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Possibilities and limitations in the use of legumes from domestic cultivation in poultry feed in the context of fodder protein deficit

Marcin Różewicz, Jerzy Grabiński, Alicja Sułek

Department of Cereal Crop Production, Institute of Soil Science and Plant Cultivation – State Research Institute
Czartoryskich 8, 24-100 Puławy, POLAND

Abstract. Poland is one of the leaders among poultry producers in Europe. There is a constant and dynamic development trend in this field of animal production. Restructuring which has occurred in Polish agriculture after the period of systemic transformation, including in poultry farming through the transition from small-farm farms with diversified animal species structure and feed production based on own production feed resources to specialized poultry farms with a production profile of eggs or poultry. This resulted in a significant increase in the demand for industrial feed as well as raw materials necessary for their production. The introduction of high-production hybrids of laying hens and broiler chickens requires proper living and feeding conditions. The poultry industry in Poland is characterized by high dynamics of development and in this respect it was ranked among the top European Union countries. Large poultry stock requires constant supply of raw materials for the production of feed, including protein components, which constitute the highest cost of feed mix.

The aim of the study is to discuss the problem of cultivation and use of native coarse-grained leguminous plants as a substitute for post-extraction soybean meal. The work focuses on four species: faba bean, pea, lupine and soybean. The problems of cultivation and use of seeds of these plants for fodder purposes are presented, with particular emphasis on the suitability of their use in poultry feeds.

Keywords: legumes, fodder protein, faba bean, peas, lupine, soybean

INTRODUCTION

The demand for energy fodder raw materials is covered by the domestic production of cereals (Jaśkiewicz, Sułek, 2017). The problem for the domestic feed industry and the threat to the stability and economic efficiency of poultry breeding in Poland is the dependence on imports of the major protein raw material which is post-extraction soybean meal. Every year, the importation of approximately 2–2.2 mln tonnes of post-extraction soybean meal is required in order to produce industrial feeds, 65% of the total production of which constitutes poultry feeds (Urban, 2015). The vast majority of its available quantities in the world market comes from the countries of Latin America and the USA, where GMO varieties cover a significant portion of the cultivation area (Dzwonkowski, 2016). The introduction of a ban on the use of raw materials derived from GMO plants may result in a significant deficit in fodder protein on the domestic raw materials market, and this may destabilize the situation of poultry production and lower its economic efficiency, consequently leading to a rise in the prices of poultry meat, which also comprises a significant share of the overall consumption structure among consumers in Poland. Taking into account the above arguments raised by the representatives of the domestic feed industry and associations of poultry breeders in Poland, the amendment to the Act from 22 July 2006 on feedstuffs, which enforced the ban on the production, placing on the market and use of genetically modified feedstuffs and genetically modified organisms intended for use as feedstuffs in animal nutrition – which was to enter into force 2 years after the date when the Act was announced, i.e. on 12 August 2008, has been postponed several times. Subsequent dates of the amendment to the Act entering into force have been postponed until January 2013, and then 2017, and now the next deadline has been set to January 2019. The legislator is also considering another postponement of the date of entering the amendment to the Act into force until January 2021. The successive postponements of the dates of entering the amendment to the Act into force are related to the difficulties in introducing other protein components into domestic production.

On 9 August 2011, the Council of Ministers adopted Resolution the No. 149/2011 on the establishment of a long-term programme entitled “Improving the domestic plant protein sources, their production, system of circulation and use in feedstuffs”. Its aim is to create conditions

Corresponding author:
Marcin Różewicz
e-mail: mrozewicz@iung.pulawy.pl
phone: +48 81 4786 818

for reducing the import of feed protein (post-extraction soybean meal) by approx. 50% as a result of improving the biological and functional value of plant protein derived from native protein raw materials that coarse legumes constitute. They include: lupines, faba beans and peas. Currently, by virtue of the decision of the Council of Ministers from 15 December 2015, the Resolution No. 222/2015 on the continuation of the long-term programme (2016–2020) entitled "Increasing the use of domestic fodder protein for the production of high-quality animal products in conditions of balanced development" was adopted. One of its elements, apart from focusing on native legumes like faba bean, pea and lupine, which has been the case so far, will also be soybean. The additional introduction of non-GMO soybean varieties into Poland may also increase the supply of protein components, such as soybean extrudate and oil cake.

THE CURRENT PROTEIN SECURITY SITUATION IN POLAND

Animal production is inherently associated with the supply of feeds that should be provided for individual groups and species of farm animals. Plant production currently constitutes the major basis for the production of feeds. The analysis carried out by Piwowar (2013) indicates that the production of industrial feeds in Poland has increased by 52% over the last 10 years. With the increase in production, the retail prices of fodders also rose significantly, among others due to the higher prices and their fluctuation. As Święcicki et al. (2007) report, the annual domestic demand for fodder protein amounts to approximately 1 million ton. The rapid development of poultry production contributes to the systematic increase in the demand for these raw materials in Poland (Jerzak et al., 2012). After the introduction of the ban on using meat-and-bone meal as a feed component, which was associated with the occurrence of BSE (Bovine Spongiform Encephalopathy) in the cattle that was given this component in the feed, it was replaced by post-extraction soybean meal. To prevent the spread of this disease, which is caused by the so-called prions, which belong to proteinaceous molecules, the European Union, by virtue of the Decision of the Council 2000/766/EC from 4 December 2000, introduced a ban on the use of meat meals, meat-and-bone meals and meals from blood and feathers as components of compound feeds for animals. Among the raw materials of animal origin, only fish meal remains to be used for poultry. Due to its limited quantities and relatively high price, it is neither popular nor widely used. Hence, the resulting fodder protein deficit has been covered by the imported post-extraction soybean meal. It is a protein component used in the production of feeds, mainly for poultry and pigs and, to a lesser extent, for cattle. The large scale of poultry production resulted in the fact that currently, this import is at the level of 2–2.2 million tonnes of raw material, which equals increase 10% compared to the year 2014 (Dzwonkowski, 2016). Due to the fact that the use of meat-and-bone meals is prohibited throughout the entire European Union and other Member States also have a significant demand for protein raw materials, the price of post-extraction soybean meal depends on the supply of this raw material, which, in turn, depends directly on the yield scale in leading producer counties, such as the USA, Argentina and Brazil. European Union countries import a total of 35 million tonnes of soybean meal per year, while their soybean yield scale amounts to only 1 million tonnes from own crops. These countries, having a large scale of animal production, depend on the import of protein raw materials and compete for this raw material against each other, which, in the case of poor yields, may cause a rapid increase in the price of post-extraction of soybean meal. The largest producers, from whom comes 90% of the raw material available on the world market, are: Argentina, Brazil, USA and India. The undisputed leader is Argentina, whose sales of soybean meal to foreign markets have increased from 5.5 million tonnes in the 1990/91 season to almost 29 million tonnes in the 2007/08 season, that is, by more than 5 times. Brazil and the US increased their exports by approximately 60%, to 13 and 8 million tonnes respectively (Dzwonkowski, Hryszko, 2011). An additional problem in the context of banning the use of GMO feed raw materials results from the fact that GMO varieties represent a significant share of the total soybean growing. As indicated by Dzwonkowski (2016), in 2014, the growing of GMO soybean accounted for 82% of this plant's cultivation area in the world and 50% of the area of all GMO crops. According to a rough estimate, it is assumed that 93–95% of the soybean meal in international trade is produced from GMO plants. In Argentina, which is the largest producer and exporter on the EU market, the yield scale of GMO soybean cultivars amounts to as much as 100% (James, 2012). In this context, alternative sources of plant feed protein are being sought to cover the needs of feed producers and factories. To some extent, it is possible to use domestic varieties of legumes, such as faba bean, pea and lupine. However, their use is hindered, on the one hand, by their limited share in poultry feed caused by the presence of anti-nutrients and, on the other hand, by the small production scale and the lack of supplies of large, systematic and homogeneous batches of raw material. Therefore, another alternative is being sought in the form of using the available soybean grains from non-GMO varieties cultivated in Ukraine, but also the possibility of cultivating this plant in Polish climate conditions. Due to the fact that it is an extremely valuable oil plant, and also because it constitutes a protein component of feeds, it is worth to popularize its cultivation.

Before the start of economic transformations, up to 1989, the need for fodder protein was covered by using native legumes, such as pea and lupine (Jerzak, 2015). After the opening of markets and the establishment of trade relations with other countries, the dynamic process of global trade development has begun in the 1990s. This initiated the phenomenon of replacing the protein from native legumes in poultry and swine feeds with the imported soybean protein, which was easily accessible and competitive in terms of its quality. This was the direct cause of the collapse of the domestic production of this raw material, which, at the same time, created conditions for a further increase in the importation of soybean meal. The development of animal production additionally increased the demand for this raw material but, at the same time, it contributed to the further decrease in the cultivation area of native legumes, which systematically exacerbated the deficit of fodder protein and the dependence on its imports (Seremak-Bulge, Hryszko, 2008). In recent years, the cultivation of leguminous plants has enjoyed some popularization and the scale on which they are cultivated has been somewhat restored, which is marked by the increase in their cultivation area on average by 6.1% per annum in the years 2000–2015 (Dzwonkowski, 2016). It is essential that these plants' cultivation area be developed, so that the demand of the ever-growing poultry stock is met. The production of complete feedingstuffs for this group of animals has almost doubled in the last decade alone (Dzwonkowski, Bodyl, 2014). According to the data of the Central Statistical Office of Poland (GUS), the area on which native legumes were grown, has increased from 119,000 ha in 2011 to 350,000 ha in 2015 (GUS 2012–2016). As shown by the study carried out by Czerwińska-Kayzer et al. (2016), in Poland, it is still possible to develop the production potential related to the cultivation of native legumes and their intended use as fodder. According to Jerzak and Krysztofiak (2017), achieving the assumed level of safety within the scope of plant protein supply will be possible if the National Indicative Target (NIT) for plant protein is set at a level of at least 8.4%. Its implementation will be possible thanks to continuing the support system for high-protein plant growers, which is also achieved by giving grants for their cultivation and cultivation area. According to an analysis by Czerwińska-Kayzer (2015), the role of grants in shaping the income from legume production is high, they offset over 60% of the costs incurred. Furthermore, as stated by the author, in the case of unprofitable crops, such as yellow lupine, it is only after grants are figured into the calculations that incomes exceed the costs incurred, which means that the cultivation starts to generate profits. A similar view as to the role of grants in the profitability of legume cultivation is held by Adamska et al. (2016). According to the economic analysis by Czerwińska-Kayzer and Florek (2012) concerning the profitability of legume cultivation carried out over a span of five years, field pea was characterized by the highest profitability among the studied cultivars. At the same time, as Florek (2017) notes, in order to increase in the interest in the production of leguminous plant seeds among farmers and thus increase the supply of this protein raw material on the feed market, initiatives aimed at facilitating its sale are needed. The profitability of growing legumes in Poland is much lower than in other EU countries, which is a result of the higher grants for the production of this group of plants and their higher selling prices (Majchrzak et al., 2010). The low yielding and low stability, as well as the fact of being poorly equipped in machinery, have a significant influence as a factor limiting the cultivation of leguminous plants in Poland. The introduction and popularization of new high-yielding varieties, as well as the implementation of new production technologies for the cultivation of these species, are justified (Księżak, Podleśny, 2008).

In addition to increasing the cultivation area, it is also necessary to create an appropriate market structure for the distribution and use of leguminous plant seeds, which would greatly facilitate sales and create opportunities for cooperation with feed factories. This is still one of the problems that constitute a barrier, despite the satisfactory profitability of the production of native legumes and the lower cost of producing 1 kg of protein in comparison to the cost of post-extraction soybean meal (Jerzak, Krysztofiak, 2016). According to Jerzak and Mikulski (2017), the marginalization of protein raw material from native legumes on the domestic market means that the grants that are currently being implemented are not mobilizing farmers to produce these plants for fodder purposes; instead, they only constitute a forecrop for the succeeding plants or a less expensive fertilizer. The highest demand for fodder determined by the scale of animal production may be observed in the north-western macroregion, where the most feed factories are located (Florek et al., 2012).

LEGUME VARIETIES IN POLAND

17 varieties of soybeans (Abelina, Aldana, Aligator, Augusta, Coraline, Erica, Comandor, GL Melanie, Madlen, Maja, Mavka, Oress, Paradis, Petrina, Regina, Sculptor, Viola) whose cropping is possible in Poland are currently entered into the register of the Research Centre for Cultivar Testing (COBORU). These varieties are adapted to and tested in the Polish climate conditions in terms of suitability for cultivation and yielding. Soybean is a short-day plant with high thermal requirements, which is why most foreign varieties do not mature in Poland. The prospect of cultivating an initially small amount of soybean in our country may cause the expansion of its cultivation area in the future under the condition of a high demand of the domestic feed industry, thus providing at least a partial supply of plant protein.

Domestic legumes, such as pea, lupine and faba bean, may become much more popular. As many as 24 varieties of field pea (Akord, Arwena, Astronaute, Audit, Batuta, Cysterki, Ezop, Hubal, Lasso, Mecenas, Mentor, Milwa, Model, Muza, Olimp, Pomorska, Roch, Sokolik, Spot, Starski, Tarchalska, Turnia, Tytus, Wenus), 12 faba bean varieties (Albus, Amigo, Amulet, Ashleigh, Bobas, Fanfare, Fernando, Granit, Julia, Oena, Olga, Sonet), 9 varieties of yellow lupine (Baryt, Bursztyn, Dukat, Lord, Mister, Parys, Perkoz, Puma, Taper), 26 varieties of blue lupine (Bolero, Boruta, Dalbor, Graf, Heros, Jowisz, Kadryl, Kalif, Karo, Koral, Kurant, Lazur, Mirela, Neptun, Nero, Oskar, Regent, Roland, Rumba, Salsa, Samba, Sonet, Tango, Tytan, Wars, Zeus) and 2 varieties of white lupine (Boros, Butan) have been entered into the national register of cultivars. As such, the possibilities of cultivation using such a vast number of varieties are unlimited and their use depends to a large extent on the economic efficiency of their growing and the yield quality, as well as the content of anti-nutrients limiting the use of particular species and varieties. Even a partial substitution of imported soybean meal may reduce the demand for it. Research is being carried out on domestic varieties of legumes. Over recent years, a growing interest in domestic protein sources has been observed in the nutrition of monogastric animals, which may contribute to a reduction in feed prices. Raw materials of domestic origin with a protein content comparable to soybean, which could be used to replace it, are products of the oil industry – post-extraction rapeseed meal and rapeseed oil cakes, as well as seeds of leguminous plants: pea, faba bean, yellow and blue lupine (Jerzak et al., 2012). These seeds are suitable for use as a replacement for soybean meal, due to their favourable amino acid composition. In this way, the demand for digestible protein and amino acids may be evened out. The total production of domestic protein currently amounts to 340,000 tonnes. This constitutes only 26% of the domestic demand for protein raw materials. The resulting deficit in the amount of 960,000 tonnes still has to be covered with imported soybean meal to ensure the safety of constant feed production for the domestic pig and poultry stock (Jerzak, Mikulski, 2017). Legumes are a group of plants significant from an economic and ecological point of view, also being of great importance within the framework of balanced and ecological agriculture (Majchrzycki et al., 2002).

YIELDING AND USE OF LEGUMES IN POULTRY NUTRITION

After the integration of Poland into the European Union (EU), many changes have occurred in the structure and regional diversification of agricultural production, including the branch of plant production (Madej, 2016). At the same time, the growing poultry production and the systematic increase in the demand for fodder protein is a challenge for agricultural practice. Current changes in the legislation necessitate the search for alternative concepts, being oriented towards the rational use of domestic feed resources and increasing the innovation and competitiveness of agriculture (Chyłek, Rzepecka, 2011). Hence, a number of studies from the field of agricultural science aiming at increasing the cultivation area of legumes and their more widespread use in the domestic feed industry are being carried out. The popularization of research and its practical implementation is a fundamental condition for the effective use of research results to support agricultural development (Chyłek et al., 2017). The possibilities of ensuring competitiveness by virtue of pursuing the alternative which the cultivation of legumes depending on the region of Poland and groups of farms constitutes are also of particular importance (Zarychta, 2013).

Faba bean (*Vicia faba minor*)

In 1989, the cultivation area of faba bean amounted to 121,000 ha, which was its highest scale. That year, the highest cultivation area of other legumes was also recorded and it totalled 372,000 ha (Florek et al., 2012). On the one hand, this was a result of the actions of the State, whose objective was to achieve self-sufficiency in the area of domestic demand for high-protein feed components (Podleśny, 2005). In 2015, the cultivation area of faba bean in Poland amounted to over 27,000 ha, from which 735,223 dt grain were obtained (GUS, 2016). Faba bean is one of the legumes with the highest yielding potential (Bobrecka-Jamro, Pałka, 1998; Borowiecki et al., 1997; Kotecki, 1994; Zając, Kulig, 2000). A long-term study by Księżak and Kuś (2005) conducted in three successive growing seasons (1999–2001) indicate that the mean faba bean yield amounts to 3.3 t/ha of seeds. As such, also in other EU countries, there is an increase in the interest in the possibility of growing this valuable plant as a source of fodder protein for various groups of animals, including poultry (Cernay et al., 2017; Kulig, Zając, 2007).

Legumin is the predominant ingredient of the total protein content in faba bean. In its amino acid composition, it contains exogenous amino acids, except for those included in the group of the so-called sulphur-containing amino acids (Pisulewska et al., 1996). The nutritional value of seeds and their chemical composition depend to a large extent on the variety and cultivation conditions, as well as the sowing date (Duc et al., 1999; Gutierrez et al., 2006; Crépon et al., 2010; Duc et al., 2010; Duc et al., 2011; Jezierny et al., 2011; Oomah et al., 2011; Vioque et al., 2012; Gnanasambandam et al., 2012; Yahia et al., 2012; Kiarie et al., 2013; Gulewicz et al., 2014; Adak and Kibritci, 2016).

Due to the difference in the content of nutrients and anti-nutrients among given faba bean varieties, it became necessary to analyse their chemical composition and use them in compound feeds for different species and production groups of animals in practice (Liu et al., 2017). Since the main purpose of this group of plants is the production of fodder protein, studies are being carried out around the world, whose aim is the constant improvement of varieties through the use of phenotyping, genotyping and transcriptome analysis. These techniques make it possible to obtain varieties with optimal nutritional and agronomic values for balanced and competitive protein production in Europe (Martos-Fuentes, 2017). Cultivation methods also allow for the selection of varieties with the lowest share of anti-nutrients and the identification of beneficial genes (Masey O'Neill et al., 2012; Murtaza et al., 2017).

In addition to introducing protein into a dose of feed, faba bean also introduces a significant dose of macroelements such as: potassium (262 mg/100 g) and magnesium (35 mg/100 g), as well as micronutrients – zinc 1.4 mg/100 g and iron 1.37/100 g, as well as, to a lesser extent, manganese – 0.4 mg/100 g (Yahia et al., 2017).

The use of faba bean in animal nutrition, especially broiler chickens, also has an economic aspect because in many European countries attempts are being made to substitute soybean protein with a meal obtained from faba bean seeds (Ceriņ, Proškina, 2017).

The limitation in the broader use of faba bean in chicken feed is the content of anti-nutrients, and particularly so, tannins (Vilariño et al., 2009). To a lesser extent, it contains other anti-nutrients – pyrimidine glucosides: vicine and convicine. By changing the metabolism of blood cells, they can cause hemolytic anaemia. Their content in different faba bean cultivars varies, in the case of vicine it may range from 3.4 to 10.4 g per one kilogram of dry matter, although faba bean varieties with a very low content of these glycosides already exist – 0.2–0.6 and 0.1–0.2 g of vicine and convicine respectively per one kilogram of dry matter (Grosjean et al., 2001). Faba bean seeds also contain phytates in the amount of up to several mg/1 g (Hagir et al., 2005).

Many studies aimed at the possibility of using faba bean in compound feed for various groups and species of poultry have been carried out in recent years. The use of low-tannin faba bean varieties is currently recommended for use in compound feeds for broiler chickens. Meanwhile, Milczarek and Osek (2017) have not recorded a negative impact on the production output while using low-tannin (Albus) and high-tannin (Granit) faba bean varieties in the starter (16%) and grover (22%) compounds as a partial substitute for post-extraction soybean meal. The authors found a slightly higher degree of muscle mass and lower fatness of birds, which is a beneficial feature from the point of view of consumers' requirements. Koivunen et al. (2014) are of a similar opinion and consider the use of a 16% share of faba bean in the diet of broiler chickens as a substitute of post-extraction soybean meal to be justifiable. Using such a share, the authors achieved optimal yields of chicken production without adversely affecting the health of broilers. In turn, Brévault et al. (2003) indicate a significant reduction in the weight of chickens when using a 20% share of a high-tannin faba bean variety, whereas when using the same share of a low-tannin variety in the feed, production outputs similar to those in the control group (based on post-extraction soybean meal) were recorded.

Faba bean also constitutes an alternative protein raw material which can be used successfully in the case of organic production. Dal Bosco et al. (2013) evaluated the use of faba bean in a fodder for slow-growing chickens bred organically and the impact of this component on the production output and slaughter output. In the control group, soybean meal protein was used, whereas a meal from faba bean seeds was introduced into the feed of the experimental group as the only source of protein throughout the entire rearing period. The production outputs of the chickens from the group fed with a faba bean compound were significantly lower than those of the control group. These chickens were characterized by a higher mortality rate, which suggests that fodder based exclusively on faba bean as the only source of protein in the feed is not able to cover the birds' nutritional needs, especially in the first period of rearing. Osek et al. (2013) conducted research on broiler chickens, where part of the extracted soybean meal was replaced with legume seeds, including faba bean (Starter – 15%, Grower – 33%). The results of these studies indicate that the partial substitution of post-extraction soybean meal with faba bean had a beneficial effect. Better body mass gains and slaughter output at a similar muscle mass and fatness of carcasses, as well as better sensory features of the meat were obtained, compared to the control group which was given post-extraction soybean meal as the sole protein component. Meanwhile, Osek et al. (2003) achieved a higher slaughter output and total muscle mass in the carcass, as well as a slight decrease in body fat compared to the control group by introducing faba bean of the Akord variety into compounds for broiler chickens (in the amount of 10% in the starter compound and 20% in the grower). Nalle et al. (2010) implemented a recipe variation of compound feeds using the seeds of faba bean, white lupine and pea with or without the addition of meat meal at two dosage levels to study the results of digestibility and quality of broiler carcasses. In the control group, a wheat and soybean-based diet was applied with or without the addition of meat meal, and in the experimental groups, the addition of pea, lupine and faba bean were used in the amount of 200 g/kg of dose with or without the addition meat meal. In the first period of rearing, in the case of doses containing faba bean and lupine, lower body mass gains were obtained than in the groups with the same meals and an addition of meat meal. Okandza et al. (2017) consider the use a 12% share of faba bean in broiler feed to be justifiable.

Faba bean is also used as a component in feeds for laying hens. Fru-Nji et al. (2007) recommend a share of this raw material amounting to a maximum of 16% of the dose. When the recommended level was exceeded, the authors noted a significant deterioration in the herd's lay and the quality of eggs, including a decrease in the durability of the shell. According to Koivunen et al. (2014), the maximum share of faba bean in the feed for laying hens should amount to 5%. Meanwhile, Gous (2011) used faba beans that had been hulled, which significantly influenced the possibility of using a higher share of them in the feed for laying hens without having an adverse impact on production indices and the quality of eggs laid by these hens. Increasing the share of faba bean in the feed is also possible with the use of enzymatic agents (El-Hack et al., 2017).

Tufarelli and Laudadio (2015) also used faba bean as a component in the fodder for slaughter guinea hens, noting its beneficial effects. According to these authors, replacing post-extraction soybean meal with faba bean resulted in an improvement in the quality of meat by reducing the bird's level of fat and lowering their cholesterol, as well as a favourable profile of fatty acids by reducing the content of saturated acids without adversely affecting production outputs.

The use of low and high-tannin faba bean varieties in the amount of 300 g/kg of feed for slaughter turkeys does not adversely affect production outputs and the quality of meat, and thus can be used as a substitute for post-extraction soybean meal for this species of poultry (Przywitowski et al., 2016, 2017).

According to Kiczorowska (2013), the amino acid that limits the nutritional value of faba bean is methionine, whose content amounts to 0.8 g – 1.2 g/100 g of protein. The next one is cysteine – 1.2 g/100 g and threonine – 3.2–3.8 g/100 g of protein. Therefore, it is advisable to enrich compound feeds containing faba bean with synthetic methionine (Gous, 2011).

Pea (*Pisum sativum*)

The cultivation of field pea in Poland has a long tradition. As a valuable high-protein plant, it is characterized by a diversity of its varieties and their suitability to use for various purposes (food and feed: dry seeds and green forage). Pea, similarly to faba bean, is characterized by very good yielding. Constant progress in cultivation, agricultural science, as well as growing new varieties results in an increase in the obtained yield and quality of seeds. However, they depend on soil factors and fertilization (Jaskulska et al., 2011). In the opinion of Gugała and Zarzecka (2009), the yield of seeds depends on such factors as: sowing density, plantation maintenance practices and climatic conditions prevailing during the growing period. In 2006, the average pea yield amounted to 1.9 t/ha to 2.6 t/ha in 2011 (Florek et al., 2012). This allows to promote the cultivation of this fodder plant and provides the possibility of using it in the feed industry, including in compounds for poultry. According to Klimek-Kopyra et al. (2017), selection of the right variety has an impact on the stability and profitability of pea cultivation. In the cultivation conditions prevalent in the Podlaskie Province, 'Turnia' is the best-yielding field pea variety and the 'Muza' variety yields the worst (Puczel, Borusiewicz, 2015). Meanwhile, Szpunar-Krok et al. (2012), when testing other varieties of pea in the conditions of the Podkarpackie Province, recommend that pea strains 1332 and 1331, which were characterized by the highest seed yield and protein content, be cultivated in this region. Pea is a protein raw material, whose cultivation may be an alternative to post-extraction soybean meal (Gugała, 2008). In addition, it is possible to separate seeds according to their quality and to obtain seed fractions with a higher protein content, which are more useful in animal nutrition, as in the case of seed selection (Jadwisieńczak et al., 2014).

A great advantage of pea from the point of view of effective animal nutrition is its relatively low content of anti-nutrients, which means that it can be used to a wider extent than other species of legumes. The harmful substances present in pea are mainly tannins and trypsin inhibitors. The content of tannins depends on the variety: the seeds of white-flowering varieties contain significantly less of them than the colourful varieties (Canbolat et al., 2007), thanks to which they are characterized by a higher level of nutrient digestibility. At the same time, as noted by Proskina and Cerina (2017), the use of pea in compounds for broiler chickens has not only a nutritional but also an economic justification.

Pea seeds contain an average of 21.9–29.6% crude protein in dry matter of a favourable amino acid profile and content of exogenous amino acids: 8.0% lysine, 1.0% methionine and 1.4% cysteine (Witten et al., 2015; Červenski et al., 2017). The total protein content depends on the variety (Barac et al., 2010) but also on the cultivation and fertilization conditions (Szwejkowska, 2005). The reserve proteins in these seeds are albumins, globulins and gluteins. In the future, however, thanks to the achievements of genetics and the identification of important genes, it will be possible to influence the variation in the protein content to increase the content of the ingredients that will have a higher digestibility (Le Signor et al., 2017). The ability to define molecular markers may accelerate the advancement in the cultivation of pea varieties with the purpose of obtaining improved varieties, better suited for animal nutrition, including by affecting the amino acid profile (Gallardo et al., 2017). Pea seeds may also constitute an energy raw material in poultry compounds, due to their highest content of metabolizable energy among all the seeds of leguminous plants (Smulikowska, Rutkowski, 2005). The content of starch and, to a smaller extent, fat is determined genetically and depends on the variety (Vasilenko et al., 2017). In comparison to other leguminous seeds, pea has the lowest content of protein and fibre in its composition, while, at the same time, it also contains the high energy (12.3–12.8 MJ/ kg).

As in the case of faba bean, pea varieties are characterized by a wide diversity in terms of their use in fodders. Wang and Daun (2004) observed a significant variation among the cultivars of this species, associated with the content of macro- and micro-nutrients such as: potassium (K), calcium (Ca), phosphorus (P), manganese (Mn) and copper (Cu). The content of other elements: iron (Fe), magnesium (Mg) and zinc (Zn) was affected by the cultivation conditions. According to these authors, cultivation conditions and fertilization had a significant influence on the content of alanine, glycine, isoleucine, lysine and threonine. The researchers also noted a positive correlation between the total protein content and the content of ADF, NDF, Fe, Mg, Zn and arginine in seeds. On the other hand, a negative correlation was recorded between the content of glycine, histidine, isoleucine, lysine, threonine and the total protein content.

Individual pea varieties differ in terms of their content of trypsin inhibitors, but also the content of vitamins, inter alia B1 and B2 (Vidal-Valverde et al., 2003). The content of tannins also depends on the pea variety (Canbolat et al., 2015). The nutritional value of pea seeds is also influenced by climatic and soil conditions, apart from the content of starch, which is fixed, except for slight deviations (Nikolopoulou et al., 2007).

Due to the significant demand for poultry feed and the ever-growing production of broiler chickens, as well as, although to a lesser extent, laying hens and other poultry species, pea grown for fodder purposes will be used with this group of farm animals in mind. For this reason, research is being conducted both in Poland, as well as in other EU countries, to determine the level and applicability of different local pea varieties in poultry nutrition.

As proven by Gabriel et al. (2008a), the digestibility of amino acids in the seeds of eight different pea cultivars, tested in in-vitro conditions, varied. In the case of 9 amino acids, the mean loss values ranged from 3.6 to 5.4%, with the highest value for threonine (8.0 to 11.0%). The mean actual digestibility ranged from 84.4 to 90.2%, with the highest values for lysine (89.0 to 95.0%), and the lowest for isoleucine (81.0 to 88.7%) and valine (82, 4 to 88.7%). As proven by Gabriel et al. (2008b), the mean apparent digestibility of amino acid was negatively correlated with the activity of the trypsin inhibitor in a given variety and the higher content of legume protein. In contrast, a positive correlation was demonstrated between higher digestibility and higher albumin content.

McNeill et al. (2004) evaluated the effectiveness of using pea at a share of 10 and 20% in the feed for broiler chickens. The feed intake obtained by them was at the same level as in the control group and the group which was given a feed with a 10% share of pea seeds. In the group with the higher share of pea seeds, a significant drop in the consumption of compounds was noted. The chickens' weight gain was similar in both the experimental groups. In turn, Diaz et al. (2006) applied a much higher pea share amounting to 30% in a feed for chickens without noting its negative impact on production outputs.

Thacker et al. (2013) tested the usefulness of feeding slaughter chickens a traditional pea variety, as well as one, whose phytate content was low. The purpose of the research was to use new varieties and increase the use of phosphorus. The total apparent availability of phosphorus was higher in the case of the dose containing peas, whose phytate content was reduced. In this case, the protein source had no effect on the weight gain and feed use. Increasing the availability of phosphorus in pea may mean that less inorganic phosphorus would be required to meet the nutritional requirements of broilers.

Pea seeds may also constitute a protein component for laying hens. The introduction of up to 20% of pea seeds supplemented with an 8% share of post-extraction rapeseed meal may replace post-extraction soybean meal (Rutkowski et al., 2015). Similarly, Halle (2017) considers the synergic use of both these components in a feed for laying hens to be justifiable. According to Ciurescu and Pana (2017), there is no need for supplementation in a dose of enzymatic agents because the authors did not record any significant differences in the production outputs or the quality of eggs between the control and the experimental group. The introduction of pea did not affect the quality of eggs. Koivunen et al. (2015) consider the introduction of a share of up to 300 g/kg peas into a fodder for laying hens without adversely affecting the laying and quality of eggs to be justifiable. The use of pea seeds in laying hens' nutrition is also an alternative in organic production, related to the ban on the application of synthetic amino acids (Van Krimpen et al., 2015).

Pea seeds may also be used in the production of compound feeds for broiler guinea hens. Laudadio et al. (2012) achieved similar production outputs in birds that were fed pea seeds as a substitute for post-extraction soybean meal as in those from the control group, at the same time improving the quality of the carcass and achieving a favourable lipid profile. Peas may also be introduced into compound feeds for slaughter turkeys (Boroojeni et al., 2018).

Lupine (*Lupinus*)

The cultivation area of lupine for fodder purposes is constantly expanding. Its seeds, depending on the species and variety, have a diverse composition and fodder suitability. Three species of this plant are cultivated in Poland: white, yellow and blue lupine. They contain anti-nutrients such as alkaloids, which, however, are only present in trace amount in the new varieties, the so-called sweet lupines obtained in the course of breeding. Despite its high nutritional value of the protein and the reduced content of alkaloids, the use of lupine in nutrition may be limited by the presence of a significant amount of non-starch polysaccharides, which may account for up to 50% of the total composition (Kocher et al., 2000). Seeds have a high energy content of approximately 14–16 MJ of digestible energy per kilogram (Kim et al., 2009). This is due to the high fat content which, in the lupine species cultivated in Europe, ranges between

6 and 12% (Strakova et al., 2006), of which up to 80% is attributed to unsaturated fatty acids (Uzun et al., 2007). However, Nalle et al. (2011) believe that blue lupine is a good source of protein, but a poor source of AME (apparent metabolizable energy) and sulphur-containing amino acids for broiler chickens. The authors found that when diets are well-balanced with regard to AME and digestible amino acids, lupines may be introduced into compound feeds for broilers in the amount of up to 20% in the starter feed without adversely affecting the growth of birds. Kaczmarek et al. (2016), however, point to the diverse chemical composition of seeds of different lupine varieties and its suitability in the nutrition of broiler chickens. Similarly, Konieczka and Smulikowska (2017) suggest that different varieties of blue lupine may be of different value regarding their practical application in broilers' diet. Hejdysz et al. (2018) recommend yellow and white lupine as a raw material alternative to post-extraction soybean meal, being of the opinion that blue lupine introduced into broilers' diet does not allow for the achievement of the same rearing results as the two previous species.

Soybean (*Glycine max*)

Soybean is considered to be the plant with the highest suitability in animal nutrition as a protein component. After the introduction of the ban on the use of meat-and--bone meal, it became the primary raw material in feeds for monogastric animals. Because it is an oil plant, the by--product of the process of oil extraction in the form of post--extraction soybean meal was acknowledged as cheap and valuable in terms of its fodder application. Despite the fact that animal production in Poland requires the provision of a constant supply of protein raw materials, soybean cultivation in Poland is not of significant economic importance, its cultivation area does not exceed 300 ha in the entire country (Faostat, 2015). This is related to the plant's climate requirements. The required length of the growing period for these varieties amounts to 120–130 days, which makes soybean cultivation significantly more challenging. In addition, it is a short-day plant, which means that its pods mature over the period of late August and early September. In Poland, there are 17 registered varieties of soybean, which may be cultivated in our country's climate conditions. The oldest variety entered into the register of the Research Centre for Cultivar Testing record is Aldana, entered in 1992; it was only after a decade, in 2002, that the next variety, Augusta, was added. The third variety, Mavka, was entered into the register of soybean varieties in 2013, and then in 2015 two more varieties, Aligator and Madlen, were added. A year later, the Abelina variety was registered, and in 2017, as many as six new varieties were recorded – Erica, GL Melanie, Maja, Paradis, Petrina, Sculptor and Viola. These varieties are adapted to growing in Polish climate conditions. Their cultivation suitability varies. Pyziak (2013) conducted research on the yielding of four soybean varieties (Aldona, Aligator, Augusta, Madlen) in Poland, indicating that two varieties: Aligator and Madlen yielded the best, at the level of 37.4 dt/ha, and the remaining varieties achieved significantly lower yields – Aldona 28.7 dt/ha and Augusta 26.7 dt/ha. Such significant differences in yielding indicate the need to select the right varieties in order to obtain rational economic benefits from soybean cultivation. As Adamska et al. (2016) demonstrated, in the case of soybean, the direct income from cultivation without taking grants into account equalled PLN 1078.70, which was influenced by the high yield (2.5 t/ha) and the high sale price of seeds (PLN 1630/t). This is also confirmed by previous studies conducted by Dobek and Dobek (2008), as well as Dobek et al. (2009). This indicates a high demand for this raw material on the market. Raw soybean seeds consist of approximately 20% oil and 40% protein, therefore, they are a valuable raw material, however, due to its high price, it is justified to use this plant in food processing, for the purpose of extracting oil from it. Meanwhile, the by-products of this process, such as: post-extraction soybean meal or soybean cake will constitute a cheap, yet valuable feed component for the feed stuff industry. For the domestic production of soybean seeds to be used effectively in the oil industry, it is necessary that they be of the appropriate quantity and quality, as well as that batches of this raw material be homogeneous. As reported by Brzóska (2017), the minimum production scale that would attract the interest of the oil industry factories in the extraction of soybean oil would be achievable with the annual harvest and purchases amounting to at least 100,000 tonnes of full-fat soybeans. This is the minimum production scale that would make the investment into and adaption of one pressing and extraction line profitable for at least 1 year in the smallest oil factory or for 1 quarter in the largest oil factories in Poland. This would also result in the attainment of by-products of the oil-pressing process in the form of post-extraction soybean meal or soybean cake. In order to obtain 100,000 tonnes of seeds, it would be necessary to provide for the annual soybean cultivation area amounting to 45,000 ha, with a mean yield of 20 dt/ha or 40,000 ha with a mean yield of 25 dt/ha (Brzóska, Śliwa, 2016). At the same time, the selection of varieties suitable in terms of their yielding and seed quality, including oil content, may also have a positive impact on the development of this segment of the food processing industry. According to the study by Jarecki and Borecka-Jamro (2015), the content of fat in seeds and their size is influenced by the soybean variety. Similarly, Biel et al. (2017) indicate that the variety factor influences the chemical composition of soybean seeds. Weather conditions are also of importance because, as noticed by Michałek and Borowski (2006), when the seeds form during a period of drought, their protein content increases.

The use of raw soybean seeds in poultry nutrition is hindered by their content of anti-nutrients. For this reason, an enriching procedure in the form of extrusion is often carried out, which eliminates thermolabile factors. The application of raw seeds in broiler chicken diets caused an increase in the weight of the pancreas (Erdaw et al., 2017a). However, other studies indicate that substituting post-extraction soybean meal with full-fat raw seeds does not have a negative impact on the health of birds (Erdaw et al., 2017b). According to Erdaw et al. (2017c,d), post--extraction soybean meal may be substituted by a meal made from raw soybean seeds in the amount of 20%, if protease is added to the feed. However, it is much more effective to take advantage of the extrusion process when full-fat soybean seeds are used (Zhaleh et al., 2015).

CONCLUSION

In spite of the advantages resulting from their cultivation and use as protein components of compound feeds, the cultivation area of coarse legumes for fodder purposes is still not sufficient, regardless of the ministerial programmes, which are designed to increase their use and reduce the protein deficit of feed ingredients. Among the factors which discourage farmers from cultivating this group of plants, the still low interest from feed factories, variable yielding, but also the restrictions with regard to the use of seeds in feeds, resulting from their content of anti-nutrients, ought to be enumerated. Nevertheless, their use is economically justified and seeds from this group of plants may constitute a partial substitute of post-extraction soybean meal in the future. By introducing the newest scientific and technical advancements into agricultural practice, as well as cultivating new varieties that are more suitable for fodder purposes due to their reduced content of anti--nutrients, technological counselling may bring significant progress in the scope of solving many problems associated with legume cultivation and popularizing it.

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Author	ORCID
Marcin Różewicz	0000-0002-3281-5533
Jerzy Grabiński	0000-0003-0427-9398
Alicja Sułek	0000-0002-9114-8857

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