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ORIGINAL PAPER

Fattening results and carcass quality of growing finishing pigs fed a mixture with different proportions of legume seeds

A. Cebulska[1,*], H. Jankowiak[1], P. Nevrkla[2] and E. Weisbauerová[3]

[1] Bydgoszcz University of Science and Technology, Faculty of Animal Breeding and Biology, Department of Animal Breeding and Nutrition, 85-084 Bydgoszcz, Mazowiecka 28, Poland
[2] Mendel University in Brno, Department of Animal Breeding, Zemědělská 1, 613 00 Brno, Czech Republic
[3] Institute of Animal Science, Prague-Uhříněves, Komenského 1239, Kostelec nad Orlicí 517 41, Czech Republic

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* Corresponding author:
e-mail: cebulska@pbs.edu.pl

ABSTRACT. The purpose of the study was to assess the fattening parameters and carcass quality traits of fatteners after replacing soybean with varying proportions of peas and yellow lupin in the mixture. Sixty fattening pigs (50% gilts and 50% barrows, with an initial body weight of approximately 31.60 ± 3.01 kg) were divided into three feeding groups: control (C) – standard feeding with 100% post-extraction soybean meal in the first and second fattening phases; experimental group (E1) – 50% of the protein sources were replaced with peas and lupin in the first fattening phase, and increased to 75% in the second phase; experimental group (E2) – 50% of the protein sources were replaced with peas and lupin in the first phase, and soybean was fully replaced by peas and lupin in the second phase (100% legume protein). Fattening performance and slaughter characteristics of pigs were evaluated. Daily weight gains of fattening pigs were similar in all groups, as was feed intake, with each group consuming just over 3 kg of feed per kg body weight gain. There was no significant impact of the diet on meatiness, which was above 56%. The average fat thickness from 5 measurements, and the values of individual measurements in various carcass sections, were also consistent among the groups. The study demonstrated that peas and lupin could partially or fully replace soybean meal in fattening pig diets without negatively affecting fattening performance or carcass quality, particularly in the final phase of fattening.

Introduction

Currently in Poland, soybean is the primary feed ingredient for fattening pigs (Sońta et al., 2021; Sieradzki et al., 2021). It is distinguished by its high protein content, which is essential in the diet of fast-growing pigs, and its lower levels of antinutritional substances compared to the seeds of other bean crops. However, this improvement is partly due to extensive genetic modifications of soybean (Tyczewska et al., 2014). Concerns have arisen about the potential effects of these modifications on products like meat, as genetic alterations may lead to the formation of new proteins, which could negatively affect consumer health, including triggering allergic reactions (Lucht, 2015).

Soybean cultivation in Polish conditions is characterised by low and highly variable yields (Sobczyński, 2020), making domestic production unreliable. Consequently, Poland relies almost entirely on imported soybean (Mordenti et al., 2012; Woźniak and Twardowski, 2018), which raises its price, a significant factor in determining the profitability of pig farming (Parrini et al., 2023).

The use of new, cost-effective, and locally accessible protein sources in animal feed is becoming more common. Among these alternatives, leguminous plants, which can be cultivated in Poland, are particularly noteworthy (Kasprowicz-Potocka et al., 2017). However, a significant concern regarding the use of peas, lupins and other legumes for feed is the presence of anti-nutritional substances, which can cause digestive disorders and potentially hinder animal growth rates, feed utilisation and production costs. Nevertheless, recent studies evaluating the composition and levels of these undesirable compounds in legume seeds indicate a reduction in their content, owing to intensive breeding programmes targeting these issues (Kim et al., 2008; Kasprowicz-Potocka et al., 2017). Based on the results of previous studies, it has been concluded that soybean proportion in fattening pig diets can be significantly reduced or replaced with seeds from other leguminous plants without negatively impacting fattening performance or slaughter traits (Sirtori et al., 2015; White et al., 2015; Hanczakowska et al., 2017; Grabež et al., 2020; Śmiecińska et al., 2021). On the other hand, a reduction in legume use is recommended in mixtures for weaned piglets, while in older animals, it seems possible to eliminate soybean completely (Śmiecińska et al., 2021). Nevertheless, some studies have indicated that excessive use of peas or legumes in the diets of fattening pigs can reduce growth rates, meatiness, and increase carcass fatness (Degola and Jonkus, 2018; Zmudzińska et al., 2020; Tuśnio et al., 2021).

Therefore, in our research, we focused on two legumes – peas and lupins – which are well-adapted to local conditions and generate stable and abundant yields. These legumes are a good option for adding to fattening pig diets and can make up a significant portion of the ration. A detailed evaluation was conducted to assess the effects of varying proportions of these components in both the first and second phases of fattening.

Material and methods

Animals and sampling

The tests did not require Ethics Committee approval. They were part of the production cycle, and the main purpose was to evaluate the fattening parameters and slaughter value of the carcasses obtained (Directive 2010/63/EU, 2010).

The experiment was carried out on 60 crossbred pigs (50% gilts and 50% barrows, with an average body weight of 31.60 ± 3.01 kg) for fattening purposes. These pigs were from the F2 generation [F1(Polish Large White × Polish Landrace) × F1(Pietrain × Duroc)] and were housed on the same farm, under identical environmental conditions, in accordance with welfare requirements (Council Directive 2008/120/EC, 2008). The animals were properly labelled and housed in pens equipped with automatic feeders and nipple drinkers, ensuring constant access to water. The fattening pigs were kept on litter with mechanical ventilation.

The animals were divided into three feeding groups of 20 animals each (50% gilts and 50% barrows). The fattening pigs were fed *ad libitum* with complete feed mixes according to the dietary recommendations for pigs (Grela and Skomiał, 2020). The groups differed in their protein sources: control group (C) – standard feeding with 100% post-extraction soybean meal administered in the first and second fattening phases; experimental group (E1) – in the first fattening phase, 50% of the protein was based on pea and lupin, and was increased to 75% in the second phase; experimental group (E2) – in the first fattening phase, 50% of the protein was based on pea and lupin, and in the second phase, soybean was completely replaced by 100% pea and lupin protein. The composition and nutritional value of the complete mixture are provided in Table 1 and those of the concentrate in Table 2.

The animals were weighed at the start of the fattening phase, after the completion of the first phase of fattening and at the end of the second fattening phase – before slaughter. The mean body weight of piglets, at the beginning of fattening was 31.60 ± 3.01 kg, and the average duration of the fattening period was 87.69 ± 7.07 days. Slaughter was scheduled to occur when the animals reached approximately 112 kg. Body weight measurements, and pre-determined duration of the entire fattening period (1st phase – 46 days, 2nd phase – 40.70 ± 7.03 days) allowed the calculation of average daily gains (ADG) in individual phases and for the entire fattening period (ADG I = weight gain 1st phase/fattening days 1st phase; ADG II = weight gain 2nd phase/fattening days 2nd phase; ADGFP = weight gain in the entire fattening period/fattening days). Additionally, total weight gain (TWG) was calculated for each phase and for the entire fattening period: TWG I = body weight at the end of 1st phase − body weight at the beginning of 1st phase; TWG II = body weight at the end of 2nd phase − body weight at the beginning of 2nd phase; TWGFP = body weight at the end of the fattening period − body weight at the beginning of the fattening period.

The average feed intake (AFI) of the fattening pigs was determined for each phase and throughout

Table 1. Nutritional value and feed composition

Dietary value	Feeding group					
	Control		E1		E2	
	phase I (30–70 kg)	phase II (70–115 kg)	phase I (30–70 kg)	phase II (70–115 kg)	phase I (30–70 kg)	phase II (70–115 kg)
Dry matter,g	877	875	877	875	877	875
Metabolic energy, MJ	13.39	13.11	13.32	13.09	13.32	13.12
Total protein, g	170	159	171	157	171	160
Fat, g	27	20	29	20	29	20
Lysine, g	10.6	9.7	10.6	9.7	10.6	9.7
Calcium, g	5.9	5.8	5.9	5.8	5.9	5.8
Phosphorus, g	5.3	5.2	5.3	5.2	5.3	5.2
Sodium, g	1.7	1.7	1.7	1.7	1.7	1.7
Vitamin A, IU	10000	10000	10000	10000	10000	10000
Vitamin D, IU	2200	2200	2200	2200	2200	2200
Vitamin E, IU	80	80	80	80	80	80
Composition of the fodder, %						
soy meal 46% total protein	16	12	10	4	10	
wheat 12%	20	20	20	20	20	20
barley 12%	35	45	30	41	30	35
triticale 10%	25.3	20	26	20	26	20
soybean oil	1	0.3	1.3	0.3	1.3	0.3
lupin 37%			7	9	7	12
pea 21%			3	3	3	10
PORKOVITAL T PEA 2.5 %	2.5	2.5	2.5	2.5	2.5	2.5
SELACID GG DRY 25 BR	0.2	0.2	0.2	0.2	0.2	0.2
Total	100	100	100	100	100	100

Control – standard feeding group (100% post-extraction soybean meal in the first and second phases of fattening), E1 – experimental group (50% of the protein sources was pea and lupin in the first phase of fattening, and 75% in the second phase), E2 – experimental group (50% of the protein sources was pea and lupin in the first phase, and soybean was completely replaced with 100% pea and lupin protein in the second phase); PORKOVITAL T PEA 2.5 % – mineral mixture, SELACID GG DRY 25 BR – feed acidifier

Table 2. Concentrate composition

PORKOVITAL T PEA 2.5%	
Components per 1 kg	
Lysine, g	120
Methionine, g	40
Threonine, g	50
Tryptophan, g	3
Total calcium, g	205
Total phosphorus, g	80
Sodium, g	64
Vitamin E + AO-mix, IU	3200
Vitamin A, IU	260000
D, IU	80000
K, mg	80
C, mg	
B_1, mg	60
B_2, mg	200
B_6, mg	88
Niacin, mg	1200
Folic acid, mg	32
Calcium pantothenate, mg	640
Choline, mg	9217
Biotin, µg	2400
Vitamin B_{12}, µg	1600
Iron, mg	4800
Manganese, mg	2400
Zinc, mg	4800
Copper, mg	1000
Iodine, mg	44
Selenium, mg	12

PORKOVITAL T PEA 2.5 % – mineral mixture

the fattening process as follows: AFI I = total feed intake of pigs in a given group in the 1st phase/number of pigs in the group; AFI II = total feed intake of pigs in a given group in the 2nd phase/number of pigs in the group; AFIFP = total feed intake of pigs during the entire fattening period/number of pigs. Additionally, the amount of feed used per kilogram of body weight gain was determined using the feed conversion ratio (FCR) for individual phases and the overall fattening period: FCR I = feed intake in the 1st phase/weight gain in the 1st phase of fattening; FCR II = feed intake in the 2nd phase/weight gain in the 2nd phase of fattening; FCRFP = total feed intake during the entire fattening period/total weight gain over the entire period.

After fattening, the pigs were transported to a slaughterhouse located approximately 20 km away, in accordance with the applicable regulations on the conditions for transporting pigs (Council Regulation [EC] No 1/2005, 2004). Upon arrival, the pigs were slaughtered in a meat processing facility using the electrical stunning method, adhering to guidelines set out in Council Regulation (EC) No 1099/2009 (2009) (Nielsen et al., 2020).

Measurements were taken on the half-carcasses at the junction of the thoracic and lumbar vertebrae to assess fat thickness and the height of the ‘eye’ of the tenderloin. These measurements were used to estimate the percentage of meat in the carcass using an ULTRA-FOM 300 apparatus. The warm carcass weight was recorded using a scale on the slaughter line, from which the warm slaughter yield was calculated. Carcass length, measured from the edge of the first rib to the pubic symphysis using a measuring tape with a centimetre scale was also recorded. Additionally, backfat thickness was measured at five locations on the carcass: over the shoulder, on the back, and above the 1st, 2nd and 3rd sacral vertebrae. The cross-sectional area of the longest dorsal muscle (the 'eye' of the tenderloin) behind the last rib was also determined. Subsequently, technological dissection of the half-carcass was performed, following the method commonly employed in the meat industry (Polish Standard PN-86-A/82002). The carcass was divided into the following primary cuts: neck, shoulder, belly, loin, ham proper and the tenderloin. Each cut was weighed, and a detailed dissection of the ham was carried out into meat, skin with lard, and bones.

Statistical analysis

All calculations were conducted using Statistica 13.3 PL software (Statistica, 2019). The results met the assumptions of normal distribution, as verified by the Shapiro-Wilk test. The arithmetic mean and standard deviation were calculated for fattening characteristics and slaughter value, along with the standard error of the mean (SEM). The significance of differences between the C, E1 and E2 feeding groups was calculated using Tukey's HSD test for equal group sizes. A probability of $P < 0.05$ was considered statistically significant.

Results

Table 3 presents the fattening parameters of the animals studied. The ADG values of fattening animals during the entire fattening period were comparable in all the experimental groups, ranging from 933 g (group C) to 946 g (group E1) ($P > 0.05$). A similar trend was observed in different phases of fattening. However, in the group of soybean-fed fatteners, there was a noticeable trend for slightly lower gains in the first phase of fattening and the highest in the second phase.

The fatteners in all groups were characterised by comparable TWG, with no significant differences observed between individual fattening phases. At the same time, their total weight gains, regardless of the group, were slightly lower in the second phase of fattening.

Table 3. Fattening parameters of the analysed animals by nutritional group

Trait	Feeding group			SEM	*P* <
	C	E1	E2		
Number of animals	20	20	20		
ADG I, g	915 ± 118	959 ± 111	945 ± 121	0.015	0.488
ADG II, g	951 ± 103	930 ± 136	932 ± 102	0.015	0.820
ADGFP, g	933 ± 088	946 ± 097	943 ± 83	0.088	0.888
TWG I, kg	42.10 ± 5.41	44.10 ± 5.12	43.48 ± 5.57	0.690	0.488
TWG II, kg	37.58 ± 5.73	37.15 ± 6.03	38.78 ± 6.92	0.798	0.697
TWGFP, kg	79.68 ± 3.13	81.25 ± 4.56	82.25 ± 4.82	0.555	0.162
AFI I, kg	119.48 ± 14.41	121.22 ± 11.68	119.80 ± 11.28	1.594	0.897
AFI II, kg	124.30 ± 15.91	127.00 ± 16.90	129.82 ± 14.64	2.032	0.548
AFIFP, kg	243.78 ± 10.75	248.20 ± 14.12	249.57 ± 12.50	1.623	0.319
FCR I, kg/kg	2.86 ± 0.29	2.77 ± 0.27	2.78 ± 0.30	0.037	0.573
FCR II, kg/kg	3.33 ± 0.30	3.48 ± 0.63	3.41 ± 0.47	0.062	0.629
FCRFP, kg/kg	3.06 ± 0.17	3.07 ± 0.27	3.04 ± 0.22	0.028	0.940

Control – standard feeding group (100% post-extraction soybean meal in the first and second phases of fattening), E1 – experimental group (50% of the protein sources was pea and lupin in the first phase of fattening, and 75% in the second phase), E2 – experimental group (50% of the protein sources was pea and lupin in the first phase, and soybean was completely replaced with 100% pea and lupin protein in the second phase), PORKOVITAL T PEA 2.5 % – mineral mixture; ADG I, II, FP – average daily gain in phases I and II, and for the entire fattening period; TWG I, II, FP – total weight gain in phases I and II, and for the entire fattening period; AFI I, II, FP – average feed intake in phases I and II, and for the entire fattening period; FCR I, II, FP – feed conversion ratio in phases I and II, and for the entire fattening period; SEM – standard error of the mean; $P < 0.05$ indicates significantly different data

The AFI of the animals ranged from 243.78 to 249.57 kg ($P > 0.05$), indicating very similar consumption in all the groups studied. Additionally, no significant differences in feed intake were observed between the different fattening phases.

Feed consumption per kg of weight gain was slightly more than 3 kg. Feed intake was also even across phases and ranged from 2.77 kg (group E1) to 2.86 kg (group C) in phase I, and from 3.33 kg (group C) to 3.48 kg (group E1) in phase II of fattening ($P > 0.05$).

Individual traits indicating the slaughter value of the carcasses of the studied animals are presented in Table 4.

No effect of differentiated feeding on the lean meat percentage of fatteners was observed, with similar values recorded in the evaluated groups, all exceeding 56% (56.37% in group E2 to 57.13% in group E1) ($P > 0.05$). The dressing percentage was typical for this animal species and was in the range of 77.35–77.70% (group C – group E2). Carcass length was consistent among all experimental groups. Additionally, the average backfat thickness, based on five measurements, was very uniform, as were the values of individual measurements from different carcass sections. Similarly, there was no effect of the varying proportions of peas and lupins in the feed on the cross-sectional area of the *longissimus dorsi* muscle, as evidenced by very similar values in all fattening groups (ranging from 53.65 to 55.99 cm^2) ($P > 0.05$).

Table 5 compares the weights of selected cuts and presents the detailed dissection of the ham proper. None of the cuts evaluated showed significant differences between the dietary groups ($P > 0.05$). Likewise, the dissection of the ham proper indicated a very similar proportion of its individual tissues – meat, skin with lard, and bone – for all groups.

Table 4. Carcass slaughter value by nutritional group

Trait	Feeding group			SEM	*P* <
	C	E1	E2		
Meatiness UFOM, %	56.42 ± 3.39	57.13 ± 3.07	56.37 ± 3.74	0.435	0.735
Hot carcass weight, kg	87.28 ± 3.18	87.48 ± 2.48	87.38 ± 3.28	0.381	0.978
Carcass yield, %	77.70 ± 2.09	77.64 ± 1.46	77.35 ± 2.53	0.264	0.853
Carcass length, cm	81.53 ± 2.46	81.58 ± 2.24	80.68 ± 2.92	0.329	0.462
Backfat thickness, mm					
over the shoulder	31.35 ± 5.42	31.35 ± 4.91	33.25 ± 5.78	0.693	0.441
on the back	18.40 ± 5.16	19.20 ± 4.30	20.00 ± 5.38	0.636	0.599
1st sacral vertebrae	17.85 ± 4.79	18.40 ± 3.02	19.15 ± 4.15	0.519	0.598
2nd sacral vertebrae	11.50 ± 4.48	13.20 ± 4.16	12.95 ± 5.99	0.634	0.506
3rd sacral vertebrae	16.35 ± 4.56	18.05 ± 4.11	18.35 ± 6.06	0.642	0.397
Aver. backfat thickness from 5 measurements, mm	19.09 ± 4.20	20.04 ± 3.42	20.74 ± 5.10	0.552	0.480
Tenderloin eye area, cm^2	53.65 ± 7.23	54.22 ± 5.04	55.99 ± 7.42	0.854	0.514

Control – standard feeding group (100% post-extraction soybean meal in the first and second phases of fattening), E1 – experimental group (50% of the protein sources was pea and lupin in the first phase of fattening, and 75% in the second phase), E2 – experimental group (50% of the protein sources was pea and lupin in the first phase, and soybean was completely replaced with 100% pea and lupin protein in the second phase); UFOM – ULTRA-FOM 300 apparatus, SEM – standard error of the mean; $P < 0.05$ indicates significantly different data

Table 5. Weight of individual cuts and detailed dissection value of the ham by nutritional group

Trait	Feeding group			SEM	*P* <
	C	E1	E2		
Neck, kg	3.86 ± 0.54	3.95 ± 0.62	4.05 ± 0.46	0.070	0.564
Shoulder, kg	6.37 ± 0.37	6.44 ± 0.43	6.53 ± 0.40	0.052	0.454
Belly, kg	3.23 ± 0.22	3.33 ± 0.18	3.26 ± 0.20	0.026	0.280
Loin, kg	5.75 ± 0.36	5.67 ± 0.46	5.84 ± 0.44	0.054	0.458
Tenderloin, kg	0.34 ± 0.04	0.33 ± 0.04	0.32 ± 0.04	0.005	0.295
Proper ham, kg	10.33 ± 0.63	10.28 ± 0.58	10.55 ± 0.70	0.082	0.375
Detailed dissection of proper ham, kg					
meat	7.86 ± 0.72	7.76 ± 0.64	7.96 ± 0.81	0.093	0.688
skin with lard	1.72 ± 0.34	1.75 ± 0.26	1.82 ± 0.42	0.044	0.644
bones	0.75 ± 0.08	0.77 ± 0.08	0.77 ± 0.15	0.014	0.732

Control – standard feeding group (100% post-extraction soybean meal in the first and second phases of fattening), E1 – experimental group (50% of the protein sources was pea and lupin in the first phase of fattening, and 75% in the second phase), E2 – experimental group (50% of the protein sources was pea and lupin in the first phase, and soybean was completely replaced with 100% pea and lupin protein in the second phase); SEM – standard error of the mean; $P < 0.05$ indicates significantly different data

Discussion

The protein requirements of fattening pigs are very high, making it essential to supply large quantities of adequate quality protein, especially rich in essential amino acids. This is often achieved through the use of soybean in pig nutrition. However, alternative feeds to soybean are being sought, including other legumes grown in Poland (Sirtori et al., 2015; White et al., 2015; Śmiecińska et al., 2021). Utilising these alternatives presents an opportunity to reduce reliance on soybean imports and employ domestic protein sources. Thus, the possibility of reducing the cost of porker production using cheaper protein components while maintaining pork carcass quality, is particularly promising (White et al., 2015).

The growth rate of fattening pigs is the most important parameter determining the fattening process. A high growth rate, reflected in significant daily gains, allows pigs to be maintained for a shorter period and, at the same time, reaching their finishing weight more quickly (Krzęcio-Nieczyporuk et al., 2015). Degola and Jonkus (2018) reported similar gains of fattening pigs fed both soybeans and other legumes in the initial phase of fattening. On the other hand, in the second phase, pigs receiving a nearly 30% addition of peas instead of soybean showed the highest daily gains. Unfortunately, this was also associated with the highest feed consumption per kg of weight gain. Slightly different results were obtained by Grabež et al. (2020), who compared the rearing effects of fattening pigs fed soybean versus those fed oilseed rape and legumes. They found consistently high growth rates in all experimental groups, with similar feed consumption rates and uniform carcass quality traits. Similarly, White et al. (2015) and Sońta et al. (2016) indicated that coarse-seed legumes could be an alternative to soybean feed, particularly with regard to fattening and slaughter traits, including both muscling and carcass fatness.

Studies on the presence of anti-nutritional compounds in legumes, including tannins, protease inhibitors, saponins or toxic alkaloids (Jezierny et al., 2010; Tyczewska et al., 2014) suggest that feeding these compounds to certain technological groups, such as piglets or weaners, should be avoided or limited. Similar findings were reported by Wang et al. (2022), who observed a systemic antibody response in juveniles to specific dietary proteins. In addition, these authors argued that in order to maintain the proper proportion of protein and fat in the ration legume seeds should be fed to pigs together with rapeseed meal. Polish studies have shown that feeding legumes in combination with rapeseed cake up to 30% of the feed ration at the beginning of fattening allows to obtain similar fattening parameters as when feeding soybean. Moreover, soybean can be completely eliminated, though with cautious supplementation of certain lupins (Hanczakowska and Świątkiewicz, 2014). Sońta et al. (2022) found that using different doses of blue lupin resulted in high and very consistent values compared to pigs receiving soybean as the main protein source, with the proportion of lupin not exceeding 17.5% in the feed ration.

The present results on carcass fatness and meatiness indicate equal values for these traits. However, it is common for these characteristics to reach similar values, with differences observed in specific measurements, such as the thickness of the *longissimus dorsi* muscle (Mordenti et al., 2012; White et al., 2015). Sońta et al. (2016) and Cámara et al. (2016), measuring the thickness of the *longissimus dorsi* muscle between the 3rd and 4th ribs, recorded significantly lower values for this trait in pigs fed soybean with the addition of narrow-leafed lupin.

Studies often report a consistent proportion of the most valuable cuts, including sirloin, shoulder, neck or ham, regardless of the soybean content in the feed ration (Mordenti et al., 2012; Degola and Jonkus, 2018). According to Cámara et al. (2016), the proper selection of protein components in the feed is crucial for achieving a favourable proportion of the most valuable cuts. In addition, Świątkiewicz et al. (2018) further pointed out the negative effects of antinutritional compounds, including tannins, on carcass meatiness and meat percentage in the primary cuts.

Conclusions

The complete replacement of soybean protein in the diet of fattening pigs with coarse legumes such as peas and lupins during the second phase of fattening did not negatively affect the fattening performance of pigs. Additionally, changing the protein source did not influence the carcass quality of the tested animals. The inclusion of coarse-seed legumes, which are considered to contain significant amounts of antinutritional substances and unbalanced yields, also did not impair the proportions of carcass yields in the present study. Therefore, the current results allow to conclude that it is feasible to incorporate peas and lupins as protein sources in the feeding of fattening pigs, and even completely replace soybean with these legumes in the final phase of fattening.

Conflict of interest

The Authors declare that there is no conflict of interest.

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