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ASSESSMENT OF THE POSSIBILITY OF REPLACING IMPORTED PROTEIN SOURCES WITH ALTERNATIVE DOMESTIC PROTEIN FEEDS IN THE FEEDING OF FATTENER PIGS IN TERMS OF THEIR FATTENING, SLAUGHTER AND ECONOMIC VALUE*

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Abstract

The aim of the research is to evaluate the replacement of post-extraction soybean meal with high-protein plants grown in Poland in the diet of fattener pigs in terms of their fattening and slaughter value as well as production profitability. Peas, faba beans, sunflower meal and hemp and linseed cake were the main source of protein in the experimental group. The experiment was carried out on 60 fatteners of the Puławska breed and lasted 119 days, and the average age at slaughter for both groups was 184.90 days. The body weight on the day of slaughter ranged from 105 to 128 kg (control group) and 105 to 124 kg (experimental group). The study included an assessment of: fattening value, slaughter value (including detailed dissection of the 5 most valuable cuts) and the economic and commercial value of the carcass. Based on the analysis of the results, a positive effect of substituting protein from post-extraction soybean meal with a mixture of domestic protein components was demonstrated. Although the experimental group was characterised by lower daily gains, higher feed intake, and thus a less favourable feed conversion ratio, the cost of feeding these fattening pigs was significantly lower. It was also found that the carcasses of the fattened pigs in the experimental group had statistically significantly lower backfat thickness and higher loin eye height and carcass leanness, which in turn resulted in higher weight of valuable cuts. There was no effect of the feeding modifications on the economic and commercial value of the carcass, however it was shown that feeding fattener pigs with a mixture of domestic protein components in the experimental group increased the profit from their production.

Key words: Puławska breed pigs, protein sources, fattening and slaughter value, economics of production

It is estimated that feed costs in fattening pig production constitute about 70% of the total costs (Kasula et al., 2021).The most expensive ingredient in animal feed is crude protein. Currently, the main source of protein in feed for pigs kept in the European Union countries is post-extraction soybean meal derived from genetically modified plants, imported mainly from the USA, Brazil and Argentina (Davison, 2010; Sieradzki et al., 2018). About 2.5 million tons are imported to Poland every year (Grela and Czech, 2019), with the price of the component rising steadily, which negatively affects the profitability of pig production. Many European Union countries are carrying out a number of measures to reduce GMO feed, especially soy, in the feeding of farm animals (Davison and Ammann, 2017; Florou-Paneri et al., 2014). Research is underway to replace soybean-derived protein with protein from seeds of domestic legumes such as peas, lupins or faba beans (Świątkiewicz, 2020; Szyndler-Nędza et al., 2024). Oilseeds, such as sunflower and rapeseed, are also important in this respect. Rapeseed or sunflower meal is a popular feed ingredient for pigs (Cortamira et al., 2000; Povod et al., 2022; Cheng et al., 2022). Numerous scientific studies also demonstrate the potential use of cake (materials obtained directly after pressing the seeds to remove oil) in pig feeding. As Hanczakowska and Świątkiewicz (2014) indicate, the addition of rapeseed cake and legume seeds can replace 30% of the soybean meal protein in "grower" diets and 100% in "finisher" diets, without negatively affecting growth performance and meat quality. Research by Carellos et al. (2005) suggests that an 8% addition of sunflower cake in pig feeding leads to increased daily weight gain and reduced feed consumption per kilogram of gain. In production practice, these components are used frequently as they allow a reduction in the cost of producing fattening pigs. In addition to rapeseed and sunflower, an increasingly popular oil plant grown in Europe is hemp (*Cannabis sativa* L.). It is undemanding to grow, which has led to the area under cultivation increasing more than fivefold in the last 10 years. Importantly, the plant can be

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used almost in its entirety. From the nutritional perspective, its seeds hold the greatest value, as they are used to extract hemp oil (Klir et al., 2019). The by-product remaining after this process, namely the cake, can be used as a valuable high-protein product (28.1–34.4% protein), applied in both human nutrition (hemp flour) and animal feed (Teterycz et al., 2021). The addition of hemp cake to the feed ration has been shown to increase the milk yield of cows (Karlsson et al., 2010) and the productivity of laying hens (Halle and Schöne, 2013). In contrast, there is a lack of studies on the effect of the addition of hemp oilcake in the feeding of fattening pigs on their performance value.

Among the pig breeds kept in Poland, the native Puławska breed is characterised by very good use of domestic feed. In addition, it easily adapts to local environmental conditions and is resistant to stress factors (Babicz et al., 2016). Compared to other European conservative breeds, it is also characterised by relatively high parameters of fattening and slaughter value (Čandek-Potokar and Nieto, 2019). Therefore, it is assumed that the protein substitutes (legumes and oil plants) of soybean meal used in mixtures for animals of this breed should not have a negative effect on their fattening and slaughter value.

The aim of the research is to evaluate the replacement of post-extraction soybean meal with plants grown in Poland with a high protein (peas, faba beans, sunflower meal and hemp and linseed cake) content in the diet of fattening pigs in terms of their fattening and slaughter value as well as production profitability.

Material and methods

Animals

In accordance with the Act of 15 January 2015 on the protection of animals used for scientific or educational purposes (OJ L 266 15.01.2015), the study did not require approval by the Ethics Committee. Moreover, it was in accordance with Directive 2010/63/EU on the protection of animals used for scientific purposes (EU, 2010).

The experiment was carried out on 60 pigs (30 gilts and 30 barrows) of the Puławska breed with an initial body weight of 27.0±3 kg and an average age of 66±3 days. The animals were divided into 2 groups (C – control, E – experimental) of 30 animals each (gilts to barrows ratio 1:1). Pigs in each group were housed in 6 bedded pens of 5 animals of the same sex.

The experiment lasted 119 days and consisted of two stages (stage I – 21 days and stage II – 98 days). In the first stage, grower feed was provided, and in the second stage, finisher feed. In the feeds of the control group, the main source of protein was soybean meal, while in the experimental group the main source of protein was peas, faba beans, sunflower meal and hemp and linseed cake (Table 1).

The proportion of basic nutrients in the feed samples was determined according to AOAC standard procedures (Latimer, 2019). All the animals had *ad libitum* access to feed and water. Temperature and relative humidity parameters were the same for all groups and remained within the welfare standards (OJ L 56/344, 15.2.2010) for weaners and fatteners.

Table 1. Ingredients (%) and nutritional value of feed

Fattening period	stage I – grower		stage II – finisher	
Groups	C	E	C	E
Ingredients				
wheat	37.00	26.00	26.40	24.00
triticale	30.00	30.00	35.00	35.00
wheat bran	10.00	4.00	13.55	7.75
barley	5.00	5.00	10.00	5.0
soybean oil	1.00	1.30	0.50	0.5
feed limestone	0.60	0.60	0.55	0.55
monocalcium phosphate	0.20	0.20	0.25	0.25
feed salt	0.40	0.40	0.45	0.45
vitamin and mineral premix	2.00	2.00	2.00	2.00
soybean meal	13.80		11.30	
sunflower meal		6.00		4.00
peas		10.00		9.00
hemp cake		10.00		9.00
faba bean		2.5		1.50
linseed cake		2.0		1.00
Content per 1 kg of feed				
dry matter g/kg	885.21	887.84	884.50	886.45
total protein g/kg	170.88	170.09	159.91	160.24
crude fat g/kg	28.24	35.87	22.94	29.76
crude fibre g/kg	31.75	69.06	35.63	63.67
crude ash g/kg	46.13	46.64	39.29	39.68
metabolic energy[1] (MJ/kg)	12.39	13.06	11.27	11.93
lysine (g/kg)	11.52	11.86	10.51	10.66
methionine + cysteine (g/kg)	7.40	7.69	6.83	6.96
threonine (g/kg)	7.62	7.90	6.94	7.05
tryptophan (g/kg)	2.41	2.49	2.21	2.24
Ca (g/kg)	7.00	7.0	4.39	4.49
P (g/kg)	7.67	6.82	7.7	6.89

C – control group, E – experimental group.
[1]Metabolic energy calculated according to the Kirchgessner and Roth equation (1983).

Fattening value assessment

The average daily feed intake (DFI) in each stage was monitored for a group of 5 animals staying in one pen by weighing portions of feed placed in an automatic feeder. The average daily gain (ADG) was monitored individually for each animal. During the experiment, each animal was weighed 3 times (at the beginning; after the end of stage 1 – day 21 of the experiment; and after the end of stage 2, i.e. before slaughter – day 119 of the experiment). The weighing of the animals was carried out by the same farm staff.

The feed conversion ratio (FCR) was calculated for stages 1 and 2 and for the entire experiment by dividing

the daily feed intake by the daily weight gain. In addition, the cost of feeding was calculated for each stage, taking into account the price of 1 kg of feed (specially prepared in the feed mixing plant for the needs of the experiment) according to the purchase price in September 2023, i.e. grower (PLN 1.73 – group C; PLN 1.46 – group E), finisher (PLN 1.82 – group C; PLN 1.58 – group E).

Slaughter value assessment

The slaughter age for both groups ranged from 182 to 188 days. The body weight on the day of slaughter ranged from 105 to 128 kg (control group) and from 105 to 124 kg (experimental group).

The pigs were transported to a slaughterhouse located 87 km away, in accordance with the regulations of the European Community Council (OJ L 3, 5.1.2005). After a 3-hour rest period, the animals were automatically electrically stunned (250 V, 5 A, 2.4 s) and slaughtered in accordance with the technology used in the meat plant, i.e. bleeding by incision of the throat blood vessels.

The weight of the hot carcasses was determined approximately 25 minutes after the start of slaughtering using a scale placed along the slaughter line. Carcass leanness was determined based on measurements taken with the SYDEL CGM device. The measurement was carried out using the loin method (backfat thickness and the height of the eye of the loin measured at point C7, i.e. at the height of the last rib, 7 cm from the line where the carcass is cut into half-carcasses), using the SEUROP carcass classification after 24 hours of cooling at 2–4°C, the right half-carcasses were cut in accordance with the PN-86A/82002 standard. The weight of the primary cuts and the tissues from the detailed dissection of the ham, loin, shoulder, neck and belly were determined on an electronic scale with an accuracy of 10 g.

Based on the weight of the half-carcass, the total carcass weight and both hot and cold dressing percentage were calculated.

Assessment of the economic and commercial value of carcasses

Considering the purchase prices of slaughter pigs according to the SEUROP classification offered by the meat processing plant on the slaughter day (E – 10.27 PLN/kg, U – 9.98 PLN/kg, R – 9.67 PLN/kg) and the post-slaughter protocol received by the farmer, the economic value of the half-carcass and the carcass was calculated.

The commercial value of the half-carcass and the carcass was calculated based on the weight and price of the main cuts: ham – 16.6 PLN/kg, loin – 21.3 PLN/kg, neck – 17.6 PLN/kg, shoulder – 14.3 PLN/kg, belly – 11.8 PLN/kg, ribs – 15.3 PLN/kg, chump – 11.4 PLN/kg, front knuckle – 11.75 PLN/kg, hind knuckle – 13.1 PLN/kg, head – 4.3 PLN/kg, jowls – 10.1 PLN/kg, back fat – 8.5 PLN/kg, tail – 4.3 PLN/kg, groin – 13.9 PLN/kg, leaf fat – 3.6 PLN/kg, tenderloin – 29.9 PLN/kg, front legs – 4.3 PLN/kg, hind legs – 5.0 PLN/kg.

The price of cuts was determined based on an analysis and the average prices from five meat plants. Additionally, the commercial value of the five most valuable cuts (loin, ham, shoulder, neck, and belly) was calculated, as well as their share in the total commercial value of the carcass. Based on the elements directly related to the farmer, i.e. the economic value of the carcass (carcass price calculated according to the SEUROP post-slaughter classification) and simplified feeding costs for pigs (i.e. feed costs), the simplified profit from fattening pig production was calculated.

The commercial value of the carcass represents the value of the carcass (the price of the carcass for individual cuts) and is of direct concern to meat processing plant owners and consumers.

Statistical analysis

The obtained research results were subjected to statistical analysis; the values of the analysed variables are presented using the mean and standard deviation. The normality of the distribution of variables in the studied groups was tested using the Shapiro-Wilk normality test. The equality of variances was assessed using Levene's test. To examine the differences between groups, the Student's t-test was used, and in the case of a statistically significant result from Levene's test, the Student's t-test with independent variance estimation was applied. For variables where the distribution in at least one of the groups deviated from the norm, the groups were compared using the Mann-Whitney test. A significance level of $P<0.05$ was adopted, indicating the presence of statistically significant differences or relationships. The database and statistical analyses were conducted using the Statistica 9.1 software (StatSoft, Poland).

Results

Table 2 presents the indicators of the fattening and slaughter value of pigs from the control and experimental groups. A statistically significant difference in body weight was observed between the two groups after 119 days of the experiment ($P\leq0.01$). The control group had a significantly higher body weight (117.73 kg) than the experimental group (114.17 kg). It was also found that animals from the control group had significantly ($P<0.05$; $P\leq0.01$) higher daily weight gains.

In relation to the parameters of daily feed intake (DFI) and feed conversion ratio (FCR), it was shown that statistically significantly ($P<0.001$) higher values of these indices were characteristic of fatteners from the experimental group. At the same time, there was a significantly ($P<0.001$) lower cost of animal feed in the experimental group, which was PLN 3.21 lower in the first 21 days of the experiment and PLN 41.69 lower over the subsequent 98 days of the experiment compared to the control group. Thus, the difference between the total costs of feeding (119 days – the entire experiment) was PLN 44.9 (E < C).

Table 2. Indicators of fattening and slaughter values in the control and experimental groups

Items	Group				P
	C		E		
	M	SD	M	SD	
Initial age (days)	66	2	66	2	1.000[B]
Initial body weight (kg)	27.2	1.53	27.3	1.84	0.551[B]
Body weight after 21 days of the experiment (kg)	39.4	1.45	38.5	2.33	0.078[C]
Body weight after 119 days of the experiment (kg)	117.7	4.79	114.2	4.63	0.005[A]
Daily weight gain during the first 21 days (g/day)	583	45	533	68	0.004[B]
Daily weight gain during the next 98 days (g/day)	799	42	772	44	0.017[A]
Daily weight gain for the entire experiment period (119 days) (g/day)	761	37	730	38	0.002[A]
Daily weight gain from birth (g/day)	637	27	617	23	0.007[B]
Slaughter age (days)	185	2	185	2	0.994[B]
DFI (21 days) (kg/day)	1.29	0.06	1.42	0.07	<0.001[B]
DFI (98 days) (kg/day)	2.87	0.06	3.04	0.13	<0.001[B]
DFI (119 days) (kg/day)	2.59	0.06	2.73	0.11	<0.001[B]
FCR (21 days) (kg/kg)	2.22	0.20	2.71	0.39	<0.001[B]
FCR (98 days) (kg/kg)	3.60	0.21	3.94	0.27	<0.001[A]
FCR (119 days) (kg/kg)	3.41	0.19	3.75	0.24	<0.001[A]
Feeding cost (21 days) (PLN)	46.80	2.09	43.59	2.16	<0.001[B]
Feeding cost (98 days) (PLN)	511.89	10.88	470.20	19.77	<0.001[B]
Feeding cost (119 days) (PLN)	558.69	12.97	513.79	21.50	<0.001[B]
Hot carcass weight (kg)	104.10	8.29	92.82	5.68	<0.001[C]
Hot dressing percentage (%)	84.08	6.98	81.27	2.41	<0.001[C]
Cold carcass weight (kg)	90.35	4.80	90.21	5.16	0.739[C]
Cold dressing percentage (%)	76.72	1.94	79.21	2.01	<0.001[A]
Cold half-carcass weight (kg)	45.18	2.40	45.10	2.58	0.739[C]
Backfat thickness (mm)	18.83	2.91	17.22	3.27	0.049[A]
Loin eye height (mm)	58.30	4.52	61.16	4.98	0.020[C]
Carcass leanness (%)	54.43	2.81	56.45	2.50	0.007[C]

C – control group, E – experimental group, M – mean, SD – standard deviation, p – statistical significance, A – Student's t-test, B – Mann–Whitney test, C – Student's t-test with independent variance estimation.

Table 3. Results of the dissection of half-carcasses of fattening pigs from the control and experimental groups

Items	Group				P
	C		E		
	M	SD	M	SD	
1	2	3	4	5	6
Ham (kg)	10.27	1.30	10.45	1.35	0.690[C]
Loin (kg)	4.73	0.56	5.07	0.41	0.008[A]
Neck(kg)	2.70	0.21	2.95	0.27	<0.001[C]
Shoulder (kg)	5.26	0.43	5.47	0.49	0.038[C]
Belly (kg)	3.68	0.39	3.41	0.43	0.013[A]
Ribs (kg)	1.49	0.42	1.45	0.33	0.813[C]
Chump (kg)	0.64	0.21	0.62	0.14	0.824[C]
Front knuckle (kg)	0.82	0.09	0.77	0.13	0.257[C]
Hind knuckle (kg)	1.40	0.16	1.27	0.25	0.060[C]
Head (kg)	2.20	0.16	2.15	0.21	0.584[C]
Jowl (kg)	1.84	0.36	1.67	0.36	0.070[C]
Back fat (kg)	4.76	0.93	4.57	1.04	0.438[A]
Tail (kg)	0.33	0.09	0.31	0.07	0.245[C]

Table 3 – contd.

1	2	3	4	5	6
Groin (kg)	1.75	0.32	1.80	0.26	0.515[A]
Leaf fat (kg)	1.58	0.36	1.38	0.39	0.048[A]
Tenderloin (kg)	0.45	0.07	0.49	0.10	0.066[C]
Front legs (kg)	0.58	0.11	0.57	0.12	0.542[C]
Hind legs (kg)	0.71	0.08	0.72	0.11	0.772[C]
Total weight of all cuts in the half-carcass (kg)	45.18	2.40	45.10	2.58	0.739[C]
Total weight of the 5 most valuable cuts (kg)	26.64	2.08	27.35	1.99	0.141[C]
Percentage share of the 5 cuts in the half-carcass (%)	58.93	2.63	60.68	3.51	0.082[C]

C – control group, E – experimental group, M – mean, SD – standard deviation, p – statistical significance, A – Student's t-test, B – Mann–Whitney test, C – Student's t-test with independent variance estimation.

Table 4. Content in kilograms and percentage of muscle tissue (meat), adipose tissue (fat), bone tissue (bones) and skin in the 5 most valuable cuts obtained from the half-carcasses of pigs from the control and experimental groups

Items	Group				P
	C		E		
	M	SD	M	SD	
1	2	3	4	5	6
Ham					
meat (kg)	7.38	0.91	7.70	1.10	0.420[C]
meat (%)	71.88	1.88	73.53	2.42	0.631[C]
fat (kg)	1.37	0.23	1.25	0.16	0.038[C]
fat (%)	13.29	1.36	12.07	1.57	0.049[C]
bones (kg)	0.99	0.17	0.97	0.16	0.894[C]
bones (%)	9.61	0.63	9.32	0.91	0.753[C]
skin (kg)	0.54	0.09	0.53	0.10	0.894[C]
skin (%)	5.22	0.62	5.08	0.64	0.801[C]
Loin					
meat (kg)	2.49	0.52	2.91	0.25	0.002[C]
meat (%)	52.65	5.48	57.40	2.49	0.029[C]
fat (kg)	0.86	0.09	0.74	0.10	0.106[A]
fat (%)	18.18	1.72	14.6	1.55	0.550[A]
bones (kg)	1.08	0.10	1.12	0.09	0.618[A]
bones (%)	22.83	3.12	22.08	1.53	0.823[A]
skin (kg)	0.30	0.03	0.30	0.03	0.874[C]
skin (%)	6.34	0.92	5.92	0.55	0.748[C]
Belly					
meat (kg)	1.94	0.18	1.94	0.21	0.956[C]
meat (%)	52.69	2.17	57.12	2.69	0.034[C]
fat (kg)	1.17	0.11	0.95	0.15	0.004[C]
fat (%)	31.82	1.77	27.73	1.41	0.042[C]
bones (kg)	0.35	0.02	0.30	0.03	0.489[A]
bones (%)	9.51	0.81	9.10	0.77	0.357[A]
skin (kg)	0.22	0.01	0.20	0.01	0.826[A]
skin (%)	5.98	0.29	6.05	0.33	0.711[A]
Shoulder					
meat (kg)	3.52	0.29	3.74	0.40	0.174[C]
meat (%)	66.99	6.23	68.37	7.17	0.802[C]
fat (kg)	0.84	0.07	0.8	0.06	0.555[A]
fat (%)	15.95	1.66	14.63	1.51	0.651[A]
bones (kg)	0.61	0.05	0.65	0.06	0.847[A]

Table 4 – contd.

1	2	3	4	5	6
bones (%)	11.57	1.22	11.88	1.36	0.823[A]
skin (kg)	0.29	0.03	0.28	0.02	0.909[C]
skin (%)	5.49	0.56	5.12	0.51	0.666[C]
Neck					
meat (kg)	1.36	0.13	1.63	0.17	0.032[C]
meat (%)	50.55	4.67	55.11	5.02	0.044[C]
fat (kg)	0.75	0.06	0.67	0.05	0.111[A]
fat (%)	27.85	3.02	22.81	2.88	0.547[A]
bones (kg)	0.42	0.03	0.47	0.04	0.517[A]
bones (%)	15.59	1.79	15.96	1.82	0.357[A]
skin (kg)	0.17	0.01	0.18	0.01	0.412[C]
skin (%)	6.01	0.05	6.12	0.06	0.707[C]

C – control group, E – experimental group, M – mean. SD – standard deviation. p – statistical significance. A – Student's t-test. B – Mann–Whitney test. C – Student's t-test with independent variance estimation.

Table 5. Economic and commercial value of fattening pig carcasses and profit from fattening pig production in the control and experimental groups

Items	Group				P
	C		E		
	M	SD	M	SD	
Economic value of the half-carcass (PLN)	454.26	25.95	460.20	27.52	0.141[C]
Economic value of the carcass (PLN)	908.52	51.90	920.39	55.04	0.141[C]
Commercial value of the half-carcass (PLN)	616.14	32.07	625.26	30.88	0.256[C]
Commercial value of the carcass (PLN)	1232.28	64.14	1250.52	61.76	0.256[C]
Commercial value of 5 cuts (PLN)	381.69	29.67	394.35	28.18	0.085[C]
Percentage share of the commercial value of 5 cuts in the total value of the carcass (%)	71.19	2.03	72.52	2.71	0.051[C]
Profit (PLN)	349.82	56.75	406.61	57.57	< 0.001[C]

C – control group, E – experimental group, M – mean, SD – standard deviation, p – statistical significance, A – Student's t-test, B – Mann–Whitney test, C – Student's t-test with independent variance estimation.

The analysis of the slaughter characteristics of the pigs revealed that the hot carcass weight and the efficiency of hot dressing of the pigs from the control group were statistically significantly higher compared to the experimental group (P<0.001). However, the cold dressing percentage of the experimental group pigs was 2.49 percentage points higher (P<0.001) compared to the half-carcasses of the control group. It was also found that the carcasses of pigs from the experimental group had statistically significantly thinner backfat (P=0.049), as well as greater loin eye height (P=0.020) and carcass leanness (P=0.007).

Table 3 presents the results of the dissection of half-carcasses from the control and experimental groups. It was found that the half-carcasses of fattening pigs from the experimental group had significantly higher weights of the loin (P=0.008), neck (P<0.001), and shoulder (P=0.038). The differences were 0.34 kg, 0.25 kg, and 0.21 kg, respectively. The carcasses from this group also had significantly lower weights of belly (P=0.013) and leaf fat (P=0.048).

The results of the detailed dissection of the ham, loin, and belly are presented in Table 4. It was shown that the modification of the pig's diet had a statistically significant effect on the increase in the percentage of meat content in: loin (C < E, P=0.029), belly (C < E, P=0.034), shoulder (C < E, P=0.044), and a decrease in fat content in: ham (C > E, P=0.049) and belly (C > E, P=0.042).

Table 5 presents the results of calculations concerning the economic and commercial value of fattened pig carcasses and the profit from fattened pig production in the control and experimental groups. There was no effect of feeding modifications on the economic value (calculated according to the EUROP classification) and commercial value (calculated according to the unit price of individual cuts) of carcasses and half-carcasses and the commercial value of the five most valuable cuts.

However, statistically significant differences were shown in the profit from fattened pig production. The production of fattened pigs from the experimental group was characterised by a higher profit by PLN 56.79 than the production from the control group.

Discussion

As confirmed by numerous studies, the composition of the feed ration is an important factor modifying the daily gain of pigs (Grela et al., 2020; Czech et al., 2023; Anestis et al., 2020). In this study, it was observed that the pigs in the experimental group had a lower final weight and, consequently, lower daily weight gains during the growth, fattening, and entire experimental period, while having a higher daily feed intake. However, as indicated by the results of the research by Hanczakowska et al. (2018), the replacement of post-extraction soybean meal with pea seeds in the feed of weaners (up to 6%) did not reduce their body weight gain and did not increase feed consumption. These studies also demonstrated a positive effect of feeding pigs with feed containing peas (up to 8%) on their fattening results. Rutkowski and Zaworska-Zakrzewska (2020) also pointed out that peas in combination with faba beans and rapeseed meal is an effective substitute for soybean meal, because it significantly enhances daily gain and reduces the amount of feed consumed per kilogram of gain. The study by White et al. (2015) also confirms that in the nutrition of hybrid white pigs, both peas and faba beans are good substitutes for soy in grower feed because they significantly increase the daily gain of weaners.

In addition to leguminous plants, the experimental feed dose contained large amounts of sunflower meal and hemp cake. Świątkiewicz et al. (2022) showed that the addition of fibre from hemp seeds to the feed of Polish Landrace piglets did not affect their daily growth or feed intake. Similarly, in a pilot study by Zhang (2024), it was shown that the use of up to 10% hemp seed meal (HSM) in the mixture did not have a negative effect on feed intake and crude protein digestibility, as well as on daily gains of fattening pigs (Yorkshire × Landrace). However. the research conducted by Carellos et al. (2005) showed that an 8% addition of sunflower meal in the diet of fattening pigs (Landrace × Large White)) increased their daily gain and reduced daily feed intake, which resulted in a more favourable feed conversion ratio.

The feed conversion ratio (FCR) is the most important factor influencing the farm's profit (Pierozan et al., 2016). The second important factor is the price of feed (Kasula et al., 2021). In our study, it was found that despite the feed intake being higher by 0.34 kg in the experimental group per 1 kg of gain, the profit from the production of one fattening pig is higher by PLN 56.79. This is the result of a lower (by PLN 44.9) cost of feeding fattening pigs with experimental feed consisting of cheaper domestic substitutes for imported soy. Numerous scientific studies confirm that sunflower meal is an economically viable alternative feed for all farm animals (de Morais Oliveira et al., 2016; Lourenco et al., 2017). Povod et al. (2022) indicate an approximately 4% higher profitability of rearing piglets that received sunflower meal instead of soybean meal in their starter feed. The results of the study conducted by Auzins et al. (2021) indicate that peas and blue lupin have the highest cost-efficiency for pig feeding. The authors were unable to find studies determining the cost effectiveness of the other protein substitutes used in this study. Similarly, Presto et al. (2011), after analysing the digestibility of amino acids in linseed cake and hemp seed cake, believe that these by-products of the food industry can be a valuable component of pig feed. The same position regarding hemp cake is held by Kasula et al. (2021), who examined the full composition of hemp cake, including feed safety parameters, i.e. the content of heavy metals, pesticides and mycotoxins.

Analysing the results of the slaughter value (Table 2), it was found that the fattening pigs of the experimental group were characterised by a higher cold slaughter efficiency by 2.49 percentage points, thanks to which, despite the lower weight on the day of slaughter, the weight of their cold half-carcass was comparable to that obtained from the control group. Conversely, the studies conducted by White et al. (2015) did not show a positive effect of substituting soy with peas or faba beans, although it was found that pigs fed peas had a higher cold dressing percentage than pigs fed faba beans. The same authors also demonstrated that fattening pigs fed peas or faba beans had a thickness of subcutaneous fat lower by 0.9 mm and 3.7 mm, respectively. Our statistical analysis showed that the replacement of imported soybean with domestic plants had a significant impact on increasing the carcass leanness of fattened pigs, the height of the eye of the loin and reducing the thickness of the back fat. Similar relationships were observed in fattened pigs whose diet partially replaced soybean meal with rapeseed cake (Hanczakowska and Świątkiewicz, 2014).

The most common factors differentiating the abovementioned parameters, apart from nutrition (Wang and Li, 2024), are gender (Vasquez-Hidalgo et al., 2024) and the breed of fattening pigs (Lebret et al., 2024; Szulc et al., 2024). In the Puławska breed, the leanness of individuals depends, among other things, on their daily gains. According to Szyndler-Nędza and Tyra (2023), gilts of the Puławska breed with slower daily gains and lower body weight on the day of assessment obtained higher values of the percentage of meat in the carcass. This relationship is consistent with our results recorded in the experimental group (lower gains, higher carcass leanness).

The percentage of primary cuts in the carcasses is an indicator influencing the commercial value of the carcass (Čandek-Potokar et al., 2024). Factors significantly influencing the weight of individual cuts are breed (Tyra, 2024) and feeding (Mas et al., 2011).

Statistically significant differences within the analysed groups (Table 3) were observed in as many as four out of five elements considered the most valuable, i.e. those which, due to their price and quantitative share, constitute the main profit for meat processing plants from the sale of pork carcasses, i.e. loin, ham, neck, shoulder and belly (Lim et al., 2024). Statistically significant higher weight of loin, neck and shoulder and lower weight of belly in the experimental carcasses is the result

of higher leanness of these carcasses; this relationship is confirmed by numerous scientific studies (Kušec et al., 2022; Pulkrábek et al., 2006).

Dissection of the most valuable cuts is one of the methods used to determine the usefulness of a given cut for processing or culinary use (Metz et al., 2024), involving a detailed determination of the share of individual tissues in a given cut (Tyra and Eckert, 2021). Considering the varying degrees of consumer acceptability of the composition of individual elements, including mainly the content of fat tissue (Soladoye et al., 2015), this is a very important element influencing economic calculations and setting retail prices for meat industry products (Pandey et al., 2024). As can be seen from the data presented in Table 4, ham obtained from fatteners fed soya contained on average 13.29% fat, while from those fed substitutes of post-extraction soybean meal it contained statistically significantly less, i.e. 12.07%. As reported by Knecht and Duziński (2016), fat content in hams is strongly negatively correlated with carcass leanness (r = –0.74). According to the results of the above authors, ham obtained from carcasses of fatteners with an average leanness of 58.19% contained 10.15% fat, while ham obtained from carcasses of fatteners with leanness of 51.91% contained 2.22 percentage points more fat, i.e. 12.37%. The obtained relationship is consistent with our results.

Scientific studies also show that the level of fat tissue deposition in the most valuable pork cuts is also strongly dependent on nutrition, age and breed (Blanchard et al., 1999; d'Souza et al., 2004; Tyra et al., 2013). In our own studies, it was also observed that the tenderloin obtained from the experimental group fatteners was characterised by a 4.75% higher meat content, which also results from the higher meat content in the carcasses of the fatteners from this group. Carcass leanness is significantly correlated with subcutaneous fat content (Tyra and Eckert, 2021), so also has an impact on significantly reducing the content of meat and fat in the belly (Metz et al., 2024). Scientific studies show that breeding progress determined by consumer preferences for leaner meat has reduced fat content in the belly by more than 30% (Scramlin et al., 2008).

This study showed that the belly obtained from the experimental fatteners (with higher leanness) contained exactly the same amount of meat as the belly from the control group. However, due to its overall lower weight, it was characterised by a statistically significantly higher percentage of meat and a lower percentage of fat. The results obtained for the experimental group are consistent with the results of Olkiewicz and Moch (2011), who report that pork belly contains about 56.83% meat, 27.56% fat,. 6.15% skin and 9.10% bones. The results obtained in our own research concerning the content of muscle tissue in the shoulder obtained from fattening pigs of the native Puławska breed are comparable to the data presented in the work of Komlenić et al. (2018) concerning the dissection of elements obtained from the Black Slavonian (Crna slavonska) pig – an autochthonous pig breed from the Republic of Croatia. Another experiment also performed on this breed confirmed the relationship observed in our own study between the increase in the content of muscle tissue in the neck and the leanness of the carcass (Kušec et al., 2022).

The weight of individual cuts affects the commercial value of the carcass (Lim et al., 2024). In our own study, no effect of the applied feeding on the economic and commercial value of the carcass was observed (Table 5). However, a statistically significant higher profit from the production of experimental fattening pigs was observed, which resulted from significantly lower feeding costs of fattening pigs receiving protein substitutes, i.e. peas, faba beans, sunflower meal, hemp and linseed cake (Table 2). According to Kasula et al. (2021), over 70% of the costs of animal production is feed, and its most expensive component is protein.

Conclusion

Based on the analysis of the results, a positive effect of substituting protein from soybean meal with a mixture of domestic protein components, i.e. peas, faba beans, sunflower meal and hemp and linseed cake was demonstrated. Although the experimental group was characterised by lower daily gains, higher feed intake, and thus a less favourable feed conversion ratio, the cost of feeding these fattening pigs was significantly lower.

It was also found that the carcasses of the fattened pigs in the experimental group had statistically significantly lower backfat thickness and higher loin eye height and carcass leanness, which in turn resulted in the higher weight of valuable cuts. There was no effect of feeding modifications on the economic and commercial value of the carcass, however it was shown that feeding fattener pigs with a mixture of domestic protein components in the experimental group increased the profit from their production.

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