Polish Journal of Agronomy
2020, 42, 46–50

doi: 10.26114/pja.iung.418.2020.42.06

The importance of grain legumes for a domestic protein security

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Abstract. Soya meal is the main high protein source in feeding pigs and poultry. Taking into account the annual value of domestic import, limited soya seed producers (USA, Argentina, Brasil) and China as the main soya seed importer (66 percent of the world import), a use of alternative protein sources (grain legumes, rape meal, DDGS) seems to be justified. An additional reason for a so called protein security in Poland are the feed regulations prohibiting a usage of GM products in feeding. Polish Government launched research projects for two periods (2011–2015 and 2016–2020) to solve main problems related to increased production and usage of domestic protein sources in animals feeding. Main strategies and research results of four areas – grain legume genetics and breeding, cropping technologies, pigs and poultry feeding and economic aspects of production, market infrastructure and turnover of domestic protein crops – are presented in the paper.

Satisfactory is an increase of acreage under grain legumes in Poland – from 100 thousand ha in 2011 to 300 thousand ha in 2019. At present, given the availability of domestic grain legumes and rape meal it is possible to decrease soya meal imports up to 60–50 percent. Over the past decade, a strong increase of poultry meat production (about 120 percent) with a rather small increase of soya meal imports (about 18 percent) is also as optimistic tendency. A lasting solution may be achieved by setting a national/European indicator target that would put the mandatory share of domestic protein sources in feed mixes at 10–20%, and creation of Polish feed companies, competitive to foreign, both large and mobile feed mixing plants, using the farmer's raw materials.

Keywords: feed protein, soya meal, domestic protein sources, indicator target

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INTRODUCTION

For the production of poultry and pork meat purposes, Poland imports about 2.5 million tons of soybean meal worth about 4–5 billion PLN annually. The world market of mentioned raw material is determined by three major producers (Argentina, Brazil, USA) and China, whose share in the global import of soya seeds amounted to 66% (FAOSTAT 2018). The above facts sufficiently justify taking action for the so-called protein (= food) security on the national level. As in the case of energy resources, diversification and increased use of domestic sources is highly required.

Feed protein is particularly important in feeding monogastric animals – poultry and pigs. The proportion of protein in the feed constitutes several percent (in turkey nutrition even up to 28 percent). World production of poultry and pork meat is approximately 120 million tons each, while annual per capita consumption in various countries ranges from 1 to 50 kg (in Poland the per capita consumption of poultry meat reaches 30 kg and that of pork meat amounts to 50 kg) (acc. to FAOSTAT 2018). Meat production is constantly growing as the population is on the rise and the standard of living is improving in many countries. With an annual production of poultry meat of about 2.5 million t, Poland is considered to be the European leader (acc. to FAOSTAT 2018).

The epidemic of bovine spongiform encephalopathy in the early 1990s (BSE, commonly known as mad cow disease) resulted in a prohibition of the use of meat and bone meal in animal feed. Fortunately, soybean meal, a by-product of seed oil extraction, containing 46% of high-quality protein, proved to be a valuable substitute (Kaczmarek et al., 2014). Soya meal preserved the world's poultry and

pork production, and its market value today stands at three times the value of the main product – oil. Therefore, the world production of soya bean seeds is developing dynamically – in the last five years from 220 million tons to over 350 million tons of seeds per year (acc. to FAOSTAT 2013, 2018).

The paper discusses the importance of alternative sources of protein to soybean meal (Święcicki et al., 2007) and presents the main directions of research carried out in the years 2011–2015 and 2016–2020 within the framework of Multiannual Programmes aimed at increased production and use of domestic protein raw materials in animal feeding (http://www.bialkoroslinne.iung.pl/).

THE SIGNIFICANCE OF ALTERNATIVE SOURCES OF FEED PROTEIN

The worldwide soybean meal market, together with the largest feed companies in Poland, is held by foreign capital. The Feed Act passed in 2006 and amended in 2019 introduced a ban on the use of GMO raw materials in feeding, whereas imported soybean meal originates almost exclusively from American GM cultivars, grown in Argentina, Brazil and the USA. As it is not possible to completely eliminate soybean meal from feed in Poland, a moratorium on implementing this ban is passed every few years, giving time to identify alternative sources of protein (currently until 1 January 2021). Fortunately, in Poland we can use our own protein resources, first of all post-extraction rapeseed meal (Kaczmarek et al., 2019) and pulses (Hejdysz et al., 2019), which to a significant extent, up to about 50% can make us independent of soya meal imports, and simultaneously keep in the country ±2–2.5 billion PLN (accordingly to the results of the above listed Multiannual Programmes, http://www.bialkoroslinne.iung.pl/). The seeds of the domestic, unmodified soybean cultivars still has a potential to be employed. However, it becomes a more expensive source of protein, requiring additional expenses to remove harmful trypsin inhibitors from the seeds. In addition, taking into account environmental requirements, yield and water content of the seeds at harvest and harvest date, current soybean cultivars can only be successfully grown in the southern part of the country. This is suggested by 'Donau Soja', the Association for the Promotion of European Soybean Cultivation. Having regard to the above situation, the Government of the Republic of Poland, with significant support of the Agriculture Committee of Polish Parliament, has twice, in the years 2011–2015 (Council of Ministers Resolution No. 149/2011) and 2016–2020 (Council of Ministers Resolution No. 222/2015) adopted the financing of comprehensive research projects, the so-called Multiannual Programmes, covering the most important challenges of increased production and use of domestic protein products in animal feeding.

The results of the research should contribute to the improvement of legume cultivars, the profitability of production (new cultivation technologies) and the application of domestic protein sources in animal feed. The development of economic issues related to the market and trade of legume seeds was considered highly important.

The extent of the research of both Multiannual Programmes (2011–2015 and 2016–2020) was divided into four thematic areas, coordinated by the Institute of Plant Genetics of the Polish Academy of Sciences and the University of Life Sciences in Poznań with the implementation of individual grants/subprojects in several other scientific centers – institutes of the Polish Academy of Sciences and departmental and university institutes. The whole of the Multiannual Programmes is coordinated by IUNG PIB in Puławy (http://www.bialkoroslinne.iung.pl/).

LEGUMES AS A SOURCE OF PROTEIN

Legume seeds (lupins, faba beans, peas, soybeans grown in the country) are likely to replace imported soybean meal to a significant extent, provided they are grown as high yielding cultivars, with a reduced content of anti-nutritional substances and adapted to environmental conditions and modern cultivation technologies. Across a broad range of research issues that need to be clarified in order to increase the stability and quality of the yield of high-protein legumes, those related to physiological processes that determine the resistance of plants to drought and tolerance to frost and the efficiency of water and nutrient use should be mentioned. Leguminous species, especially faba beans, lupins and peas, have a high yield potential. Regrettably, during the development of the plants, pods are formed only from a limited part of the flowers (the so-called blossom fall). Knowing the causes, regardless of genetic or physiological nature, would eliminate this defect and contribute to a significant increase in cultivar productivity (Wilmowicz et al., 2018, 2019).

A cultivar is an agricultural asset and its owner holds a proprietary, exclusive right to license the benefits of trade and use of certified seed material. The plant variety breeding is long lasting process and a lot of research is devoted to its shortening and effective selection methods that do not damage the biological material. In the case of legumes, it is very essential to develop methods for obtaining several generations of plants per year, and especially the combination of valuable traits of different species through inter-species hybridization. For some species such attempts have been made (Surma et al., 2013; Święcicki et al., 1999).

The condition for effective selection of improved traits of varieties is to know how to identify the gene/genes that control the trait of interest and to learn in what manner they are inherited. In the field of interest of this specific program were features such as, stiffness of the pea stem, determinate vs. indeterminate manner of growth, low con-

tent of anti-nutritional substances in seeds (alkaloids, oligosaccharides, tannins) and genes that control the formation and maintenance of generative organs (Górynowicz et al., 2014; Wilmowicz et al., 2019). The value of the results thus obtained are proved by their prompt, practical implementation in the applied breeding. For example, the *in vitro* embryo culture method in combination with the single seed descent technique enables the cycle of pea, narrow-leafed lupin and faba bean breeding to be shortened by several years (Surma et al., 2013). Moreover, in the Multiannual Programme, lupin initial materials containing less than 0.01% of alkaloids in the seeds were produced. Research on narrow-leafed lupin showed the possibility of replacing oligosaccharides from the raffinose group with less harmful galactosyl cyclitols. High expectations are associated with the possibility of improving the efficiency of physiological processes via the inclusion of mobile measuring equipment in breeding programs, testing physiological indicators of plants in the field (http://www.bialkoroslinne.iung.pl/).

The research of the Institute of Plant Physiology of the Polish Academy of Sciences in Cracow revealed the influence of some substances (e.g. ASASHI, Zearalenone) on the decreased fall of plant generative organs. Confirmed in practice, the beneficial effect of spraying by these substances can contribute to stabilize the yield of legumes.

THE EFFECT OF MODERN CULTIVATION TECHNOLOGIES ON THE YIELD OF GRAIN LEGUMES

As part of the advances in agricultural sciences, an increase in the world's food production that was more dynamic than the rise in population has been observed since the 20th century. If cereal yields stopped at the level of the mid-20th century (without progress in cultivar breeding and crop management), the cultivation area would have to be tripled for current global needs (Święcicki, Surma, 2002). Moreover, nowadays, apart from food production, environmental protection is crucial. Thus, in developing modern cultivation technologies, the aim is to combine three elements: obtaining high yields with possibly low inputs and limited chemical-treated environment (Święcicki et al., 2012). Here, legumes are an expression of a great advantage. As a result of atmospheric nitrogen fixation by symbiotic root bacteria, legumes do not require nitrogen fertilization and leave nitrogen in the soil for the successive crops. According to Szukała, the benefits arising from the non-application of mineral nitrogen and higher yields of the successive crops in Poland amounted to about 350 million PLN in 2019 (at 300 thousand hectares) (http://www.bialkoroslinne.iung.pl/). And every tonne of mineral fertilizer – from production to field use – requires 1 tonne of diesel (Jensen, 2002). The EU and the Government of the Republic of Poland appreciate the importance of leguminous plants in crop rotation and encourage their production with appropriate subsidies to the area of their cultivation. New technologies, leading to an increase in the area under cultivation and production of legumes and their use in animal nutrition must take into account their biological potential and profitability. Among the specific objectives is the development of technologies that reduce energy inputs and soil degradation in the current crop rotations with a dominant share of cereals, with a concomitant reduction in the occurrence of fungal pathogens, pests and weeds (Szukała, 2019). In the discussed Multiannual Programs the effects of precise sowings and winter cropping possibilities are studied. Experiments carried out in different regions of the country will enable the assessment of natural, production and economic effects of different cultivation practices intensity, and especially the assessment of the permanent impact of reduced tillage on the yield of legumes and economic effects, taking into account their evaluation as preceding crops for other non-leguminous crops. New, simplified technologies are transferred to the practice, ensuring high yields with labour and energy consumption reduced by about 20% (http://www.bialkoroslinne.iung.pl/). The results from monitoring of toxin-forming fungal pathogens colonizing legume seeds will be of particular importance. Their presence in food as carcinogens is more harmful than antinutritional substances or salmonella (EFSA and ECDC, 2017; Hussain, 1985).

GRAIN LEGUMES AS FEED MATERIAL

Domestic protein-enriched feed must be palatable to and used effectively by the animals. Therefore, a separate, particularly important package of studies is devoted to the specific issues, which allow the assessment of the suitability of domestic sources of protein for feeding different animal species and estimate the relevance of usage directions in different types of farms.

Before elaborating the feed formulas, the nutritional value of domestic raw materials, including macro- and microelements content, energy value and digestibility, as well as the possibility of improving the nutritional value through additional technological procedures, and the impact of these raw materials on the functioning of the gastrointestinal tract of animals and product quality had to be assessed. The formulas were to be developed using the real-life values, rather than the tabular ones. The results of animal experiments are very positive. It turns out that the borderline shares of domestic sources of protein in feeds may be significantly higher (by an average of 10 percent) than those recognized so far (Hejdysz et al., 2018; Kaczmarek et al., 2016). Furthermore, for many more parameters assessing the value of feed with domestically-produced protein, similar or higher values (of weight gain, feed intake, or protein digestibility) has been shown to be obtained in comparison to soybean meal. The price of 1 kg of lupine protein (PLN 2.63), faba bean (PLN 2.84) or domestic rapeseed meal (PLN 2.51) is lower than that of soybean meal (PLN 3.40) (according to Agricultural

Market Quotation of Ministry of Agriculture, 2011–2019), lower cost and less feed used to produce 1 egg or 1 kg of meat. In most studies, domestic raw materials represented only a part of the high-protein component of the feed, but compositions in which soybean meal was replaced by a 100% domestic component were also tested. In that case, the best results were reached with yellow lupin seeds, containing more than 40% protein (Kaczmarek et al., 2016).

ECONOMIC CONDITIONS OF PRODUCTION AND MARKETING OF GRAIN LEGUMES

Considerable importance is also assigned to the market – demand, supply of raw material, etc. The economic conditions of production development had to be familiarized with, and thus the demand and supply factors determining its current size and the cost-effectiveness of using domestic protein sources for feed purposes had to be determined. It was also necessary to analyze the existing market infrastructure and the system of trade of indigenous protein plants (Jerzak et al., 2015). On this basis, a model marketing system has been developed, which should ensure both the management of rapeseed meal and the promotion of the development of legume seed production as a source of feed protein. The above-mentioned system is also supposed to enable risk management and stabilization of income of actors involved in production, marketing and use of domestic protein sources. Two models of legume seeds marketing were developed and proposed. The first one is based on a system of integration links of meat production entities using domestic feed protein (intended for small local feed mixing plants and production groups), while the second one assumes the widespread use of domestic protein as a feed component applied in different proportions to imported soybean meal. As an important element of the system, an internet integration platform together with the institution of the "market maker", ensuring smooth commodity trading and market stability has been proposed to introduce. Therefore, further analyses concerned the creation of a model, stimulating the demand for indigenous plant proteins business strategy for the market creator, as well as monitoring the economic and financial effects of entities participating in the indigenous feed protein market (Research Area 5, Multiannual Programme "Increasing the use of domestic feed protein for the production of high quality animal products under the sustainable development conditions", Govermental Resolution No. 222/2005 of 15 December 2015).

SUMMARY

The scope and results of research from the four presented areas of the Multiannual Programmes clearly show the possibilities of increasing the food security of the country through the use of domestic sources of feed protein. The results were continuously transferred to the so-called practice during numerous training seminars. A total of 152 seminars for Agricultural Advisory Centres, producer groups and agricultural schools were organized in 2011–2020 for over 12 thousand participants. At the beginning of the Programme in the years 2011–2015 the area of leguminous crops in Poland amounted to about 100 thousand ha, and all domestic protein raw materials covered about 20% of demand. In 2019 the area increased to 300 thousand ha (about 600 thousand tons of harvested seeds), which together with rapeseed meal may satisfy about 40% of annual demand for fodder protein (http://www.bialkoroslinne.iung.pl/). The farmer has at his disposal high yielding cultivars, profitable cultivation technologies, effective feed formulas, first-processor companies and even a virtual seed store, which acts as an intermediary in purchasing. In the last decade the production of poultry meat in Poland increased by 120% and the imports of soybean meal by only 18% (FAOSTAT 2018). Therefore, domestic fodder protein was used. Unfortunately, attempts to use domestic sources of protein in a significant way meet with a strong reluctance of feed companies with foreign capital, related to soybean meal suppliers. This is a struggle for ± 2.5 billion PLN a year, which these companies may lose as a result of using domestic protein. The paradoxes even take place when legume seeds and rapeseed meal are sold abroad to return to the domestic market in imported feeds. The government should undertake decisive measures, e.g. by stimulating the development of domestic feed companies, both large and mobile feed mixing plants, using the farmer's raw materials. Another solution is to establish the so-called national or even European Indicator Target, i.e. according to a model of rapeseed ester in fuels to determine the mandatory share of domestic protein sources in feeds (Jerzak, Krzysztofiak, 2017). The development of demand for domestic protein may also be significantly influenced by the Act on labelling of food products "without GMOs" in force in Poland since 2020, taking into account the needs of a large part of consumers. For their production, domestic protein from unmodified plants is necessary.

Using domestic sources of protein is not only a Polish concern (Gawłowska, Święcicki, 2007). The European Parliament worked on the strategy for the promotion of protein plants, and in 2018 the European Commission prepared a report on the development of the plant protein market in the EU (Brussels, 22.11.2018, COM (2018) final). The report takes into account the importance of alternatives to soya, EU's own protein sources in different types of feed, e.g. conventional and premium (without GMO). In addition, direct consumption of plant proteins is growing rapidly in Western Europe, considering the environmental benefits of leguminous crops. As stated in the report, the share of feed "without GMO" in poultry nutrition reaches 100% in Sweden and Hungary, 85% in Austria, 49% in Germany (presumably with a significant share of Polish rapeseed meal), and only 5% in Poland.

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received – 25 February 2020
revised – 21 May 2020
accepted – 7 September 2020