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The efficiency of fattening pigs with mixtures containing yellow lupine (*Lupinus luteus*)

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During a three-stage fattening period, 30 weaners, gilts and young boars of a three-breed cross – ♀ (Landrace x Yorkshire) x ♂ Duroc – were fattened from body weight 27.2 to 117.5 kg. The animals were divided into three groups of 10, a control (K) and two experimental groups (D1 and D2). The pigs were fed total mixed rations and their daily weight gain and feed conversion were monitored. Soybean extraction meal was the only source of protein in the mixtures for the control pigs. In the mixtures for the experimental animals, the soybean extraction meal was partially replaced with seeds of yellow lupine. The proportion of the seeds was constant, irrespective of the stage of fattening, at 7.5% (D1) or to 15% (D2). After fattening and slaughter, basic carcass parameters were determined: hot carcass weight (kg), backfat thickness between the 3rd and 4th rib (mm), thickness of *m. longissimus dorsi* (MLD) and meatiness (%). Economic calculations, i.e. the differences between revenue (sale of the fatteners) and costs, were performed as well. The introduction of 7.5% and 15% yellow lupine in the mixtures for the experimental fatteners did not negatively affect the results of fattening. Daily weight gains in groups K, D1 and D2 were very good, amounting to 1,056 g, 1,075 g and 1,081 g, respectively (P>0.05). Feed consumption per kg of BW gain was also good: K – 2.72, D1 – 2.72, and D2 – 2.69 kg/kg. The carcass parameters in the groups were similar (statistically insignificant differences). A simplified analysis of production efficiency showed a positive rate of change, i.e. D1 vs. K – 18.53% and D2 vs. K – 8.56%, which confirms the benefits of using yellow lupine seeds in pig fattening.

KEY WORDS: fatteners / yellow lupine / production traits / economic effectiveness of fattening

Domestic production of pulse crops currently meets only 25% of the demand for fodder protein, which has led to measures aimed at increasing the acreage of Fabaceae cultivation [7, 18]. An additional motivation is the high price of soybean extraction meal and limitations on the use of animal meal to feed pigs and poultry.

Protein security in production of foods of animal origin is closely linked to the cultivation, acquisition and utilization of inexpensive, domestically produced protein material, particularly new cultivars of fava bean, pea, lupine, rapeseed and soybean. Finding eco-

nomical solutions that increase productivity is of great importance for the public good [6]. Possibilities for exploiting domestically produced vegetable protein material have been presented by Fiedorowicz and Sobotka [2], Hanczakowska and Księżak [4] and Hanczakowska and Świątkiewicz [5]. In the last 20 years breeding progress and implementation of new technologies for processing pulse seeds have increased the nutritional value of species and cultivars of these plants and their suitability as feed components, owing to a marked reduction in antinutrients. Their suitability has been confirmed in studies on pigs [3, 8, 9, 10, 12, 14, 15, 17, 21]. It has been demonstrated that they can be used in compound feeds for monogastric animals with no detrimental effect on their health, the homeostasis of the organism, performance outcomes, or product quality [21].

Breeding progress with respect to plant and animal material and the diverse opinions regarding the suitability of pulses to feed monogastric animals were the basis for the experiment conducted. The aim of the study was to determine the effect of partially replacing soybean extraction meal with yellow lupine in compound feeds for growing pigs on growth parameters and fattening efficiency.

Material and methods

The experimental material consisted of 30 weaners, gilts and young boars of a three-breed cross, i.e. ♀ (Landrace x Yorkshire) x ♂ Duroc, with an initial body weight of 27.2 kg. The animals were individually weighed, marked and divided into groups: control (K) and experimental (D1 and D2), with 10 animals per group (1:1 sex ratio). They were placed in pens with 10 animals each (housing conditions were in accordance with recommendations [16]). The pigs were weighed again every two weeks until the end of the fattening period. During a three-stage fattening period (stage I – 41 days; stage II – 28 days, and stage III – 17 days) the pigs were fed ad libitum [19], with constant access to water. Fattening was completed when a mean body weight of about 117.5 kg was attained.

The only protein component in the compound feed for the pigs in the control group was soybean extraction meal. In the mixtures for the fatteners in the experimental groups, some of the soybean meal was replaced with yellow lupine of the Mister variety (Table 1). The percentage of lupine seeds was constant; in all stages of fattening it was 7.5% (group D1) or 15% (group D2).

The mixtures were prepared on the farm using on-farm cereal grain and lupine seeds and purchased soybean extraction meal, soybean oil, and premix. The cereal grain and lupine seeds were crushed in a grain mill and then all of the components, according to a formula, were mixed in a vertical mixer.

Total lupine alkaloids in the lupine seeds used in the experimental mixtures were measured at the Chemical and Technological Laboratory of the National Research Centre for Cultivar Testing, Experimental Cultivar Testing Station in Słupia Wielka. Gas chromatography was used for quantitative analysis and alkaloids were identified with a mass detector [11]. The chemical composition of the mixtures (Table 2) and lupine seeds and the protein content of the other raw materials were determined according to AOAC [1].

Table 1
Proportions of raw materials in feed mixtures (%) and energy value (MJ/kg)

Raw feed materials	Fattening period								
	I			II			III		
	group								
	K	D1	D2	K	D1	D2	K	D1	D2
Wheat – meal	30.0	26.5	23.5	30.0	26.5	23.5	34.0	30.5	27.5
Barley – meal	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
Triticale – meal	20.0	20.0	20.0	20.0	20.0	20.0	16.5	16.5	16.5
Oats – meal	5.0	5.0	5.0	7.5	7.5	7.5	10.0	10.0	10.0
Soybean extraction meal	19.0	15.0	10.5	17.0	13.0	8.5	14.0	10.0	5.5
Yellow lupine – meal	–	7.5	15.0	–	7.5	15.0	–	7.5	15.0
Premix*	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Soybean oil	0.5	0.5	0.5	–	–	–	–	–	–
Metabolizable energy	13.4	13.3	13.3	13.2	13.2	13.1	13.2	13.2	13.1

K – control group
D1 – experimental group 1
D2 – experimental group 2
*Premix: lysine – 7.2%; methionine – 2.2%; threonine – 2%; Ca – 19.6%; P– 6.5%; Na – 2.5%; Fe – 2,900 mg; Mn – 2,000 mg; Zn – 2100 mg; Cu – 800 mg; I – 46 mg; Se – 11,5 mg; vitamins: A – 310,000 j.m., D_3 – 57,000 j.m., E – 2,300 mg, K_3 – 58 mg, B_1 – 58 mg, B_2 – 140 mg, B_6 – 85 mg, B_{12} – 700 mg, biotin – 2 900 mg, folic acid – 23 mg, pantothenic acid – 250 mg, nicotinic acid – 560 mg, choline – 4600 mg; amino acids: L-lysine, L-threonine, DL-methionine; antioxidants: BHA, BHT, ethoxiquin; enzymes: phytase, beta-xylanase, beta-glucanase, calcium carbonate, monocalcium phosphate (monophosphate), NaCl

Daily weight gains, feed intake, and feed consumption per unit weight gain were determined. When the fattening period was completed the animals were transported to a specialized slaughter facility. After a period of rest the animals were stunned and then slaughtered according to the procedures of the facility. On the processing line the half-carcasses were weighed on an electronic scale and measured with an IM-03 opto-needle apparatus. The following measurements were made: hot carcass weight (kg), backfat thickness between the third and fourth ribs (mm), length of the *longissimus dorsi* muscle (MLD) between the third and fourth ribs (mm), and meatiness (%).

Economic calculations were performed for the three groups, K, D1 and D2, i.e. the difference between income (sale of fatteners) and costs: purchase of piglets, fodder material (percentage in mixture x price), water, electricity, medicines, and veterinary care. To calculate the unit prices of compound feeds we used the mean prices of feed materials from

Table 2
Results of chemical analysis of feed mixtures (%)

Mixtures	Period of fattening	Dry matter	Crude ash	Crude protein	Crude fat	Crude fibre	N-free extract
Control (K)		88.64	6.82	15.30	1.97	4.16	60.39
Experimental 1 (D1)	I	87.17	4.18	15.19	2.07	5.28	60.45
Experimental 2 (D2)		85.81	4.28	15.74	2.16	5.33	58.3
Control (K)		86.20	5.76	15.39	1.66	4.07	59.32
Experimental 1 (D1)	II	85.74	4.00	15.27	1.73	5.69	59.05
Experimental 2 (D2)		85.20	3.93	15.42	1.81	6.20	57.84
Control (K)		86.14	4.60	14.68	1.37	5.04	60.45
Experimental 1 (D1)	III	85.29	4.06	15.18	1.49	6.82	57.74
Experimental 2 (D2)		85.30	4.43	14.80	1.70	6.59	57.78

October 2014 to January 2015 [13]. The price of 1 kg of feed mixture (PLN) in successive fattening periods, for groups K, D1 and D2, respectively, was as follows: I – 0.94; 0.94; 0.95; II – 0.93, 0.90, 0.90; and III – 0.88; 0.85; 0.85. Water intake was monitored using water meters and the cost of water consumption was calculated. Calculation of the cost of electricity was based on the power of the grain mill and mixer and the time needed to crush a tonne of grain and to mix a tonne of feed.

The results were analysed statistically in the SPSS Statistics 21 software package. As the distribution of variables was not normal (Shapiro-Wilk test), the differences between groups were tested by the Mann-Whitney U test.

Results and discussion

Crude protein content in the lupine seeds was 36.17%, which was lower than the recommended levels [1, 19]. The percentage of alkaloids in the dry weight of the seeds was 0.0129% and the percentage of lupanine and sparteine were 12.09% and 87.91%, respectively.

During the 86-day fattening period the daily weight gains (Tab. 3) of all the pigs were very good and comparable between groups, with a slight (+1.80% and +2.38%) advantage for the experimental groups, which should be considered a beneficial phenomenon. One of the factors that may have beneficially affected the fattening results for the experimental

Table 3
Fattening and carcass results

Specification	Group			SEM	P
	K	D1	D2		
Body weight of fatteners (kg)					
at start of fattening	27.2	27.7	26.7	0.727	0.946
after 1st stage of fattening	69.2	69.4	66.1	1.623	0.579
after 2nd stage of fattening	101.9	101.0	98.9	2.311	0.913
after 3rd stage of fattening/at slaughter	117.6	118.2	116.6	2.337	0.964
Daily weight gain (g)					
during 1st stage of fattening	1019	1017	960	25.750	0.669
during 2nd stage of fattening	1170	1129	1175	36.662	0.795
during 3rd stage of fattening	978	1078	1108	31.434	0.339
during fattening	1056	1075	1081	20.864	0.850
Hot carcass weight (kg)	88.1	89.8	88.7	1.853	0.858
Dressing percentage (%)	75.4	76.9	75.9	1.684	0.874
Backfat thickness (mm)	14.2	13.3	14.1	0.743	0.656
Length of *longissimus dorsi* muscle (mm)	62.9	68.6	66.3	1.540	0.295
Meatiness of carcasses (%)	58.8	59.4	59.2	0.405	0.858

K – control group
D1 – experimental group 1
D2 – experimental group 2

pigs was the low content of alkaloids in the lupine used in the feed mixtures. Due to the acidity level (pH=5) of the soil on which the lupine was grown, the quantity of alkaloids accumulated in the grain was small. As reported by Hanczakowska and Księżak [4], citing Chango et al. (1993) and Petterson et al. (1998), sweet lupines can be used in animal diets as substitutes for soybean protein because the level of alkaloids in the seeds does not exceed the acceptable norm of 0.02%. An excess of alkaloids (more than 0.03%) and/or an excessive percentage of lupine grain in the feed ration has been found to limit feed intake by pigs [4]. No problems with the pigs' feed intake were noted in the present study.

The analysis showed that consumption of the feed mixture by the growing pigs was fairly good: 2.72 kg/kg in the control and 2.72 and 2.69 kg/kg in experimental groups D1 and D2, respectively. This result confirms the suitability of yellow lupine for feeding fatteners. Feed consumption changed in successive stages of fattening. The third, relati-

vely short stage of fattening began after the pigs had attained a body weight of about 100 kg (K – 101.9 kg, D1 – 101.0 kg, D2 – 98.9 kg). It is likely that at this body weight the potential for growth in Danish hybrid pigs is lower than in the earlier period of growth and at a lower weight. The use of different lupine varieties as feed materials in mixtures for growing pigs has been the subject of various experiments [3, 14, 15, 21]. In an experiment by Roth-Maier et al. [15], the rate of growth of the control and experimental pigs (gilts and young boars of German Landrace x Pietrain cross-breeds) was poor. By replacing some of the protein from soybean extraction meal with yellow or narrow-leafed lupine seeds, the authors obtained greater, though statistically insignificant, body weight gain in the experimental groups in comparison with the control. In the present study, daily weight gain and feed conversion in the experimental fatteners were slightly better. The differences in the results of the experiments may have been due to different body weights of the animals at slaughter. Pisařiková et al. [14], using whole or hulled white lupine seeds in feed mixtures for fatteners, noted higher daily weight gain and feed conversion in the experimental groups than in the control, but the results obtained were less pronounced than in our study. Zralý et al. [20] replaced soybean extraction meal with white lupine seeds and observed a slight decrease in body weight gain in the growing pigs. Froidmont et al. [3] also noted a decrease in weight gain following administration of lupine seeds in feed mixtures. Sońta et al. [17] partially replaced soybean extraction meal with narrow-leafed lupine seeds and obtained comparable weight gain in fattened pigs (1.78% difference in favour of the control) and feed conversion (2.58% difference in favour of the experimental group). Hejdysz and Rutkowski [6], who studied the influence of combined administration of lupine seeds with various protein components on performance results in pigs, observed increased weight gain in comparison with a group receiving a mixture with soybean extraction meal as their only source of protein, while feed conversion was comparable in all groups.

The dressing percentage of the pigs studied was similar and typical of the species (Tab. 3) [3, 21]. Both the dressing percentage and meatiness of the pigs in groups D1 and D2 were somewhat higher than in group K. The backfat thickness in the experimental groups was smaller than in the control: by 6.34% in group D1 and 0.7% in D2. The LD muscle was 9.06% and 5.41% longer in the pigs in groups D1 and D2, respectively, in comparison to group K ($P>0.05$). Meatiness in the groups was good and comparable in the groups, and on this basis the carcasses were assigned to class E in the EUROP system [15, 20, 21]. Zralý et al. [20] report that animals in an experimental group fed on lupine had a lower dressing percentage and lower fatness, as well as slightly greater meatiness, in comparison with the control. In another experiment [21], fattening pigs (gilts and young boars of a Large White x Landrace cross) fed a mixture containing lupine seeds were characterized by a higher dressing percentage and lower fatness. Froidmont et al. [3], who included lupine seeds in the diet of fattening pigs (young boars of a Pietrain x Landrace cross), obtained a good dressing percentage and hot carcass weight in the experimental pigs. Sońta et al. [17] noted lower hot carcass weight, backfat thickness and loin muscle length (by 3.7 kg, 1.4 mm and 7.2 mm, respectively) following the use of narrow-leafed lupine in pig diets. Fluctuations in carcass indices following the use of

various proportions of lupine seeds in feed mixtures for growing pigs are small, and in the opinion of many authors [3, 15, 17, 20, 21] are not a contraindication for the use of pulses in fattening.

Table 4
Simplified calculation of production efficiency of fatteners

Specification	Group		
	K	D1	D2
INCOME			
Sale of fatteners (PLN)	5057.2	5085.7	5015.5
COSTS			
Purchase of piglets for fattening (PLN)	2261.0	2261.0	2261.0
Feed (kg)	2462.1	2461.9	2419.8
Feed consumption in 1st period (kg)	847.3	875.5	816.9
Cost of feed in 1st period (PLN)	796.5	823.0	776.1
Cost of feed per kg BW gain in 1st period of fattening (PLN)	1.95	2.01	1.89
Feed consumption in 2nd period (kg)	965.5	960.0	947.2
Cost of feed in 2nd period (PLN)	897.9	864.0	852.5
Cost of feed per kg BW gain in 2nd period (PLN)	3.10	3.09	3.06
Feed consumption in 3nd period (kg)	649.3	626.4	655.7
Cost of feed in 3nd period (PLN)	571.4	532.4	557.4
Cost of feed per kg BW gain in 3rd period (PLN)	3.22	3.12	3.29
Total cost of feed (PLN)	2265.8	2219.4	2186.0
Water (PLN)	14.4	14.4	14.4
Electricity (PLN)	74.1	77.4	80.8
Medicine and veterinary care (PLN)	56.6	56.8	55.0
TOTAL COSTS (PLN)	4671.9	4629.0	4597.2
DIFFERENCE income – costs (PLN)	385.30	456.70	418.30
Rate of change (%)	–	+18.53	+8.56

K – control group
D1 – experimental group 1
D2 – experimental group 2

A simplified analysis was performed of costs and revenue for the pigs studied in the experiment (Tab. 4). The costs of electricity, water, and medicine were comparable among the groups. Other expenses were varied, so the rate of change calculated for experimental groups D1 and D2 was +18.53% and +8.56%, respectively, with respect to the control (K). Sońta et al. [17] demonstrated a reduction in the costs of feeding growing pigs after using a 5% addition of narrow-leafed lupine in feed mixtures. The rate of change in favour of the experimental group was 3.23%. The cost of feed per kg body weight gain was also reduced in group D in comparison with the control, by 4.82% in the first fattening period and by 3.24% in the second. Hejdysz and Rutkowski [6] showed that the use of domestically produced protein material reduced the average cost of concentrate (raw material) consumed per kg weight gain by 0.24 PLN with respect to concentrate from soybean extraction meal, and in a second experiment by 0.23 PLN with respect to the control. Fiedorowicz and Sobotka [2] report that the price of 1 kg of digestible protein from soybean extraction meal is 4.87 PLN and slightly less in the case of yellow lupine, at 4.66 PLN. The authors conclude that the small difference in the unit price of protein between the two materials (a 4.31% difference) does not make yellow lupine a good economical alternative to soybean extraction meal. However, it seems advisable to observe the prices of feed materials, the relationships between them, and their supply and demand, since over a longer period changes and correlations may occur between imported and domestic feed materials. In the present study the price of 1 kg of digestible protein in soybean extraction meal and lupine seeds was 4.48 PLN and 4.04 PLN, respectively (a 9.82% difference), which justified the use of yellow lupine seeds in the diet of pigs.

The experiment showed that the use of 7.5% or 15% yellow lupine in compound feed for the experimental pigs had no detrimental effect on fattening results. Somewhat lower fatness and better musculature were noted in the carcasses obtained from the experimental pigs in comparison with the control. The positive rate of change obtained in the assessment of feeding and production efficiency and confirms that soybean extraction meal can be replaced with yellow lupine seeds to fatten pigs.

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