Scientific Annals of Polish Society of Animal Production - Vol. 11 (2015), No 1, 35-46

Effectiveness of the use of mixtures containing narrow-leafed lupin in the diet of growing pigs

Marcin Sońta, Anna Rekiel, Justyna Więcek

Warsaw University of Life Sciences, Faculty of Animal Sciences,
Department of Animal Breeding and Production, Pig Breeding Section,
ul. Ciszewskiego 8, 02-786 Warszawa

The aim of the study was to determine the suitability of narrow-leafed lupin as a partial substitute for soybean extraction meal protein in mixtures for growing pigs. A total of 100 (Landrace x Yorkshire) x Duroc hybrid piglets were assigned to experimental (D) and control (K) groups, with 50 pigs in each group. The animals were kept in the same conditions, with 10 piglets in each pen. During two-stage fattening from body weight of 27 to 113 kg the pigs were fed complete mixed rations. The pigs in group D group received feed containing 5% narrow-leafed lupin. Performance testing was carried out and carcass analysis was performed after slaughter. In addition, simplified economic evaluation of production efficiency was conducted. The results of the performance testing and slaughter analysis were very good and were comparable in groups K and D. The use of narrow-leafed lupin was found to be justified by the lower unit price of the mixture containing it. The costs of feed consumed per 1 kg of body weight gain were lower in group D than in group K by 4.82% (0.11 PLN) and 3.24% (0.09 PLN) in the 1st and the 2nd fattening stage, respectively, and the feed conversion rate was better as well. The economic analysis of fattening efficiency revealed a 3.23% advantage of group D over group K, which indicates that the use of narrow-leafed lupin seeds is justified for fattening of pigs.

KEY WORDS: fatteners / fattening characteristics / carcass traits / narrow-leafed lupin / economic efficiency of fattening

Due to the ban on the use of animal meal to feed pigs, domestic pig production has become dependent on imported feeds. At the same time, the demand for high-protein feeds of plant origin has increased by about 300,000 tonnes [9]. Pigs are fed soybean and rapeseed extraction meal, rapeseed cake, and the seeds of domestically produced leguminous plants [28]. Legumes supply about 0.3 million tonnes of protein, of which 0.13 million tonnes come from cultivation of lupines. Within 5-6 years the increase in the area of legume crops will reduce imports of soybean extraction meal by about 50%. The increase in legume production means production of about 300,000 tonnes of fodder protein. According to various estimates, production of these plants currently meets only about 25% of the demand for fodder protein for feeding monogastric animals [29].

In Polish conditions sweet lupins (white, yellow and narrow-leafed), peas and fava beans are grown for animal feed. Lupin seeds, even of the same cultivar, differ from one another in their content of antinutrient substances and also have varying nutritional and calorific value, which may cause differences in the digestibility of nutrients and in the amount of nitrogen excreted by the animals in their faeces and urine. The protein content of lupin seeds ranges from 29% to 52% of their dry weight [3, 5, 7, 11, 13, 25, 26].

The use of lupins in concentrate feed prepared in feed mixing plants is limited. This is due to the lack of a regular supply of large batches of material. Each delivery requires determination of basic parameters, including protein content. The variable content of antinutrient substances, fluctuating from year to year, limits the use of lupins for feeding animals [19]. Alkaloids contained in lupins inhibit conduction in the nervous system and cause changes in the digestive and circulatory systems. The main symptom of the effects of alkaloids in animals is reduced feed consumption [13].

Many studies have been conducted on model animals (rats) and pigs to determine the value and suitability of seeds of various lupin species and cultivars in feeding monogastric animals [10, 14, 20, 22, 23, 25]. Including lupin seeds in feed rations has produced varying results, but they have mostly been encouraging [2, 6, 18, 20, 27, 30, 31]. Kasprowicz-Potocka and Frankiewicz [12], however, summarizing the results of studies conducted by Nevel et al. (2000) and Hanczakowska et al. (2000), indicate lower feed intake and weight gain in pigs whose feed includes lupin or lupin with rapeseed cake. King et al. [14] also emphasize the possibility of reduced feed conversion and depressed weight gain in pigs fed mixtures containing lupin. Salgado et al. [22] indicate certain changes in enzyme activity, the structure of the intestinal epithelium, and the weight of internal organs in pigs receiving mixtures containing lupin seeds. Hanczakowska and Księżak [7], analysing the results of numerous experiments, suggest that a 20% share of lupin in the feed ration can be considered safe. Results obtained by Zraly et al. [30, 31] and Pisarikov et al. [18] seem to confirm this.

Genetic gain and implementation of new seed-processing technologies have led to favourable changes in the value and suitability of various species and new cultivars of plants. The needs and requirements of pigs, including crossbreeds of modern genotypes, have changed as well.

Taking into account the facts presented above, as well as the need for alternative, less expensive sources of protein for feeding pigs, a study was undertaken to determine the suitability of narrow-leafed lupin seeds for fattening pigs.

Material and methods

The experiment was conducted in the spring/summer period of 2013, on a private farm in the Łódź Voivodeship. The material for the experiment consisted of 100 weaners—gilts and young boars of three-breed crosses ((♀ Landrace x Yorkshire) x ♂ Duroc). The animals were weighed and then assigned to a control (K) or experimental (D) group (sex 1:1, similar mean body weight between groups, 50 pigs each in groups K and D). The weaners were kept in groups with 10 pigs per pen, in conditions compliant with the Regulation of the Ministry of Agricultural and Rural Development [21]. One female and one male from each pen (with body weight similar to the mean for the sex in the pen) were ear-tagged and weighed every two weeks during the fattening period. Individual body weights of growing pigs were obtained from 20% of the animals—10 pigs each from groups K and D. The pigs were slaughtered when the body weight of the tagged pigs was about 113 kg. On the day of slaughter all pigs were weighed individually.

During two-stage fattening (stage I – 8 weeks from body weight of 27 kg, stage II – 6 weeks) total mixed rations were used, prepared according to a formula developed by a nutritionist from NEOROL Sp. z o.o. (Tab. 1). The control mixtures contained soybean and rapeseed extraction meal, and the experimental mixtures additionally contained crushed seeds of narrow-leafed lupin. The mixtures were prepared on the farm using on-farm cereals and premixes: during the first fattening period NEOMIX HMG 3 (lysine – 9.6%, methionine – 2.65%, threonine – 2.73%, Ca – 20%, P – 1.8%, Na – 5.5%, Fe – 4,000 mg, Mn – 2,400 mg, Zn – 2,600 mg, Cu – 800 mg, J – 55 mg, Se – 13.5 mg; vitamins: A – 380,000 IU, D_3 – 69,000 IU, E – 4,700 mg, K_3 – 68 mg, B_1 – 68 mg, B_2 – 170 mg, B_6 – 105 mg, B_{12} – 830 mg, C – 1,000 mg, folic acid – 27 mg, pantothenic acid – 410 mg, niacinamide B_3 – 690 mg, biotin – 3450 mg, choline chloride – 10,000 mg; amino acids: L-lysine, L-threonine, DL-methionine; antioxidants: BHA, BHT, ethoxyquin; enzymes: phytase, beta-xylanase, beta-glucanase; calcium carbonate, monocalcium phosphate (monophosphate) and sodium chloride, and in the second fattening period NEOMIX GROWER MAX 3 (lysine – 9.5%, methionine – 1.3%, threonine – 2.7%, Ca – 22%, P – 1.5%, Na – 5.5%, Fe – 3,400 mg, Mn – 1,950 mg, Zn – 2,100 mg, Cu – 800 mg, J – 44 mg, Se – 11,0 mg; vitamins: A – 330,000 IU, D_3 –56,000 IU, E – 3,000 mg, K_3 – 55 mg, B_1 – 55 mg, B_2 – 140 mg, B_6 – 85 mg, B_{12} – 930 mg, C – 1,500 mg, folic acid – 23 mg, pantothenic acid – 340 mg, niacinamide B_3 – 560 mg, biotin – 2,800 mg, choline chloride – 10,000 mg; amino acids: L-lysine, L-threonine, DL-methionine; antioxidants: BHA, BHT, ethoxyquin; enzymes: phytase, beta-xylanase, beta-glucanase; calcium carbonate, monocalcium phosphate (monophosphate) and sodium chloride).

The cereal grain and lupin seeds were crushed in a grain mill and then all of the components (according to the formula), were mixed in a vertical mixer.

The pigs were given feed twice a day in the rationed feeding system [16], with continual access to water. Uneaten feed was monitored.

Total lupin alkaloids were determined in duplicate 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 [15]. Protein content in the lupin was determined at the NEOLAB feed analysis station of NEOROL Sp. z o.o. The total content of alkaloids was 0.0539% in the dry weight of the seeds and protein content was 34%. The proximate chemical composition of the feed mixtures was determined according to AOAC [1].

Daily weight gains, feed intake, and feed conversion per unit weight gain were determined. When the fattening period was completed all the animals were transported in a specialized vehicle to the BRAT-POL Sp. z o.o. meat plant (60 km), where after a rest period and electrical stunning they were slaughtered according to the procedures of the facility (HACCP system). The following were determined after slaughter: hot carcass weight (%), backfat thickness between the third and fourth ribs, the length of the longissimus dorsi muscle (MLD) between the third and fourth ribs (mm), and lean meat content (%), measured with a SYDEL CGM choirometer with an optical probe.

Unit prices for the mixtures were calculated using averaged prices for the feed materials from April-July 2013 [17]. Water intake by the pigs was monitored daily using water meters installed in the piggery and the costs were calculated. Energy costs included the electricity used to crush the cereals and mix the feed. Calculations of energy costs took into account the power of the grain mill and mixer, the time needed to crush a tonne of grain and to mix a tonne of feed, and the amount of compound feed produced. The economic efficiency of production of fatteners was calculated in groups, based on the difference between revenue from the sale of fatteners and the costs incurred, i.e. feed material (share in the mixtures x price), purchase of weaners, electricity, water, medicine, and veterinary care.

Table 1
Composition of feed mixtures (%)

Specification	Mixtures			
	1st period of fattening		2nd period of fattening	
	group			
	control (K)	experimental (D)	control (K)	experimental (D)
Barley – meal	40	40	35	33.5
Triticale – meal	31	28.2	34	33
Wheat – meal	10	10	10	10
Oats – meal	–	–	6	6
Soybean extraction meal	10.5	8	7.5	5
Rapeseed extraction meal „00”	5	5	5	5
Narrow-leafed lupin – meal	–	5	–	5
Premix NEOMIX HMG3	2.5	2.5	–	–
Premix NEOMIX GROWER MAX 3	–	–	2.5	2.5
Soy oil	1	1,3	–	–
TOTAL	100	100	100	100

The results were analysed statistically in the SPSS Statistics 21 software package [24]. Normality of distribution was tested by the Shapiro-Wilk test. Differences between groups were tested by Student's t-test (features with normal distribution) or the Mann-Whitney U test (other features).

Results and discussion

Table 2 presents the results of the chemical analysis of the compound feeds, and Table 3 shows the fattening results. Fattening from a mean body weight of about 27 kg until slaughter (113 kg) lasted 97 days; fattening stages I and II lasted 56 and 41 days, respectively. Differences in body weight between groups K and D were noted after the completion of fattening stage I and at slaughter (Tab. 3). After the completion of fattening stages I and II the body weight of the group D pigs was 6.37% and 2.49% lower, respectively, than in group K (statistically non-significant differences).

Table 2
The results of chemical analysis of feed mixtures (%)

Specification	Mixtures			
	1st period of fattening		2nd period of fattening	
	group			
	control (K)	experimental (D)	control (K)	experimental (D)
Dry matter	87.57	88.25	87.28	86.99
Crude ash	4.33	5.19	4.56	4.52
Crude protein	16.03	16.17	15.69	15.29
Crude fat	2.44	2.42	1.93	2.05
Crude fibre	4.54	4.73	4.82	5.42
Nitrogen-free extract	72.66	71.49	73.00	72.72

During the fattening, which was carried out under veterinary control, there were isolated medical interventions, but no deaths. Daily weight gain and feed conversion were varied in stages I and II, but were good (Tab. 3) considering that the share of alkaloids contained in the lupin used to prepare the compounds exceeded the acceptable level. However, the recommended proportion of lupin was not exceeded in the mixtures [7, 12, 13]. Pigs are particularly sensitive to lupin alkaloids. According to Hanczakowska and Księżak [7], pigs do not eat all of their feed if the content of alkaloids in the seeds contained in the feed exceeds

0.03%. Analysis of scientific studies shows that good production results can be obtained by using compound feeds for piglets and fatteners in which lupin does not exceed 10% and 20%, respectively [7, 18, 30, 31]. Previously the acceptable share of lupins in feed rations for older piglets and for lighter and heavier fatteners was lower, at 0-10%, 5-10% and 10-15%, respectively [12]. In the present study, in fattening stage I the weight gain in the group D fatteners was 91 g (9.70%) lower than in group K (P=0.06), while in stage II it was 59 g (7.01%) higher (P>0.05). Feed conversion by the control and experimental pigs differed only slightly. In fattening stage I the group D animals consumed 2.60% more feed per kg of body weight gain than the group K pigs. In fattening stage II feed conversion by the group D pigs improved in comparison to group K; feed consumption per unit weight gain was 6.07% lower (Tab. 3); the differences were statistically non-significant. The costs of feed per kg weight gain were 2.28 and 2.17 PLN in fattening stage I in groups K and D, respectively, and 2.78 and 2.69 PLN in fattening stage II, i.e. they were lower in group D; the difference in fattening stages I and II was 0.11 and 0.09 PLN (4.82% and 3.24%).

Table 3
Fattening results and slaughter value of fatteners

Specification	Groups		P
	control (K)	experimental (D)	
Mean body weight at start of fattening (kg)	27.20	27.25	0.974
Mean body weight after 1st stage of fattening (kg)	80.90	75.75	0.121
Mean body weight of fatteners at slaughter (kg)	114.6	111.75	0.850
Daily weight gain during 1st stage of fattening (g)	959	866	0.060
Daily weight gain during 2nd stage of fattening (g)	842	901	0.341
Daily weight gain during fattening (g)	900	884	0.700
Feed conversion during 1st stage of fattening (kg/kg)	2.31	2.37	0.174
Feed conversion during 2nd stage of fattening (kg/kg)	3.13	2.94	0.370
Hot carcass weight (kg)	89.45	85.74	0.284
Backfat thickness between 3rd and 4th rib (mm)	12.0	10.6	0.270
Musculus *longissimus dorsi* thickness between 3rd and 4th rib (mm)	64.9	57.7	0.053
Meatiness of carcasses (%)	60.47	60.40	0.936

The high digestibility of protein and amino acids of lupin seeds and their energy value have been emphasized by various researchers [10, 12]. These properties are the basis for good production results. Gdala et al. [6] found that pigs receiving feed mixtures containing yellow lupin and narrow-leafed lupin or soybean extraction meal had comparable growth rates during fattening.

Our own results obtained in fattening stage I were comparable to those of experiments by Falkowski and Jabłonowski [2] and by Froidmont et al. [4]. The results of experimental fattening conducted by Roth-Maier et al. [20] were different. During the first period of fattening high daily weight gains, at a level of 958 g, were noted in the group of pigs fed a mixture containing 20% narrow-leafed lupin. The pigs receiving compound feed with soybean extraction meal grew more slowly (daily weight gain 6.47% lower, 896 g/day).

Feed conversion by the pigs in the present study was good, but in the experiment by Roth-Maier et al. [20] it was even better: the difference was 7.39% for the control mixture and 14.35% for the experimental mixture. The variation may have been due to different body weights in the pigs completing the first stage of fattening (change in feed) and to the quality of the lupin used. The content of antinutrient substances in lupin is sometimes varied, depending on the site, water resources and the pH of the soil where the plant is cultivated [8]. Lacking analyses of soil pH, we can only surmise that this factor may have affected the quality of the lupin and the somewhat inferior feed conversion by the pigs in our study. It should be emphasized, however, that feed conversion in the experiments compared was very good, and in the study cited [20] may have been due to better nutrient balance.

In the second fattening stage, lasting 41 days, the difference in daily weight gain in the group D pigs as compared to group K was 59 g (Tab. 3), while in the experiment by Roth--Maier et al. [20] it was lower (17 g, 1.76%). In the present study feed conversion was better in the group D pigs, while Roth-Maier et al. [20] obtained the reverse results. However, the differences for this characteristic between groups in the two experiments were slight, so that the values can be considered comparable (Tab. 3).

For the entire fattening period comparable body weight gains were obtained in the groups (Tab. 3). In a study by Sumisławski and Grudniewski [27], better weight gains were obtained in a group fed a mixture with a small (only 4%) percentage of narrow-leafed lupin than in pigs receiving a mixture containing animal components—fish meal or powdered non-fat milk.

Zraly et al. [31] studied the effect of white lupin on the health, production indicators, carcass quality, fatty acid profile in the intramuscular fat, and sensory characteristics of meat. With a proportion of lupin seeds of no greater than 20% in the feed mixture they observed no reduction in feed consumption. The authors noted a positive, though non-significant effect of adding fat to the mixtures on weight gain (from 2.3% to 10%). Feeding pigs mixtures containing lupin did not affect the carcass and meat quality. Pisarikova et al. [18] also used white lupin in a study on growing pigs, replacing soybean extraction meal with whole or hulled seeds at a level of 50% or 100%. In the case of both groups with lower content of lupin, digestibility of the most important nutrients, i.e. protein, fat and fibre, was significantly better than in the control. The mean daily weight gain was also better in the experimental groups than in the control (P>0.05). The authors concluded that it is most beneficial to completely replace soybean extraction meal with hulled lupin seeds.

In a study on young pigs (about 30 kg body weight) fed for three weeks on mixtures containing narrow-leafed lupin seeds, Salgado et al. [22] observed significant or non-significant negative changes in enzyme activity (including maltase and aminopeptidase) and in the structure of the intestinal epithelium (including the width of the crypts in the analysed segments of the small intestine—the duodenum, jejunum and ileum, post mortem). The authors also noted a slight (P>0.05) decrease in the weight of the stomach, small and large intestines, liver, kidneys, pancreas, and thymus and an increase in the size of the gall bladder. Taking into account this information we can surmise that anatomical and physiological changes may negatively affect conversion of feed containing lupin, which in the present study may have been the cause of the periodically slower growth rate and/or inferior feed conversion.

Very good results were obtained for the carcass evaluation in both groups (Tab. 3). Meatiness was somewhat above 60%, while the dressing percentage was 78.05% in the group K pigs and 76.72% in group D (a difference of about 1.33 percentage points in favour of the control). In the experiment by Roth-Maier et al. [20], the body weight of the animals at slaughter was about 10 kg higher than in the present study, and their carcasses were fattier (15.3-16.4 mm) and less meaty (56.6-56.8%). This was independent of the composition of the compound feed [20]. Most of the carcasses were assigned to class E, while in the present study the percentage of carcasses with higher meat content (class S) was high. The percentages of carcasses in classes S and E were 70% and 30%, respectively, in group K and 60% and 40% in group D.

A simplified analysis of costs and revenues was performed for the pigs from groups K and D (Tab. 4). The costs of feed per kg body weight gain were 4.82% and 3.24% lower for group D than for group K in fattening stages I and II, respectively. The difference between costs and revenues was more favourable in group D than in group K; the rate of change was 3.23% in favour of group D, whose feed included narrow-leafed lupin. Fiedorowicz and Sobotka [3] report that the cost of 1 kg of digestible protein from soybean extraction meal containing 46% crude protein is 4.87 PLN, as compared to only 3.35 PLN in the case of narrow-leafed lupin containing 36% crude protein (31.21% less). According to the authors [3], the cheapest alternative to soybean extraction meal is sunflower seed extraction meal, followed by narrow-leafed lupin. The unit prices of digestible protein are largely dependent on the current prices of the feed materials, and these fluctuate depending on supply and demand.

The new Rural Development Programme begun on 1 January 2014 introduced a 'greening' requirement for agricultural land on farms over 10 ha. This means that the area of pulse cultivation will increase rapidly and import of soy from abroad will be reduced [29]. These measures should contribute to more common use of pulses, including lupins, to feed pigs, and to a reduction in the cost of feeding fatteners.

To sum up, the use of a 5% share of lupin seeds in the feed rations did not significantly affect the growth performance of the growing pigs. The daily weight gain in the control and experimental groups was 900 and 884 g, respectively. Feed conversion per kg weight

Table 4
Simplified calculation of costs and income in control and experimental groups (PLN)

Specification	Group	
	control (K)	experimental (D)
INCOME		
Sale of fatteners (PLN)	32664	32460
COSTS		
Purchase of pigs for fattening (PLN)	15000	15000
Feed (kg)	10971.9	10716.6
Price 1 kg feed in 1st fattening period (PLN)	1.113	1.097
Feed consumption in 1st period (kg)	5731.1	5541.1
Cost of feed in 1st period (PLN)	6378.14	6083.77
Price 1 kg feed in 2nd fattening period (PLN)	1.034	1.013
Feed consumption in 2nd period (kg)	5240.8	5175.5
Cost of feed in 2nd period (PLN)	5418.99	5241.22
Feed (PLN)	11797.13	11324.99
Water (PLN)	140	140
Electricity (PLN)	393.75	395.43
Medicine and veterinary care (PLN)	642.24	636.69
TOTAL COSTS (PLN)	27973.12	27497.11
DIFFERENCE income – costs (PLN)	4690.88	4962.89
Rate of changes (%)		+3.23

gain was comparable in the groups in fattening stages I and II. While fat content was 11.67% lower in the experimental group than in the control, meat content was comparable (60.47% and 60.40% for the control and experimental pigs, respectively).

The use of lupin in compound feeds is justified, as confirmed by the lower unit cost of the mixtures and the lower cost of consumed feed per kg of body weight, as well as the highly favourable meat content of the pigs. The favourable rate of change for the group of experimental pigs as compared to the control (3.23%), revealed by the simplified economic analysis of production efficiency, also indicates benefits arising from the use of narrow-leafed lupin seeds to feed pigs.

REFERENCES

1. AOAC 2005 – Official methods of analysis of the association of official chemists. 16th Edition. Arlington, Virginia, USA.
2. FALKOWSKI J., JABŁONOWSKI K., 1993 – Przydatność mieszanek z udziałem nasion bobiku, peluszki i łubinu wąskolistnego w żywieniu prosiąt. ***Acta Academiae Agriculturae Technicae Olstenensis Zootechnica*** 38, 81-95.
3. FIEDOROWICZ E., SOBOTKA W., 2013 – Poekstrakcyjna śruta sojowa a alternatywne źródła białka roślinnego dla trzody chlewnej. ***Przegląd Hodowlany*** 4, 14-17.
4. FROIDMONT E., WATHELET B., BECKERS Y., ROMNEÉ J.M., DEHARENG F., WAVREILLE J., SCHOELING O., DECAUWERT V., BARTIAUX-THILL N., 2005 – Improvement of lupin seed valorisation by the pig with the addition of α-galactosidase in the feed and the choice of a suited variety. ***Biotechnology, Agronomy Society and Environment*** 9, 225-235.
5. GAWŁOWSKA M., ŚWIĘCICKI W., 2007 – Uprawa, rynek i wykorzystanie roślin strączkowych w Unii Europejskiej. ***Zeszyty Problemowe Postępów Nauk Rolniczych*** 522, 505-513.
6. GDALA J., JANSMAN A.J.M., VAN LEEUWEN P., HUISMAN J., VERSTEGEN M.W.A., 1996 – Lupins (*L. luteus, L. albus, L. angustifolius*) as protein source for young pigs. ***Animal Feed Science and Technology*** 62, 239-249.
7. HANCZAKOWSKA E., KSIĘŻAK J., 2012 – Krajowe źródła białkowych pasz roślinnych jako zamienniki śruty sojowej GMO w żywieniu świń. ***Roczniki Naukowe Zootechniki*** 2, 171-187.
8. JANSEN G., JÜRGENS H.U., SCHLIEPHAKE E., GORDON F., 2012 – Effect of the soil pH on the alkaloid content of *Lupinus angustifolius*. ***International Journal of Agronomy*** 1. ID 26987.
9. JERZAK M.A., CZERWIŃSKA-KAYZER D., FLOREK J., ŚMIGLAK-KRAJEWSKA M., 2012 – Determinanty produkcji roślin strączkowych jako alternatywnego źródła białka – w ramach nowego obszaru polityki rolnej w Polce***. Roczniki Nauk Rolniczych*** G, 1, 113-120.
10. JEZIERNY D., MOSENTHIN R., BAUER E., 2010 – The use grain legumes as a protein source in pig nutrition: A review. ***Animal Feed Science and Technology*** 157, 111-128.
11. KASPROWICZ-POTOCKA M., CHILOMER K., ZAWORSKA A., NOWAK W., FRANKIEWICZ A., 2013 – The effect of feeding raw and germinated *Lupinus lueus* and *Lupinus angustifolius* seeds on the growth performance of young pigs. ***Journal of Animal and Feed Sciences*** 22, 116-121.
12. KASPROWICZ-POTOCKA M., FRANKIEWICZ A., 2001 – Nasiona łubinu w żywieniu trzody chlewnej. ***Roczniki Naukowe Zootechniki,*** Supl., 13, 55-62.
13. KIM J.C., PLUSKE J.R., MULAN B.P., 2007 – Lupins as a protein source in pigs diets. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. CAB International, Wallingford, 2, No. 003, 1-12.

14. KING R.H., DUNSHEA F.R., MORRISH L., EASON P.J., VAN BARNEVELD R.J., MULLAN B.P., CAMPBELL R.G., 2000 – The energy value of *Lupinus angustifolius* and *Lupinus albus* for growing pigs. ***Animal Feed Science and Technology*** 83, 17-30.
15. MAŃCZAK T., DOLATE A., WIATR K., 2007 – Udział alkaloidów chinolizydynowych i graminy w nasionach odmian łubinów zarejestrowanych w Polsce. ***Zeszyty Problemowe Postępów Nauk Rolniczych*** 522, 463-471.
16. Normy Żywienia Świń, 1993 – IFiŻZ PAN w Jabłonnie. Omnitech-Press.
17. Notowania. Rynek Pasz, 2013 – Zintegrowany System Rolniczej Informacji Rynkowej. Biuletyny Informacyjne (5-7); http://www.minrol.gov.pl
18. PISAŘIKOVÁ B., ZRALÝ Z., BUŇNKY F., TRČKOVÁ M., 2008 – Nutritional value of white lupine cultivar Butan in diets for fattening pigs. ***Veterinarni Medicina*** 53 (3), 124--134.
19. PRUSIŃSKI J., 2007 – Postęp biologiczny w łubinie (*Lupinus sp.)* – rys historyczny i stan aktualny. ***Zeszyty Problemowe Postępów Nauk Rolniczych*** 522, 23-37.
20. ROTH-MAIER D.A., BÖHMER B.M., ROTH F.X., 2004 – Effects of feeding canola meal and sweet lupin (*L. luteus, L. angustifolius*) in amino acid balanced diets on growth performance and carcass characteristics of growing-finishing pigs. ***Animal Research*** 53, 21-34.
21. ROZPORZĄDZENIE Ministra Rolnictwa i Rozwoju Wsi z dnia 15 lutego 2010 r. w sprawie wymagań i sposobu postępowania przy utrzymaniu gatunków zwierząt gospodarskich, dla których normy ochrony zostały określone w przepisach Unii Europejskiej. Dziennik Ustaw nr 56, poz. 344.
22. SALGADO P., MARTINS J.M., CARVALHO F., ABREU M., FREIRE J.P.B., TOULLEC R., LALLÈS J.P., BENTO O., 2002 – Component digestibility of lupin *(Lupinus angustifolius)* and pea *(Pisum sativum)* seeds and effects on the small intestine and body organs in anastomosed and intact growing pigs. ***Animal Feed Science and Technology*** 98, 187-201.
23. SOBOTKA W., STANEK M., BOGUSZ J., MATUSEVICIUS P., 2013 – The effect of oligosaccharides and alkaloids contained in yellow and blue lupine seeds on feed intake, body weight and fermentation processes in the cecum of rats. ***Veterinarija ir Zootechnika*** 63 (85), 63-70.
24. SPSS Statistics v. 21 for Windows user,s guide, 2012 by SPSS Ins., USA.
25. STANEK M., BOGUSZ J., SOBOTKA W., 2010 – Nutrient digestibility and nitrogen balance in growing-finishing pigs fed diets containing blue lupine (*Lupinus angustifolius*) seeds. ***Ecological Chemistry and Engineering A*** 17 (6), 671-676.
26. STANEK M., BOGUSZ J., SOBOTKA W., BIENIASZEWSKI T., 2012 – Wartość odżywcza nasion łubinu wąskolistnego. ***Fragmenta Agronomica*** 4, 160-166.
27. SUMISŁAWSKI K., GRUDNIEWSKA B., 1994 – Zastosowanie w żywieniu warchlaków i tuczników nasion łubinu wąskolistnego odmiany Kazan. ***Acta Academiae Agriculturae Technicae Olstenensis Zootechnica*** 40, 111-121.
28. ŚWIĘCICKI W., SZUKAŁA J., MIKULSKI W., JERZAK M., 2007 – Możliwość zastąpienia białka śruty sojowej krajowymi surowcami. ***Zeszyty Problemowe Postępów Nauk Rolniczych*** 522, 515-521.
29. UCHWAŁA Rady Ministrów nr 149/2011 z dnia 9 sierpnia 2011 roku w sprawie ustanowienia programu wieloletniego pod nazwą „Ulepszanie krajowych źródeł białka roślinnego, ich produkcji, systemu obrotu i wykorzystania w paszach”.

30. ZRALÝ Y., PISAŘIKOVÁ B., TRČKOVÁ M., HERZIG I., JŮZL M., SIMEONOVOVÁ J., 2006 – Effect of lupine and amaranth on growth rfficiency, health, and carcass characteristics and meat quality of market pigs. ***Acta Veterinaria Brno*** 75, 363-372.
31. ZRALÝ Y., B., TRČKOVÁ M., HERZIG I., JŮZL M., SIMEONOVOVÁ J., 2007 – The effect of white lupine on the performance, health, carcass characteristics and meat quality of market pigs. ***Veterinarni Medicina*** 52 (1), 29-41.