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Economic efficiency of the production of fatteners fed blue lupine as a replacement for GM soybean meal

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The aim of the study was to estimate the basic production parameters and economic efficiency of fattening pigs when GMO soybean meal is replaced with increasing proportions of blue lupine, as a native Polish plant source of protein. The experimental material comprised 50 fatteners divided into a control group (C) and four experimental groups (E1, E2, E3 and E4), with 10 pigs per group. Basic fattening parameters, i.e. daily weight gain and feed consumption per kg of body weight gain, were very good: 1201–1272 g and 2.35–2.59 kg/kg, respectively. These parameters were slightly better in group C than in the experimental groups. Comparison of the costs incurred and revenue obtained showed that the production of fatteners was found to be unprofitable, assuming market prices for the feed materials used, including lupine seeds. The financial result was a consequence of market determinants independent of the producer. The use of unprocessed lupine seeds as a replacement for GM soybean meal in fattening pigs proved to be clearly unprofitable.

KEY WORDS: fatteners, nutrition, replacement for GM soybean meal – blue lupine, production efficiency

Genetically modified soybean meal is the primary protein raw material used in compound feed for pigs and poultry. Although the latest scientific research shows no negative impact of first-generation GMO plant-based feed on animal health (de Vos and Swanenburg, 2018) or products obtained from livestock (Świątkiewicz et al., 2014), public opinion is often opposed to the use of feed containing GMO materials. Due to high and fluctuating prices of imported soybean meal and the anticipation of a ban on its use from 1 January,

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2021, there is an ongoing search for alternative sources of protein, including vegetable protein (Jerzak et al., 2012; Jerzak, 2015). In this context, it is reasonable to increase the area of legume cultivation for feed purposes (Jerzak and Krysztofiak, 2016). Subsidies for growing these crops provide an incentive (Czerwińska-Kayzer, 2015), which is contributing to the growth of the legume market (Sońta and Rekiel, 2016). Area payments have a significant impact on agricultural income and strongly reduce the income risk of crop plants (Majewski and Wąs, 2009; Bojarszczuk and Podleśny, 2017). In a study by Bojarszczuk and Podleśny (2017), crop subsidies constituted over 30%, while Czerwińska-Kayzer and Florek (2012a) reported nearly 50% depending on the plant, and Bojarszczuk and Księżak (2014) determined that the share of subsidies in the final income reached 90% or more in some cases. Given the demand for feed protein, current plans include a further increase in the area of legume crops while existing subsidies are maintained; an increase in rapeseed protein production; and an increase in the production of protein from dried distillers grains with solubles (DDGS). In total, production of domestic feed protein is expected to increase to about 650 thousand tonnes, which will reduce the import of soybean meal by 50% (Księżak, 2015; Bajer, 2018; Szukała, 2018).

The last decade has seen the implementation of two long-term programmes concerning domestic sources of feed protein. In 2011-2015, the programme 'Improvement of domestic sources of vegetable protein, their production, marketing system and use in feed' was implemented. Currently, the programme 'Increasing the use of domestic feed protein for the production of high-quality animal products under sustainable development', planned for 2016-2020, is underway. Due to the steady growth of animal production in Poland and other European Union countries, an increase in the area of legume cultivation is being promoted, especially in the context of food security (Hejdysz and Rutkowski, 2015; Czerwińska-Kayzer et al., 2016). If farmers are to willingly grow legume crops, it must be profitable; however, as reported by Augustyńska and Bębenista (2019) in their study on soybean and lupine cultivation, the gross margin varies between years. Area payments have a significant impact on agricultural income and strongly reduce the income risk of crop plants (Majewski et al., 2008; Bojarszczuk and Podleśny, 2017). It should be added that legume crops may be unreliable, and varied weather conditions lead to variability in the content of anti-nutrient substances in seeds, which creates problems in the efficiency of their use in animal feeding (Różewicz, 2019).

Significant progress has recently been made in the cultivation of new legume varieties. Legume seeds have increased protein content and reduced levels of anti-nutrients, and their nutritional value and suitability as components of compound feed for monogastric animals – pigs and poultry – have also been improved. The favourable changes in the value of legume seeds, as well as the use of treatment processes, have opened up new perspectives in their use as livestock feed. Breeders and producers of slaughter animals are using domestic sources of protein, such as sweet lupines, peas, and fava beans. Many studies carried out in Poland and abroad have confirmed that the use of moderate amounts of legume seeds in livestock diets has no adverse effect on their basic production parameters (Sońta and Rekiel, 2017).

For producers, profitability is paramount. This applies to both crop production (Czerwińska-Kayzer and Florek, 2012b; Just and Śmiglak-Krajewska, 2013; Jerzak and Krysztofiak, 2016) and animal production (Sońta et al., 2015). Therefore, in the case of livestock production, especially pig farming, farm owners are attempting to gain independence from the industrial feed market wherever possible. One of the solutions is on-farm production of high-protein fodder plants such as legumes.

The price of feed and its consumption per kg of weight gain affects the economic efficiency of pork production. The price of compound feed is determined by the unit cost of the feedstuffs used to manufacture it. The quality and proportions of feedstuffs in compound feed and the growth potential of animals determine the consumption of feed per kg of weight gain.

The aim of the study was to assess the economic efficiency of fattening, taking into account the basic production parameters of growing pigs, when GMO soybean meal is replaced with increasing proportions of blue lupine seeds.

Material and methods

The experiment was conducted on growing pigs receiving a diet n which GMO soybean meal was replaced with blue lupine as a native feed component.

Animals; time and place of the experiment

A total of 50 purchased three-breed weaners (♀ (Landrace × Yorkshire) × ♂ Duroc) were used in the experiment. The animals were divided into five groups of ten pigs each (5 barrows and 5 gilts): control (C) and four experimental groups (E1, E2, E3 and E4). The experiment was carried out at a private piggery in the Łódź Voivodeship. The experiment lasted from 10 November 2017 to 23 January 2018.

Animal housing

All fatteners included in the study were housed in accordance with the applicable regulation (Regulation of the Ministry of Agriculture and Rural Development of 15 February 2010) in group pens with slatted floors (10 animals per pen). Fattening was begun at a body weight of about 33.5 kg. During the fattening period the animals were weighed individually every two weeks, and the date of slaughter was set when the average body weight of the pigs surpassed 120 kg. All pigs included in the experiment were slaughtered at one time.

The animals were under veterinary supervision during the experiment.

Diet

The experimental design is presented in Table 1.

Table 1
Experimental design

Material	Group				
	C	E1	E2	E3	E4
Blue lupine in 1st and 2nd period of fattening (%)	–	5.0	10.0	15.0	17.5
GM soybean meal					
1st period of fattening (%)	15.0	10.5	8.0	5.5	2.0
2nd period of fattening (%)	12.8	8.2	5.6	3.1	–

C – control group, E1 – experimental group 1, E2 – experimental group 2, E3 – experimental group 3, E4 – experimental group 4

Cereals (barley, wheat, triticale, and oats) and blue lupine were produced on-farm.

Compound feeds

Complete feeds prepared professionally on the farm were used in two stages of fattening (Tables 2 and 3). The experiment lasted 10 weeks (1st fattening period – 4 weeks, 2nd period – 6 weeks). The protein component in the diets was GMO soybean meal for the control and the Regent cultivar of blue lupine for the experimental groups. The proportions of lupine and GMO soybean meal are shown in Table 1. Rapeseed meal was also used to prepare the diets for pigs in the experimental groups. All diets provided the same amounts of energy and protein (Grela and Skomiał, 2015). The pigs were fed dry feed ad libitum and had uninterrupted access to water.

Simplified economic efficiency analysis for fattening pigs

A simplified economic analysis was carried out by calculating the difference between revenue (sales of fattening pigs) and the costs incurred for production: weaners, feedstuffs (share of raw materials in feeds × price), water, electricity (cost of grinding and mixing feedstuffs), medicine, and veterinary care.

Prices of feedstuffs (Quotations. Feed Market, Grain Market, 2017, 2018) were used to calculate the unit prices of the compound feeds. Water meters installed in the pig house were used to monitor the animals' water intake and calculate the cost of its consumption. Calculation of energy costs took into account the power of the grain mill and mixer and the time required to grind a tonne of grain and mix a tonne of feed. The price of 1 kg of compound feed and the rate of change (income minus costs) were calculated for the experimental and control groups.

Table 2
Feed material in diets in the 1st period of fattening (%) and price of 1 kg of feed

Material	Group				
	C	E1	E2	E3	E4
Cereals (barley, triticale, wheat, oat)	81.6	78.7	76.0	73.4	70.3
GM soybean meal	15.0	10.5	8.0	5.5	2.0
Rapeseed meal	–	2.5	2.5	2.5	6.0
Blue lupine	–	5.0	10.0	15.0	17.5
Soybean oil	0.4	0.3	0.5	0.6	1.2
Premix – Neomix 600+	3.0	3.0	3.0	3.0	3.0
Price of 1 kg of feed (PLN)	0.98	0.98	1.00	1.01	1.03

C – control group, E1 – experimental group 1, E2 – experimental group 2, E3 – experimental group 3, E4 – experimental group 4

Table 3
Feed material in diets in the 2nd period of fattening (%) and price of 1 kg of feed

Materials	Group				
	C	E1	E2	E3	E4
Cereals (barley, triticale, wheat, oat)	84.7	81.8	79.4	76.8	73.8
GM soybean meal	12.8	8.2	5.6	3.1	–
Rapeseed meal	–	2.5	2.5	2.5	5.6
Blue lupine	–	5.0	10.0	15.0	17.5
Soybean oil	–	–	–	0.1	0.6
Premix – Neomix 600+	2.5	2.5	2.5	2.5	2.5
Price of 1 kg of feed (PLN)	0.92	0.92	0.94	0.96	0.97

C – control group, E1 – experimental group 1, E2 – experimental group 2, E3 – experimental group 3, E4 – experimental group 4

Statistical analysis

Statistical analysis of the results was performed using the IBM SPSS Statistics 21 package. The tables present the means ($\overline{x}$) and standard deviations (SD). The normality of the distribution of variables in the groups was tested by the Shapiro-Wilk test. For parameters with a normal distribution (body weight at the start of fattening and after the end of the first fattening period; weight gain in the first and the entire fattening period; daily gains in the first and entire fattening period), ANOVA was used to compare the groups. In the absence of normal distribution (body weight after the end of the second fattening period; weight gain and daily gains in the second fattening period), the Kruskal-Wallis test was used.

Results and discussion

After the first and second fattening period, pigs from group E3 had the highest body weight (Table 4). The highest average weight gain in the first fattening period was attained by pigs in group E3 and the lowest in group E4 (4.2 kg difference between groups). In the second fattening period, the largest average weight gain was recorded for pigs from group C (control) and the smallest in group E4 (2.2 kg difference between groups). During the entire fattening period, the E3 pigs gained the most weight, while the pigs in group E4 gained the least (5.2 kg difference between groups).

The average weight gain of fattening pigs in all groups and fattening periods was over 1100 g/day (Table 4). In the first and second fattening period and in the entire fattening period, pigs in group E4 had the smallest daily gains. No statistically significant differences ($P > 0.05$) were found between groups in daily gains, although some variation in this parameter was noted between groups. In the first period of fattening, the extreme values were recorded in groups E3 and E4 (difference 149 g), and in the second period in groups C and E4 (difference 49 g). For the entire fattening period, there was a 71 g difference in average daily gains between groups E3 and E4.

The lowest feed conversion rate per kg of body weight gain was recorded in group C; it was slightly higher in the experimental groups (Table 4). Feed conversion in the experimental groups compared to the control differed by 0.16-0.28 kg/kg of weight gain in the first fattening period, by 0.05-0.26 kg/kg in the second fattening period, and by 0.13-0.24 kg/kg for the entire fattening period.

The simplified analysis of revenue and production costs (not including labour and building depreciation) for the control group (C) and experimental groups E1-E4 (Table 5) revealed that the value of the pigs sold was lower in groups E1, E2 and E4 compared to group C (1.6%, 0.4%, and 3.6%, respectively) and slightly higher in group E3 compared to C (0.8%). The costs of purchasing weaners and raw feedstuffs for compound feed were high. The total cost of feed was higher in the experimental groups than in the control group. Total costs incurred in groups E1-E4 were greater than in group C. The difference (revenue minus costs) per sold pig was positive in groups C (PLN 17.9) and E2 (PLN 0.7) and negative in groups E1, E3 and E4 (5.0 PLN; 2.4 PLN; 24.0 PLN, respectively). The rate of change in all experimental groups was negative, with the largest noted in group E4 in comparison to C (Table 5).

Table 4
Results of fattening performance ($\overline{x}$, SD)

Traits		Group					P-value
		C	E1	E2	E3	E4	
Body weight (kg)							
Start of fattening	$\overline{x}$ SD	33.5 1.4	33.1 1.5	33.9 1.5	33.7 1.8	33.4 1.5	0.810
After 1st period of fattening	$\overline{x}$ SD	68.1 3.8	66.9 3.2	68.0 3.2	70.4 3.7	65.9 5.1	0.121
After 2nd period of fattening	$\overline{x}$ SD	125.5 8.7	123.5 5.8	125.1 4.8	126.6 7.7	121.1 7.4	0.483
Body weight gain (kg)							
In 1st period of fattening	$\overline{x}$ SD	34.6 3.7	33.8 2.6	34.1 2.9	36.7 3.4	32.5 3.9	0.098
In 2nd period of fattening	$\overline{x}$ SD	57.4 5.5	56.6 5.1	57.1 4.6	56.2 4.8	55.2 4.8	0.944
Entire fattening period	$\overline{x}$ SD	92.0 8.6	90.4 5.9	91.2 5.1	92.9 7.8	87.7 6.8	0.529
Daily gain (g)							
In 1st period of fattening	$\overline{x}$ SD	1236 132	1207 96	1216 106	1310 120	1161 141	0.098
In 2nd period of fattening	$\overline{x}$ SD	1276 122	1257 114	1269 102	1248 107	1227 106	0.944
Entire fattening period	$\overline{x}$ SD	1260 119	1238 82	1249 70	1272 107	1201 92	0.642
Feed conversion/kg of body weight gain (kg/kg)							
In 1st period of fattening	$\overline{x}$	1,78	2,05	2.06	1.94	2.00	–
In 2nd period of fattening	$\overline{x}$	2,69	2,83	2.74	2.92	2.95	–
Entire fattening period	$\overline{x}$	2,35	2,54	2.48	2.53	2.59	–

C – control group, E1 – experimental group 1, E2 – experimental group 2, E3 – experimental group 3, E4 – experimental group 4

The fattening results were very good – comparable to or better than in experiments by other authors (Zralý et al., 2006; Kim et al., 2008; Smith et al., 2013; Hanczakowska and Świątkiewicz, 2014; Sońta et al., 2015; Degola and Jonkus, 2018). Animals of various genotypes were used in the studies cited, but in all cases pigs from the experimental groups, fed diets containing lupine (including blue lupine) in place of GMO soybean meal, achieved production results comparable to those of the control animals, whose only source of protein was soybean meal. This definitively confirms that legume seeds, including lupine, can be used in compound feed for growing pigs.

Table 5
Simplified calculation of efficiency of production of fatteners

Item	Group				
	C	E1	E2	E3	E4
Revenue					
Number of animals (head)	10	10	10	10	10
Sales of fatteners (PLN)	5271.00	5184.90	5252.10	5315.10	5084.10
Feed consumption					
In 1st period of fattening (kg)	617.4	693.9	700.8	712.3	648.1
In 2nd period of fattening (kg)	1546.6	1604.3	1563.3	1609.9	1627.6
Expenses					
Purchase of weaners for fattening (PLN)	2930.00	2930.00	2930.00	2930.00	2930.00
Feed in 1st period of fattening (PLN)	603.20	678.00	700.60	722.20	667.00
Feed in 2nd period of fattening (PLN)	1419.90	1481.80	1471.70	1543.20	1583.40
Total feed (PLN)	2023.10	2159.80	2172.30	2265.40	2250.40
Water (PLN)	14.80	14.80	14.80	14.80	14.80
Electricity (PLN)	68.50	73.90	74.80	78.40	76.60
Medicine and veterinary services (PLN)	55.40	56.00	53.60	50.40	52.80
Total expenses (PLN)	5091.80	5234.60	5245.50	5339.00	5324.60
Difference (revenue – expenses) (PLN)	179.20	–49.70	6.60	–23.90	–240.50
Rate of change (%)	–	–127.7	–96.3	–113.4	–234.1

C – control group, E1 – experimental group 1, E2 – experimental group 2, E3 – experimental group 3, E4 – experimental group 4

The economic analysis of the results indicates that the costs incurred in groups E1-E4 were greater (differences from 2.8% to 4.6%) than for group C. The highest value of pigs sold was recorded in group E3. The final outcome, expressed as the rate of change, proved to be unfavourable for all experimental groups (E1-E4). Only for group E2 was the unfavourable difference between costs and revenue relatively small.

Legume seeds are a good replacement for GMO soybean meal in the diet of poultry and pigs (Hejdysz et al., 2015; Sońta and Rekiel, 2017; Święcicki et al., 2017). Hejdysz et al. (2015) and Sońta et al. (2015) also indicate that the profitability of production is comparable or slightly better when they are used. However, this question is debatable in the light of the results presented in this study. In an analysis of meat poultry, Hejdysz et al. (2015) showed that 20% replacement of soy protein with legume seeds reduces soy protein imports by 0.24 million tonnes. This approach to the problem provides an economic justification for the use of legume seeds in poultry feeding.

In the present study, the unfavourable financial outcome was significantly influenced by market conditions independent of the producer. Factors dependent on the producer were the genetic value of animals purchased for fattening, the quality of feed used, and housing conditions. All of these were satisfactory (Grela and Skomiał, 2015; Kameczek, 2017), which was confirmed by the very good production results.

Results presented by Majewski et al. (2008) indicate that pig farming has a very high income risk, due to fluctuating selling prices of fattening pigs and purchase prices of production inputs – weaners for fattening and feedstuffs. The results of the present study confirm this problem. In order to limit the negative impact of these factors on economic production outcomes, an attempt can be made at cooperation between producers (horizontal integration) and/or cooperation between the livestock producer and the purchaser (vertical integration) in the pig market (Knecht, 2012).

Fiedorowicz and Sobotka (2013) report that the price of a unit of digestible protein in blue lupine seeds is more than 30% lower than in the case of soybean meal, which in economic terms is a point in favour of lupine seeds as an alternative feedstuff to GMO soybean meal. However, the proposition that replacement of soybean meal with lupine seeds is justified must be confirmed by up-to-date information on price relations between imported and domestic feed materials as well as supply and demand for slaughter animals. This is because there may be changes in the prices of feedstuffs and of pigs for slaughter, as well as short-term or long-term changes in their supply and demand on the market, which affects or will affect the relationship between their prices and production profitability or lack thereof.

Conclusion

Very good production results were achieved in the experiment, confirming the suitability of blue lupine as a replacement for GMO soybean meal in the diet of growing pigs.

The simplified economic analysis of the results, however, was clearly unfavourable in the case of the experimental groups.

In conclusion, the financial outcome was a consequence of adverse market conditions independent of the producer. The use of unprocessed blue lupine seeds as a replacement for GMO soybean meal in pig fattening was unprofitable.

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