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Effect of dehulling and α-galactosidase supplement on the ileal digestibility of yellow lupin based diets in broiler chickens and adult roosters*

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ABSTRACT

Two hundred fifty six broiler chickens, 22-days-old, allocated to four groups of four replicate pens with 16 birds each, and six adult ileostomized roosters were used. Four diets containing maize starch and 550 g/kg whole or 458 g/kg dehulled lupin seeds (*Lupinus luteus* L. cv. Amulet) as the only protein source were offered to birds with or without α-galactosidase supplementation. The apparent ileal digestibility of dry matter and nitrogen of the diets was determined. In chickens digesta was collected from the lower part of the ileum immediately after slaughter, while in roosters digesta was collected *via* a T cannula placed in the terminal ileum during three 12 h periods in a change-over design.

Dehulling of lupins significantly increased apparent ileal digestibility of dry matter of the diet by 10% in roosters ($P<0.01$) and 14% in broilers ($P<0.001$), while α-galactosidase supplementation increased DM digestibility by 3% only in roosters ($P<0.05$). Dehulling of lupins increased the apparent ileal digestibility of N only in roosters ($P<0.01$). There was no difference between roosters and broiler chickens with regard to the DM digestibility, but the apparent digestibility of N was lower in roosters, than in broilers. The viscosity of ileal digesta was measured only in chickens. It was generally low and was highest (2.92 mPas.s) in broilers fed the whole lupin diet without α-galactosidase. Viscosity was about 37% lower after dehulling the seeds, and decreased about 15% after α-galactosidase supplementation.

KEY WORDS: yellow lupin, dehulling, enzyme supplementation, digestibility, poultry

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INTRODUCTION

Sweet lupins are commonly used as protein source in poultry diets. The metabolizable energy value of lupin seed for poultry is relatively low (Alloui et al., 1994), as non-starch polysaccharides (NSP) and oligosaccharides, which are not digested by poultry, constitute more than half of their organic matter. According to Gdala and Buraczewska (1996) seeds of *L. luteus* contain about 320 g/kg DM NSP and 120 g/kg DM oligosaccharides. The seed coat, containing about 80% dietary fibre, constitutes 25% of the seed weight (Zduńczyk et al., 1994; Smulikowska et al., 1995). Dehulling of lupins decreases the level of structural carbohydrates in the seed. Soluble and non-soluble NSPs can interfere with digestion of nutrients and stimulate secretion of endogenous proteins in the lumen of the digestive tract. Therefore, dehulling increases the nutritional value of lupins in poultry diets (Smulikowska et al., 1995).

Within the oligosaccharide fractions of yellow lupin α-galactosides of raffinose series predominate, in particular stachyose (Zduńczyk et al., 1994; Gdala and Buraczewska, 1996). Oligosaccharides are not hydrolysed by digestive enzymes of chickens, but they may be fermented by microflora in the terminal ileum and caeca (Carré et al., 1990). In the small intestine, α-galactosides may have a detrimental osmotic effect, may increase passage rate of digesta and promote the growth of microflora. Supplementation of lupin based diets with the enzyme α-galactosidase can decrease the antinutritive effects of oligosaccharides and can increase the energy value of the diet. In pigs, a positive effect of α-galactosidase supplementation of a yellow- and narrow-leafed lupin based diet on the ileal digestibility of oligosaccharides and amino acids had been observed (Gdala et al., 1997).

The aim of the present study was to evaluate the effect of dehulling of lupins and/or α-galactosidase supplementation of lupin diets on the ileal digestibility of nutrients as measured in broiler chickens and in adult cannulated roosters.

MATERIAL AND METHODS

Seeds of yellow lupin (*Lupinus luteus* L.) cv. Amulet of Polish origin were used. Whole or mechanically dehulled seeds were ground at 0.5 mm prior to inclusion into the diet. Four semi-synthetic diets were prepared (Table 1) with or without 5g/kg of α-galactosidase (AlphaGal 500 L produced by NovoNordisk, containing 500 GALU/g). Lupin seeds were the only source of protein in diets. Chromic oxide (1 g/kg diet) was used as a digestibility marker. Diets were cold pelleted.

Experiment 1

Six adult roosters with a body weight 2.5 kg, on average, were surgically ileostomized with a T type cannula (van Leeuwen et al., 2000). Birds were housed individually in wired cages. Following a recovery period the experiment was conducted in four identical 5-days periods in a change-over design. Between-periods, birds were fed for four days a standard diet. In each experimental period the roosters received 80 g of the respective experimental diet (Table 1), fed twice daily in equal portions at 8.00 and 20.00 h. Digesta were collected into containers mounted on the cannula for the three last days of each period between 8.00 and 20.00 h. Containers were replaced every 2 h, feathers incidentally appearing in containers were removed, digesta were pooled within period, weighed, frozen and kept in -18°C until further analysis.

TABLE 1

Composition of diets[1], g/kg

	Dietary treatments			
Lupins	whole	whole	dehulled	dehulled
Enzyme supplementation	–	+	–	+
Yellow lupin seeds	550.0	550.0	458.0	458.0
Maize starch	239.0	234.0	305.7	300.7
Dextrose	100.0	100.0	100.0	100.0
Soya oil	32.0	32.0	5.0	5.0
Animal fat	40.0	40.0	40.0	40.0
Limestone	11.5	11.5	12.4	12.4
Cellulose	-	-	50.0	50.0
Monocalcium phosphate	8.0	8.0	9.4	9.4
NaCl	3.0	3.0	3.0	3.0
$KHCO_3$	5.0	5.0	5.0	5.0
DL-methionine	1.5	1.5	1.5	1.5
Vitamin-mineral premix[2]	10.0	10.0	10.0	10.0
α-galactosidase[3]	-	5.0	-	5.0

[1] Cr_2O_3 was added on top of diet at amount 1g/kg
[2] fulfilling broiler chickens or adult roosters requirements, respectively
[3] Alpha Gal 500 L (NovoNordisk)

Experiment 2

A total of 256 day-old broiler chickens (Hybro, Euribrid) were allocated to 16 cages, 16 chickens in a cage and fed with commercial starter diet to 21 days of age. At 22 days of age four cages (replicates) were randomly assigned to each of four groups and birds were offered the respective experimental diets (Table 1) *ad* *libitum*. After 8 days of feeding the experimental diets all birds were killed by a pentobarbitol injection, the abdominal cavity was opened and clips were placed at the Meckel's diverticulum, 15 cm anterior from the ileocecal junction and at the ileocecal junction. Digesta from upper and lower parts of the ileum were collected separately by gentle manually squeezing and pooled within replicate. Digesta from the upper part of ileum was immediately centrifuged at 10,000×g for 10 min at 4ºC, and the viscosity of the supernatant (0.5 mL aliquot) was measured with the use of a Brookfield Digital cone/plate viscometer (model LVDV II+, Brookfield Engineering Laboratories, Stoughton, MA, USA). Readings were expressed in centipoise (1cP=1mPa·s). Digesta from lower part of ileum was frozen and kept in -18ºC until further analysis.

Chemical analyses

Prior to analysis the contents from the lower part of ileum were thawed and homogenized. The chemical composition of lupin seeds, hulls and dehulled seeds, as well as dry matter and total nitrogen content in diets and ileal contents was determined according to AOAC (1990). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) fractions in lupin material were assayed with Fibertec System M (Tecator) according to Van Soest and Wine (1967) and Van Soest (1973). Cr_2O_3 content in diets and ileal contents was analysed spectrophotometrically according to Bosch et al. (1988).

Statistical analysis

The experimental data were subjected to three-way analysis of variance (ANOVA), generated by Statgraphics® ver. 5.1, using "dehulling", "enzyme supplementation" and "type of bird" as factors.

RESULTS

Dehulled seeds contained more protein and less fibre than whole seeds (Table 2). Dehulling of lupins significantly increased the apparent ileal digestibility of dry matter (DM) in both types of birds, however to a lesser extent in ileostomized roosters (on average 6 digestibility units; $P<0.01$) than in broilers (on average 8.5 digestibility units; $P<0.001$). Supplementation the diets with α-galactosidase increased the digestibility of DM with on average 2 digestibility units ($P<0.05$) in roosters and 1.6 units in broilers as compared to unsupplemented diets. Dehulling of lupins also significantly increased the apparent ileal digestibility of

TABLE 2

Chemical composition of whole and dehulled seeds and hulls of yellow lupin cv. Amulet, g/kg DM

Lupin seed fraction	Crude protein	Crude ash	Crude fat	Crude fibre	ADF	NDF
Whole	428	53	37	169	222	256
Dehulled	544	64	57	38	69	136
Hulls	87	23	15	546	670	794

N in roosters (P<0.01), while in broilers dehulling did not influence N digestibility (Table 3). The ileal DM digestibility was not significantly different in roosters and broilers, while the apparent digestibility of N was significantly higher (P<0.001) in broilers than in roosters (Table 3). The viscosity of ileal digesta was generally low and the highest value (2.92 mPas.s) was observed in broilers fed the diet with unsupplemented whole lupins. Viscosity decreased after dehulling (P<0.001), as well as after α-galactosidase supplementation (P<0.05).

TABLE 3

Apparent ileal digestibility of dietary DM and N in broiler chickens and adult roosters (%) and viscosity of the ileal contents in broiler chickens (mPas.s)

Group	Dietary treatment		DM digestibility		N digestibility		Viscosity
no	seeds	enzyme	roosters	broilers	roosters	broilers	broilers
1	Whole	-	70.6^{a}	68.7^{a}	82.1^{a}	91.3	2.92^{a}
2	Whole	+	73.8^{b}	70.0^{a}	81.8^{a}	90.8	2.39^{b}
3	Dehulled	-	77.7^{c}	78.6^{b}	86.8^{b}	92.3	1.76^{c}
4	Dehulled	+	78.5^{c}	77.1^{b}	86.6^{b}	93.0	1.59^{c}
Pooled SEM			0.80	0.75	0.80	0.64	0.10
Effect of dehulling (D)			**	***	**	ns	***
Effect of enzyme (E)			*	ns	ns	ns	*
Roosters vs. broilers (M)			ns		***		-

ns - not significant * (P≤0.05), ** (P≤0.01), *** (P≤0.001)

interactions: for DM digestibility - D×E, D×M, E×M and D×E×M were not statistically significant; for N digestibility DxM was significant (P≤0.05), remaining interactions were not statistically significant

^{a,b} - values within column with no common superscripts are significantly different at P≤0.05

DISCUSSION

The content of nutrients and fibre in seeds, dehulled seeds and hulls of yellow lupin cv. Amulet was similar to the Polish cultivars of yellow lupin analysed by Zduńczyk et al. (1994) and Smulikowska et al. (1995). The level of crude fibre and NDF in dehulled seeds was markedly reduced, in comparison with whole seeds; diets with dehulled lupin contained about 20% less poorly digestible fibre.

It largely explains the positive effect of dehulling on the ileal digestibility of DM and N in both, roosters and broilers.

The experimental diets were semi-synthetic, so it may be assumed that viscosity of digesta was induced mainly by soluble NSPs of yellow lupin. Dehulling significantly reduced the viscosity of ileal digesta. This indicates that the proportion and/or viscosity of soluble NSPs in the seed coat of yellow lupin may be greater than in the cotyledons. Within the NSP fraction in lupins pectic polysaccharides rhamnogalacturonans predominate. These are complex branched structures containing α-arabinian and β-galactan side chains attached to pectin-like main chain of rhamnose and galacturonic acid linked by β-(1-4) and α-(1-2) bonds (Carré et al., 1985; Cheetham et al., 1993). Viscosity depends on the physico-chemical characteristics of these carbohydrates, which differ largely between the lupin species and even between varieties within lupin species. The highest ileal viscosity value, measured in the present study in the group fed diet with 550 g/kg of whole *L. luteus* seeds (2.92 mPas.s) was lower than those measured in experiments with white or narrow-leafed lupins. Mieczkowska et al. (2004) reported the ileal viscosity of 7 mPas.s in broilers fed diet with 300 g/kg white lupins, while Annison et al. (1995) and Kocher et al. (2000) found that the ileal viscosity in broilers fed diet with 300 or 350 g/kg narrow-leafed lupins reached 10-11 mPas.s. This may indicate, that viscosity of soluble NSPs of *L. luteus* seeds is much lower, than that of *L. albus* or *L. angustifolius*.

It is interesting, that α-galactosidase supplementation of lupin-containing diets in broilers did not affect apparent ileal digestibility of DM and N, while it decreased viscosity of the ileal digesta. In a study of Alloui et al. (1994) also no positive effect of α-galactosidase supplementation of diets containing white, yellow or narrow-leafed lupins on faecal digestibility of DM or N in broilers could be demonstrated. It may suggest, that in the present study other enzyme activities than α-galactosidase affected viscosity of soluble NSPs. In the present study the ileal digestibility of DM increased in roosters after α-galactosidase supplementation of the diet. Also in pigs positive effects of exogenous α-galactosidase added to lupin diets on the digestibility of dry matter and oligosaccharides of the raffinose family were found (Gdala et al., 1997). It may indicate, than in gastrointestinal tract of roosters sugars released by α-galactosidase are absorbed, similarly as in pigs.

Apparent ileal nitrogen digestibility was much higher in broilers than in roosters. It may be partly explained by the difference in feeding level between roosters (around maintenance) and broilers (*ad libitum*). At a low feeding level the unevitable endogenous N losses expressed per unit of feed intake may be relatively higher compared to *ad libitum* feeding. This difference could also related to the behavioural observation during the study, that the individually housed roosters were pulling and ingesting their own feathers. Although the digesta samples were cleaned from larger feathers, some of the undigested N in digesta could be related to the presence of a small amount of feather material.

CONCLUSIONS

The results of the study indicate, that the nutritive value of yellow lupins for poultry can be increased by dehulling, while the benefits from supplementation of the lupin diet with α-galactosidase is larger in adult birds than in growing chickens.

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STRESZCZENIE

Wpływ obłuszczania i dodatku α-galaktozydazy na strawność jelitową diet z łubinem żółtym u kurcząt brojlerów i dorosłych kogutów

W doświadczeniu użyto 256 kurcząt brojlerów, w wieku 22 dni, które przydzielono do czterech grup, w każdej po cztery klatki mieszczące po 16 kurcząt oraz 6 dorosłych kogutów z założoną przetoką prostą do jelita biodrowego. Cztery diety zawierające skrobię kukurydzianą i 550 g/kg całych lub 458 g/kg obłuszczonych nasion łubinu żółtego (*Lupinus luteus* L. odm. Amulet), jako jedyne źródło białka, podawano ptakom bez lub z dodatkiem α-galaktozydazy. Oznaczano pozorną strawność jelitową suchej masy i azotu diet w treści zbieranej po uboju z końcowej części jelita biodrowego kurcząt i w treści zbieranej z przetoki prostej umieszczonej w końcu jelita biodrowego kogutów przez 3 okresy 12 godzinne w układzie przemiennym.

Obłuszczenie łubinu spowodowało zwiększenie pozornej strawności jelitowej suchej masy diet o 10% u kogutów ($P<0,01$) i o 14% u brojlerów ($P<0,001$) i zwiększenie pozornej strawności jelitowej N tylko u kogutów ($P<0,01$). Dodatek α-galaktozydazy zwiększył tę ostatnią wartość o 3% tylko u kogutów ($P<0,05$). Nie stwierdzono istotnych różnic w strawności jelitowej suchej masy diet między kogutami i kurczętami brojlerami, lecz pozorna strawność jelitowa N była znacznie niższa u kogutów niż u brojlerów. Lepkość treści jelita biodrowego była mierzona tylko u brojlerów. Była ona niska, największa (2,92 mPas.s) u ptaków żywionych nie uzupełnioną dietą z całymi nasionami łubinu. Lepkość była o 37% mniejsza w grupie żywionej nasionami obłuszczonymi i zmniejszyła się o 15% po uzupełnieniu diety α-galaktozydazą.