NUTRIENT DIGESTIBILITY AND NITROGEN BALANCE IN FATTENING PIGS FED DIETS CONTAINING YELLOW LUPINE SEEDS AND ENZYMES

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Summary. The results obtained show that partial substitution of yellow lupine seeds in the amount of 11.5% for soybean meal in diets for pigs had a positive effect on the digestibility of all nutrients. Enzyme supplementation of a diet containing 11.5% of yellow lupine seeds had no influence on nutrient digestibility. A higher yellow lupine content (18%) of the diets caused a decrease in the digestibility of crude fiber, N-free extractives and gross energy. A higher yellow lupine content of the diets required enzyme supplementation, which affected positively the digestibility of crude protein, crude fiber and N-free extractives.

Adding 18% of yellow lupine seeds to diets for fatteners had a negative effect on nitrogen balance. Partial substitution of yellow lupine seeds for soybean meal resulted in a high nutritive value of the diets. Enzyme supplementation of the diet with a higher lupine content had a considerable effect on the level of metabolizable energy.

Keywords: pigs, yellow lupine, enzymes, digestibility, nitrogen balance.

MAISTO MEDŽIAGŲ VIRŠKINIMAS IR AZOTO BALANSAS ORGANIZME PENIMŲ KIAULIŲ, ŠERIAMŲ PAŠARU SU GELTONAISIAIS LUBINAIS IR FERMENTAIS

Santrauka. Tyrimo rezultatai parodė, kad dalinis sojų išspaudų pakeitimas geltonųjų lubinų sėklomis (11,5%) turėjo teigiamą poveikį maisto medžiagų virškinimui. Racionas, kurio sudėtyje buvo 11,5% geltonųjų lubinų sėklų, papildytas fermentu, jokios įtakos maisto medžiagų virškinimui kiaulių organizme neturėjo. Didesnis geltonųjų lubinų kiekis (18%) sumažino žaliosios ląstelienos, neazotinių ekstraktinių medžiagų ir bruto energijos virškinimą. Fermentinis preparatas pašaruose, kuriuose buvo daugiau geltonųjų lubinų sėklų, pagerino baltymingumo, žaliosios ląstelienos ir neazotinių ekstraktinių medžiagų virškinimą kiaulių organizme.

18% geltonųjų lubinų sėklų penimų kiaulių pašare neigiamai veikė azoto balansą. Dalinis sojų išspaudų pakeitimas geltonaisiais lubinais sąlygoja aukštą raciono maistinę vertę. Pašarų, turinčių daugiau lubinų, papildymas fermentu, daro didelį poveikį apykaitos energijai.

Raktažodžiai: kiaulės, geltonieji lubinai, fermentai, virškinimas, azoto balansas.

Introduction. The deficiency of protein concentrates often has a negative effect on pig production results. The source of protein in diets for pigs is usually imported high-quality soybean meal. However, the role of a high-protein feed component may be also played by seeds of leguminous plants, which was confirmed by the results obtained, among other, by Jacyno et al.(1990) or Czarnecki et al. (1991). Special attention should be paid to yellow lupine (*Lupinus luteus*) whose varieties are high-yielding and characterized by a low alkaloids content (Święcicki et al. 1997). The protein content of dry matter of yellow lupine seeds is 42 to 44% (Flis 1993, Pastuszewska et al. 1994, Wasilewko and Buraczewska 1999). However, apart from a high protein content, lupine seeds are also characterized by the highest (compared with the other leguminous plants) concentration of structural carbohydrates, represented mainly by non-starchy polysaccharides. Their presence makes it difficult for digestive enzymes to get access to nutrients, which disturbs their digestion and reduces the nutritive value of diets (Cyran et al. 1995). Numerous attempts have been made to increase lupine carbohydrate utilization in growing pigs, by diet supplementation with properly selected enzymatic preparations.

The aim of the present studies was to determine the effects of substitution of yellow lupine seeds for soybean meal in diets for growing pigs on nutrient digestibility and nitrogen balance. The effects of diet supplementation with enzymatic preparations containing β-glucanase, pentozanase, hemicellulase, pectinase and xylanase on nutrient digestibility, nitrogen balance and the nutrient value of diets were also analyzed.

Material and Methods. The experiment was performed on 25 young hogs (Polish Large White x Polish Landrace) with body weights of 50 kg. Nutrient digestibility and nitrogen balance were determined by the simple balance method. The hogs, divided into five groups (five head each), were kept and fed individually. They received complete diets whose composition is presented in Table 1. The control diet (1) contained soybean meal as the main source of protein (19%). In the experimental diets a part of soybean meal was replaced with yellow lupine seeds. Diets 2 and 3 contained 11.5% of yellow lupine seeds + 10% of soybean meal, whereas diets 4 and 5 -18.0% of yellow lupine seeds + 5% of soybean meal. The cereal component was barley grain. The diets were also supplemented with: NaCl, dicalcium phosphate, limestone, Polfamix T and synthetic amino acids (Pig Nutrient Requirements 1993). Enzymatic preparations were added to diets 3 and 5. The preparation Ronozyme VP contained: endo-1,3(4)-β-glucanase with activity > 50 FBG/g, pentozanase with activity ~ 7000 PSU/g, hemicellulase and pectinase. The preparation Ronozyme WX contained endo-1,4-β-xylanase with activity of 1000 FSU/g.

Table 1. **Composition of concentrates for growing pigs**

Components, %	Diet				
	Control 1	LLC 2	LLC +E 3	HLC 4	HLC+E 5
Ground barley	78.26	75.26	75.68	74.22	74.14
Soybean meal	19.00	10.00	10.00	5.00	5.00
Yellow lupine seeds	-	11.50	11.50	18.00	18.00
Feed additives [1]	2.74	2.74	2.74	2.78	2.86
Ronozyme VP[2]	-	-	0.06	-	0.06
Ronozyme WX[3]	-	-	0.02	-	0.02

[1] limestone, dicalcium phosphate, NaCl, mineral-vitamin premix, synthetic AA
[2] β-glucanase, pentozanase, hemicellulase, pectinase
[3] β-xylanase
LLC – low lupine content (11.5%)
LLC + E - low lupine content (11.5%) + enzymatic preparations
HLC – high lupine content (18.0%)
HLC + E – high lupine content (18.0%) + enzymatic preparations

Over the experimental period the hogs received 2.2 kg of feed. They were fed twice a day, about 7 a.m. and 2 p.m. Each time they were given a half of the daily ration, with water (at a ratio of 1:1).

The basic analysis of all samples of particular components, diets, feces and urine was made by standard methods (AOAC 1990). The nutritive value of the diets was determined on the basis of the nutrient digestibility coefficients.

The results of the experiment were elaborated statistically by one-factor analysis of variance in an orthogonal design.

Results. The nutrient digestibility coefficients are shown in Table 2. The lowest organic matter digestibility was observed in the hogs fed a diet with 18% of yellow lupine seeds (4) and those receiving the control diet (1) - 81.17% and 81.50% respectively. The highest organic matter digestibility was noted in the hogs fed a diet with 11.5% of yellow lupine seeds - 84.68%. The difference was statistically significant.

Table 2. **Apparent digestibility coefficients**

Specification	Groups				
	Control 1	LLC 2	LLC+E 3	HLC 4	HLC+E 5
Organic matter	81.50^{Bb}	84.68^{A}	83.63^{ac}	81.17^{Bbd}	83.84^{a}
Crude protein	73.80^{Bb}	76.90^{a}	77.60^{a}	74.37^{Bb}	78.88^{A}
Crude fat	35.91^{B}	50.99^{A}	60.01^{A}	49.89^{A}	63.27^{A}
Crude fiber	39.28^{a}	44.11^{A}	37.72^{a}	35.42^{Bb}	44.50^{A}
N-free extractives	87.38^{B}	87.64^{B}	89.28^{A}	87.48^{B}	88.92^{A}
Energy	78.23^{b}	79.74^{a}	79.96^{a}	78.32^{b}	80.59^{a}

Means within a row with different superscripts are significantly different: a, b, c, - $P<0.05$, A, B, C – $P<0.01$

Crude protein digestibility was different in particular groups. In the hogs fed a diet with 18% of yellow lupine seeds, without enzymes, it amounted to 76.90, 77.60 and 78.88%, and was statistically significantly higher than in the control group (73.80%). Although the level of protein digestibility in the hogs fed a diet with 18% of yellow lupine seeds was relatively low, it was still slightly higher than in the control group. Considerable differences were also observed in crude fat digestibility. It was the lowest in the hogs given the control diet (35.91%). Compared with the experimental groups, this difference was highly statistically significant. The highest crude fat digestibility was noted in the hogs fed a diet with a higher yellow lupine content, supplemented with enzymes (63.27%).

Analysis of crude fiber digestibility shows its slight increase in the hogs fed a diet with 11.5% of yellow lupine seeds (39.28 vs. 44.11%). It was at a much lower level (35.42%) in diet 4, containing 18% of yellow lupine seeds. However, in the hogs fed diet 5, with the same amount of yellow lupine seeds, but supplemented with enzymes, crude fiber digestibility was 44.50%. The difference was highly statistically significant.

The digestibility of N-free extractives was high, but different in particular groups. It varied from 87.38 to 89.28%. Enzyme supplementation of diets 3 and 5 had a considerable effect on the digestibility of this carbohydrate fraction. The digestibility coefficients of N-free extractives were 87.38, 87.64 and 87.48% in groups 1, 2 and 4 respectively. They were highly significantly lower, compared with the groups fed enzyme-supplemented diets with yellow lupine seeds.

Gross energy digestibility was less differentiated – it varied from 78.23% to 80.59%. It was higher in the hogs fed a diet with 11.5% of yellow lupine seeds and enzyme-supplemented diets with 18.0% of lupine seeds.

The data concerning nitrogen balance are presented in Table 3. The amount on nitrogen taken in particular groups was similar and ranged from 58.36 g to 59.24 g. The highest level of nitrogen retention was observed in the hogs fed a diet with 11.5% of yellow lupine seeds - 30.47g. It was similar in the control group (29.56g), and the lowest (22.57g) in the hogs receiving diet 4, with 18% of yellow lupine seeds, without enzymes. Enzyme supplementation of diet 5 allowed to increase nitrogen retention to 27.22g.

Table 3. **Daily N balance**

Specification	Groups				
	Control 1	LLC 2	LLC+E 3	HLC 4	HLC+E 5
N taken, g	59.24	58.36	58.40	58.61	58.68
N retained, g	29.56^{A}	30.47^{A}	27.19^{a}	22.57^{Bb}	27.22^{a}
N retained/N taken, %	49.90^{Aa}	52.21^{Aa}	46.56^{b}	38.51^{B}	46.39^{b}
N retained/N digested, %	63.92^{A}	62.71^{A}	56.35^{a}	49.02^{Bb}	54.57^{a}

Nitrogen utilization, in relation to nitrogen taken and digested, was slightly better in the control group and group 2 (a diet with 11.5% of lupine seeds). It was found that the enzymes added to diet 5 had a positive effect on nitrogen utilization.

Table 4 shows the nutritive value of diets, determined on the basis of digestibility coefficients. Distinct differences were noted in the level of metabolizable energy. It should be emphasized that all experimental diets were characterized by higher concentration of metabolizable energy than the control diet. The highest energy value was found for diets 2 and 5 (12.91, 12.90MJ). The level of crude protein was similar in all diets, and varied from 165.8 g to 168.3 g. However, their content of digestible protein was different, which was confirmed by the digestibility coefficients. The lowest concentration of total digestible protein was reported for diet 4 - 123.8 g. It was almost the same in the control diet (124.2 g). The other diets contained 127.5 g, 128.7 g and 131.5 g of digestible protein respectively.

Table 4. Nutritive value of 1 kg of diets

Specification	Control 1	LLC 2	LLC+E 3	HLC+E 4	HLC+E 5
Metabolizable energy, MJ	12.35	12.91	12.75	12.45	12.90
Crude protein, g	168.3	165.8	165.9	166.5	166.7
Digestible crude protein, g	124.2	127.5	128.7	123.8	131.5
Crude fiber, g	4.74	4.97	4.89	4.72	4.74

Discussion. The organic matter digestibility determined for the experimental diets amounted to 81.17 - 84.68%, and was slightly higher than reported by other authors. In the experiment performed by Flis et al. (1996), aimed at determining organic mater digestibility for diets with 18% of soybean meal or 20% of yellow lupine seeds, it varied from 80.2% to 80.9%. Petkov et al. (1994) examined seven lupine varieties and found that the digestibility of organic matter was approx. 82%.

Enzyme supplementation of a diet containing 11.5% of yellow lupine seeds was inefficient, but had a positive effect on organic matter digestibility in the case of a diet with their higher content (18%).

Partial substitution of yellow lupine seeds for soybean meal in diets 2, 3 and 5 caused an increase in crude protein digestibility (76.90, 77,60 and 78.88%), compared with the control group (73.80%). The differences were statistically significant.

The results concerning the digestibility of this component are partly consistent with literature data. Similar protein digestibility (75.4%) was observed by Chachułowa et al. (1994) in fattening pigs fed a diet containing 18% of soybean meal. Flis et al (1996) reported higher crude protein digestibility (78.6%) for fatteners fed a diet with 16% of soybean meal. Partial substitution of yellow lupine seeds for soybean meal had no negative effect on crude protein digestibility. The digestibility coefficient was in this case 77.1%. It should be noted that relatively high digestibility of this component observed in fatteners fed diets with lupine seeds resulted from high digestibility of these seeds. According to Wasilewko and Buraczewska (1999), the digestibility of lupine protein determined at the end of the small intestine was 81.9% to 84.9%. Its true digestibility was high – 87.5% to 90.5%. These results are comparable with soybean meal digestibility. Similar digestibility of lupine protein was reported by Wünsche et al. (1990), Pastuszewska (1994), Kasprowicz and Frankiewicz (2001). Analysis of crude protein digestibility shows that it was highly significantly affected by enzyme supplementation of diet 5. This indicates that the enzymes influencing non-starchy polysaccharides facilitated the digestion of not only this carbohydrate fraction, but also crude protein.

Major differences were observed in crude fat digestibility. In the hogs fed diet 2, containing 11.5% of yellow lupine seeds, it was 50.99%; diet supplementation with enzymes caused its increase to 60.01%. It was similar in the hogs fed diets 4 and 5, where enzyme supplementation allowed to increase fat digestibility from 49.89% to 63.27%. According to Petkov et al. (1994), the digestibility of lupine seed fat in pigs varied from 50 to

54%. Similar results were obtained by Kasprowicz and Frankiewicz (2001). Gdala et al. (1994) noted lower fat digestibility, i.e. 42.4%.

Partial replacement of soybean meal with 11.5% of lupine seeds caused some increase in crude fiber digestibility (39.28 vs. 44.11%). However, an increase in their content to 18% (diet 4) resulted in a decrease in the digestibility of this fraction of carbohydrates to35.43%. Crude fiber digestibility in the hogs fed diet 5, with the same amount of lupine seeds, but supplemented with enzymes, was 44.50%. This difference was highly statistically significant. Petkov et al. (1994) report that the digestibility of lupine fiber is at a level of 53 to 54%, whereas according to Kasprowicz and Frankiewicz (2001) – 52 to 55%.

Analysis of the digestibility of N-free extractives shows that it was negatively affected by a higher lupine seed content of diets. The hogs fed diet 4 were characterized by the lowest digestibility of N-free extractives (87.48%). Chachułowa et al. (1994) noted its higher level (89.3%) in pigs fed a diet with 20% of lupine seeds. Similar digestibility of N-free extractives (89.4%) was noted by Gdala et al. (1994) in young boars fed diets containing lupine. Their highest digestibility (89.28%) was found in the case of an enzyme-supplemented diet with a lower lupine content. In the control group it was at a level of 87.38%. Similar digestibility of N-free extractives, i.e. 87.48%, was observed in group 4 (18% of lupine seeds, no enzymes). It was found that enzyme supplementation had a positive effect on digestibility in diets with both lower and higher yellow lupine content. Flis et al. (1998) analyzed the efficiency of enzyme supplementation of diets containing lupine seeds. They found that the preparation with β-glucanase and xylanase increased the digestibility of N-free extractives, but had no effect on the digestibility of other nutrients. In the studies conducted by Gdala et al. (1995) an enzymatic preparation with galactosidase was added to a diet containing 30% of yellow lupine seeds, which allowed to increase considerably the digestibility of α-galactosides in the small intestines of growing pigs.

The lowest gross energy digestibility was observed in the control group, where the main source of protein was soybean meal. Its slightly higher level was noted in the hogs fed diet 4 (18% of lupine seeds). Gross energy digestibility was the highest in the hogs fed a diet with 18.0% of yellow lupine seeds + enzymes. All results were confirmed statistically. Flis et al. (1996) observed higher gross energy digestibility for a diet with soybean meal than for that with 14% of lupine seeds. In the experiment performed by Chachułowa et al. (1994) on fatteners fed a diet containing 20% of lupine seeds, gross energy digestibility was 89.3%.

The differences in the nutritive value of diets resulted from different nutrient digestibility and concerned first of all the level of metabolizable energy. The highest energy content of diets 2 and 5 indicates a positive effect of lupine seeds, but their higher content required enzyme supplementation. The crude protein content of all diets was similar, but differences in its digestibility resulted in different levels of total digestible protein. The differences in crude fiber concentrations were connected with the levels of particular diet components. It should be stressed that partial substitution of yellow lupine seeds for soybean meal resulted in a high nutritive value of the diets.

Despite the differences in nitrogen balance results, its amount retained by the experimental hogs should be considered high. In the studies carried out by Flis et al. (1996) nitrogen retention in pigs fed diets with soybean meal was much higher, i.e. 20.7 g. The experiment performed by Chachułowa et al. (1994) also confirms low nitrogen retention (20.8 g). Replacement of soybean meal with 18% of yellow lupine seeds reduced nitrogen retention to 22.57 g. Its similar level (23.2 g) was reported by Flis et al. (1996) for pigs fed a diet containing 20% of yellow lupine seeds. Enzyme supplementation of the diet with a higher lupine content allowed to increase nitrogen retention to 23.9 g.

The utilization of nitrogen retained in relation to nitrogen taken was similar in the control group and in the hogs fed a diet with a low lupine content, i.e. 49.90% and 52.21% respectively. Much worse nitrogen utilization was noted for the hogs fed a diet with 18% of lupine seeds. In the experiment performed by Flis et al. (1996) the utilization of nitrogen retained in relation to nitrogen taken was 34.4%. Enzyme supplementation of diet 5, with a high lupine seed content, slightly improved its utilization (46.39%). Enzyme supplementation of the diet with a lower yellow lupine content turned out to be ineffective. The best utilization of nitrogen retained in relation to nitrogen digested was observed in the control group (63.92%). It was slightly worse in the hogs fed a diet with 11.5% of yellow lupine seeds - 62.71%. The enzymatic preparation added to diet 5 (with a higher lupine seed content) allowed to improve the utilization of nitrogen retained in relation to nitrogen digested (54.57%). Similar coefficients of nitrogen utilization by pigs fed diets with a high level of yellow lupine seeds were obtained by Chachułowa et al. (1994) and Flis et al. (1994).

The results obtained show that partial substitution of yellow lupine seeds in the amount of 11.5% for soybean meal in diets for pigs had a positive effect on the digestibility of all nutrients. Enzyme supplementation of a diet containing 11.5% of yellow lupine seeds had no influence on nutrient digestibility. A higher yellow lupine content (18%) of the diets caused a decrease in the digestibility of crude fiber, N-free extractives and gross energy. A higher yellow lupine content of the diets required enzyme supplementation, which affected positively the digestibility of crude protein, crude fiber and N-free extractives.

Adding 18% of yellow lupine seeds to diets for fatteners had a negative effect on nitrogen balance. Partial substitution of yellow lupine seeds for soybean meal resulted in a high nutritive value of the diets. Enzyme supplementation of the diet with a higher lupine content had a considerable effect on the level of metabolizable energy.

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