Arch. Geflügelk. 2003, **67** (4), 175 – 178, ISSN 0003-9098. © Verlag Eugen Ulmer GmbH & Co., Stuttgart

Feeding and nutritional value of sweet blue and yellow lupin seed (*Lupinus angustifolius* L., *Lupinus luteus* L.) for broiler chicks

Einsatz und Futterwert von Samen blauer und gelber Süßlupinen (*Lupinus angustifolius* L., *Lupinus luteus* L.) bei Masthähnchen

Dora A. Roth-Maier and Brigitte R. Paulicks

Manuskript eingegangen am 20. September 2002, angenommen am 21. Dezember 2002

Introduction

The importance of sweet lupin seeds as a component in animal feeds is increasing with the background of replacing critical or expensive protein sources. There is no heat treatment required for lupin seed prior to the use as animal feed, which eases its exertion. Especially, certified organic farms in Germany are in need of feedstuffs without genetic treatment and of farm sources of protein to expand the feed base. Newly breeded varieties of lupins are more resistant against anthracnosis, a mycotical plant disease, which is often a problem in lupin cultivation. Data of the nutritional value and use of sweet lupin seeds, particularly of the newer varieties grown in Germany, are rare. As a follow-up to previous investigations (ROTH-MAIER and KIRCHGESSNER, 1993, 1994) this study with broiler chicks was conducted to determine nutrient metabolisability, energy content and acceptable feed inclusion rate of sweet blue and yellow lupin seeds (*Lupinus angustifolius* L. and *Lupinus luteus* L., resp.) for broiler chicks.

Materials and methods

Two varieties of sweet blue lupin seeds (*Lupinus angustifolius* L., var. Bordako and var. Borweta) and one sweet yellow lupin seed (*Lupinus luteus* L., var. Borsaja), all cultivated in Mecklenburg-Vorpommern (North-Eastern Germany) in 1999 were used. The mean concentrations of organic matter, crude protein, crude fiber and ether extract were 960 g, 350 g, 165 g, and 50 g per kg dry matter, respectively; total alkaloid concentration averaged 0.038% in *Lupinus angustifolius* varieties and 0.007% in the *Lupinus luteus* variety (for further details see ROTH-MAIER and PAULICKS, 2002). Metabolisability of nutrients and energy content of sweet blue lupin seeds (*Lupinus angustifolius* L. var. Borweta and Bordako) were determined in a metabolism trial with broilers according to the "Guidelines for balance trials" of the GESELLSCHAFT FÜR ERNÄHRUNGSPHYSIOLOGIE DER HAUSTIERE (GfE, 1973). The difference method was used with chromium oxide (Cr_2O_3) implemented as an indicator for metabolisability in total. Energy content was calculated according to official methods (WPSA, 1984). In total, 108 broiler chicks with an average initial body weight of 1539 ± 91 g were divided at random in 3 groups, with 36 birds each in 6 replicates, that means 6 birds per pen. The experiment was run for 12 days in an environmentally controlled unit. The animals received a diet based on wheat provided with all the necessary minerals and vitamins (97.7% wheat, 2% vitaminised mineral mix, 0.3% Cr_2O_3). For the experimental groups the diets were supplemented with 35% lupin seed meal in partial replacement for wheat. The feed was given ad lib. After a 7 days preperiod excreta were collected quantitatively during 5 days and freeze-dried. Samples were subjected to proximate analysis. All analyses were done according to the methods of VDLUFA (NAUMANN et al., 1988). Results were given as treatment means and standard deviation based on individual values.

In an additional fattening trial 350 one-day-old male chicks (ROSS) were used for a 5 weeks experiment. The chicks were divided at random in 5 treatment groups and were kept in a total of 35 pens in a wire-floored battery brooder with 10 chicks per pen. Each 7 pens were allocated to the same diet. The unit was maintained under controlled environment: temperature was decreased during the experiment from 33 to 23 °C, relative humidity (55–60%) and lighting (20 hours) were kept constant. Feed and water were offered ad libitum. The control group (treatment 1) received a diet consisting mainly of wheat, corn, soybean meal, oat bran, oil, and vitamin-mineral-amino acid premixes (cf. Table 1), which met all nutrient recommendations for broiler chicks according to the GESELLSCHAFT FÜR ERNÄHRUNGSPHYSIOLOGIE (GfE, 1999). Oat bran was used to provide identical contents of fiber in the control diet and in the lupin diets. For the experimental groups 20 or 30% lupin seed meal were used in partial exchange for soybean meal, corn, oil, and oat bran to obtain mostly isonitrogenic (22% XP) and isoenergetic (13.5 MJ AME/kg dry matter) diets. Amino acids were supplemented when necessary. The tested lupin seeds were the blue variety Bordako (*Lupinus angustifolius* L.) and the yellow variety Borsaja (*Lupinus luteus* L.). Feed and water were provided ad libitum. The chicks were daily observed twice. Body weight of each individual bird and feed consumption on a pen basis were recorded weekly. Daily weight gain, daily feed consumption and feed efficiency (kg feed/kg weight gain) were calculated. All analyses were done according to the methods of VDLUFA (NAUMANN et al., 1988). Results were given as treatment means and standard deviations based on individual values.

Unit of Animal Nutrition, Technical University Munich, Freising-Weihenstephan, Germany

Table 1: Composition and nutrient content of the diets
Zusammensetzung und Nährstoffgehalte der Rationen

Treatment	1	*Lupinus angustifolius* var. Bordako 2	3	*Lupinus luteus* var. Borsaja 4	5
Ingredients (%)					
Lupin seed	–	20.0	30.0	20.0	30.0
Soybean meal	35.8	21.4	14.3	17.1	7.7
Wheat	30.0	30.0	30.0	30.0	30.0
Corn	20.9	16.7	14.6	21.9	22.4
Oat bran	4.0	1.3	–	1.3	–
Soybean oil	6.0	7.0	7.5	6.1	6.1
Mineralpremix[1]	2.7	2.7	2.7	2.7	2.7
Vitaminpremix[2]	0.3	0.3	0.3	0.3	0.3
Lysin-HCl	0.11	0.23	0.29	0.32	0.42
DL-Methionin	0.21	0.27	0.30	0.27	0.29
L-Threonin	–	–	–	0.01	0.03
L-Tryptophan	–	–	0.01	–	0.02
Nutrients (analysed) in dry matter (%)					
Crude protein	23.8	21.3	21.3	22.8	21.5
Ether extracts	7.7	9.8	10.0	8.7	8.9
Crude fibre	5.5	7.7	9.2	6.4	7.1
Starch	39.2	37.4	34.5	40.1	41.0
Sugar	5.4	4.5	3.9	4.5	3.9
Energy, MJ AME/kg[3]	13.6	13.5	13.0	13.8	13.7

[1] Supplement per kg diet: Ca 6.8 g, P 2.8 g, Na 0.9 g, Mn 47 mg, Zn 32 mg, Cu 3.2 mg, Fe 62 mg, Se 0.1 mg
[2] Supplement per kg diet: vitamin A 8,000 IE, vitamin D_3 1,000 IE, vitamin E 20 mg, thiamin 2.2 mg, riboflavin 2.2 mg, vitamin B_6 2.9 mg, vitamin B_{12} 4 µg, biotin 0.1 mg, folic acid 0.2 mg, niacin 9.9 mg, pantothenic acid 2.2 mg, Cholin 1.0 g
[3] calculated according to: AME (MJ/kg DM) = (15.51 · protein + 34.31 · fat + 16.69 · starch + 13.01 · sugar)/1,000

Treatment effects were analyzed using the General Linear Models (GLM) procedure of SAS (1989) in an one factorial analysis of variance. Means were tested by Student-Newman-Keuls test for significant differences ($P < 0.05$) and were marked with different superscripts.

Results

Metabolism trial

The metabolisability of nutrients (with the exception of protein) was lower for Bordako than for Borweta (cf. Table 2). The quotients for ether extracts were statistically significant different, those for crude fiber and nitrogen-free extracts showed a clear tendency to be lower for Bordako ($P < 0.1$). Protein metabolisability seemed to be higher for Bordako than for Borweta. The content of metabolisable energy was by 0.7 MJ AME/kg DM lower in Bordako than in Borweta.

Table 2: Metabolisability of nutrients (%) and energy content (MJ AME/kg DM) of sweet blue lupin seeds for broiler chicken
Umsetzbarkeit der Nährstoffe (%) und Energiekonzentration (MJ AME/kg T) von Samen blauer Süßlupinen für Masthähnchen

	Lupinus angustifolius var. Bordako	Borweta	P = [1]
Dry matter	42.8 ± 12.1	49.2 ± 7.0	n.s.[2]
Organic matter	43.0 ± 11.8	49.5 ± 6.7	n.s.
Crude ash	36.5 ± 20.7	38.2 ± 14.1	n.s.
Crude protein	42.9 ± 15.9	36.4 ± 8.2	n.s.
Crude fibre	24.4 ± 14.5	41.7 ± 12.8	0.053
Ether extracts[3]	68.8 ± 11.2[a]	83.1 ± 5.4[b]	0.018
N-free extracts	46.1 ± 13.7	58.0 ± 8.4	0.098
Metabolisable energy (MJ AME/kg DM)	7.54 ± 1.73	8.22 ± 0.95	n.s.

Significant differences ($P < 0.05$) are marked with different superscripts
[1] error rate for difference according to analysis of variance
[2] not significantly different ($P > 0.1$)
[3] determined in feed and excreta after HCl-hydrolysis

Fattening trial

The results of the fattening trial are summarized in table 3. Starting with an average initial body weight of 39.8 g, all groups, except group 3 (30% *Lupinus angustifolius* seed), reached a similar final body weight of approximately 1560 g with an average daily weight gain of more than 43 g. There were no significant differences between the treatments, however treatment 3 tended to be 4% lower, reaching only 1472 g body weight with a daily weight gain of 41 g. Daily feed consumption of all the groups ranged from 64.5 g to 70.2 g with an up to 9% higher consumption of the lupin diets in comparison with the control diet. The amount of kg feed consumed per kg weight gain, recorded as feed efficiency, was significantly higher for those treatments with lupin seed in the diet, namely when 30% lupin seed was included (1.51 without, 1.64 with 30% lupin seed). With 20% *Lupinus angustifolius* seed in the diet, feed efficiency was significantly higher (1.60), too. Using 20% *Lupinus luteus* in the diet, feed efficiency was comparable to the control treatment.

Discussion

The nutritional value of the *Lupinus angustifolius* seeds Bordako and Borweta showed a low metabolisability of

Table 3: Results of the fattening trial
Ergebnisse des Mastversuchs

Treatment	1	*Lupinus angustifolius* var. Bordako 2	3	*Lupinus luteus* var. Borsaja 4	5
Initial body weight (g)	39.8 ± 0.2	39.9 ± 0.3	39.9 ± 0.3	39.7 ± 0.3	39.9 ± 0.3
Final body weight (g)	1535 ± 113	1562 ± 128	1472 ± 156	1586 ± 108	1536 ± 67
Daily weight gain (g/day)	42.7 ± 3.2	43.5 ± 3.7	40.9 ± 4.5	44.2 ± 3.1	42.8 ± 1.9
Daily feed intake (g/day)	64.5 ± 5.1	69.6 ± 5.9	67.2 ± 7.4	67.9 ± 4.1	70.2 ± 3.7
Feed efficiency (kg feed/kg weight gain)	1.51[a] ± 0.04	1.60[b] ± 0.05	1.64[b] ± 0.04	1.54[a] ± 0.06	1.64[b] ± 0.04

Significant differences ($P < 0.05$) are marked with different superscripts

the organic matter resulting in energy concentrations reaching only 65% and 79%, respectively, of wheat, and only 79% and 68%, respectively, of soybean meal (according to PETERSEN, 1993). Previous experiments showed similar values of yellow lupins for the metabolisability of organic matter (46%) and metabolisable energy (8.7 MJ AME/kg DM) (ROTH-MAIER and KIRCHGESSNER, 1993). The metabolisability of crude protein was higher in the present study than in previous experiments with white and yellow lupins (*Lupinus albus* L. *and Lupinus luteus* L., resp.), where 37.5% and 39.9%, were found for white, and 27.7% for yellow lupin seed. Metabolisability of N-free extracts, especially from the blue Bordako (42.6%), was on a very low level compared with white and yellow varieties (55.5%, 85.2%) of previous experiments (ROTH-MAIER and KIRCHGESSNER, 1993). These differences cannot be finally clarified by the present examinations. Probably one reason (cf. CHEEKE and KELLY, 1989) might be the higher concentration of alkaloids in the Bordako seed of 0.057% in dry matter compared with 0.018% in the Borweta seed (ROTH-MAIER and PAULICKS, 2002), nevertheless both of them were declared as sweet lupins. But also variations in the composition of carbohydrates, e.g. higher proportions of poorly digestible polysaccharides like galactanes (AGUILERA et al., 1985; ACAMOVIC et al., 2002) in the blue lupin seed Bordako might be responsible for the lower nutritional value and lower energy content of this variety. Compared with data published earlier for metabolisability of nutrients and energy concentration in sweet white (*Lupinus albus* L.) and yellow (*Lupinus luteus* L.) lupin seed (averaging metabolisability quotients for organic matter of 41% and 50%, respectively, and energy concentrations of 7.7 MJ AME/kg DM and 8.7 MJ AME/kg DM, respectively, ROTH-MAIER and KIRCHGESSNER, 1993) the presented sweet blue lupin seeds are intermediate.

In feeding of lupin seed to broiler chicks the inclusion of 30% sweet blue lupin seed decreases feed efficiency and growth performance up to an 8% reduction. In most of the international literature inclusions of 9–40% lupin seed (*Lupinus angustifolius, Lupinus luteus* or *Lupinus albus*) in the diet showed no effect on growth performance (SON and PAIK, 1987; PEREZ-ESCAMILLA et al., 1988; PEREZ-ALBA et al., 1990, TEIXEIRA, 1995, OLVER, 1987, OLVER and JONKER, 1997) and no apparent variety effect. In contrast ALLOUI et al. (1994) reported a variety dependent influence starting with a significantly lowered performance for 15% white lupins in the diet and for 30% white, blue and yellow varieties except one white variety.

Generally, seeds of the new cultivars of sweet blue and yellow lupins can provide a good alternative to soybean meal in broiler diets. However, when formulating diets, the differences in nutrient concentrations (ROTH-MAIER and PAULICKS, 2002) combined with a lower metabolisability of nutrients and lower energy contents in comparison to soybean meal (DLG, 1991) need to be taken into consideration. Attention has to be given to the concentration of the essential amino acid methionine, which amounts to only 30% of soybean protein (0.5 versus 1.5 g/100 g protein; DEGUSSA, 1996). Previous publications (ROTH-MAIER und KIRCHGESSNER, 1994) reporting detrimental effects of white lupin seed on faeces viscosity and decreases in feed consumption are not confirmed by these investigation.

The inclusion of 20% sweet yellow lupin seed in broiler diets can be recommended without negative effects on growth or health performance provided adequate amino acid supplementation is assured. By adding 30% sweet yellow lupin seed to diets, an impairment in feed-to-gain efficiency has to be accepted. A content of 20% sweet blue lupin seed in the diet decreases feed efficiency by 6%, but neither growth performance nor feed intake is affected.

Acknowledgement

We express our appreciation to Mr. U. Schmiechen, Saatzucht Steinach GmbH, Station Bornhof, Bocksee, Germany, for supplying the lupins.

This work was supported by the Bayerische Arbeitsgemeinschaft Tierernährung (BAT) e.V., Freising-Weihenstephan.

Summary

In a metabolism trial with a total of 108 broiler chicks the nutrient metabolisability and energy content of the seeds of sweet blue lupins (*Lupinus angustifolius* L. var. Bordako and var. Borweta) were determined resulting in nutrient metabolisability quotients for organic matter, protein, ether extracts, and N-free extracts of 43% and 50%, 43% and 36%, 69% and 83%, and 46% and 58%, respectively. Energy concentration was calculated as 7.54 MJ AME/kg DM for Bordako and 8.22 MJ AME/kg DM for Borweta.

In a 5-week fattening trial with 350 day-old male broiler chicks seeds of sweet yellow lupin (*Lupinus luteus* var. Borsaja) and of sweet blue lupin (*Lupinus angustifolius* var. Bordako) were used in isoenergetic and isonitrogenic diets in amounts of 20% and 30%. Feed intake (64.5 g/d without lupin seed) was increased to up to 70 g/d by including lupin seed but growth performance was rather similar for all groups (42.8 g/d; 40.9 g/d for the group 3 with 30% *Lupinus angustifolius*) resulting in a higher feed expense for the lupin seed diets (up to 1.64 versus 1.51 in the control group). Up to 20% yellow lupin seed can be included in broiler diets in replacement of soybean meal without impairing growth performance and feed-to-gain efficiency, when amino acid supplementation is adjusted. However, 30% yellow lupin seed impaired feed-to-gain efficiency by 9%. The inclusion of 20% blue lupin seed showed the same growth performance as the control, but feed-to-gain efficiency was reduced by 6%.

Keywords

Broiler, nutrition, Lupins, Lupinus angustifolius, Lupinus luteus, growth performance, metabolisability of nutrients, metabolisable energy

Zusammenfassung

Einsatz und Futterwert von Samen blauer und gelber Süßlupinen (*Lupinus angustifolius* L., *Lupinus luteus* L.) bei Masthähnchen

In einem Stoffwechselversuch mit insgesamt 108 männlichen Broilern wurden die Umsetzbarkeit der Nährstoffe und der Gehalt an umsetzbarer Energie in den Saaten von zwei Sorten (Bordako und Borweta) blaublühender Lupinen (*Lupinus angustifolius* L.) untersucht, wobei sich teilweise deutlich Sortenunterschiede (Umsetzbarkeit von 43% bzw. 50% für die organische Masse, 43% bzw. 36% für Protein, 69% bzw. 83% für Fett, 46% bzw. 58% für die N-freien Extraktstoffe, 7.54 MJ/kg T bzw. 8.22 MJ/kg T für die Umsetzbare Energie) zeigten.

In einem 5wöchigen Mastversuch mit insgesamt 350 männlichen Eintagsküken wurden Saaten von blauen und gelben Süßlupinen (*Lupinus angustifolius* var. Bordako bzw. *Lupinus luteus* var. Borsaja) in weitgehend isoenergetischen (12,5 MJ AME/kg) und isonitrogenen (22% Rohprotein, 1,2% Lys, 0,9% Met) Rationen in Anteilen von 20% und 30% in der Gesamtration eingesetzt. Die Futteraufnahme (64,5 g/Tag ohne Lupinen) war bei Lupineneinsatz auf bis zu 70 g/Tag erhöht, jedoch war die Wachstumsleistung nahezu gleich für alle Gruppen (42,8 g/Tag; 40,9 g/Tag für Gruppe 3 mit 30% *Lupinus angustifolius*). Dadurch war der Futteraufwand für den Zuwachs (kg Futter/kg Zuwachs) höher bei Rationen mit Lupinen (bis zu 1,64 gegenüber 1,51).

Aufgrund der vorliegenden Ergebnisse können im Broilerfutter anstelle von Sojaextraktionsschrot bis zu 20% gelbe Lupinen eingesetzt werden, ohne dass Wachstumsleistung und Futterverwertung beeinträchtigt werden, vorausgesetzt die Aminosäurenversorgung wird ausgeglichen. Mit 20% blauen Lupinen kann es allerdings bei gleicher Wachstumsleistung wie in der Kontrollgruppe zu einer Beeinträchtigung der Futterverwertung um 6% kommen.

Stichworte

Broiler, Fütterung, Süßlupinen, Lupinus angustifolius, Lupinus luteus, Nährstoffverdaulichkeit, umsetzbare Energie

References

ACAMOVIC, T., GILBERT, C., COWIESON, A. J., 2002: An update on the nutritive value of lupin seeds for poultry. *In:* VAN SANTEN, E. (Ed.), Wild and cultivated lupins from tropics to the poles. Proc. 10th International Lupin Conference, June 19–24, 2002, Laugarvatn, Iceland, in press

ALLOUI O., SMULIKOWSKA S., CHIBOWSKA M., PASTUSZEWSKA B., 1994: The nutritive value of lupin seeds for broiler chickens as affected by variety and enzyme supplementation. J. Anim. Feed Sci. **3**, 215–227

AGUILERA, J. F., MOLINA, E., PRIETO, C., 1985: Digestibility and energy value of sweet lupin seed (*Lupinus albus* var. multopa) in pigs. Anim. Feed Sci. Tech. **12**, 171–178.

CHEEKE, P. R., KELLY J. D., 1989: Metabolism, toxicity and nutritional implications of quinolizidine (lupin) alkaloids. *In:* HUISMAN, J., VAN DER POEL, T. F. B., LIENER, I. E., (Eds.), Recent advances of research in antinutritional factors in legume seeds. Proc. First Int. Workshop on 'Antinutritional Factors (ANF) in Legume Seeds', November 23–25, 1988, Wageningen, The Netherlands, Pudoc Wageningen 1989

DEGUSSA 1996: The amino acid composition of feedstuffs. 4. überarbeitete Auflage, Degussa AG, Hanau, Germany.

DLG – DEUTSCHE LANDWIRTSCHAFTSGESELLSCHAFT, 1991: DLG-Futterwerttabellen für Schweine. 6. erweiterte und völlig neugestaltete Auflage. DLG-Verlag, Frankfurt/Main.

GFE – GESELLSCHAFT FÜR ERNÄHRUNGSPHYSIOLOGIE DER HAUSTIERE, 1973: Richtlinien zur Durchführung von Bilanzversuchen mit Hühnern. Arch. Geflügelk. **37**, 49–57

GFE – GESELLSCHAFT FÜR ERNÄHRUNGSPHYSIOLOGIE, Ausschuss für Bedarfsnormen, 1999: Empfehlungen zur Energie- und Nährstoffversorgung der Legehennen und Masthühner (Broiler). DLG-Verlag, Frankfurt am Main

NAUMANN, K., BASSLER, R., SEIBOLD, R., BARTH, K., 1988: *In:* Methodenbuch. Bd. III. Hrsg. VDLUFA – Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten. Verlag J. Neumann, Neudamm, Melsungen.

OLVER, M. D., 1987: Sweet lupins as a feedstuff for broilers. South African Journal of Animal Science, **17**, 4, 168–170

OLVER, M. D., JONKER, A., 1997: Effect of sweet, bitter and soaked micronised bitter lupins on broiler performance. Brit. Poultry Sci. **38**, 203–208

PEREZ-ALBA, L. M., DIAZ-ARCA, J. F., CEJAS-MOLINA, M. A., PEREZ-HERNANDEZ, M., 1990: Comparing soybean meal and lupin seed meal as protein supplements to growing-finishing diets for broiler chickens. Arch. Zootec. (Spain) **39**, 271–283

PEREZ-ESCAMILLA, R., VOHRA, P., KLASING, K., 1988: Lupins (*Lupinus albus* var. Ultra) as a replacement for soybean meal in diets for growing chickens and turkey poults. Nutrition reports international (USA), Sep 1988, **38**, **3**, 583–593

PETERSEN, U. (Hrsg.), 1993: Jahrbuch für die Geflügelwirtschaft. Eugen Ulmer Verlag, Stuttgart

ROTH-MAIER, D. A., KIRCHGESSNER, M., 1993: Nährstoffzusammensetzung und Futterwerte verschiedener weißer und gelber Lupinen (*Lupinus albus* L. und *Lupinus luteus* L.) für Schwein und Geflügel. Agribiol. Res. **46**, 218–228.

ROTH-MAIER, D. A., KIRCHGESSNER, M., 1994: Zum Einsatz von weißen Lupinen (*Lupinus albus* L.) als Ersatz für Sojaextraktionsschrot in der Broilermast. Arch. Geflügelkde. **58**, 111–114.

ROTH-MAIER, D. A., PAULICKS, B.R., 2002: Blue and yellow lupin seed (*Lupinus angustifolius* L. and *Lupinus luteus* L.) in the feeding of pigs. *In:* VAN SANTEN, E. (Ed.), Wild and cultivated lupins from tropics to the poles. Proc. 10th International Lupin Conference, June 19–24, 2002, Laugarvatn, Iceland, in press

SAS INSTITUTE INC. 1989: SAS Cary, NC USA, Vers. 6.08

SON, I. S., PAIK, I. K., 1987: Energy value and using level of Australian lupin seeds in the broiler chicken diet. Korean J. Anim. Sci. (Korea R.) 29, **5,** 223–227

TEIXEIRA, A. S., 1995: Replacement of soyabeans by lupins (lupinus luteus) in the feeding of broiler fowls. Revista Portuguesa de Ciencias Veterinarias, 90, **513**, 20–28.

WPSA – Working Group No. 2 – Nutrition, 1984: The prediction of apparent metabolizable energy values for poultry in compound feeds. World's Poult. Sci. J. **40**, 181–182.

Correspondence: Prof. Dr. Dora A. Roth-Maier, Animal Nutrition Unit, Technical University Munich, Hochfeldweg 6, 85350 Freising-Weihenstephan, Germany; E-mail: Roth-Maier@wzw.tum.de