Polish Journal of Agronomy
2019, 38, 66-74

doi: 10.26114/pja.iung.389.2019.38.08

Production, use and efficiency of utilising grains of various cereal species as feed resources for poultry production

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Abstract. Poland's accession to the European Union resulted in a change of the livestock production structure. A constant and systematic increase in the poultry production is observed and in this respect Poland is a leader in the production of poultry meat and eggs. A significant increase in the poultry population resulted in the need to supply the animal feed industry with appropriate raw materials for the production of feed for various species and different market destinations. Stable poultry production is associated with economic efficiency and the production of grain, the basic component of compound feed. Improvement in cereal yield and oversupply of grain on the domestic market stimulate the production and increase the poultry population in Poland. Grain has various effectiveness and usefulness as well as restrictions resulting from poultry breed characteristics. This has caused changes in the demand from animal feed industries for grain of particular cereal species.

The current study aims to discuss the issues of growing and using particular cereal species as a raw material base for the production of poultry feed. The work focuses on the main species of feed grains: wheat, triticale, barley, oats, rye and maize. The study also presents the problem of cultivation and utilising those grains for animal feed, with particular emphasis on the scale of production and their usefulness in poultry feed production.

Keywords: cereals, animal feed, poultry, wheat, triticale, barley, oats, rye, maize

INTRODUCTION

Poultry production has become one of the largest animal production sectors in Poland. The production of poultry meat, in particular turkey broiler chickens, geese for fattening and the production of eggs for consumption, cause a steady increase in the population of poultry. The production of poultry meat takes up the leading position in Poland, as evidenced by the dynamics of its growth, share in the overall production, structure of meat and its value (Utnik-Banaś and Krawczyk, 2016). In 2016, it amounted to 11.4 billion PLN and was 12.9% higher than the production of pig livestock (Mroczek, 2018). The steady increase in poultry meat production is determined by the need on the internal market and the constantly increasing demand, as well as the exports of poultry meat to the internal EU market and external markets. Due to the high scale production of poultry meat and its stable markets, Poland achieves a positive balance of meat marketing in the range of 1.9 billion in 2016. The increase in poultry meat production in Poland per year is on average approx. 8.4% (Mroczek, 2017). This trend has continued since Poland's accession to the EU and as a result of this Poland has become a leader in the production of poultry meat. In 2012–2017, Polish foreign trade turnover of chicken products showed an upward trend. In relative terms, the average annual growth rate of chicken product exports was 19.4% (Pasińska, 2018). In the European Union countries, the largest increase in the poultry production was recorded in Poland. This is related to the demand on the internal market as well as to significant exports (Czakowski, 2015). Because of the good quality of Polish poultry products and competitive prices, Poland has been the largest producer of poultry meat in the European Union since 2014, with an average annual production of approximately 2.69 million tonnes (Utnik-Banaś, 2018).

Consumer eggs is another very important direction in poultry production. Eggs are obtained mainly from laying hens kept in intensive systems (cage and barn), which provide the vast majority of eggs available on the market. Thanks to the dissemination of knowledge and technology in poultry production, the seasonality of production has been eliminated, ensuring a constant supply of consumption eggs. The marginalisation of backyard farming

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in favour of the progressive concentration of poultry farms keeping large flocks of laying hens with high genetic potential for egg production resulted in a significant increase in production. An additional group are reproduction flocks, which provide hatching eggs for production of chicks of all poultry species. The effectiveness of the poultry market and its structure is important as it affects many business entities that operate in it (Pasińska, 2015). The economic efficiency of individual poultry production chains, producers of cereals, animal feed and poultry breeders is the basis for ensuring the stability of production and food security of the country as well as the economic growth in the agricultural production sector. Numerous stocks require a solid feed base, whose main raw material is cereal. In 2017, 6,362,000 tonnes of poultry feed was produced overall (GUS, Central Statistical Office of Poland, 2017). The growing demand for feed raw materials, as well as the fluctuations and decrease in yields of particular cereal species due to the occurrence of drought, directly affect the feed prices and profitability of production (Mierzejewski and Lampart, 2018).

CEREALS IN THE FEED BALANCE FOR THE POULTRY POPULATION

The population of all poultry bird species is estimated at around 1.127 billion, 1.112 billion of which are chickens (broilers and laying hens) (GUS, 2017). The production of feed for such a significant group of animals requires ensuring a constant supply of cereal raw materials, which are the main source of the compound feed (up to 60% of the raw material composition). Cereals are of strategic importance for the food economy, they are intended directly for processing into food products (milling, bakery and flour products) and animal feed. Cereal production accounts for 23% of the sales value of the overall food industry (Trajer et al., 2013). The animal population strongly determines the demand for grain as well as for particular grain species. The resources of feed raw materials and the required crop area depend on the scale of production and its intensity. Intensive and large scale production requires a much larger supply of raw materials for the production of poultry feed (Ravindran, 2013). In Poland, animal production is still the dominant division of the market agricultural output, whose needs, including primarily animal nutrition, are subordinated to the quantitative and qualitative structure of the feed production (Kopiński, 2016). The increase in poultry production caused changes in the demand for grain species structure. Cereals less useful in the production of feed for this group of animals recorded a decrease in the area of their cultivation. This involves rye, whose acreage has significantly decreased in favour of triticale and maize (Figura, 2017). Poultry feed has the largest share in the production structure of the industrial feed, which is associated with a significant population of this group of farm animals. The share of compound feeds for poultry in the total production of industrial feed for farm animals varies in individual years; however, it is at the level of 58–66% (Piwowar, 2013). The increase in feed production for this group is also conditioned by a significant reduction in the pig population. The effective use of industrial poultry feed provides an opportunity for further development of this segment of the feed industry (Urban, 2015). Purchase costs and the relation of its price to the price obtained per kg of poultry have a significant impact on the overall costs and are the main element of the profitability calculation of this branch of production. Moreover, these factors can be controlled directly by the poultry producer (Grużewska, 2006). The price of feed is mainly determined by the harvest. Ultimately, many factors affect the size of harvests. Individual years may be characterised by high variability of harvest size, which is associated with agro-climatic conditions, as well as with changes in the farming intensity. Both of these groups of conditions influence the level of yields and the overall balance of cereals in the country (Jaśkiewicz, Sułek, 2017). The conversion of a vegetable protein into an animal protein is possible by ensuring adequate genetic progress in the cereal cultivation (better yielding drought-resistant and disease-resistant species, with higher nutritional value and reduced anti-nutrient content), as well as in the poultry farming. The example of Hungary shows an increase in the efficiency of the cereal feed base where unchanged crop areas accompanied by an increase in the production of broiler chickens. Biological progress in both areas has resulted in a significant increase in poultry feed production with economically limited land resources (Horn, 2018). Drought, which reduces the yield of cereal grain, has been an increasing negative phenomenon in recent years. An attempt to solve this problem is cultivation of drought-resistant species (Rybka and Nita, 2014). Lower grain yield results in lower market supply, which causes an increase in the price of feed. Cereals are the main feed component for poultry and pigs, which determines the economic efficiency of the production, while cattle farming has less influence on the changes in cereal prices (Utnik-Banaś and Żmija, 2016).

According to the latest data from the Central Statistical Office of Poland (GUS), in 2018, the total cereal grain harvest was 31,925,000 tonnes. Wheat constituted the largest proportion of the total production of all cereals (11,665,700 tonnes), while the other species had respectively lower harvests: triticale (5,312,100 tonnes), corn (4,021,600 tonnes), barley (3,793,000 tonnes), rye (2,673,600 tonnes) and oats (1,464,600 tonnes). The harvests and their scale determine the unit price of grain, its economic nutritive value for animal feed. Such situation is unfavourable and negatively affects the economics of poultry production (Koreleski, 1992).

THE USE OF INDIVIDUAL CEREAL SPECIES IN POULTRY NUTRITION

Cereal grains are the basic raw materials in complete compound feeds for poultry, constituting approximately 60–80% of their composition (Smulikowska and Rutkowski, 2018). The six most commonly grown cereals in Poland are wheat, triticale, barley, oats, rye and corn. Despite their analogous chemical composition, the usefulness of individual cereals in feeding particular species and production groups of poultry varies. Modern poultry nutrition utilises precisely selected recipes, taking into account the needs of birds depending on the species, age and market destination, as well as economic efficiency. Cereal grain primarily constitutes the energy component of the feed due to the starch content, which ranges from 39.3% of dry mass in oats to 61.4% in maize. This determines the energy value of cereals expressed in the metabolic energy content, which ranges from 10.65 MJ/kg in rye to 13.94 MJ/kg in maize. Cereal grain in poultry compound feed is not only a basic source of energy, but also provides approximately 30% of protein. The average content of the total protein in cereals ranges from 9% in maize to 14% in naked oats. Cereals contain relatively little fat, i.e. 1.4% in triticale, 1.6% in rye and approximately 2% in wheat and barley. Much higher quantities of this nutrient can be found in maize and husked oats (approximately 4%), as well as in naked oats (almost 7%). The digestibility of cereal grain nutrients is mainly determined by the fibre content. The so-called naked species (barley, oats) contain the least amount of fibre, which is on average 1.2% in barley and 1.6% in oats. The fibre content in hulless cereals ranges from 2.3% in maize to 2.9% in wheat, while in hulled cereals it ranges from 4.8% in barley to 8.9% in oats. In terms of amino acid composition and the content of important exogenous amino acids including lysine, the lowest share is found in wheat and maize grains. Compared to maize, wheat contains 0.5 g/16 g N less sulphur amino acid – methionine. On the other hand, among the cereal species grown in Poland, maize is distinguished by nearly twice as much leucine content. Cereal grains contain substances that reduce nutrient utilisation or that have a negative impact on the health and development of poultry. Anti-nutritional compounds include non-starch polysaccharides, alkylresorcinols and digestive enzyme inhibitors. According to Yin et al. (2001), the variable nutritional value of cereals is primarily caused by the presence of different content of non-starch carbohydrates (NSC) present in the cell walls. The water-soluble fraction of non-starch carbohydrates increases the viscosity of the intestinal content, impeding the diffusion of digestive enzymes, which reduces the absorption of nutrients. According to Saki (2005), wheat and barley are some of the cheapest energy sources for poultry; however, the amount of these cereals in feed should be limited due to the content of β-glucans in barley and arabinoxylans in wheat.

Wheat

In Poland, wheat has the largest scale of cultivation and is of highest economic importance. This cereal has both winter and spring forms. The advantage of growing wheat is that it is extensively used for both human and animal consumption. The area of cultivation of this cereal in 2017 was 2,392,000 ha (GUS, 2018). Thirty-six spring wheat cultivars and 123 winter wheat cultivars exist in the National Register. Wheat grain is characterised by a good fodder value; however, it is considered as a bread grain, and a significant part of the harvest is allocated to food purposes. The intended use of the grain is the basic criterion for selecting the cultivar for cultivation. Different requirements apply to cultivars intended for milling and baking, and different to grains for feed (Sułek, 2017). In both cases, however, significant attention is paid to the level of yield and the total protein content, as well as to the economic efficiency of the crop. The analysis carried out by Sułek and Jaśkiewicz (2015) regarding the concentration and regionalisation of wheat cultivation in Poland revealed that the environmental (climate, soil) and organisational-economic factors are crucial. The main areas of widespread cultivation of wheat are located in the western and northern parts of Poland, which is influenced by higher production intensity and better agrarian structure. According to the quoted authors, the best conditions for wheat production, ensuring higher yields and better quality, are in the Lower Silesian and Opole voivodeships, where the wheat production has developed significantly, supplying larger batches of homogeneous grain. Wheat grain that does not meet the quality requirements, e.g. appropriate protein and gluten content, is intended for feed purposes (Podolska, 2008). The quality parameters to be met by feed wheat include: the content of impurities, moisture content, protein content, sedimentation rate and bulk density of grain. The quality of feed wheat grain varies according to the growing season (Dziura et al., 2017; Belcar et al., 2018). Wheat grain is a universal component of industrial mix feed. As a grain with a relatively low crude fibre content (2.9%) and high starch content, it has a high energy value (12.85 MJ/kg). The protein content of wheat is varied and depends on the cultivar and growing conditions. Nitrogen fertilisation has a particular impact during the heading period (Duncan et al., 2018). Wheat is an important source of energy and, to a lesser extent, of the total protein in broiler nutrition. Amino acids of protein contained in high-protein wheat grains are digested by poultry better than the lower-protein grains (Barteczko et al., 2010). As a result of low protein content and high starch content, wheat grain, like the grain of other cereals, is used as an energy source. The widespread cultivation of wheat in Europe leads to high amounts of grain intended for the production of poultry feed. The grain content can constitute up to 60% of the composition of feed mixes, which covers up to 60–80% of energy and

40% of protein requirement (McNab, 1991). The biological value of wheat grain protein is relatively low due to the low content of lysine and sulphur-containing amino acids important in poultry nutrition. Approximately 70% of phosphorus is in the form of phytin compounds. However, its assimilability increases to an average of 50% when the enzymatic phytase is added. Biotin in wheat is not assimilable, which makes it necessary to supplement mix feeds with a high content of wheat with this vitamin. There are no clear restrictions regarding its content in poultry mix feeds except for the economic aspect; however, using it in quantities exceeding 40% requires an addition of enzyme preparations. This is a result of the presence of pentosans and a much smaller amount of β-glucans, which increase the viscosity of digestive tract content and the viscosity and moisture of animal faeces. Wheat grain is a good component of feed for laying hens. It adds the optimal amount of energy into the feed dose (Barzegar et al., 2019). Wheat is a good substitute for maize grain, which is especially useful in feeding broiler chickens. According to research conducted by Panwar et al. (2016), replacing maize grain with wheat in feed does not adversely affect the production results of broilers, but improves the economic efficiency. When it comes to laying hens, replacing 40% of maize with wheat, along with the addition of enzyme preparation does not adversely affect the quantity and quality of the produced eggs (Ogunleye et al., 2019).

Triticale

Triticale occupies a significant part of the cereal sowing area in Poland. Its sown area was 333,000 ha in 2010, and is currently 1,352,000 ha (GUS, 2018). A large increase in the area of triticale cultivation, which currently constitutes 18.5% of the total area sown to cereals, caused an increase in grain supply, which significantly affects the country's cereal balance (Jaśkiewicz and Sułek, 2018). It has lower soil requirements than wheat with simultaneously better quality and forage usefulness in comparison to rye. Therefore, it is an alternative to rye both in terms of cultivation and forage use (Achremowicz et al., 2014). The obtained grain yield depends on the soil conditions, but also on the cultivars. The results of studies carried out by Noworolnik and Jaśkiewicz (2018) demonstrated that different varieties cultivated on inferior soils reacted with varying degrees of yield reduction. Currently, the COBORU (Centralny Ośrodek Badania Odmian Roślin Uprawnych, Research Centre for Cultivar Testing) register (2019) includes 16 spring and 47 winter triticale varieties. Due to the fact that this grain is grown on a fairly large acreage and its use is aimed mainly for feed purposes, it is a relatively cheap and valuable component of the poultry feed. Triticale has the same content of metabolic energy as wheat, but the individual varieties of this cereal have different protein content in the grain and give a differentiated total yield of protein (Jaśkiewicz, 2017). The amino acid composition of the protein is influenced by agrotechnical factors, including seeding density, as well as weather conditions (Stankiewicz, 2005). Results obtained by Siegert et al. (2017) revealed the effect of nitrogen fertilisation on the amino acid composition of triticale grain protein, but also on the digestibility of amino acids for laying hens. This is confirmed by Zuber et al. (2016), who by using different triticale varieties found a diverse range of amino acid digestibility for laying hens. Research on the possibility of utilising triticale in the feeding of broiler chickens has been carried out for decades; however, there are no unambiguous answers as to the share of this grain in the mixture and its effect on the rearing indexes and carcass quality. Some research results have shown that triticale may be the sole cereal component in mixtures, because when enzymatic preparations are used, it does not reduce the performance of birds (Matyka and Rubaj, 2004; Józefiak et al., 2007). According to Zarghi and Golian (2009), the introduction of 40% triticale to a corn-soy mix does not adversely affect the final weight of broilers and feed consumption per unit of the weight gain. Research by Osek et al. (2010) demonstrates that the use of triticale in broiler chickens as a substitute for wheat or corn, decreases the cost of feeding birds; however, negatively affects the production results of birds (body weight). Triticale can also be used to feed other domestic poultry species. According to the studies on the possibility of replacing maize in duck nutrition with this cereal, no differences in the production results are determined (Arroyo et al., 2014). The grain of this cereal is also used in turkey nutrition. The use of triticale in turkey feed has no negative effect on the growth rate, slaughter performance, and at the same time it has a positive effect on the economic results of birds fattening (Konca et al., 2012). Triticale is also a valuable component of the pheasant feed (Kokoszyński et al., 2018).

Rye

Rye has much lower soil requirements than other cereals. It is willingly cultivated throughout Poland due to the significant amount of poor soil quality classes, as it is able to fully utilise their production potential. Sixty-one varieties of winter rye are entered in the national register of rye varieties. According to the latest forecasts, in the perspective of the next decade, rye will be an increasingly profitable crop in cultivation, and its acreage in Europe will increase (Skarżyńska and Pietrych, 2018). The highest yields can be obtained by cultivating rye on good wheat complex soils. However, due to the economic conditions, rye complex usability classes, from very good to very weak, are allocated more often for the cultivation of this crop. Rye is characterised by high tolerance to soil acidification. It has a well-developed root system. Cultivated on light and permeable soils, where water loss occurs, it achieves hi-

gher yield than other cereals under the same conditions. Soil quality has an indirect impact on the rye yield and climatic conditions are more important. Depending on the amount of rainfall, different crops are obtained at different locations. During a dry summer, the highest yields are achieved on soils of the wheat complex; however, in years with optimal precipitation, good yields are also achieved on soils of the rye complexes. Despite the good amino acid composition of the protein (better than in the wheat protein), the nutritional value of rye is lower compared to other cereals, especially when it comes to its use in feeding young chickens (Silva and Smithard, 2002; Lázaro et al., 2003). It is associated with a high content of non-starch polysaccharides in a rye grain, which causes a decrease in the growth rate and deterioration of feed utilisation in broiler chickens fed with it, and sometimes results in deficiency of vitamins and micro-elements, increased fermentation in the intestines, diarrhoea and increased viscosity of faeces. All symptoms can be observed mainly during the first rearing period of chickens receiving increased amounts of rye meal in the feed. In older chickens (above 3 weeks of age), this component can be used in an amount of up to 20% in the compound feed with the addition of xylanase (Arczewska-Wlosek et al., 2019). The share of rye up to 15% supplemented with a mixture of wheat and corn has a positive effect on the development of the skeleton and tendons of birds, and therefore on their wellbeing (Muszyński et al., 2019). Rye grain can be used as a component of compound feed for laying hens. In the research concerning the possibility of using this component as a substitute for more expensive maize and wheat in an amount of 20–40%, it was shown that it did not negatively affect the weight and quality of eggs (Grabiński et al., 2007). Bederska-Łojewska et al. (2019) indicate the lack of negative effect on laying hens and egg quality with a 25% share of rye in feed except for a lower intensity of yolk colouration. However, the digestibility of rye protein and individual amino acids in laying hens are varied (digestibility range Lys. 35–59%; Met 57–75%; Thr 34–54%; Trp 36–71%) depending on the variety (Zuber et al., 2016). New varieties with a reduced content of pentosans (Kobylyanskij et al., 2017) may have an outlook for a wider use of rye grain in poultry nutrition, but always in combination with supplementation of compound feed of this grain with enzymes that hydrolyse components of non-starch polysaccharides.

Barley

Barley is a crop of great economic importance. The area of cultivation of this cereal increased from 574,000 ha in 2010 to 954,000 ha in 2017 (GUS, 2018). Barley cultivation in Poland shows regional diversity, which is shaped by many factors, including soil quality, level of crop management and the area structure of farms (Leszczyńska, 2015). Winter and spring forms of barley are grown in two variants: hulled and hulless barley. In the national COBORU register, there are 33 winter barley varieties and 81 spring varieties, including one hulless. Barley grain is used for feed as well as in the brewing industry. Grain of husked varieties contains more fibre (over 4%), and in hulless varieties there is four times less of this component, which makes them have greater energy value and better usefulness in poultry feeding. The grain of this cereal is characterised by an energy value from 11.85 (hulled barley) to 12.43 (hulless barley) MJ EM kg^{-1}. The total protein content is approximately 110 g kg^{-1}. Moreover, the raw fat content in barley is 21.00 g kg^{-1}, while the starch content is from 57.5% to 68.7%. In addition to the varietal factor, the feed value is also affected by fertilisation and the cultivation system. Research by Michalak et al. (2003) has shown that the quantity of raw fibre is influenced by the production conditions, i.e. the cultivation system (monoculture, crop rotation) as well as weather factors and the year of harvest. Cultivation of barley in crop rotation increased the concentration of raw fibre. However, there were smaller differences between the varieties. Due to the high content of β-glucan in barley, in order to obtain better nutritional efficiency of this grain, it is necessary to add an enzyme preparation (Perera et al., 2019). The addition of β-glucanase significantly improves the digestibility of nutrients in broiler feeds with barley grain (Lamp et al., 2015). Barley grain can also be used in turkey nutrition as a substitute for wheat and corn. By using barley as the only cereal component or together with triticale, good bird production results are obtained with higher economic fattening efficiency (Konca et al., 2012).

Oat

In Poland, oat grain has long been recognised as a valuable feed material, in particular for horses. Therefore, its acreage was much larger when the domestic population of horses used particularly in agriculture as the draft force was significant. The decrease in the population of this group of animals also resulted in a decrease in the area of oat cultivation from 1,325,000 ha in 2010 down to 492,000 ha in 2017 (GUS, 2018). Currently, 29 cultivars of oats and 5 cultivars of the nacked form exist in the COBORU register. At present, among the poultry species, the grain of this cereal is mainly used for feeding geese. For many years, in Poland, geese have been fed exclusively with oats and water in the last 3 weeks of fattening (from 15 to 17 weeks of age) (Kłopotek and Brzóska, 2018). This way of feeding these birds gives their meat specific sensory and nutritional values. The unsaturated fatty acids contained in oat oil are allocated in the intramuscular fat of birds, and thus constitute their source in the human diet (Brzóska et al., 2017). Whole oat grain is the most effective form of feeding geese compared to powdered grain (Kłopotek, 2018). For other species of poultry, the use of oat grain in the feed is prob-

lematic due to the high proportion of husk, and thus fibre. This means that the digestibility and nutritional value of this grain is lower than in other species. Therefore, it can only be used in small quantities in feeding broiler chickens. It can, however, constitute a separate supplement in the feeding of reproductive flocks of meat hens. When the grain is spilled on the litter, looking for it keeps the chickens occupied and has them move around the building, thus preventing them from getting excessively fat. Obesity of birds in breeding flocks reduces their reproductive performance. The content of husk gives the birds the feeling of satiety as it swells up in the crop. Although husk is a source of fibre, which is an unfavourable feature from the point of view of poultry feeding, it also has beneficial compounds in its composition, including cellulose, which positively affects the water management of the digestive tract of chickens, and improves intestinal motility. Hulless varieties of oats contain more than four times less fibre, more fat and protein, and their energy value is equal to maize's, which means that they can be introduced into mixtures intended for chickens for fattening. However, their yield is on average 30% lower compared to husked oats (Prażak and Romanowicz, 2014). This results in lower economic efficiency and profitability of the crop. Production of one tonne of naked oat grain is 8% more expensive than grains of husked one (Wróbel et al., 1999). Research conducted by Osek et al. (2006) shows that naked oats can constitute up to 40% of the composition of the mixture instead of corn or wheat, because it does not affect the production results and most post-slaughter and quality indicators of broiler chicken meat. The fat content of 40–100 g kg^{-1} means that domestic oat varieties have significantly higher levels of this nutrient than other cereals. Oat fat is rich in unsaturated fatty acids, constituting approximately 80% of the total fat composition. It has more essential unsaturated fatty acids, which results in optimal taste of the meat and a delicate fat texture. An unfavourable feature of both husked and naked oats is the high content of β-glucans – anti-nutritive substances that can cause changes in the morphological structure of the walls of the gastrointestinal tract and can affect the digestibility and absorption of nutrients. Dosage supplementation with β-glucanase enzyme eliminates the adverse effects of these substances (Pranczk and Kosieradzka, 1997). However, thanks to the palatability of oats, as well as the metabolic stimulant properties and good dietary qualities, it is a very desirable component of the mixture for geese and other species of poultry.

Maize

Maize is a grain crop that only recently started being cultivated in Poland. To a large extent, the green mass of this grain was used as silage for cattle. Only since the last decade, owing to the enormous breeding progress, an increase in the sowing of this corn for grain has been observed. The area of cultivation for grain in 2010 was 173,000 ha, while in 2017 it was already 562,000 ha (GUS, 2018). The increased acreage also influences a rise in the acquisition of maize grain and its supply on the domestic market. In the years 2010–2013, maize production increased from 9.23 to 40.4 million tonnes, which was the result of an increase in the sown area by over 400%, and forecasts for 2030 indicate an even greater increase in cultivation and yield (Syp, 2015). Currently, 216 corn varieties are listed in the COBORU register. In addition to wheat, maize is the main cereal raw material for producing mixtures for broiler chickens. Corn grain is the most versatile cereal feed material for poultry of all ages and production groups. It is characterised by a high amount of starch (from 64.5% to 71.5%) and fat – 44.0 g kg^{-1}, and therefore contains quite a lot of metabolic energy, 14.8 MJ kg^{-1}. Moreover, maize grain has a low content of total protein (90 g kg^{-1}) and crude fiber (20 g kg^{-1}). Among minerals, maize grain contains Ca – 0.6 g kg^{-1} and P – 3.8 g kg^{-1}, of which 30% is in a form that is digestible for poultry. The digestibility of organic matter is approximately 85%. Corn is also a source of particularly well absorbed natural xanthophylls, which cause intense yellow colouring of the skin of slaughter birds and egg yolks (Smulikowska and Rutkowski, 2018). Phosphorus in maize is poorly digestible due to the lack of endogenous phytase. Like all cereals, maize has low sodium and calcium content. Therefore, these microelements must be balanced by the addition of components containing them or the addition of a premixes The feed value of individual maize varieties differs. The utilisation of nutrients and energy of maize grain in broiler chickens depends on the variety. Higher content of a given nutrient in grain increases its digestibility (Barteczko et al., 2008). In the case of freshly harvested corn grains, the addition of an enzyme supplement based on amylase, glucoamylase and protease is justified. The addition of these enzymes significantly increases the digestibility of starch and improves the production results of broiler chickens (Yin et al., 2018). Compared to wheat, barley, sorghum, rye and other cereal grains, maize has the highest feed value for poultry, in particular for broiler chickens. Nevertheless, due to the higher price of maize grain, its partial substitution with cheaper wheat or triticale grain is often used (Cowieson, 2005).

CONCLUSIONS

Cereals are the component with the largest share in compound feed for various poultry production groups and poultry species. The use of a particular type of cereal grain depends on its nutritional value and economical efficiency. Maize, wheat and triticale are characterised by the highest usefulness. Other cereal varieties can be used in limited quantities and using enzyme preparations. Only oat is the basic component in goose nutrition. The area of cultivation

and the volume of production to a large extent meet the needs of the feed industry for cereal grains intended for poultry feed mixtures, but also for other species of farm animals, which keeps the grain prices at a stable level. Drought phenomena that reduce crop yields and lower the supply of cereal grains can cause price increases and destabilisation on the poultry market. The situation may then force a partial replacement of wheat, triticale and maize with less valuable cereal varieties in order to reduce the costs of producing mixtures. The current area of cereal cultivation and low, decreasing pig population stimulate the growth of poultry production. Additional stimuli for the development of this branch include a stable price, high internal demand and export of meat and eggs. A supplementary element of support should be the breeding of new cereal varieties with reduced anti-nutrient content, which will significantly facilitate balancing of compound feed formulas.

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received – 8 July 2019
revised – 12 August 2019
accepted – 19 August 2019

Ministerstwo Nauki i Szkolnictwa Wyższego

„Przetłumaczenie na język angielski wybranych prac zgłoszonych do Polish Journal of Agronomy" – zadanie finansowane w ramach umowy Nr 692/P-DUN/2018 ze środków Ministra Nauki i Szkolnictwa Wyższego przeznaczonych na działalność upowszechniającą naukę