszów Bolesławiecki, Uhnin (Fig. 1).

Blue lupine was cultivated on soils belonging to the very good rye complex (Bobrowniki, Cicibór D., Kawęczyn, Kościelec, Marianowo, Rawino, Ruska Wieś, Wyczechy), and good rye complex (Głodowo, N. Lubliniec, Wrócikowo). Soil pH_{KCl} ranged 5.2-7.2. The yellow lupine was cultivated in the soils of the very good rye complex (Białogard, Bobrowniki, Cicibór D.,

Fig. 1. Sites of experiments in Poland.

Marianowo, Ruska Wieś, Uhnin), good rye complex (Głodowo, N. Lubliniec, Sulejów, Tomaszów B.), good wheat complex (Świebodzin), and weak rye complex (N. Wieś Ujska). Soil pH ranged pH_{KCl} 5.0-7.2.

Total rainfall during the growing season in individual localizations ranged from 194 to 488 mm (Table 1). The seeds of legumes were determined for the contents of the most important nutrients: crude fibre (by weight method), crude fat (by Soxhlet's weight method), N (by flow spectrophotometry), and sugars and starch (by Bertrand's titrimetric method). The results were statistically analyzed with the use of the analysis of variance using Statistica v. 10.0 program (Tukey's test $\alpha = 0.05$). The analysis of the correlation between the content of nutrients in the seeds of blue and yellow lupine and selected agrotechnical factors was also performed.

Results and Discussion

Studies have shown that regardless of the agroecological conditions, the cultivars of blue lupine (Graf, Tango) and of yellow lupine (Dukat, Talar, Lord, Barite) had the highest protein content, while Sonet of blue lupine and Perkoz of yellow lupine had the smallest (statistically significant differences; Tables 2 and 4). Much larger amounts of this component were recorded for the seeds of yellow lupine compared to blue. It was also found that cultivars of blue lupine growing in the northern region of Poland accumulated fewer proteins in the seeds, while in the southeastern they were significantly more (Table 3). The region of cultivation had a relatively low effect on the accumulation of protein by yellow lupine seeds. Only in the northern part of Poland was a lower content of this component recorded (Table 5). Niwińska [22] recorded higher protein content in yellow lupine compared to white and blue ones, with a large variability among individual cultivars. Different protein contents in several cultivars of *L. albus, L. luteus,* and *L. angustifolius* were reported

Table 1. Monthly sum of precipitation and mean temperature in locations of cultivation of blue lupine and yellow lupine.

Location	Precipitation (mm)					Temperature (ºC)				
	IV	V	VI	VII	Sum (IV-VII)	IV	V	VI	VII	Average (IV-VII)
	2010									
Bobrowniki	37.3	83.1	12.5	95.6	228.5	7.9	11.2	16.5	21.5	14.3
Cicibór Duży	23.0	126.8	67.7	48.2	265.7	8.7	14.5	17.9	21.6	15.7
Głodowo	29.2	143.3	44.7	130.7	347.9	8.5	12.5	16.8	21.4	14.8
Kawęczyn	15.1	155.5	37.0	67.4	275.0	9.0	13.0	17.1	20.8	15.0
Kościelec	25.0	147.7	41.3	87.5	301.5	10.2	13.5	19.0	23.1	16.5
Marianowo	34.8	151.8	75.5	108.1	370.2	8.3	13.4	16.9	21.1	14.9
Nowy Lubliniec	27.2	195.1	98.4	167.3	488.0	9.3	14.8	17.7	20.9	15.7
Nowa Wieś Ujska	30.5	150.4	36.2	112.4	329.5	7.9	11.0	16.8	21.8	14.4
Rarwino	20.0	85.1	27.7	74.8	207.6	6.5	8.7	14.1	20.0	12.3
Ruska Wieś	42.8	140.1	125.9	94.9	207.6	7.0	12.8	16.1	20.7	14.2
Sulejów	25.7	148.9	58.3	86.7	207.6	8.3	12.4	16.9	20.6	14.6
Świebodzin	53.8	24.3	128.3	111.7	207.6	7.9	13.8	15.0	18.4	13.8
Tomaszów Bolesławiecki	50.8	29.3	128.1	119.7	207.6	7.8	13.8	14.8	18.2	13.7
Uhnin	17.1	93.0	63.8	63.1	207.6	9.2	14.9	18.2	21.8	16.0
Wrócikowo	16.9	153.0	80.8	64.1	314.8	7.3	11.9	15.8	20.5	13.9
Wyczechy	54.3	214.6	61.2	97.6	314.8	8.7	12.4	17.1	21.0	14.8
	2011									
Bobrowniki	5.0	32.7	65.2	152.2	255.1	11.4	14.9	18.3	17.8	15.6
Cicibór Duży	37.6	61.2	65.4	201.6	365.8	9.6	13.8	18.4	18.7	15.1
Głodowo	12.4	43.4	36.2	179.3	271.3	10.4	14.2	18.2	17.1	15.0
Kawęczyn	40.2	31.5	51.4	179.8	302.9	10.6	14.4	18.6	18.2	15.5
Kościelec	16.5	50.2	51.6	117.0	235.3	12.3	16.4	21.0	19.9	17.4
Marianowo	38.7	58.0	58.3	273.9	428.9	9.6	13.4	17.7	18.5	14.8
Nowy Lubliniec	52.2	31.2	86.9	201.5	371.8	10.0	14.1	18.4	19.2	15.4
Nowa Wieś Ujska	8.1	44.1	48.1	174.4	274.7	10.8	13.9	18.0	17.6	15.1
Rarwino	12.1	52.7	62.9	175.2	302.9	10.1	12.7	17.0	16.9	14.2
Ruska Wieś	35.7	67.1	43.9	191.6	338.3	8.7	12.6	17.1	18.4	14.2
Sulejów	21.6	49.8	52.6	175.5	299.5	9.8	13.6	18.1	17.6	14.8
Świebodzin	14.9	20.5	37.2	143.0	215.6	11.6	14.5	18.6	17.8	15.6
Tomaszów Bolesławiecki	25.0	48.0	63.5	187.3	323.8	10.7	13.6	18.2	17.5	15.0
Uhnin	39.9	46.2	116.3	169.7	372.1	9.6	14.0	18.4	18.7	15.2
Wrócikowo	26.6	40.9	63.2	203.4	334.1	9.2	12.7	17.0	17.6	14.1
Wyczechy	14.1	50.6	55.9	166.8	287.4	10.2	13.1	17.2	17.4	14.5

Table 1. Continued.

	2012									
Bobrowniki	30.0	40.4	90.8	127.5	288.7	8.6	14.8	16.5	19.0	14.7
Cicibór Duży	37.5	55.8	126.1	27.5	246.9	8.9	14.8	16.9	21.0	15.4
Głodowo	34.9	17.9	124.4	89.7	266.9	9.1	15.4	16.1	20.9	15.4
Kawęczyn	46.0	46.5	67.3	74.3	234.1	9.6	15.4	17.0	20.6	15.7
Kościelec	11.1	32.8	121.5	100.5	265.9	9.5	13.8	18.5	21.9	15.9
Marianowo	44.6	60.3	105.5	101.1	311.5	8.5	14.1	15.5	19.7	14.5
Nowy Lubliniec	39.2	92.0	148.9	50.6	330.7	9.7	14.6	17.8	21.4	15.9
Nowa Wieś Ujska	50.0	59.4	156.6	129.7	395.7	8.6	14.3	15.3	17.8	14.0
Rarwino	39.8	12.8	83.0	161.1	296.7	7.1	12.5	15.1	17.3	13.0
Ruska Wieś	64.5	65.6	99.1	126.8	356	7.1	13.0	13.4	18.9	13.1
Sulejów	41.5	22.7	69.0	60.3	193.5	8.8	14.7	17.0	20.5	15.3
Świebodzin	32.6	54.8	79.3	154.4	321.1	9.4	15.5	16.5	19.3	15.2
Tomaszów Bolesławiecki	45.5	45.8	74.8	118.1	284.2	8.5	14.4	16.1	18.8	14.5
Uhnin	30.0	38.0	100.8	53.1	221.9	9.1	14.9	16.8	21.8	15.7
Wrócikowo	79.5	48.5	97.6	106.0	331.6	7.8	13.3	15.1	18.9	13.8
Wyczechy	53.8	24.3	128.3	111.7	318.1	7.9	13.8	15.0	18.4	13.8

Source: own elaboration based on IMGW-PIB data (2010, 2011, 2012)

Table 2. Nutrient contents (% DM) in blue lupine seeds by cultivar.

Cultivar	CP[1]	CFb[2]	CF[3]	WSC[4]	Sta[5]	Alk[6]
Baron	32.76^{ef}*	14.68^{ab}	6.54^{abc}	6.90^{ab}	27.02^{a}	0.043^{a}
Bojar	30.27^{abc}	15.06^{b}	6.86^{abcd}	6.58^{ab}	29.35^{a}	0.039^{a}
Boruta	31.75^{bcd}	14.95^{b}	6.41^{a}	6.60^{ab}	26.13^{a}	0.030^{a}
Dalbor	31.80^{bcde}	14.42^{ab}	6.73^{abcd}	6.95^{ab}	28.51^{a}	0.008^{a}
Graf	33.28^{fg}	15.04^{b}	6.72^{abcd}	6.76^{ab}	26.38^{a}	0.020^{a}
Heros	30.76^{abcd}	14.47^{ab}	6.45^{abcd}	6.70^{ab}	28.52^{a}	0.013^{a}
Kadryl	32.12^{def}	15.08^{b}	6.62^{abc}	7.13^{b}	27.73^{a}	0.024^{a}
Kalif	30.67^{abcd}	14.70^{ab}	7.02^{bcd}	6.86^{ab}	29.32^{a}	0.019^{a}
Karo	31.13^{bcd}	14.94^{b}	6.43^{ab}	6.50^{a}	27.06^{a}	1.113^{b}
Mirela	33.03^{ef}	14.54^{ab}	6.80^{abcd}	6.36^{a}	26.07^{a}	1.070^{b}
Neptun	33.08^{ef}	13.74^{a}	6.74^{abcd}	7.14^{b}	27.80^{a}	0.020^{a}
Oskar	32.59^{def}	14.58^{ab}	6.62^{abcd}	6.10^{a}	28.47^{a}	0.996^{b}
Regent	30.13^{ab}	14.71^{ab}	7.04^{cd}	6.69^{ab}	28.56^{a}	0.011^{a}
Sonet	29.36^{a}	14.85^{ab}	6.69^{abcd}	7.11^{b}	28.26^{a}	0.024^{a}
Tango	33.60^{g}	14.66^{ab}	6.77^{abcd}	6.47^{ab}	27.27^{a}	0.038^{a}
Zeus	31.88^{def}	14.39^{ab}	7.23^{d}	7.18^{b}	27.90^{a}	0.019^{a}

[1]crude protein, [2]crude fibre, [3]crude fat, [4]water-soluble sugars, [5]starch, [6]alkaloids

*Values in column marked with same letter did not differ statistically ($\alpha = 0.05$)

Table 3. Nutrient contents (% DM) in blue lupine seeds depending on cultivation region.

Location	CP	CFb	CF	WSC	Sta	Alk
Bobrowniki	32.03^{ab}	14.39^{bc}	6.43^{abc}	6.74^{abcd}	-	0.222^{ab}
Cicibór D.	32.56^{ab}	16.37^{d}	6.11^{a}	7.16^{d}	-	0.211^{ab}
Głodowo	31.78^{ab}	14.60^{c}	6.78^{bcd}	6.88^{bcd}	-	0.175^{a}
Kawęczyn	33.32^{c}	16.51^{d}	6.32^{ab}	7.02^{cd}	27.44^{a}	0.228^{ab}
Kościelec	32.43^{ab}	16.06^{d}	6.76^{bcd}	6.62^{abc}	-	0.269^{b}
Marianowo	31.14^{a}	14.33^{bc}	6.96^{cd}	6.62^{abc}	-	0.225^{ab}
N. Lubliniec	32.87^{bc}	16.66^{d}	6.00^{a}	7.16^{d}	27.67^{a}	0.211^{ab}
Rarwino	31.78^{a}	13.47^{ab}	6.83^{bcd}	6.43^{ab}	28.20^{a}	0.222^{ab}
Ruska W.	31.66^{a}	13.12^{a}	6.96^{bcde}	6.61^{abc}	-	0.232^{ab}
Wrócikowo	28.84^{a}	12.71^{a}	7.52^{e}	6.26^{a}	-	0.197^{ab}
Wyczechy	31.01^{a}	13.21^{a}	7.37^{de}	6.77^{bcd}	-	0.201^{ab}

Explanations as in Table 1

by different Authors [23-26]. According to Lagunes-Espinoza et al. [27], the protein content in the seeds of the same lupine species was relatively little diversified. More differences occurred within species, i.e., in *L. exaltatus* and *L. campestris*. Muzquiz et al. [28], and Garcia-Lopez et al. [29] showed a lower protein content in the seeds of *L. mariae-josephi* than *L. luteus, L. hispanicus*, or *L. albus*, and a similar amount of this component in *Lupinus angustifolius*, *L. exaltatus*, and *Lupinus montanus*. The results of the research of Ruiz-Lopez et al. [30] have shown a high similar protein content for three species of wild lupine: *L. exaltatus, L. reflexus,* and *L. mexicanus* (respectively, 38.4, 38.3, and 36.7%), which contained all the essential amino acids for human beings except glutamine and asparagine in their seed protein. The authors considered these species as important sources of high-quality protein and edible oil, but only after reducing or eliminating the risk of alkaloid toxicity. Similar protein content in the seeds of *L. mexicanus* (36.8%) was also noted by Barrientos et al. [31]. According to Maknickiene et al. [32], lupine seeds contain relatively small amounts of compounds such as lectins or protease inhibitors compared with other legume species, but they contain nutritionally active factors such as alkaloids, α-galactosides, and inositol phosphates, which limits the possibilities for their use. Martinez-Villaluenga et al. [33] found that a-galactoside extraction produces functional *L. albus* and *L. luteus* seeds, which are very nutritive lupin products with high protein, dietary fibre, and fat contents as well as acceptable levels of thiamin, riboflavin, and vitamin E.

Rybiński et al. [34] reported that *L. mutabilis* and *L. luteus* cv. Lord, R-1017, R-851, and R-867 breeds had the highest amount of proteins in seeds. As for *L. angustifolius* cultivars, these authors recorded the most contents of proteins in Graf, Baron, Neptun, and Boruta. According to Sawicka [35], protein content is the most important use of *L. mutabilis*. In contrast, Brücher [36]

Table 4. Nutrient contents (% DM) in yellow lupine seeds by cultivar.

Cultivar	CP	CFb	CF	WSC	Sta	Alk
Baryt	43.84^{b}	14.48^{ab}	5.96^{a}	7.32^{a}	18.30^{a}	0.013^{a}
Dukat	42.54^{b}	14.33^{ab}	6.33^{a}	7.63^{a}	19.92^{a}	0.029^{a}
Lord	42.75^{b}	14.65^{ab}	5.87^{a}	7.10^{a}	18.67^{a}	0.023^{a}
Mister	41.48^{ab}	14.85^{bc}	6.04^{a}	7.48^{a}	20.80^{a}	0.026^{a}
Parys	42.14^{ab}	14.02^{a}	6.36^{a}	7.36^{a}	17.59^{a}	0.013^{a}
Perkoz	39.90^{a}	15.38^{c}	7.06^{b}	7.36^{a}	19.61^{a}	0.017^{a}
Talar	42.54^{b}	14.66^{ab}	6.09^{a}	7.50^{a}	19.78^{a}	0.017^{a}
Taper	41.48^{ab}	14.64^{ab}	6.20^{a}	7.64^{a}	18.72^{a}	0.019^{a}

Explanations as in Table 1

Table 5. Nutrient contents (% DM) in yellow lupine seeds depending on cultivation region.

Location	CP	CFb	CF	WSC	Sta	Alk
Bobrowniki	43.56^{b}	12.96^{a}	6.43^{cde}	7.42^{abc}	18.46^{a}	0.015^{a}
Cicibór D.	41.64^{ab}	15.28^{c}	5.77^{abc}	7.80^{c}	-	0.035^{a}
Głodowo	41.96^{ab}	13.42^{ab}	6.50^{de}	7.08^{ab}	-	0.013^{a}
Marianowo	40.34^{a}	16.22^{cd}	5.82^{ab}	6.91^{a}	-	0.017^{a}
N. W. Ujska	42.33^{ab}	14.14^{b}	6.88^{e}	6.93^{a}	-	0.021^{a}
N. Lubliniec	41.80^{ab}	15.30^{c}	5.61^{ab}	7.94^{c}	-	0.016^{a}
Ruska W.	40.65^{a}	16.45^{d}	6.27^{bcd}	6.85^{a}	19.56^{a}	0.016^{a}
Sulejów	43.05^{ab}	14.16^{b}	6.47^{de}	7.58^{abc}	-	0.028^{a}
Świebodzin	42.44^{ab}	13.75^{ab}	6.51^{de}	7.73^{bc}	-	0.014^{a}
Tomaszów B.	42.87^{ab}	13.53^{ab}	6.75^{de}	7.68^{bc}	19.90^{a}	0.025^{a}
Uhnin	41.80^{ab}	15.69^{cd}	5.62^{a}	7.75^{bc}	18.79^{a}	0.017^{a}

Explanations as in Table 1

states that protein of this lupine is rich in cysteine and relatively rich in lysine, but deficient in methionine and other sulfuric amino acids. Niwińska [37] found that the seeds of sweet lupine cultivars contained more proteins than the bitter ones.

The assessed cultivars of yellow lupine had similar fibre content; only in the case of Perkoz and Mister was it considerably higher than in Parys. As for blue lupine, the seeds of Neptun had the lowest content of this component, while Karo, Boruta, Graf, Bojar, and Kadryl were significantly higher. In the northern part of Poland, the mean fibre content in the seeds of both lupine species was lower than in the eastern and southeastern regions. Niwińska [22] also showed that different species and cultivars varied in terms of fibre accumulation. Most of this component was found in blue lupine seeds cv. Sur, while the least was for white lupine cv. Bardo and blue lupine cv. Emir.

Fat is a significant component of lupine seeds, regardless of the species. Its higher amount was found in the seeds of yellow lupine than of blue. Among the cultivars of blue lupine, the least of this component was accumulated by Boruta, while significantly more by Kalif, Regent, and Zeus. In the case of yellow lupine, cv. Perkoz is especially worth attention as it shows a significantly higher fat content compared to other cultivars. Also, Rybiński et al. [34] observed a higher content of this component in the seeds of blue lupine than yellow lupine, whereas among varieties of blue lupine, the highest protein content was found for Regent and Zeus (respectively, 7.7 and 7.6%), while among yellow lupine for cv. Parys the amount was 8.8%. The region of cultivation also affected the contents of that component in lupine. It was the least accumulated by the seeds collected in the eastern part, and the most in the northern and western parts of Poland. Niwińska [22] recorded the highest amount of fat in cv. Bac of yellow lupine, while the least was in cv. Sur of blue lupine. Guemes-Vera et al. [38] compared the contents of the main nutrients in seeds of three lupine species: *L. albus, L. barkeri,* and *L. montanus*. The obtained results indicated that the lowest amounts of fat were accumulated in the seeds of *L. albus*, while significantly higher were

Table 6. Simple correlation coefficients between nutrient content in blue lupine seeds and some agrotechnical factors.

Trait	CP	CFb	CF	WSC	Sta	Alk
CFb	-0.183					
CF	-0.145	0.083				
WSC	-0.081	**0.382*****	0.050			
Sta	**-0.398*****	**-0.263****	**0.275***	**-0.313****		
Alk	0.108	0.021	-0.105	-0.121	-0.65	
pH	**-0.518*****	0.031	0,036	-0.059	**0.840*****	-0.039
Precipitation	-0.054	**-0.564*****	**-0.488*****	-0.184	-0.062	0.011

Explanations as in Table 1; Significant correlation *** $p<0.001$; **$p<0.01$; *$p<0.05$

Table 7. Simple correlation coefficients between nutrient content in yellow lupine seeds and some agrotechnical factors.

Trait	CP	CFb	CF	Alk	WSC	Sta
CFb	**-0.392*** **					
CF	**-0.376*** **	**0.312*** **				
Alk	0.569	0.072	-0.005			
WSC	-0.038	-0.116	-0.084	0.059		
Sta	0.008	-0.279	-0.148	**-0.425** **	0.135	
pH	-0.004	-0.092	-0.055	0.44	-0.089	**0.640*** **
Precipitation	0.035	0.077	-0.085	-0.028	-0.039	**0.763*** **

Explanations as in Table 1; Significant correlation *** p<0.001; **p<0.01; *p<0.05

found in *L. barkeri*. In the studies of Muzquiz et al. [28], fat content in the seeds of *L. mariae-josephi* was similar to *L. luteus* and *L. hispanicus*, and at the same time lower than in the seeds of *L. mutabilis* and *L. albus*. Garcia-Lopez et al. [29] determined that fat content in *L. mexicanus* amounted to, on average, 5.7%, while in *L. montanus* it was two-fold higher. In the studies of Sawicka [36], fat content in the seeds of *L. mutabilis* was 14%. Mason and Romero [39] reported, however, that in certain selected forms of lupine, fat content reached up to 21%. Rybiński et al. [34] observed a significantly wider range of variability of fat content among the studied cultivars and families of yellow and blue lupine (from 4.86 to 8.76%) than noted in our research (from 6.41 to 7.23%). According to Uzun et al. [40] fat content in the seeds of *L. albus* was statistically significantly correlated with linoleic, linolenic, and arachidic acids at the genotypic level, and the fatty acid composition is useful for human consumption.

A higher amount of starch was accumulated in the seeds of blue lupine compared to the yellow one, whereas there was no significant variability across individual cultivars of both species. In addition, yellow lupine cultivars did not differ in terms of water-soluble sugar content, while blue lupines were significantly different in this respect. Zeus, Naptun, Kadryl, and Sonet cultivars accumulated the most of this component, while Oskar, Karo, and Mirela accumulated significantly less. Among the cultivars of blue lupine, the highest content of alkaloids had Karo, Mirela, and Oskar (statistically significant differences), whereas there was no significant variability across individual cultivars of yellow lupine. The accumulation of starch and alkaloids to a small extent was determined by habitat conditions in the cultivation area. The most favorable conditions for sugar accumulation were recorded in the eastern part, while the least favorable were in the central and northern parts of Poland.

Correlation analysis showed that the protein content in blue lupine seeds was adversely affected by starch content and lowered soil pH, and fiber content by rainfall (Table 6). In both lupine species, starch content was highly positively correlated with soil pH. In the case of yellow lupine, starch content was also favorably affected by the amount of rainfall (Table 7). Guemes-Vera et al. [38] demonstrated that the protein content was significantly positively correlated with fiber content. Rybiński et al. [34] observed a significant positive correlation of protein content with fat content and polyunsaturated fatty acids (linoleic and linolenic). In turn, fat content was significantly positively correlated with the content of saturated fatty acids (palmitic and stearic) with monounsaturated oleic acid, while negatively correlated with polyunsaturated linoleic acid. Fiber content in blue lupine was also positively influenced by water-soluble sugars content, and negatively by the quantity of starch and the amount of rainfall during the growing season. The content of this component in yellow lupine seeds was positively correlated with the fat content, while the amount of fibre, fat, and sugars did not depend on other nutrients or on any agrotechnical factors. According to Rybiński et al. [34], the increase of fat content increases the percentage of less desirable saturated acids and of favorable oleic acid, while it significantly reduces the amount of linolenic acid. Therefore, according to this author a balanced fatty acid profile is even more important than the increase in fat content.

Conclusions

1) Yellow lupine seeds had higher protein content then blue lupines. Among blue lupine cultivars, the highest amount of this component was recorded for Graf and Tango, while among yellow lupine cultivars it was Dukat, Talar, Lord, and Baryt.
2) Fibre content in lupine seeds was little varied, both between species and cultivars. The highest amount of this component was recorded in the seeds of yellow lupine cv. Perkoz, while the lowest was in blue lupine cv. Neptun.
3) Average fat content in the seeds of blue lupine was slightly higher than for yellow lupine. Among blue lupine cultivars, the highest amount of fat was accumulated by Zeus, while among yellow lupine cultivars it was Perkoz.

4) Blue lupine showed by a much higher amount of starch but a slightly lower amount of water-soluble sugars than yellow lupine. The studied cultivars of both lupine species did not differ in terms of starch content.
5) The contents of tested components, except starch, varied depending on the area of cultivation due to different habitats and precipitation.

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