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Original Research

Evaluation of the Concentration of Nutrients in the Seeds of Faba Bean (*Vicia faba* L. major) and PEA (*Pisum sativum* L.) Depending on Habitat Conditions

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Abstract

The aim of our study was to determine the effect of habitat conditions on the nutrients content in the seeds of different cultivars of faba bean and pea (edible and fodder cultivars). Experiments were located in some different parts of Poland (9 for faba bean, 11 for field pea). Nine cultivars of faba bean, 17 edible cultivars of pea, and 13 fodder cultivars of pea were used in these experiments. The study showed that the contents of components varied between cultivars of both species depending on examined factors. The contents of the components also varied depending on location. In southern Poland the average crude fibre and crude protein contents were higher than in the northern and northwestern parts of the country. Significant differences between cultivars of faba bean were found in the contents of crude fibre, crude protein, and soluble sugars. All the tested faba bean cultivars contained a similar amount of crude fat. The average crude protein and crude fibre content in pea seeds was higher in the fodder cultivars than in the edible ones. The smallest content of fibre among all the cultivars was noted in the northern and the largest in the southeastern regions of Poland. Most cultivars of pea showed a similar sugar content. The most favorable conditions of sugar accumulation occurred in the southern part and the least in the northeastern and the northern parts of the country. Fodder cultivars showed relatively little variability in starch content. The agro-ecological conditions influenced content of concentration of nutrients in the seeds of faba bean and pea.

Keywords: faba bean, pea, cultivar, regions, nutrients content

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Introduction

Production of feed protein in Europe and Poland is insufficient, which encourages us to explore the possibilities of using domestic protein raw materials to replace or supplement the imported post-extraction soy pellets. In Poland, this demand might be partially covered by legume seeds, such as faba bean and peas. However, due to differences in protein content, crude fiber, and antinutritional substances, they cannot be added to the mix in the same dosage as soybean meal [1-5]. The protein content of seed legumes ranges from about 20% in peas to 45% in yellow lupine. The level of crude fibre is conditioned by, among other factors, the thickness of the outer cove. Climatic conditions in Poland allow for the cultivation of legumes across the country [6]. They can be cultivated both in holdings with organic farming and sustainable production systems. Due to their high energy and protein content, the seeds are widely used for animal feed and food [7]. Cultivating these species in Poland is fully justified, as they improve soil fertility, improve its structure, and leave a very good position for subsequent plants. In addition, due to their ability to bind nitrogen, faba beans or peas significantly reduce the negative effects of intensive technology used in the cultivation of certain species (frequently in monoculture), thus preventing land degradation [8]. The seeds of these species can be used as the source of functional compounds [9-10]. Moreover, an increasing consumer awareness of the potential health benefits of consuming protein may stimulate the production of legumes [10-11]. The increasing demand for feed protein and expectations as regards environmental protection have spurred an expectation that the importance of these species will grow in the coming years. Their cultivation will be more and more profitable, and their seeds will become a valuable commodity.

The aim of our study was to determine the effects of habitat (agri-environmental) conditions on the content of nutrients in the seeds of faba bean and pea.

Materials and Methods

The influence of agroecological conditions on the content of nutrients was evaluated on the basis of the analysis of the material obtained from the experiments carried out in 2010-2012 at the Research Centre for Cultivar Testing (COBORU) located in different parts of Poland (Fig. 1). The experiments took into account the currently registered cultivars of faba bean: Albus, Amulet, Bobas, Granit, Kasztelan, Leo, Olga, Optimal, and Sonet; edible cultivars of pea: Akord, Batuta, Bohun, Boruta, Brylant, Cysterski, Ezop, Kavalir, Lasso, Mecenas, Medal, Mentor, Santana, Tarchalska, Terno, Wenus, Zekon; and fodder pea: Eureka, Gwarek, Hubal, Klif, Marych, Milwa, Model, Muza, Pomorska, Roch, Sokolik, Turnia, and Wiato.

Fig. 1. Locations of experiments.

The faba bean experiment was located in the northern and northwestern regions of Rarwino, Wrócikowo, Radostowo, and Karżniczka, and the southwestern and southeastern regions of Kochcice, Głubczyce, Pawłowice, Zybiszów, and Przecław. The locations of the pea experiment (edible cultivars) were the western and northwestern regions of Chrząstowo, Głębokie, Kościelna Wieś, and Radostowo, and the southern, central, and southeastern regions Bezek, Cicibór Duży, Kawęczyn, Krzyżewo, Pawłowice, Słupia, and Sulejów. Fodder pea locations were the northern and northwestern regions of Białogard and Wyczechy, the western regions of Bobrowniki, Świebodzin, and Tomaszów Bolesławiecki, the southern and southeastern regions of Marianowo, Pawłowice, and Ruska Wieś, the eastern region of Cicibór Duży, and the central regions of Głodowo and Kościelec.

In the first year of the study (2010) faba bean was cultivated on soils belonging to the very good wheat complex (Głubczyce, Przecław, Radostowo, Zybiszów), good wheat (Karżniczka, Pawłowice) and very good rye (Rarwino). In 2011-2012 this species was cultivated on the soil of the very good and good complex, and only in Rarwino on the soil of a very good rye complex. The soil on which faba bean was cultivated was pH 5.7-7.3.

In 2010 most of the edible cultivars of pea were cultivated on the soil of the good wheat complex, only in Cicibór Duży, Kawęczyn, and Krzyżewo in the soil of the very good rye complex, and in Radostowo in the soil of the very good wheat complex. Soil pH ranged between pH 5.5 and 7.2. In 2011 and 2012 peas were also grown on very good soils belonging to the good wheat complex (Bezek, Chrząstowo, Krzyżewo, Pawłowice, Słupia, Sulejów), very good rye (Cicibór Duży, Kawęczyn), and on the soil of the very good wheat complex (Głębokie, Radostowo).

In all years of research, fodder pea was cultivated in very good and good rye soils, and in Świebodzin in the soil of the good wheat complex. Soil pH ranged pH_{KCl} 5.0-7.2.

The seeds of faba bean and pea were determined for the contents of major important nutrients: crude fibre (by weight method), crude fat (by Soxhlet's weight method), N (by flow spectrophotometry), crude ash (by weight method at 580ºC), and soluble sugars and starch (by Bertrand's titration method). The analyses were performed in the Main Laboratory of Chemical Analyses of IUNG-PIB in Puławy and in the laboratory of COBORU in Słupia Wielka. Total precipitation during the growing season of faba beans in individual locations (average from three years of the study) ranged 199.8-563.1 mm (Table 1), of pea (edible cultivars) 171.2-486.0 mm (Table 2), and of fodder pea ranged 188.6-428.9 mm (Table 3). 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 correlations between the content of nutrients in the seeds of different cultivars of faba bean and field pea and selected agrotechnical factors were also performed.

Results and Discussion

The studies have shown that regardless of the agroecological conditions, the cultivars of faba beans: Albus, Amulet, Bobas, Leo, Kasztelan, and Olga had the highest protein content, while cvs. Optimal, Sonet, and Granit had the smallest (significant differences; Table 4).

In the northern and northwestern regions of Poland, faba bean cultivars accumulated the least of protein in their seeds, while in the southern ones – the most (Table 5). According to Fordoński et al. [12], faba bean cultivars proved to the species giving the highest yields of all the tested legume crops in Northern Poland. This was confirmed by Florek et al. [13], who recorded that faba beans and peas were the most productive in the Polish conditions, while the lowest yield was obtained from yellow lupine. Sarah et al. [14] found that the content of proteins, carbohydrates, ash, fat, and fibre depends on a cultivar. In contrast, Mekkei [15] stated that regardless of a cultivar, large faba bean seeds contained more protein and carbohydrates. When assessing protein concentration in numerous cultivars, Hendawey and Younes [16] found the largest concentration of this component in the seeds of Sacha 3, Sacha 2, Sacha 4, and Missr 1, while the smallest was in Giza 3. According to these authors [16], the differences between faba bean cultivars resulted from both genetic and environmental factors. Other authors [12, 17-18] have found that the nutritional value of legume seeds is variable and depends on a number of factors, among others: species and varieties of seeds and agrotechnical factors (conditions of cultivation, fertilization). Księżak [19] recorded similar concentrations of protein, fibre, fat, ash, and nitrogen-free extract compounds in faba bean cvs. Nadwiślański, Bronto, Tino, and Martin. Simultaneously, the contents of these components did not differ from the values cited in the literature [20]. According to Księżak [19], only the seeds of cv. Caspar contained fewer proteins and more nitrogen-free extract compounds. Musalam et al. [21] studied the chemical composition of faba bean seeds under soil irrigation conditions. They found that such seeds had higher protein, ash, and fibre contents, but significantly lower fat and carbohydrate contents. Sarah et al. [14] showed significant differences in protein content among the seeds of faba bean cultivars.

Simultaneously, these authors recorded almost two-fold higher digestibility of cooked protein compared to raw. Fordoński et al. [12] found that protein content in faba bean seed ranged from 28.6 to 29.5% of dry matter. Much the same protein content in faba bean seeds were obtained in long-term research carried out by the Research Centre for Cultivar Testing [22]. They also found less protein content in faba bean seeds compared to those attached in NŻŚ [23]. Faba bean seeds of all varieties had lower crude protein content compared to the content determined in the tested cultivar (Albus) by Szpunar-Krok et al. [24], but the figure was close to that reported by Hanczakowska and Świątkiewicz [25].

In our own studies, the cultivars exhibited a diverse fibre content, with its lowest amount being recorded for

Table 1. Monthly sum of precipitation and mean day and night temperatures in locations of cultivation of faba bean (2010-2012).

Location	Precipitation (mm)					Temperature (ºC)				
	IV	V	VI	VII	Sum (IV-VII)	IV	V	VI	VII	Average (IV-VII)
2010										
Głubczyce	58.2	193.2	103.2	208.5	563.1	7.6	11.8	16.7	20.4	14.1
Karżniczka	9.8	112.4	16.4	142.4	281.0	6.8	9.7	15.0	19.7	12.8
Kochcice	-	-	-	-	-	-	-	-	-	-
Pawłowice	54.3	214.6	61.2	21.0	351.1	8.7	12.4	17.1	97.6	34.0
Przecław	50.5	170.0	100.9	174.2	495.6	8.9	14.2	18.3	20.8	15.6
Radostowo	7.8	92.4	41.8	77.3	219.3	7.2	11.2	15.3	20.5	13.6
Rarwino	20.0	85.1	27.7	74.8	207.6	6.5	8.7	14.1	20.0	12.3
Wrócikowo	16.9	153.0	80.8	64.1	314.8	7.3	11.9	15.8	20.5	13.9
Zybiszów	34.5	118.1	32.4	109.7	294.7	9.2	12.7	17.9	21.1	15.2
2011										
Głubczyce	28.8	43.4	99.5	167.5	339.2	9.7	14.2	17.4	17.4	14.7
Karżniczka	24.0	42.0	75.2	100.4	241.6	9.3	12.5	16.5	17.7	14.0
Kochcice	16.0	65.4	90.8	132.5	304.7	10.3	13.5	17.8	16.6	14.6
Pawłowice	21.4	57.4	42.8	111.2	232.8	10.4	13.6	18.3	17.6	15.0
Przecław	51.8	38.1	71.3	291.8	453.0	10.0	23.5	18.1	18.5	17.5
Radostowo	17.2	32.1	36.2	114.3	199.8	9.1	12.5	17.2	18.2	14.3
Rarwino	12.1	52.7	62.9	175.2	302.9	10.1	12.7	17.0	16.9	14.2
Wrócikowo	26.6	40.9	63.2	203.4	334.1	9.2	12.7	17.0	17.6	14.1
Zybiszów	32.7	56.3	48.2	206.3	343.5	11.5	13.7	18.7	18.1	15.5
2012										
Głubczyce	54.0	29.3	97.8	66.6	247.7	8.3	14.8	17.4	19.9	15.1
Karżniczka	42.1	18.9	123.7	172.2	356.9	7.6	4.6	14.7	18.0	11.2
Kochcice	43.2	41.4	73.8	68.4	226.8	9.0	14.5	17.2	19.6	15.1
Pawłowice	64.8	35.2	70.7	50.9	221.6	9.0	15.9	17.8	20.9	15.9
Przecław	21.7	66.7	66.9	65.6	220.9	9.9	14.8	17.7	20.9	15.8
Radostowo	34.5	28.6	136.1	89.9	289.1	8.0	13.6	15.1	18.1	13.7
Rarwino	39.8	12.8	83.0	161.1	296.7	7.1	12.5	15.1	17.3	13.0
Wrócikowo	79.5	48.5	97.6	106.0	331.6	7.8	13.3	15.1	18.9	13.8
Zybiszów	33.1	34.7	81.7	101.6	251.1	9.6	15.4	17.3	20.2	15.6

Source: own elaboration based on IMGW-PIB data [2010, 2011, 2012]

Bobas and Granit. The region of cultivation also affected the contents of that component in faba bean. It was the least accumulated by the seeds collected in the northern part, and the most in the southern parts of Poland (Table 5). The contents of crude fibre were similar to the levels reported by Kiarie et al. [26].

The amount of crude fat was similar in all the evaluated cultivars (insignificant differences). When assessing fat content in seeds of faba bean cultivars, Hendawey and Younes [16] found its higher concentration in cvs. Giza 843 and Giza 3. In our study a higher fat concentration in faba bean seeds was recorded in the northern part of Poland and lower in the south. Pisulewska et al. [20] found a strong relationship between the fat content in the seeds and weather conditions during the growing season. These authors undermine the thesis

Table 2. Monthly sum of precipitation and mean day and night temperature in locations of cultivation of field edible pea cultivars (2010-2012).

Location	Precipitation (mm)					Temperature (°C)				
	IV	V	VI	VII	Sum (IV-VII)	IV	V	VI	VII	Average (IV-VII)
2010										
Bezek	18.9	72.4	94.4	156.3	342.0	9.0	14.5	17.6	21.6	15.7
Cicibór Duży	23.0	126.8	67.7	48.2	265.7	8.7	14.5	17.9	21.6	15.7
Chrząstowo	35.4	119.7	9.5	147.9	312.5	7.8	11.3	16.6	21.7	14.4
Głębokie	32.4	35.4	27.2	162.4	257.4	8.3	12.5	16.8	21.5	14.8
Kawęczyn	15.1	155.5	37.0	67.4	275.0	8.9	13.4	17.1	21.5	15.2
Krzyżewo	29.8	148.0	74.1	87.0	338.9	8.0	14.0	17.2	21.3	15.1
Pawłowice	54.3	214.6	61.2	97.6	427.7	8.7	12.3	17.1	21.1	14.8
Radostowo	7.9	92.4	41.8	77.3	219.4	7.2	11.5	15.3	19.7	13.4
Słupia	40.8	197.8	78.5	168.9	486.0	8.1	12.8	16.5	20.1	14.4
Sulejów	25.5	136.9	58.3	86.7	307.4	8.3	12.8	16.9	20.7	14.7
2011										
Bezek	30.6	40.8	80.0	178.9	330.3	9.9	14.6	18.3	19.4	15.6
Cicibór Duży	37.6	61.0	65.4	201.6	365.6	9.5	13.7	18.4	18.1	14.9
Chrząstowo	9.0	38.4	39.7	115.5	202.6	10.9	13.7	18.6	17.8	15.3
Głębokie	6.4	39.7	87.5	95.2	228.8	11.2	14.7	18.1	18.0	15.5
Kawęczyn	40.2	31.5	51.4	179.8	302.9	10.6	14.3	18.6	18.8	15.6
Krzyżewo	42.5	66.4	44.6	218.0	371.5	9.8	13.3	18.0	19.2	15.1
Pawłowice	21.4	57.4	42.8	111.0	232.6	10.4	13.4	19.3	17.7	15.2
Radostowo	17.2	32.1	36.2	114.3	199.8	9.3	12.4	16.8	18.2	14.2
Słupia	29.4	49.7	25.6	166.9	271.6	9.7	13.9	18.4	17.5	14.9
Sulejów	21.6	49.8	22.6	175.5	269.5	9.8	13.5	18.1	18.2	14.9
2012										
Bezek	33.4	40.3	66.5	31.0	171.2	9.3	15.1	17.2	21.5	15.8
Cicibór Duży	37.5	55.8	126.1	27.5	246.9	8.9	14.8	16.9	21.0	15.4
Chrząstowo	30.4	42.9	113.9	144.3	331.5	8.8	14.6	15.6	18.9	14.5
Głębokie	16.3	29.3	103.7	68.8	218.1	9.3	15.3	16.1	19.6	15.1
Kawęczyn	46.0	46.5	67.3	74.3	234.1	9.6	15.4	17.0	20.6	15.7
Krzyżewo	40.4	46.5	87.3	91.7	265.9	8.2	14.1	15.5	19.8	14.4
Pawłowice	64.8	35.2	70.7	50.9	221.6	9.0	15.9	17.8	20.9	15.9
Radostowo	34.5	28.6	136.1	89.9	289.1	8.0	13.6	15.1	18.1	13.7
Słupia	55.7	17.3	100.0	81.3	254.3	8.9	14.5	17.4	20.2	15.3
Sulejów	41.5	22.7	69.0	60.3	193.5	8.8	14.7	17.0	20.5	15.3

Source: own elaboration based on IMGW-PIB data [2010, 2011, 2012]

provided in the literature that the chemical composition of faba bean seeds depends little on environmental factors. In our own study we found that the highest soluble sugar content was recorded for cv. Leo, while the lowest was for cvs. Albus and Bobas (significant differences). The differences in chemical composition

Table 3. Monthly sum of precipitation and mean day and night temperatures in locations of fodder pea cultivation (2010-2012).

Location	Precipitation (mm)					Temperature (°C)				
	IV	V	VI	VII	Sum (IV-VII)	IV	V	VI	VII	Average (IV-VII)
2010										
Białogard	11.7	95.6	58.3	114.7	280.3	7.3	10.1	15.6	20.6	13.4
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
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
Pawłowice	54.3	214.6	61.2	21.0	351.1	8.7	12.4	17.1	97.6	34.0
Ruska Wieś	42.8	140.1	125.9	94.9	403.7	7.0	12.8	16.1	20.7	14.2
Świebodzin	22.8	84.0	13.1	68.7	188.6	8.7	11.4	17.3	21.7	14.8
Tomaszów Bolesławiecki	36.9	105.5	35.6	73.7	251.7	8.1	11.7	16.2	20.8	14.2
Wyczechy	54.3	214.6	61.2	97.6	427.7	8.7	12.4	17.1	21.0	14.8
2011										
Białogard	13.8	38.2	63.6	109.8	225.4	10.0	13.2	17.1	17.4	14.4
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	18.1	15.2
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
Pawłowice	21.4	57.4	42.8	111.2	232.8	10.4	13.6	18.3	17.6	15.0
Ruska Wieś	35.7	67.1	43.9	191.6	338.3	8.7	12.6	17.1	18.4	14.2
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
Wyczechy	14.1	50.6	55.9	166.8	287.4	10.2	13.1	17.2	17.4	14.5
2012										
Białogard	31.6	24.7	104.2	102.2	262.7	8.0	13.7	15.6	18.2	13.9
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
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
Pawłowice	64.8	35.2	70.7	50.9	221.6	9.0	15.9	17.8	20.9	15.9
Ruska Wieś	64.5	65.6	99.1	126.8	356.0	7.1	13.0	13.4	18.9	13.1
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
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 4. Nutrient contents in faba bean depending on the cultivar (% DM).

Cultivar	Crude protein	Crude fibre	Crude fat	Sugars
Albus	28.28*^{b}	7.15^{b}	1.44^{a}	4.58^{a}
Amulet	28.41^{b}	7.11^{b}	1.47^{a}	4.97^{bc}
Bobas	28.47^{b}	6.42^{a}	1.45^{a}	4.56^{a}
Granit	26.46^{a}	6.49^{a}	1.54^{a}	4.69^{ab}
Kasztelan	27.86^{b}	7.20^{b}	1.43^{a}	4.80^{abc}
Leo	28.29^{b}	6.86^{ab}	1.52^{a}	5.06^{c}
Olga	27.92^{b}	7.01^{b}	1.57^{a}	4.90^{abc}
Optimal	26.51^{a}	6.97^{b}	1.52^{a}	4.78^{abc}
Sonet	26.40^{a}	6.77^{ab}	1.46^{a}	4.59^{abc}
Mean	**27.64**	**6.89**	**1.49**	**4.77**

*values in column marked the same letter did not differ statistically (α = 0.05)

between faba bean cultivars were also noted by Abusin et al. [27] and El-Saber [28].

Correlation analysis showed that the content of proteins in faba bean seeds was negatively affected by the contents of fibre and tannins (significant differences), but it was positively affected by crude fat (Table 6). In previous studies, Księżak [19] found a negative correlation between protein content in the seeds and the contents of ash, nitrogen-free compounds, potassium, and magnesium, but a positive correlation between the content of nitrogen-free extract compounds and 1,000 seed weight. These relationships were confirmed in the study of Jasińska and Kotecki [29]. An increase of crude fibre content in faba bean seeds was significantly affected

Table 5. Nutrient contents in faba bean depending on the cultivation region (% DM).

Location	Crude protein	Crude fibre	Crude fat	Sugars
Głubczyce	28.14*^{def}	6.82^{cd}	1.53^{abcd}	4.76^{a}
Karżniczka	27.49^{bcd}	6.32^{a}	1.78^{d}	4.86^{a}
Kochcice	27.74^{cde}	7.74^{e}	1.31^{a}	4.82^{a}
Pawłowice	28.51^{ef}	6.98^{d}	1.42^{ab}	4.79^{a}
Przecław	29.20^{f}	7.07^{cd}	1.30^{ab}	4.94^{a}
Radostowo	26.97^{abc}	6.57^{bc}	1.59^{bcd}	4.67^{a}
Rarwino	26.39^{a}	6.60^{bc}	1.66^{cd}	4.69^{a}
Wrócikowo	26.42^{ab}	6.95^{bc}	1.54^{abcd}	4.75^{a}
Zybiszów	28.77^{def}	6.96^{cd}	1.56^{bcd}	4.80^{a}
Mean	**27.71**	**6.89**	**1.52**	**4.79**

*see the explanation under Table 1

Table 6. Correlation coefficients between nutrient contents in faba bean seeds and some agrotechnical factors.

	Crude protein	Crude fibre	Crude fat	Tannins	Sugars
Crude fibre	**-0.177**				
Crude fat	0.019	-0.193			
Tannins	**-0.387**	-0.208	-0.040		
Sugars	-0.056	0.214	**0.175**	**-0.193**	
Soil complex	**-0.662**	**-0,054**	**0.421**	-0.02	-0.185
Soil pH	**-0.322**	**0.099**	-0.024	0.022	0.031
Forecrop	**-0.462**	**0.214**	0,171	0.360	-0.069
Precipitations	0.106	0.253	**-0.156**	0.025	0.120

***-** bold letters means significant differences

by the amount of precipitation during the growing season and the content of soluble sugars. On the other hand, its amount was reduced by the concentration of tannins and crude fat. Crude fat concentration was negatively correlated with the amount of precipitation while being positively correlated with soluble sugars (significant

Table 7. Nutrient contents in edible pea depending on the cultivar (% DM).

Cultivar	Crude protein	Crude fibre	Sugars	Starch
Akord	21.47*^{abc}	5.46^{bcd}	6.29^{abc}	44.62^{bcdef}
Batuta	22.15^{abc}	5.38^{bc}	6.67^{bc}	44.79^{bcdef}
Bohun	21.62^{ab}	5.79^{d}	6,43^{abc}	47.18^{ef}
Boruta	21.70^{ab}	5.28^{abc}	6.37^{abc}	41.96^{abcd}
Brylant	21.78^{abc}	5.20^{abc}	6.35^{abc}	46.67^{cdef}
Cysterski	21.58^{a}	5.49^{d}	6,19^{abc}	44.22^{bcde}
Ezop	22.72^{c}	5.34^{bc}	6.27^{abc}	48.75^{f}
Kavalir	22.57^{ab}	5.14^{ab}	5.96^{ab}	40.95^{abc}
Lasso	21.45^{a}	5.22^{abc}	6.53^{bc}	49.19^{f}
Mecenas	21.96^{abc}	4.87^{a}	6.72^{bcd}	46.85^{defg}
Medal	21.70^{ab}	5.28^{abc}	6.21^{abc}	46.15^{def}
Mentor	21.54^{ab}	5.32^{abc}	6.32^{abc}	47.81^{fg}
Santana	22.18^{abc}	5.52^{cd}	6.53^{bc}	41.20^{abc}
Tarchalska	21.50^{a}	5.36^{bc}	6.03^{ab}	47.60^{fg}
Terno	22.05^{abc}	5.25^{abc}	6.54^{bc}	37.12^{a}
Wenus	21.65^{ab}	5.23^{abc}	5.69^{a}	47.03^{fg}
Zekon	22.30^{abc}	5.48^{bc}	6.74^{d}	39.47^{ab}
Mean	**21.88**	**5.33**	**6.34**	**44.81**

*see the explanation under Table 1

Table 8. Nutrient contents in edible cultivars of field pea depending on the cultivation region (% DM).

Location	Crude protein	Crude fibre	Sugars	Starch
Bezek	22.84*^{cd}	5.82^{b}	6.70^{c}	47.25^{d}
Chrząstowo	20.94^{a}	4.70^{a}	6.14^{ab}	-
Cicibór Duży	22.75^{cd}	6.19^{c}	6.64^{bc}	45.51^{bc}
Głębokie	21.94^{b}	5.07^{ab}	6.38^{abc}	-
Kawęczyn	22.76^{cd}	5.73^{b}	6.48^{bc}	-
Kościelna Wieś	18.15^{a}	4.80^{a}	6.09^{ab}	-
Krzyżewo	22.68^{bc}	4.78^{a}	5.88^{a}	-
Pawłowice	23.48^{d}	6.12^{c}	6.50^{bc}	45.11^{b}
Radostowo	22.49^{bc}	4.79^{a}	5.90^{a}	41.31^{a}
Słupia	22.29^{bc}	4.86^{a}	6.24^{abc}	-
Sulejów	23.01^{cd}	5.76^{b}	6.42^{abc}	-
Mean	**22.12**	**5.33**	**6.31**	**44.80**

*see the explanation under Table 1

correlations). According to Rybiński et al. [30], the increase of fat content increases the percentage of less desirable saturated acids and of favorable oleic acid, while significantly reducing 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. The amount of tannins was negatively correlated with the content of soluble sugars. Soil complex positively affected the content of crude fat and negatively affected crude protein. Soil pH and forecrop has a negative impact on crude protein content in faba bean seeds. Increasing the sum of precipitation caused an increase of crude fibre content and a decrease in crude fat content.

The study showed that regardless of agro-ecological conditions or the cultivation location of pea, the variability

Table 9. Correlation coefficients between nutrient contents in edible cultivars of pea seeds and some agrotechnical factors.

	Crude protein	Crude fibre	Sugars	Starch
Crude fibre	0.0400			
Sugars	-0.1393	**-0.1085**		
Starch	0.1761	0.0697	**-0.5634**	
Soil complex	**0.1646**	-0.0642	-0.0738	
Soil pH	-0.0145	**-0.1865**	**0.2217**	0.0358
Forecrop	**0.1091**	-0.0015	**0.1397**	-0.0193
Precipitations	0.0499	**-0.1368**	**-0.1878**	**-0.2705**

Bold letters means significant differences

Table 10. Nutrient contents in fodder pea depending on the cultivar (% DM).

Cultivar	Crude protein	Crude fibre	Sugars	Starch
Eureka	23.62*^{bcd}	5.48^{ab}	6.04^{abc}	46.65^{b}
Gwarek	24.42^{cdef}	5.33^{a}	6.24^{c}	46.40^{b}
Hubal	23.86^{bcde}	5.54^{abc}	6.28^{c}	44.70^{ab}
Klif	25.20^{g}	5.23^{a}	6.28^{c}	44.95^{ab}
Marych	24.98^{ef}	5.48^{abc}	6.30^{c}	38.61^{a}
Milwa	23.58^{bc}	6.16^{d}	5.70^{ab}	47.35^{b}
Model	23.49^{abcd}	5.36^{ab}	6.25^{bc}	46.78^{b}
Muza	23.62^{bcd}	5.37^{b}	5.59^{a}	48.31^{b}
Pomorska	23.56^{abcd}	6.13^{d}	6.35^{c}	42.39^{ab}
Roch	24.28^{bcdef}	5.79^{bcd}	6.05^{abc}	44.07^{ab}
Sokolik	23.39^{ab}	5.88^{cd}	6.17^{bc}	46.09^{b}
Turnia	22.35^{a}	5.59^{abc}	6.35^{c}	47.01^{b}
Wiato	24.77^{def}	5.56^{abc}	6.11^{abc}	44.56^{ab}
Mean	**23.93**	**5.61**	**6.61**	**45.22**

*see the explanation under Table 1

of the protein content was relatively small, whereas its higher concentration characterized was recorded for cultivars Kavalir and Ezop (Table 7). However, fodder cultivars Wiato, Klif, and Marych showed the highest protein content, while cvs. Turnia and Sokolik the lowest (Table 10). The mean protein content in the seeds of

Table 11. Nutrient contents in fodder cultivars of field pea depending on the cultivation region (% DM).

Cultivar	Crude protein	Crude fibre	Sugars	Starch
Białogard	23.42*^{c}	4.80^{a}	6.07^{ab}	46.57^{b}
Bobrowniki	23.66^{bc}	6.17^{c}	6.14^{ab}	-
Cicibór Duży	25.04^{d}	5.01^{ab}	6.36^{ab}	43.07^{a}
Głodowo	23.51^{d}	6.43^{c}	6.13^{a}	-
Kościelec	25.00^{d}	6.45^{c}	6.14^{ab}	-
Marianowo	22.60^{ab}	4.89^{ab}	6.12^{ab}	-
Pawłowice	25.35^{d}	6.30^{c}	6.36^{ab}	-
Ruska Wieś	23.27^{abc}	4.86^{b}	6.01^{ab}	-
Świebodzin	23.65^{bc}	5.00^{ab}	6.33^{b}	-
Tomaszów Bol.	25.40^{d}	4.83^{a}	6.33^{b}	46.02^{b}
Wyczechy	22.91^{abc}	4.79^{a}	5.97^{ab}	-
Mean	**23.98**	**5.41**	**6.18**	**45.22**

*see the explanation under Table 1

Table 12. Correlation coefficients between nutrient contents in fodder pea seeds and some agrotechnical factors.

	Crude protein	Crude fibre	Tannins	Sugars	Starch
Crude fibre	-0.037				
Tannins	**-0.124**	-0.007			
Sugars	**0.213**	**-0.170**	**0.136**		
Starch	**-0.392**	0.174	-0.075	-0.190	
Soil complex	**0.133**	**-0.529**	-0.139	0.089	0.181
Soil pH	**-0.146**	**-0.148**	**0.197**	**0.163**	-0.460
Forecrop	**0.189**	**-0.213**	-0.004	**0.260**	-0.107
Precipitation	**-0.116**	**-0.189**	0.103	-0.015	-0.008

***-** bold letters means significant differences

fodder cultivars was higher than in edible cultivars. Significantly more of this component was recorded in the seeds of all cultivars from southern Poland (Tables 8, 11). Canbolat et al. [31] noted significant differences in the chemical composition of the studied pea genotypes depending on the color of seeds and flowers. According to these authors, the protein content in the dark seeds was higher than in light ones. According to Fordoński et al. [12], protein content in the pea seeds equaled 20.7% of dry matter. Canbolat et al. [31] indicated that the energy value of pea seeds is similar to the energy value of soybean. Rybiński et al. [30], evaluating the protein content of pea seeds, recorded its highest amount in cv. Moreover, this author found that pea seeds have a low fat content, whereas it was higher content found in cv. Medal and strain PRH 179. The authors emphasized the high content of unsaturated fatty acids, i.e., of linolenic acid belonging to the group of EFA (essential fatty acids). In our own study, the lowest content of crude fibre in all cultivars was recorded in northern, more in central, and the largest in southeastern Poland (Tables 8, 11). Fordoński et al. [32] reported that the seeds of fodder and edible peas cultivated in northern Poland characterized similar content of crude protein, crude fibre, crude fat, and ash. The tested cultivars had varied fibre content. It was generally higher in fodder cultivars. Among edible cultivars, its lowest amounts were recorded for Mecenas, while among fodder ones for Klif, Gwarek, Model, and Muza. The highest amounts of crude fibre were found for edible cvs. Cysterski, Santana, and Bohun, and for fodder cvs. Pomorska and Milwa (Tables 7, 10). According to Kotecki [33], cv. Ergo contained more fibre and protein, while cv. Diament less. This author also found that the change of crop density did not have a major impact on the content of essential nutrients. The research conducted by Wang et al. [34] demonstrated significant differences in the content of protein, and crude fibre in pea seeds depending on the system and location of cultivation.

Most of the evaluated cultivars had a similar soluble sugar content; it was only slightly smaller in cvs. Wenus (edible) and Muza (fodder), and higher in cvs. Zekon (edible), Klif, Hubal, Marych, Pomorska, and Turnia (fodder) (Tables 7, 10). The most favorable conditions for sugar accumulation occurred in southern Poland, while the least favorable were in northeastern and northern Poland (Tables 8, 11). The seeds of edible cultivars Bohun, Mentor, Lasso, Ezop, and Wenus accumulated the most starch, and the seeds of cv. Terno the least. The location of pea cultivation had little effect on starch content, although its bigger amounts were generally recorded in eastern Poland (Table 8). However, fodder pea cultivars showed a relatively small variability in starch content, with the lowest amount being recorded in cv. Marych (Table 8). According to Mikić et al. [35], tannins are most often present in the seeds of cultivars of colorful flowers that may be used in the production of feed, although they are often characterized by a lower digestibility of proteins compared to other cultivars of pea. However, according to those authors [35], the seeds of cultivars without tannins have a wide application both in human and animal feeding.

Correlation analysis showed that the protein content in the seeds of all tested edible pea cultivars was positively affected by soil pH and forecrop, after which pea was grown (significant differences; Table 9). Kotecki [33] found that the amount of this component in pea seeds depended mainly on weather conditions, while to a lesser extent on the genetic characteristics of a cultivar or plant density per unit area. Soil complex has a positive effect on crude protein content in the seeds. Improvement of soil pH has a positive effect on sugars and negative on crude fibre content. Forecrop, after which field pea was grown was positively correlated with crude protein and sugar content. Increasing the sum of precipitation caused a decrease of crude fibre, sugars, and starch content in the pea seeds. The crude protein content in the seeds of fodder peas was negatively affected by the content of tannin and starch, while positively correlated with the amount of soluble sugars (Table 12). The crude fibre content in the seeds of all the tested cultivars was significantly reduced by the sugar content. The amount of tannins in the seeds accumulated in fodder pea seed cultivars increases together with higher sugar content. All evaluated agronomic factors such as soil complex, soil pH, forecrop, and sum of precipitations negatively affected crude fibre content in fodder cultivars of field pea seeds (significant correlations). Soil pH negatively affected content of crude protein while positively affecting content of tannins and sugars. Forecrop has a positive effect on crude protein and sugar content. Increasing the sum of total precipitation in vegetation season caused a decrease of crude fibre and crude protein contents.

Conclucions

1) Regardless of the agro-ecological conditions, a lower amount of protein was recorded for faba bean cultivars: Sonet, Opitmal, and Granit, while higher

for Kasztelan, Leo, Olga, Bobas, Amulet, and Albus. The lowest crude fibre content was found in cultivars Bobas and Granit. In southern Poland the mean crude fibre and crude protein contents were higher than in the northern and northwestern parts of the country.

2) The average protein content in field pea seeds was higher in the fodder cultivars than in the edible ones. A larger concentration of crude protein in edible cultivars was recorded in cvs. Kavalir and Ezop. Fodder cultivars Wiato, Klif, and Marych had the highest protein content, and Turnia and Sokolik the smallest. The region of pea cultivation influenced protein and fibre contents: in southern Poland, pea cultivars contained the most crude protein and crude fibre compared with other regions.
3) The seeds of edible cultivars Wenus, Bohun, Mentor, Lasso, and Ezop accumulated the most starch, while the seeds cv. Terno accumulated the least. The region of pea cultivation had little impact on its quantity. Fodder cultivars showed relatively little variability in starch content.
4) Fodder pea cultivars exhibited a higher fibre content compared with edible ones. The least fibre was recorded for edible cv. Klif, and fodder cvs. Klif, Gwarek, Model, Muza, while the most, respectively, were found in edible Cysterski, Santana, Bohun, and fodder cvs. Pomorska and Milwa. The smallest content of fibre among all the cultivars was noted in the northern, while the largest in the southeastern regions of Poland. Most cultivars of field pea showed a similar sugar content. The most favorable conditions of sugar accumulation occurred in the southern part and the least in the northeastern and northern parts of the country.

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