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Cultivation and use of faba beans (*Vicia faba minor*) as a component in poultry feed

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Abstract. Popularization of faba bean cultivation among growers can increase the supply of seeds of this crop on the Polish market. Thanks to the fact that more seeds will be available, especially low-tannin varieties, it may also increase the interest of the feed industry in this component, mainly of the poultry feed production sector. Studies have shown that the partial replacement of soybean meal with faba bean in mixture feeds does not adversely affect the production performance of birds. Refining treatments additionally increases nutritional value of seeds and the use of protein from them. Thanks to their starch content faba bean seeds bring a certain amount of energy into the mixtures. This is particularly important in view of the ban on the use of GMO feed materials in animal nutrition and, to some extent, in view of the improvement in the supply of Poland with domestic feed components.

Keywords: faba beans, fodder protein, poultry feed, legumes

INTRODUCTION

Poultry production is the most dynamically developing area of animal production. The systematic increase in meat and egg production in Poland in recent years, means that there is a strong demand for mixture feeds for poultry. In 2017, a total of 6362 thousand tonnes of feed were produced for all poultry species (GUS, 2018). Such a significant production requires the provision of a stable raw material base. Cereals constitute about 75% to the total area under crops, and domestic cereal production largely satisfies the needs of the feed market (Jaśkiewicz and Sułek, 2017). Lower profitability of leguminous plant production in relation to cereal resulted in a decrease in the area of their cultivation in Europe (Magrini et al., 2016). The introduction of a ban on the use of meat and bone meal in the feed industry would result in a large deficit of feed protein, amounting to approximately 900 thousand tons per year. Currently, it is covered by vegetable protein, mainly through the import of soybean meal. Therefore, in order to cover the demand and ensure constant access to feed protein and the so-called "protein safety", legumes should be cultivated, as their seeds can, at least in part, replace soybean meal (Różewicz et al., 2018). Imports of soybean meal is a very topical problem today. In addition, the price of this raw material depends on the soya harvest in South and North America. An important problem is also the fact that the source of vast majority of imported soybean meal are GMO plants. A prospect of banning their use may have a negative impact on feed prices, and thus on the economics of poultry production (Dzwonkowski, 2018). One of the solutions to this problem may be to increase the area under leguminous crops such as lupine, peas or faba beans (Zander et al., 2016). In order to cover the demand for protein of leguminous plants, taking into account the limitations of their use in feed, the current production of feed requires 770 thousand tonnes of legumes seeds (Dzwonkowski, 2018). In recent years, there has been a discussion on the renewal of legume production. Its additional advantage is the ability to bind atmospheric nitrogen, thanks to the symbiosis with bacteria, which allows the use of mineral fertilizers to be reduced by up to 20–25% (Prusiński et al., 2008). Moreover, the remaining harvest residues of legumes enrich the soil with humus and potassium in the amount of about 35 kg ha^{-1}, as well as phosphorus in the amount of 25 kg ha^{-1}. Legumes also have a positive effect on the soil structure and leave some nitrogen in the soil (Śmiglak-Krajewska, 2018). They are, therefore, plants that are desirable to be introduced in crop rotation. An additional advantage of their production is to obtain subsidies (Czerwińska-Kajzer and Florek, 2012b). Use of leguminous crops from domestic cultivation in Europe will reduce greenhouse gas (GHG) emissions such as carbon dioxide (CO_2) and nitrous oxide (N_2O) (Stagnari et al., 2017). Negative features of

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this group of plants are significant sensitivity to unfavourable weather changes, unstable yields, and thus variable profitability and low competitiveness in relation to prices of soybean meal (Czerwińska-Kajzer and Florek, 2012a). About 65–70% of legume seeds produced in Poland were destined for feed, mainly for animals, including poultry and pigs (Podleśny and Księżak, 2009). Fragmented and small acreage is a problem when using legumes in the feed industry. Also, small and heterogeneous portions in terms of nutritional value of raw seeds, cause lower interest in legumes. All these factors make it difficult for legume growers to sell crop at a convenient time, as well as the need to accept prices that do not always ensure the profitability of production (Bojarszczuk and Księżak, 2018). Another difficulty in legume use as a feed component for poultry is the presence of anti-nutritive agents. Recently, however, new cultivars with reduced content of such compounds have been tested. Also in the case of faba beans, low-tanin cultivars are recommended (Cho et al., 2019).

CULTIVATION OF FABA BEAN IN POLAND

Faba bean cultivation in Poland has a long tradition. This is evidenced by the fact that in 1923, Lucjan Kaznowski developed a faba bean cultivar named Nadwiślański. The fact that it was not removed from the National Register until 2008 may indicate its popularity for adaptation to the conditions of the Polish climate. Initially, it was treated as a valuable, high-protein feed for horses. This plant was called in various countries adding the adjective "horse", e.g. from German *Pferdebohne*, English *horse* bean and Czech *koòský* bob. The area of faba bean cultivation, similarly to other *Fabaceae* plants, was subject to changes. In Poland in 1989, the area under faba beans was 121,000 hectares, which was the highest in the world. It was the year in which the highest cultivated area of other legumes plants was recorded, totaling 372 thousand ha (Florek et al., 2012). This resulted from the Polish government's actions aimed at achieving self-sufficiency in domestic demand for high-protein feed components (Podleśny, 2005), and the ban on use of GMO soybean cultivars. In the following years, we observed a decrease in the area under legume cultivation – in 2005 it was 12,000 ha, while in 2013 – it was only 6,000 ha). These activities resulted in an increase in interest in seed material and a gradual increase in the area of legume cultivation. The increase in demand for the seeds resulted in the increase of seed plantations of legumes plants from 6 455 ha in 2013 to 18 667 ha in 2015 (a three-fold increase). In the case of faba beans alone, it was about four-fold increase from 558 ha in 2013 to 2095 ha in 2013. Between 2010 and 2017, the area under faba bean increased four times, which was the highest increase in the area of fodder legumes. This constitutes an advantage of faba bean in comparison with other leguminous plants, as it has a high yield potential in relation to them (Zając and Kulig, 2000; Kulig, 2004). Under favourable weather conditions and good agricultural technology, 3 to 6 t of seeds per hectare can be obtained. However, the long-term research of Księżak and Kuś (2005) in the following three growing seasons (1999–2001) indicates that the average yield of faba beans is rather in the lower range (by 3.3 t ha^{-1}). However, data from the Central Statistical Office (GUS, 2017) showed that in 2016 faba beans yielded at the level of 2.69 t ha^{-1}. Crop production in Europe are increasingly difficult due to drought. Appropriate agronomic practices for the cultivation of field beans in this conditions including right plant density, fertilization and irrigation systems, weed, pest and disease management, and harvesting times.

NEW CULTIVARS OF FABA-BEAN AND THEIR SUITABILITY FOR USE IN POULTRY FEED

The main breeding strategy for new legume cultivars is primarily to increase the seed yield (Maalouf et al., 2018). This is related to the economic aspect, as farmers receive the price for the weight of seeds they offer at purchase. The high yield of new cultivars encourages farmers to invest in their cultivation. Other important features include shortening of the growing season of plants and reducing their susceptibility to lodging, as well as increasing their resistance against diseases and pests. The feed industry, on the other hand, places demands on the quality of the seeds and large batches of homogeneous raw material. In this context, an important strategy of breeding new cultivars of faba beans is to improve the quality of yields: protein content in seeds and its amino acid composition, as well as the reduction or possible elimination of substances of an anti-nutritional nature. The traditional, formerly grown, cultivars of faba beans, classified as indeterminate cultivars and entered in the National Register include: Ashleigh, Bobas, Oena and

Table 1. Chemical composition [g kg^{-1} dry matter] of seeds of faba bean cultivars (Nalle et al., 2010).

Cultivar	PGG Tic	Spec Tic	South Tic	Broad
Dry matter	873	863	872	876
Crude protein	306	300	305	229
Ether extract	20.7	19.5	21.3	23.7
Ash	33.7	32.7	33.0	43.3
Starch	405	341	389	367
Non-starch polysaccharides				
Soluble	19.9	21.6	17.4	16.1
Insoluble	185	218	182	227
Total	205	240	199	243
Trypsin inhibitor activity (TIU mg DM^{-1})	0.45	0.40	0.42	0.55

Sonet. Their characteristic features include coloured flowers and a top shoot ended with leaves above the flowers, coloured, most often beige seeds, changing colour during long storage due to the oxidation of tyrosine. The usefulness of field bean seeds derived from traditional cultivars in poultry feed is limited. This is due to the high content of anti-nutritional substances such as tannins, which decrease protein and carbohydrate digestibility, and deteriorates the taste of the feed as they give it a bitter aftertaste (Nalle et al., 2010). In order to be able to increase the use of faba beans in feeding poultry and other animals, new cultivars with reduced tannin content, the so-called low-tannin cultivars, were obtained during the breeding process. Other characteristics of these cultivars are the white colour of the flowers and grey beige seeds, which, unlike the traditional cultivars, do not darken during storage. The low tannin content ensures that the utilization is utilized due to its higher digestibility, deterioration of the feed quality. There are 4 cultivars of white and flowering faba beans in the National Register: Albus, Amulet, Kasztelan, and Olga. A slight regression can be observed in the breeding of new faba bean cultivars, despite a certain increase in interest in their cultivation. The last new low-tanning variety – Amulet – was registered in 2008. Today, in faba bean seed production, nearly 90% of this seed area is made up of four main cultivars – Bobas, Albus, Amulet and Granit, so that their seeds are the most readily available for farmers in the seed centres (COBORU, 2019). As shown by the research of Księżak et al. (2018), the different cultivars of faba beans vary for their chemical composition of seeds. According to the quoted authors, the cultivars Kasztelan, Leo, Olga, Bobas, Amulet, and Albus had higher protein content in seeds than Sonet, Opitmal and Granit.

NUTRITIONAL VALUE OF FABA BEANS AND INFLUENCE OF THEIR PERCENTAGE IN MIXTURES ON POULTRY PRODUCTION RESULTS

Faba beans can be used as a component of mixture feeds, which results in a fairly favourable nutritional composition. Due to the significant content of starch (about 40%) and protein, faba bean constitutes a protein-energy raw material (Korsvold, 2020). Despite lower protein content in relation to soybean meal, it is also found as a valuable source of this component. The total protein content of faba bean seeds is dominated by globulin (80%) and legumin (Warsame et al., 2018). They contain exogenous amino acids, except for sulphuric ones (Pisulewska et al., 1996). According to Kiczorowska (2013), the amino acid limiting the nutritional value of faba bean seeds is methionine. Its content being 0.8–1.2 g/100 g of protein, followed by cysteine 1.2 g/100 g, and threonine 3.2 3.8 g/100 g of protein.

It is therefore appropriate to enrich mixture feed containing faba beans with synthetic methionine (Osek et al., 2003; Gous, 2011). The nutritional value of faba bean seeds and their chemical composition depend to a large extent on the cultivar, interaction with growing conditions, and sowing date (Gulewicz et al., 2014; Adak and Kibritci, 2016). Due to the differences in the content of nutrients and anti-nutrient substances in individual faba bean cultivars, it was necessary to study their chemical composition and to assess their percentage in feed mixtures for various animal species and animal production groups (Liu et al., 2017). Since the main purpose of leguminous plants is the production of feed protein, research is being carried out throughout the world into the constant improvement of cultivars with phenotyping, genotyping, and transcriptomic analyses. These techniques allow to create cultivars with optimal nutritional and agronomic values for sustainable and competitive protein production in Europe (Martos-Fuentes, 2017). Breeding methods also allow identifying the cultivars with the lowest levels of anti-nutritional components and identifying beneficial genes (Masey-O'Neill et al., 2012; Murtaza et al., 2017) (Table 3). Besides the introduction of protein into the feed ration, faba bean also provides a significant amount of macroelements such as potassium (262 mg/100 g) and magnesium (35 mg/100 g), as well as microelements – zinc 1.4 mg/100 g and iron 1.37/100 g, and to a lesser extent, manganese 0.4 mg/100 g (Yahia et al., 2017).

Table 2. Amino acid concentration [g kg^{-1} dry matter] in the seeds of the four faba bean cultivars (Nalle et al., 2010).

Amino acid	PGG Tic	Spec Tic	South Tic	Broad
Indispensable				
Arginine	25.0	23.8	25.0	21.2
Histidine	7.01	6.43	6.84	5.96
Isoleucine	9.55	8.91	9.72	8.49
Leucine	17.6	16.7	18.1	14.5
Lysine	14.4	13.7	15.0	13.0
Methionine	2.26	2.11	2.21	2.18
Phenylalanine	9.61	9.22	9.71	8.54
Threonine	7.51	7.38	8.13	7.08
Valine	10.9	10.2	10.8	9.87
Dispensable				
Alanine	10.5	9.93	10.7	9.39
Aspartic acid	26.2	28.0	27.9	22.1
Cystine	3.86	3.57	3.71	3.22
Glycine	10.2	9.56	10.2	8.82
Glutamic acid	40.0	39.6	40.3	32.9
Proline	8.79	8.82	8.68	7.00
Serine	9.16	8.83	9.40	8.15
Tyrosine	7.78	7.39	7.98	6.74

A restriction to the wider use of faba beans in chicken feed is the content of anti-nutritional substances, especially tannins (Vilarińo et al., 2009). To a lesser extent, they contain other anti-nutritive substances, pyrimidine glucosides: vicine and convicine. By changing the metabolism of blood cells, they can cause haemolytic anemia. Their

Table 3. The content of tannins in seeds of faba bean cultivars (Księżak, Bojarszczuk, 2014).

Cultivar	Tanins content [% d.m.]
Leo	0.062
Kasztelan	0.064
Albus	0.067
Amulet	0.068
Olga	0.069
Bobas	0.616
Sonet	0.643
Granit	0.706

content in the various cultivars of faba beans is diversified, ranging from 3.4 to 10.4 g per kg of dry matter, although there are already cultivars of faba beans with a very low content of these glycosides – 0.2–0.6 and 0.1–0.2 g per kg of dry matter, respectively of vicine and convicine (Grosjean et al., 2001). Seeds of faba beans also contain phytates in amounts up to several mg/1 g (Hagir et al., 2005). Seeds of faba beans contain about 28–30% protein in dry matter. It is very valuable because of its favorable amino acid composition. Legumine is the basic protein present in the seeds of faba beans. Faba bean covers the birds requirements for exogenous amino acids, with the exception of sulphuric amino acids (Brzóska, 2003). It is also a good component because of its high lysine content, which is poor in cereal protein. The fodder value of faba bean seeds can be increased by refining treatments such as hulling and extrusion. Studies by Milczarek and Osek (2016) indicate that a hulling treatment increases protein content by up to 13%. Milczarek and Osek (2016) report that the faba bean seed extrusion did not affect the level of protein and crude fibre, but the content of dry matter and fat in faba bean extrudate was decreased. In the research of Hejdysz et al. (2019), the application of the faba bean extrusion process reduced feed consumption and resulted in a better feed conversion factor (FCR). Faba bean seeds can also be an energy source. As Arija et al. (2006) points out, the use of hulling and extrusion of faba beans increases their energy value. Also studies by Milczarek and Osek (2016) showed that faba bean seed hulling affects the increase of their energy value. As the hull contains the most fiber, its removal during the hulling process causes the simultaneous removal of a significant part of the fiber, thus increasing the concentration of energy. In addition to a high nutrient content, keeping as low as possible the seed content of tannins and phytate is also important aspect from a nutritional point of view. To some extent, the breeding of new faba bean cultivars allowed reducing their tannins content. However, despite their lower level, some tannins are still found in faba bean seeds. It would therefore be beneficial to further reduce their level through the use of refining treatments. According to the research of Milczarek and Osek (2016), raw seeds of faba beans contained 11.4 g kg^{-1} tannins of dry matter. The application of refining treatments i.e. hulling and extrusion allowed reducing the content of tannins in relation to raw seeds by 48% and 31%, respectively. However, in the case of phytate, the applied treatments did not result in a significant decrease in the level of these compounds. According to the authors, the studies conducted indicate that of the two treatments hulling is the more effective method of improving the nutritional value of legume seeds, including faba beans. The use of raw faba bean seeds is limited. In the feed fed to laying hens, no more than 25% of soybean meal can be replaced by raw faba bean seeds, and on condition that an enzyme additive of up to 50% of the total feed weight is used (Alagawany et al., 2019). Also, Lessire et al. (2017) concluded in their studies that up to 25% of raw seeds of low-tannin faba bean can be used in the diets of laying hens without any harmful effect on the quantity and quality of eggs. Whereas Laudadio and Tufarelli (2010) used faba bean seeds which had been previously hulled and then micronized as a partial substitute of soybean meal in a feed for laying hens. In this experiment, faba bean seeds accounted for 24% of the feed mix. The researchers assessed the basic production parameters of laying hens, such as the percentage of egg laying, the weight of eggs, shell thickness, and mortality. No differences were found between the experimental group vs. the control group that was fed soybean meal as the protein component of the feed mix. Also in experiments on slaughter chickens, no negative effect of 25% of low-tannin field bean level on their production results was found (weight gain, feed intake, feed conversion ratio). Studies were carried out on one day-old broiler chickens that received feed containing beans (20, 30 and 40%), raw or autoclaved at 120 °C for 30 minutes, as a substitute for soybean meal (Rachwał, 2013). Additionally, mixtures with faba beans were supplemented with 0.25% of methionine. According to the authors, the results of the study indicate that the more effective method of improving the nutritional value of legumes seeds, including faba beans, is their dehulling (Rachwał, 2013).

CONCLUSIONS

In Poland, the area under faba bean grown for seed as fodder is still too small. An inadequate supply of the raw material in the form of seeds on the market is the problem for the feed industry. The content of anti-nutritive substances in faba bean seeds is also an obstacle to the use of faba bean as a substitute for soybean meal. Therefore, raw faba bean seeds can be used to a limited extent. The use of refinement treatments such as extrusion or dehulling allows increasing the recommended level of faba bean seeds in poultry feed. The advantage of faba bean, apart from the protein content, is also the starch content, thanks to which it introduces a certain dose of energy into the feed for poultry. Cultivation of faba bean also has the advantage of introducing a dose of nitrogen into the soil from crop residues. Further development of the cultivation and use of faba bean should include cultivation of varieties with increased feed value and reduced content of anti-nutrient ingredients.

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