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# USE AND IMPORTANCE OF RYE GRAIN IN POLAND

## WYKORZYSTANIE I ZNACZENIE ZIARNA ŻYTA W POLSCE

**Summary:** Rye used to be of great economic importance. The cold winters that existed in the past caused winter cereals to freeze, but rye was characterized by the highest winter hardiness, which is why it provided food for society and eliminated the problem of hunger. For this reason, it was a cereal grown on a large area. Rye grain is a raw material for milling, but is mainly used as a feed raw material. The milder climate observed in the recent years, which is manifested by winters with a short-term drop in temperature to negative values, has made growers more willing to grow other species of winter cereals. Despite the decline in the cultivation area in Poland, it is still one of the leaders in Europe in terms of cultivation area and rye grain production. The supply of grain on the market is the source of raw material for development. From the consumer point of view, the rye grain has a high nutritional value, but the decline in bread consumption per capita is associated with the need to use the excess raw material for feed purposes. The supply of grain on the market significantly exceeds the demand for food purposes. Therefore, it is justified to use excess rye grain for feed purposes, but also to increase the possibility of grain export. Rye can be used to feed various species of farm animals. Its use has numerous advantages, including nutritional value and measurable economic benefits associated with a much lower price compared to grain of other cereal species. However, due to the limitations resulting from the presence of anti-nutritional substances in the grain, it can be used in limited amounts. An innovative direction in the management of rye grain is the possibility of using it for energy purposes.

**Keywords:** rye, economic importance, food use, feed, energy use

**Streszczenie:** Żyto miało niegdyś bardzo duże znaczenie gospodarcze. Występujące dawniej mroźne zimy, powodowały wymarzenie zbóż ozimy, przy czym żyto cechowało się najwyższą zimotrwałością, dlatego zapewniało wyżywienie dla społeczeństwa i niwelowało problem głodu. Z tego względu było to zboże uprawiane na dużym areale powierzchni. Ziarno żyta stanowi surowiec do przemiału, ale w głównej mierze wykorzystywane jest jako surowiec paszowy. Obserwowane w ostatnich latach złagodzenie klimatu, czego objawem są zimy o krótkotrwałym obniżeniu temperatury do wartości ujemnych spowodowało, że plantatorzy chętniej uprawiają inne gatunki zbóż ozimych. Mimo regresu arealu uprawy w skali naszego kraju, Polska pozostaje wciąż jednym z liderów w Europie pod względem powierzchni uprawy i pozyskania ziarna żyta. Podaż ziarna na rynku jest źródłem surowca do zagospodarowania. Z konsumpcyjnego punktu widzenia ziarno żyta ma wysoka wartość odżywczą, jednak spadek spożycia pieczywa na mieszkańca wiąże się z koniecznością zagospodarowania nadmiaru surowca na cele paszowe. Podaż ziarna na rynku przekracza bowiem znacząco zapotrzebowanie na cele spożywcze. Dlatego też uzasadnione jest wykorzystanie nadmiaru ziarna żyta na cele paszowe, ale także zwiększenie możliwości eksportu ziarna. Żyto może być wykorzystywane w żywieniu różnych gatunków zwierząt gospodarskich. Jego wykorzystanie ma liczne zalety, do których zaliczyć należy wartość pokarmową oraz wymierne korzyści ekonomiczne związane ze znacznie niższą ceną w stosunku do ziarna pozostałych gatunków zbóż. Jednak ze względu na ograniczenia wynikające z obecności w ziarnie tego zboża substancji antyodżywczych może je wykorzystać w ograniczonej ilości. Nowatorskim kierunkiem zagospodarowania ziarna żyta jest możliwość jego przeznaczenia na cele energetyczne.

**Słowa kluczowe:** żyto, znaczenie gospodarcze, wykorzystanie spożywcze, pasza, wykorzystanie energetyczne

### Importance of rye in the sowing structure in Poland

Rye is an economically important cereal grown in Poland. According to the Central Statistical Office, Poland ranks 2nd in the world in terms of rye grain production. This is due to the fact that most soils in Poland are unsuitable for growing wheat, or yields are very low and do not cover production costs. In Poland, the largest quantities of rye are used for food, accounting for 40.4% of domestic consumption. About 27.3% is used for fodder, industrial use accounts for 18.8%, 7.8% is used for sowing, while other uses amount to 6.0% of the total national supply (Fig. 1.).

Rye was once of great economic importance. The cold winters of the past caused winter cereals to die out, with rye

having the highest winter hardiness. For this reason, it was cultivated over a large area of land. An additional advantage in favour of rye cultivation in Poland is its lower soil requirements, which, combined with the predominance (around 60%) of poor soils, predisposes this species to a much wider cultivation [17]. The climate mellowing observed in recent years, symptomatic of winters with short-lived temperature reductions to negative values, has made growers more willing to cultivate winter wheat, which yields more profit. This is indicated by the noticeable trend towards a decrease in rye acreage relative to the 1980s and 1990s. The analysis of the rye grain harvest shown in Fig. 2, indicates fluctuations in rye grain production. The most recent data from 2022 showed that 2381 thousand tonnes

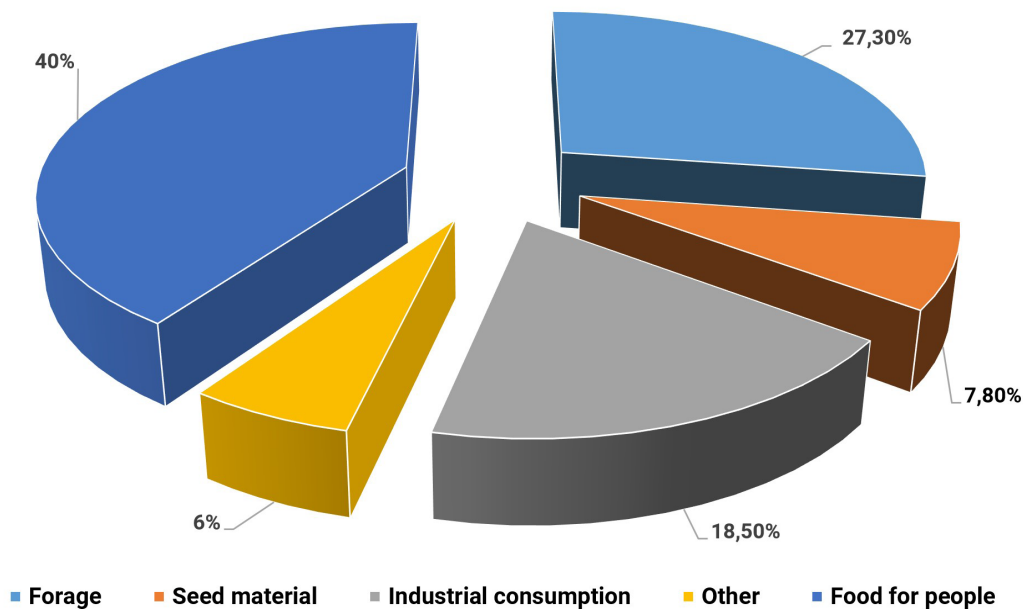


Fig. 1. Rye grain consumption in Poland (%)

were produced then, and this was slightly lower than the 2014-2022 average. The annual value of rye grain production was 0.8 billion in 2022, which ranked this cereal in penultimate place (Fig. 3). Opportunities should therefore be sought to develop the cultivation and use of this cereal grain. Despite the regression in the acreage cultivated in our country, Poland is still one of the leaders in Europe in terms of acreage cultivated and rye grain harvested. However, the reduction in rye acreage resulted in a decrease in the share of global grain production of this cereal from 23.9% in 2010 to 18.7% in 2021 [30], indicating a decline of 5.2% over the period. On average, the annual decrease was 0.5% of the decline in rye grain production per year. Germany retained its leading position in rye grain production with a 25.1%

share of global production [30]. Compared to other EU member states, Germany has the leading position, with Poland in the second place. However, a decline in the production share from 39% in 2010 to 31.1% in 2021 is also evident here. Germany is now Poland's biggest competitor for the rye grain production in Europe. It exceeds Poland in terms of grain yield per hectare. In Germany, the average grain yield in 2010 was 4.6 tonnes/hectare, while in 2021 it was already 5.7, an increase of 24%. In Poland, over the same period, the average rye grain yield per hectare was 2.7 in 2010 and 3.2 in 2021, an increase of 19% [30]. The slower increase in rye yield and the decrease in the area under cultivation resulted in a decline in rye grain production in Poland. Progress in rye yield is linked to appropriate agrotechnology, mainly

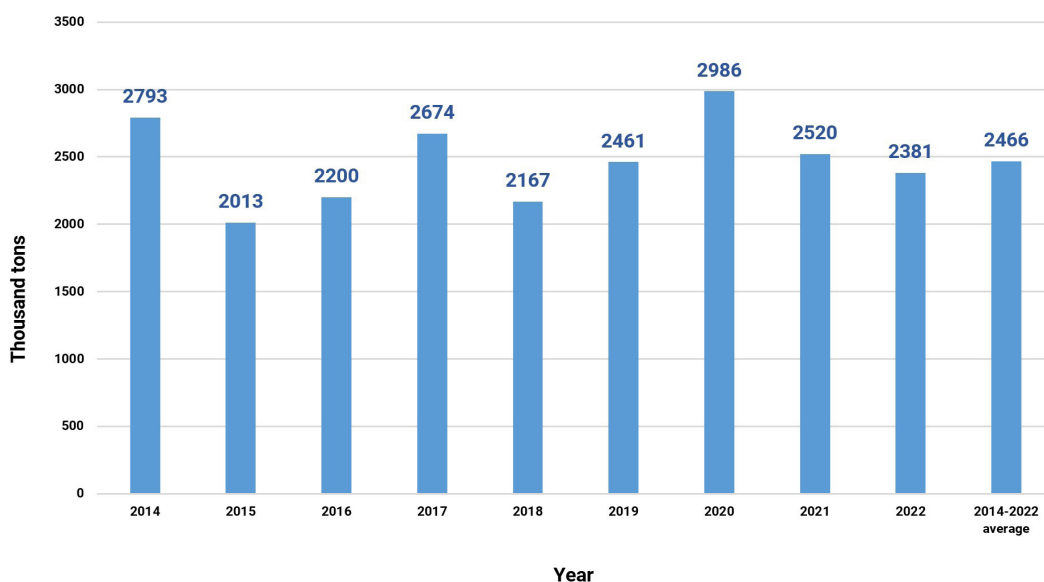


Fig. 2. Rye grain harvest (thousand tonnes) in Poland 2014–2022. (Own compilation based on CSO [30])

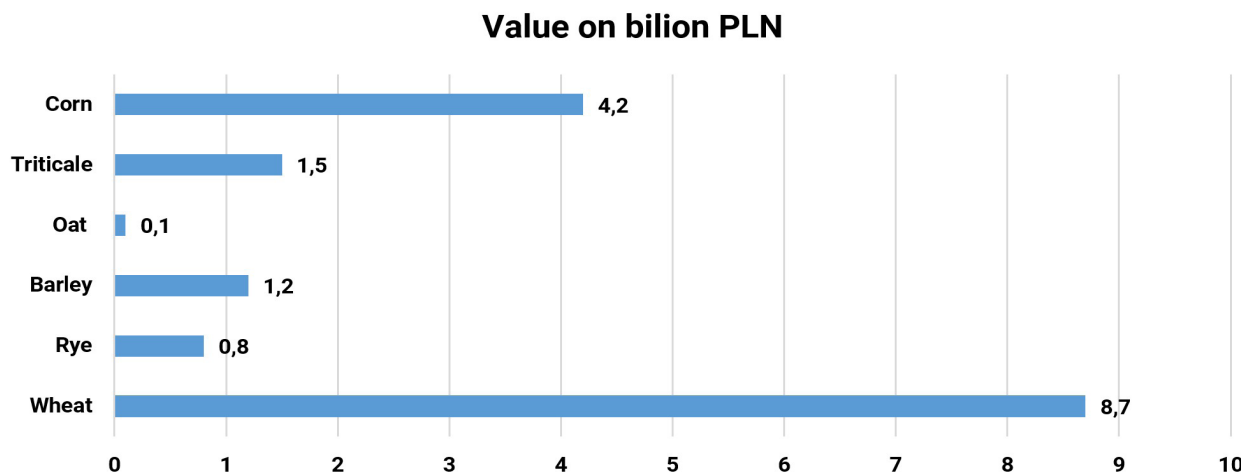


Fig. 3. The value of cereal production in Poland in 2022 in billion PLN (Own compilation based on CSO [30])

fertilisation, as well as breeding progress and the production of higher yielding cultivars. The breeding of new cultivars aims to increase grain yield and quality by using cultivars with stable yields under variable climatic conditions [6]. The breeding progress related to the selection and production of new cultivars is expected to account for 32–41% of the share [40], with the remainder being appropriate agrotechnology and weather conditions. A particular direction of progress in breeding cultivars with high yield potential is to obtain hybrid cultivars of rye [13, 22]. The heterosis effect occurring in hybrid cultivars allows higher grain yields to be obtained, resulting from higher ear density [8, 28, 41]. Higher grain yield and better grain quality are influencing the increased interest in the cultivation of hybrid cultivars. Especially in Western European countries, there is a considerable interest in the cultivation of hybrid rye cultivars, which account for 81% of total rye grain production, with population cultivars making up the remainder [15]. A decrease in the pig population, for which rye is the main feedstock, is also not insignificant for the decrease in cultivation acreage. The supply of grain on the market is a source of raw material for management. From a consumption point of view, rye grain has a high nutritional value, but the decrease in per capita consumption of bread is linked to the need to manage the surplus raw material for feed purposes. Indeed, the supply of grain on the market significantly exceeds the demand for food purposes. It is therefore reasonable to use surplus rye grain for feed purposes. Rye can be used in the feeding of various livestock species. Its use has numerous advantages, which include its feed value and the tangible economic benefits associated with its significantly lower price compared with grain from other cereal species. However, due to the limitations arising from the presence of anti-nutritional substances in the grain of this cereal, it can only be used in limited quantities.

### Food uses of rye grain

Rye grain is an important processing raw material, used mainly for the production of pasta and baked goods, but also processed into cereal flakes. Products made from rye grain

introduce many valuable health-promoting nutrients into the human diet. Rye is the species with the highest content of bioactive compounds among cereals, which makes it a very valuable component of our food. Among commonly consumed cereals, this species contains the most dietary fibre, as well as phenolic acids and alkylresorcinols [12]. It also contains many other active compounds that positively affect human health which include minerals, antioxidants, vitamins, phytoestrogens and polyphenols [9]. The most commonly consumed product, and at the same time a source of these valuable substances, is rye bread [4]. Rye grain contains biologically valuable protein that contains essential amino acids, mainly lysine. Rye flour, like the grain, has a high nutritional value, which depends on the fineness and purification of the grain from the fruit and seed coat. Whole-milled rye flour is a source of fibre, superior to wheat flour in this respect. It is characterised by a higher content of fructo-seed coat and aleurone layer, as well as a higher content of protein, vitamins (especially B vitamins) and minerals (iron, phosphorus and magnesium). Fibre is also recognised as an important dietary component. Its content in rye grain depends on the cultivation method [21]. The fibre fraction is dominated by pentosans (arabinoxylans) and betaglucans, which have beneficial effects in human nutrition, in contrast to their use in animal nutrition. Rye, with its high arabinoxylan content, and the flour produced from it contain significant amounts of tocopherols (vitamin E derivatives). The unique properties of rye arabinoxylans predispose the cereal as a valuable component of the daily diet [7]. Wholemeal rye flour is used to bake wholemeal bread, which contains an increased content of health-promoting substances [34]. Another important criterion guiding consumers in their choice of food products is their calorific value, which in the case of rye is the lowest compared to other cereals. In addition, the acid fermentation process that rye dough undergoes releases greater amounts of calcium than wheat dough [20]. Rye bread retains its freshness and consumability much longer [35]. In addition, rye bread is also characterised by the most elastic and resilient crumb, which is a desirable quality characteristic for consumers.

In addition to the strictly food use of rye grain, it can be used in the distilling industry. Currently, more than 70% of the spirit produced by domestic distilleries is obtained from rye [27]. Rye grain is characterised by a high carbohydrate content, of which starch accounts for around 60%. This enables a high yield and efficiency in the alcohol production process [39]. Spirits produced from the raw material rye grain are of very good quality. It contains a small amount of undesirable compounds such as aldehydes (0.07g/dm<sup>3</sup> on average). The final quality of the final product, however, depends on the quality of the grain. If it is of poor quality, overgrown or infested with mould fungi, the crude spirit obtained contains excessive amounts of aldehydes and organic acids [33].

## Use for fodder purposes

Cereal grain is an essential component of compound feed formulations for livestock. It is a valuable component which, due to its high starch content, significantly increases the energy value and energy concentration of the feed. In general, domestic cereal grain production secures the raw material base for the production of compound feeds. Of the cereal species grown, rye is characterised by the lowest net price per tonne. The net exchange price relationship in Poland is much more favourable for rye, as the cost per tonne is only 73 per cent of that for wheat. For the price relationship between rye and triticale, the net purchase cost of 1 tonne of rye is approximately 81 per cent of the value of 1 tonne of triticale. It therefore makes economic sense to use rye grain for feed purposes. It has a more favourable amino acid composition of protein, which translates into a higher feed value for rye. The livestock population determines the demand for grain, as well as for a particular cereal species. The fodder resources and the required cultivated area depend on the scale of production and its intensity. Intensive and large-scale production requires a much larger supply of feed raw materials, especially for poultry [29]. In the recent years, poultry production has become one of the largest animal production sectors in Poland. Both the production of poultry meat, in which the rearing of turkey broiler chickens and the rearing of table eggs plays a major role, means that the production of poultry feed is constantly increasing. Hence, the use of rye as a cheaper feed component compared to other cereals, especially when it comes to feeding young broiler chickens, is justified [18, 32]. The negative aspect is the high content of non-starch polysaccharides, which results in reduced growth rate and deterioration of feed utilisation in broiler chickens, and sometimes in vitamin and micronutrient deficiency states through reduced bioavailability and increased faecal viscosity. All symptoms can be observed mainly in the first period of rearing chickens receiving increased levels of rye middlings in the feed due to their pentosan content. Their level is similar to that of wheat, while the amount of  $\beta$ -glucans is significantly lower than in barley. Rye grain has a higher content of trypsin inhibitors, whose antinutritional effect is based on the formation of inactive complexes with digestive enzymes, which reduces the utilisation of protein by the body and ultimately leads to growth inhibition in young animals. This limits

the wider feed use of this cereal [38]. Newer rye cultivars contain lower levels of these compounds comparable to their content in triticale. The tannins contained in rye, which belong to the tannins, are also anti-nutritional substances. They form permanent bonds with proteins, making them difficult to digest and utilise by animal organisms. However, rye has the advantage of a higher degree of resistance to fungal infestation and mycotoxin contamination [36]. To a lesser extent, it is also affected by the threat from the red mace (*Claviceps purpurea*), known as ergot, whose spores on the grains have been a cause of poisoning in humans and animals.

Rye grain can be used in laying hen feed, as in the studies conducted on the possibility of using this raw material in recipes as a substitute for more expensive maize and wheat at a rate of 20–40%, it did not adversely affect egg weight and quality [10]. Mikulski and Jankowski [23] draw attention to the form of grain used in laying hen feeding. When using grain middlings, a higher proportion of rye can be used in laying hens' diets than when whole grain is used. Bederska-Łojewska et al. [2] indicate that there is no negative effect on laying hen performance and egg quality with 25% rye in the feed apart from lower yolk colour intensity. However, the digestibility of rye protein as well as individual amino acids in laying hens varies (digestibility range Lys. 35–59%; Met 57–75%; Thr 34–54%; Trp 36–71%) depending on the cultivar [42]. However, the use of rye in feed for young broiler chickens is difficult. Even a small proportion of it in the feed mixture negatively affected weight gain. In older chickens (over 3 weeks of age), this component can be used up to 20%, with the addition of the enzyme xylanase [1]. The proportion of rye up to 15%, supplemented with a mixture of wheat and maize, has a positive effect on the development of the skeleton and tendons of the birds, which is beneficial for their welfare [25]. When using rye in poultry nutrition, the species of birds should also be taken into account. In the case of geese, the use of rye in the feeding of these birds does not adversely affect the pre-slaughter body weight and has a beneficial effect on some meat quality traits compared to feeding oats to geese [19]. The prospect of a wider use of rye grain in animal nutrition may be the use of new cultivars with reduced pentosan content [16]. Reducing the pentosan content in rye will allow increasing the level of grain in feed, without negatively affecting poultry performance. Due to the varietal variation associated with the content of these substances, the grain of some modern rye cultivars may have a higher feed value [31]. Rye grain of hybrid cultivars can be used in poultry nutrition in a higher proportion than population cultivars [11, 14, 24].

The use of rye grain in feed for young monogastric animals, mainly pigs, is difficult. However, the use of enzyme preparations in feed makes it possible to use this grain as a component in feed, as well as to increase its level. In older animals, however, it is possible to use it more effectively without compromising fattening performance at 30–60% in the feed. Rye grain is also used as concentrate feed for ruminants (cattle, sheep, goats). It is used in its milled form and added to feed in various animal feeding systems. The addition of rye grain increases the energy value of the feed and promotes higher milk yields. It can make up to 40% of the mixture. At the same time, as a widely available raw material on the market and much cheaper than other cereals, it contributes to

better economic indicators for milk production. For beef cattle, rye grain can have a higher proportion of up to 60% in the ration. Rye can also replace oats to a certain extent in the horse feed ration. However, its high proportion has consequences in terms of the occurrence of colic, so it cannot be used in the feeding of foaling mares and youngstock because it causes constipation and colic. Once accustomed, 3–6 kg of rye can be fed to working horses in the form of moistened chopped middlings or whole grain previously soaked.

### Energy use of rye

European Union policy imposes an obligation on the member states to use raw materials from renewable sources for energy purposes. Under Polish climatic and economic conditions, raw materials of plant origin are becoming more important. A new trend currently observed is the use of cereal grain for energy purposes – the production of bioethanol. The anticipated increase in demand for biofuels will be a factor in the further growth of cereal processing for industrial purposes. The processing of cereals for this purpose may increase from about 5–6% to over 10% of the total cereal stock in Poland [37]. In this context, rye grain that does not meet the quality requirements for milling and bakery and feed processing can be used for energy purposes. This applies to low-quality grain, largely infested by fungal diseases and contaminated with mycotoxins. However, the grain is a valuable raw material for bioethanol production [5]. It is extracted from agricultural renewable raw materials and then used as a fuel additive. The production of bioethanol from grain entails the benefit of obtaining waste products that can be reused. In the bioethanol production process, by-products are produced – dried distillers' broths (DDGS), which are increasingly used as substitutes for post-extraction soya meal. Hybrid cultivars of winter rye, which provide significant amounts of both fresh and dry biomass, can be used for biogas production [26]. Biogas derived from rye is unlikely to compete with biogas from winter rape due to the higher energy efficiency of rape – in the order of 43.1 GJ·ha<sup>-1</sup> [3].

### Final conclusions

Winter rye is a cereal with low soil requirements, which, given the high proportion of low-quality soils, is a factor predisposing this species to cultivation in our country. Another advantage of rye grain is that it can be used in many ways, both for baking, fodder and energy purposes. The grain of this species is characterised by its high content of many health-promoting substances. Despite the decline in the consumption of bread in general, wholemeal rye is becoming increasingly popular. As a feed raw material, despite certain restrictions due to the content of anti-nutritional substances, rye grain can be used as a feed component for various groups of livestock. Its advantages are the availability of domestically grown grain, its constant supply and its low price. This translates into tangible economic benefits by reducing the unit cost of feed. Grain that does not meet quality requirements can be used for energy purposes.

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