

Comparison of Amino Acid Digestibility in Broiler Chickens, Turkeys, and Pekin Ducks¹

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ABSTRACT The objective of this study was to compare prececal amino acid (AA) digestibilities in broilers, turkeys, and Pekin ducks that were 3 wk old. Five diets were used: a basal diet and diets that contained either soybean meal (SBM) or rapeseed meal (RSM) at the expense of starch each at either 150 or 300 g/kg. The differences in dietary CP and AA concentrations resulted only from the inclusion of SBM or RSM. Titanium dioxide was used as an indigestible marker. Each diet was allocated to 6 pens of 12 birds from each species and provided ad libitum for 1 wk starting at 14 d of age. Digesta were sampled on a pen basis from the distal two-thirds of the section between Meckel's diverticulum and 2 cm anterior to the ileocecolonic junction. Ingested and digested amounts of AA were determined for each pen. Digestibilities for the 2 meals were then determined by a multiple linear

regression analysis, which makes a correction for basal endogenous AA losses unnecessary. Digestibilities for essential AA from the meals varied between 92% (Met, RSM, broilers) and 62% (Val, RSM, ducks). Digestibilities were not significantly different between SBM and RSM for broilers and turkeys, but the average digestibility across all AA was slightly higher for SBM and lower for RSM in turkeys than in broilers. Digestibilities were lower in ducks than in the 2 other species, and significant differences between SBM and RSM were detected for some AA in ducks. Amino acid digestibility ranking was very similar between broilers and turkeys but different for the 2 meals. It was concluded that differences among species cannot be explained by differences in basal endogenous AA losses among species. Amino acid digestibilities determined with broilers should not be used in formulating feed for ducks.

Key words: amino acid, digestibility, regression, comparison, bird

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INTRODUCTION

Digestibility of amino acids (AA) at the end of the ileum (prececal or ileal digestibility) is currently widely considered a suitable measure of feed protein quality in birds, as postileal fermentation may have variable contribution to AA excretion (Ravindran et al., 1999). In this paper, the term "digestibility" always refers to the prececal digestibility, unless otherwise stated. Most of the recent digestibility studies were conducted with broilers (Ravindran et al., 1998, 1999; Short et al., 1999; Kadim et al., 2002; Bryden and Li, 2004; Kluth et al., 2005a). A few studies on CP (Palander et al., 2004) and AA digestibility (Yi et al., 1996; Wendt and Rodehutsord, 2004) were conducted with turkeys as well as ducks (Martin et al., 1998). In chickens, digestibility was affected by the age

(Johns et al., 1986) and gender (Ten Doeschate et al., 1993; Huang et al., 2000) of the birds.

Feed formulation on a digestible AA basis requires information on whether digestibilities are similar for the 3 species or whether different ingredient values need to be considered for each species. This has hardly been studied. It is known, however, that the development of the digestive tract during growth is different between broilers and waterfowl (Jamroz et al., 2001, 2002, 2004), which might affect AA digestibility. Jamroz et al. (2001) found that at the age of 6 wk, the mean digestibility of AA in broilers, ducks, and geese was 76, 69, and 56%, respectively.

Digestibility values for AA are affected to a variable extent by AA contained in the secreted and nonreabsorbed endogenous protein. The basal endogenous protein is commonly assumed to depend mainly on dry matter intake, although results by Ravindran and Hendriks (2004) suggest that this is not the case in broilers. The specific endogenous protein is affected by the amount and nature of the feed under study (i.e., its digestibility, fiber content, nonstarch polysaccharide content and digesta viscosity, and other antinutritional factors (Angkanaporn et al., 1997; Dänicke et al., 2000; Souffrant, 2001). Comparative studies on the protein value of ingredients

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Table 1. Composition of diets differing in inclusion of solvent-extracted soybean meal (SBM) and rapeseed meal (RSM; g/kg)

Item	Inclusion (g/kg)		
	0	150	300
Corn	—	452	—
Wheat gluten	—	120	—
Soybean oil	—	45	—
L-Lys·HCl	—	6	—
DL-Met	—	3	—
L-Thr	—	1	—
Premix ¹	—	10	—
Dicalcium phosphate	—	40	—
Limestone	—	15	—
NaCl	—	3	—
TiO ₂	—	5	—
Cornstarch	300	150	0
SBM or RSM	0	150	300

¹Premix supplied the following according to the supplier (BASU-Mineralfutter GmbH, Bad Sulza, Germany; per kilogram of complete diet): Ca, 2.3 g; vitamin A, 12,000 IU (as retinyl acetate); cholecalciferol, 0.008 mg; vitamin E, 42 IU (as DL- α -tocopheryl acetate); vitamin K₃, 2 mg; thiamine, 2 mg; riboflavin, 6.6 mg; vitamin B₆, 5 mg; vitamin B₁₂, 0.02 mg; niacin, 99 mg; folic acid, 1 mg; biotin, 0.15 mg; Ca-d-pantothenate, 15 mg; choline chloride, 0.7 g; Cu, 5 mg; Zn, 51 mg; Fe, 60 mg; Mn, 71 mg; I, 0.6 mg; Se, 0.2 mg.

based on AA digestibility depend, therefore, on an adequate consideration of endogenous losses. However, attempts to measure endogenous AA loss lead to highly variable results (Donkoh and Moughan, 1999) with poorly identified reasons for this variation. Rutherford et al. (2004) pointed out a relatively large amount of variation between endogenous flows determined in different laboratories and within the same laboratory. Therefore, an approach that does not depend on a separate determination of endogenous losses appears advantageous to feed evaluation. As an alternative, without the need for a separate measure of endogenous AA loss, digestibility of AA in broilers was studied by linear regression analysis (Short et al., 1999; Rodehutscord et al., 2004; Kluth et al., 2005a).

It is unclear whether the above-mentioned differences in AA digestibility among species can be explained by differences in the endogenous AA loss among species or whether they are an actual difference in the birds' ability to digest feed protein. For this reason, the objective of the present study was to compare AA digestibility in broilers, turkeys, and Pekin ducks of the same age by applying a linear regression approach and to find out whether the values determined in 1 species can be applied to another. Solvent-extracted soybean meal (SBM) and solvent-extracted rapeseed meal (RSM) were used as the studied ingredients.

MATERIALS AND METHODS

Diets

Five diets were mixed, and the same diets were used in all experiments. The basal diet (BD; Table 1) was based mainly on corn, wheat gluten, and cornstarch. A CP level of about 15% was chosen for the BD. This was intended as a compromise to avoid a severely reduced intake of

the BD as well as to provide a wide range for supplementing the test proteins. In the 4 other diets, SBM or RSM was included at levels of either 150 or 300 g/kg at the expense of cornstarch. Hence, the variation in the diet's AA content originated from the respective oilseed meal only. Diets contained TiO₂ as an indigestible marker at a level of 5 g/kg. With the exception of the variable ingredients (cornstarch, SBM, RSM), all the other ingredients were combined in 1 batch to ensure uniformity of the mix. This mix was divided into 5 portions. Cornstarch, SBM, and RSM were then added in the respective amounts. Diets were remixed and subsequently pelleted through a 3-mm die without steam. Analyzed concentrations of proximate nutrients and AA are given in Table 2 for the diets and the 2 oilseed meals.

Birds and Experimental Protocol

Three experiments were run consequently, 1 with each species: male broiler chickens (Ross 308, Geflügelhof Möckern, Germany), male White Pekin ducks (Stolle Seddin Vital, Seddiner Zucht-und Mastenten GmbH, Wriezen, Germany), and male turkeys (British United Turkeys, Big 6, Moorgut Kartzfehn, Bösel, Germany). Experiments were approved by the animal welfare authorities in accordance with the German Animal Welfare Regulations. Four hundred fifty hatchlings from each species were kept in groups of 15 in floor pens with a mixed bedding of straw chaff and wood shavings and temperatures and illumination according to the recommendations given for the respective species. Birds were fed a starter feed specific for each species containing 12.6 (broilers), 11.4 (turkeys), and 11.4 (ducks) MJ of ME/kg and 230 (broilers), 290 (turkeys), and 210 (ducks) g of CP/kg of diet for 1 to 14 d posthatch. Birds had free access to drinking water from nipple drinkers with attached cups and feed from 1 trough per pen.

On d 14, the number of birds per pen was reduced to 12, based on BW uniformity. The mean BW at this stage was 517 (broilers), 362 (turkeys), and 729 g (ducks). Each of the 5 experimental diets was then randomly allocated to 6 pens, and diets were offered ad libitum for 7 d. At the end of this period, all birds were asphyxiated with CO₂, and the intestine section beginning at Meckel's diverticulum up to 2 cm anterior to the ileocecolonic junction was immediately removed. Only the terminal two-thirds of this section were used for digesta sampling, as suggested by Kluth et al. (2005b). The gut content was flushed out with distilled water. Contents were pooled within the 12 birds of 1 pen, immediately frozen at -18°C, freeze-dried, and ground through a 0.5-mm screen for later chemical analyses. The birds' BW was determined at the beginning and end of the experimental period, and feed consumption was measured for each pen.

Chemical Analyses

Diets were analyzed for DM, ash, CP, crude fat, crude fiber, AA, gross energy (GE), and TiO₂. Freeze-dried di-

Table 2. Analyzed concentrations of proximate nutrients and amino acids in the experimental diets and in soybean meal (SBM) and rapeseed meal (RSM; g/kg)

Item	Pure		Basal diet	Diet			
	SBM	RSM		SBM		RSM	
	—	—		150	300	150	300
CP	402	339	152	215	262	188	241
Crude fat	27	43	76	78	85	83	76
Crude fiber	97	155	35	41	41	49	63
Ala	16.5	16.6	5.9	8.4	10.6	7.7	9.6
Arg	27.2	19.4	4.9	9.3	13.2	7.7	10.1
Asp	45.2	25.9	6.6	13.4	19.6	10.1	13.3
Cys	6.3	7.8	3.3	4.3	5.1	4.3	5.4
Glu	74.0	58.2	48.1	60.7	68.5	52.7	62.4
Gly	16.6	16.1	4.7	7.3	9.2	6.8	8.9
Ile	18.2	12.9	5.3	7.9	9.7	6.6	8.4
Leu	29.8	23.2	12.8	17.4	21.1	15.6	18.9
Lys	24.6	18.0	6.9	11.0	14.2	9.9	12.4
Met	5.7	6.6	5.1	6.2	6.6	5.7	7.1
Phe	20.1	15.5	7.9	11.0	13.5	9.6	11.9
Ser	19.5	14.4	6.9	10.1	13.0	8.7	11.0
Thr	15.4	14.7	5.0	7.6	9.6	6.9	9.2
Val	18.8	16.6	6.1	9.1	10.9	7.9	10.3

gesta samples were analyzed for CP, AA, energy, and TiO₂. Crude nutrients were determined according to the official methods in Germany (Naumann and Bassler, 1976). The AA analysis also followed standard procedures, and details were given by Timmler and Rodehuts-cord (2003). After an oxidation step, samples were hydrolyzed in 6 N HCl. Norleucine was used as the external standard. Tryptophan, His, and Tyr were not determined. Separation of AA was done with an AA analyzer (Eppendorf LC 3000, Eppendorf, Hamburg, Germany) using different buffer solutions and ninhydrin. The TiO₂ content was determined by the method described by Brandt and Allam (1987). Energy was determined with a bomb calorimeter (IKA-Calorimeter C7000 isoperibolic, Janke & Kunkel IKA Analysentechnik, Staufen, Germany).

Calculations and Statistical Analyses

The digestibility (DC) of AA for each diet (DC_{AA Diet}) was calculated according to the following equation:

$$\text{DC}_{\text{AA Diet}} (\%) = 100 - 100 \times \left[\frac{(\text{TiO}_2 \text{ Diet} \times \text{AA}_{\text{Digesta}}) / \text{TiO}_2 \text{ Digesta} \times \text{AA}_{\text{Diet}}}{\text{AA}_{\text{Diet}}} \right]$$

where TiO_{2 Diet} and TiO_{2 Digesta} = respective concentrations of TiO₂ in the diet and digesta samples (g/kg); and AA_{Diet} and AA_{Digesta} = respective concentrations of the AA in the diet and digesta samples (g/kg)

To calculate the DC of CP and GE, the same equation was used with the respective concentrations of CP (g/kg) or GE (MJ/kg) in place of AA concentrations.

The partial DC of AA from the 2 oilseed meals was assessed by multiple linear regression analysis using data on daily intakes and digested amounts, as described by Kluth et al. (2005a). Daily intakes of AA and CP were calculated separately for the BD and oilseed meals. The

total daily intake was calculated as feed intake (g/d) × analyzed AA (or CP) concentration in the diet (mg/g). Amino acid (or CP) intake attributable to the BD could be computed as feed intake (g/d) × analyzed AA (or CP) concentration in the BD (mg/g). Because SBM and RSM were included in the diets at the expense of starch, inclusion had no effect on the concentration of AA from the BD in the total diet. Daily intake of AA from the supplemented meals was calculated as the difference between the total intake and intake attributable to the BD. The quantity of AA digested up to the terminal ileum was calculated as AA intake (mg/d) × DC_{AA Diet}/100. The following model was applied to simultaneously determine the partial DC of AA and CP from the 2 oilseed meals (Kluth et al., 2005a):

$$y = \alpha + \beta_b / 100 \times i_b + \beta_i / 100 \times i(s_i)$$

where y = daily amount of AA (or CP) digested; α = intercept; β_b = DC of AA (or CP) originating from the BD; i_b = daily intake of AA (or CP) with BD; β_i = DC of AA (or CP) from oilseed meal i (SBM or RSM); and $i(s_i)$ = daily intake of AA (or CP) from oilseed meal i (SBM or RSM).

The assumption of linearity between the intake and digested amounts of AA was based on previous findings (Short et al., 1999; Rodehuts-cord et al., 2004) and was confirmed in this study.

The data were analyzed according to a completely randomized block design using the GLM procedure of the statistical software package SAS (Version 8.2, SAS Institute Inc., Cary, NC). Differences in DC between the 2 oilseed meals were tested for significance using the ESTIMATE statement (*t*-test). Linear regressions were calculated using GraphPad Prism 4.02 (GraphPad Software, Inc. San Diego, CA). Data for the DC of GE from the complete diets were subjected to 2-factorial ANOVA. Be-

Table 3. The digestibility (DC; %) of CP and amino acids determined for the basal diet (BD) and diets containing soybean meal (SBM) and rapeseed meal (RSM) at 2 inclusion levels (g/kg)

Item	Broilers					Turkeys					Ducks					Pooled SEM
	BD		SBM		RSM	BD		SBM		RSM	BD		SBM		RSM	
	—	150	300	150	300	—	150	300	150	300	—	150	300	150	300	
CP	84	83	81	81	83	72	82	81	78	77	85	70	78	74	74	0.6
Ala	81	76	75	76	81	64	78	76	74	74	81	62	73	70	69	0.7
Arg	80	83	83	85	85	57	80	80	75	75	77	63	76	69	69	1.0
Asp	68	73	73	70	74	44	73	74	66	66	70	54	70	58	59	1.0
Cys	82	79	77	79	79	66	74	71	74	69	84	69	76	75	71	0.7
Glu	94	91	89	91	91	89	91	89	90	89	94	86	88	89	87	0.3
Gly	74	75	73	74	76	58	73	72	71	70	75	54	66	63	62	0.8
Ile	83	81	78	79	82	68	81	78	76	75	84	67	75	72	70	0.7
Leu	87	82	80	82	85	76	84	81	81	80	88	73	80	80	78	0.5
Lys	84	85	84	83	84	66	81	80	77	75	82	64	74	71	69	0.8
Met	93	91	89	90	92	86	90	87	88	88	92	81	85	86	85	0.4
Phe	88	84	82	84	86	78	86	83	82	81	89	76	82	80	79	0.5
Ser	81	80	79	79	80	64	79	78	74	73	84	70	79	74	74	0.6
Thr	75	77	76	74	77	52	73	72	67	68	77	57	70	64	65	0.9
Val	81	80	77	77	79	64	78	76	73	72	82	64	72	69	68	0.7

cause of a significant interaction between the diet effect and the species effect, the effect of diet on the DC of GE was tested for each species separately using Tukey's test and a level of significance of $P \leq 0.05$.

RESULTS

The mean BW gain during the 7 d on treatment of the diets BD, RSM 150, RSM 300, SBM 150, and SBM 300 was (in g) 152, 415, 514, 510, and 576 (broilers); 63, 161, 249, 209, and 313 (turkeys); and 404, 686, 672, 689, and 725 (ducks). The mean BW gain:feed for the respective treatments was (in g) 0.42, 0.63, 0.79, 0.72, and 0.81 (broilers); 0.22, 0.46, 0.55, 0.52, and 0.65 (turkeys); and 0.48, 0.62, 0.65, 0.70, and 0.69 (ducks).

The DC determined for the diets varied from 44 to 94% for individual AA (Table 3). Among the analyzed essential AA, Met had the highest and Thr had the lowest DC, irrespective of the species. For CP, a high level of DC was determined in broilers for all diets. The DC of individual AA (except Glu) in turkeys was higher when the oilseed meals were included in the diet. In broilers and ducks, the level of AA DC was similar and unchanged by oilseed meal supplementation.

The relationship between AA intake and AA digested up to the terminal ileum was linear in all species. For broilers, this is shown in Figure 1. Partial DC for essential AA from the oilseed meals varied from 92% (Met, RSM, broilers) to 62% (Val, RSM, ducks; Table 4). Within species, partial DC was not significantly different between SBM and RSM for broilers and turkeys. In ducks, significant differences were detected for Arg, Met, and Phe. Partial DC for individual AA differed among species. The level of partial DC of AA was lower in ducks than in the other 2 species, which showed similar partial DC values without significant differences. For SBM, significantly higher DC was detected for Lys, Met, Thr, and Val in broilers than in ducks. All AA from RSM, with the exception of Phe and Ser, tended to be less digested in ducks

than in broilers. The ranking of individual AA in DC was relatively similar between broilers and turkeys (Table 5). The ranking of the values for ducks differed from the other 2 species but still showed similarities. For example,

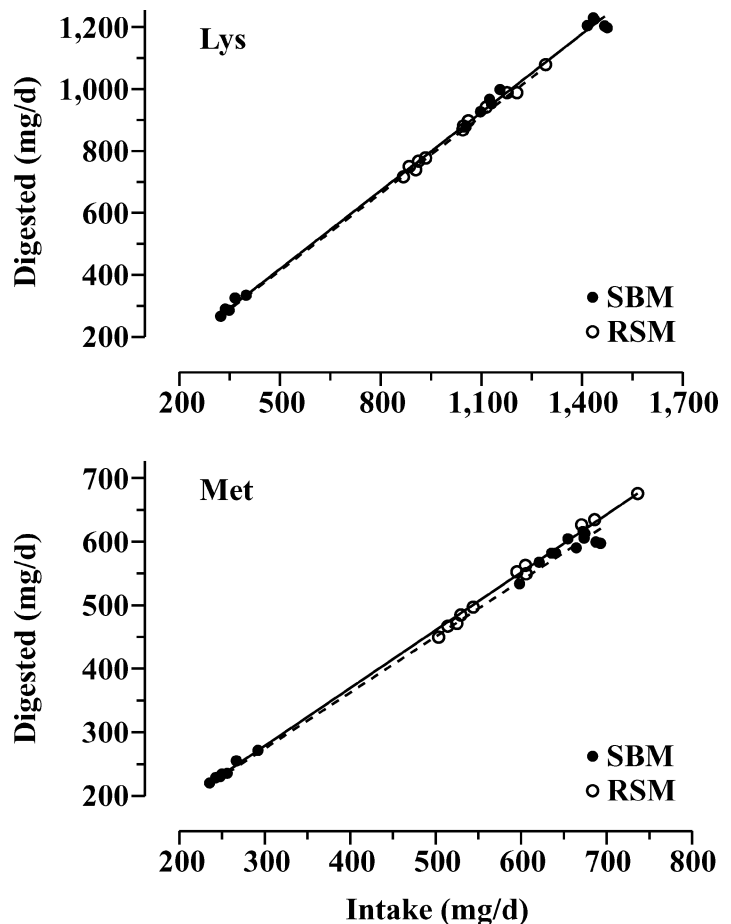


Figure 1. Linear relationship for Lys (upper panel) and Met (lower panel) between intake and amounts digested up to the terminal ileum of broilers fed diets containing soybean meal (SBM; closed circles) and rapeseed meal (RSM; open circles)

Table 4. Partial digestibilities (%) of amino acids and CP from soybean meal (SBM) and rapeseed meal (RSM), determined by multiple linear regression analysis (estimate of slope \pm SE of estimate)

Item	Broilers		Turkeys		Ducks		r ²
	SBM (Slope)	RSM (Slope)	SBM (Slope)	RSM (Slope)	SBM (Slope)	RSM (Slope)	
CP	81 \pm 3.4	82 ^a \pm 4.1	85 \pm 6.1	78 \pm 6.0	74 ^x \pm 2.2	69 ^{b,y} \pm 2.6	0.99
Ala	75 \pm 4.4	82 ^a \pm 5.3	81 \pm 7.8	75 \pm 7.8	67 \pm 2.9	66 ^b \pm 3.3	0.97
Arg	84 \pm 3.2	87 ^a \pm 4.8	85 \pm 5.7	79 \pm 7.1	76 ^x \pm 2.1	71 ^{b,y} \pm 3.0	0.98
Asp	75 \pm 3.3	76 ^a \pm 5.9	80 \pm 6.0	72 \pm 8.7	70 ^x \pm 2.2	60 ^{b,y} \pm 3.6	0.97
Cys	73 \pm 3.8	76 ^a \pm 3.6	71 \pm 6.9	69 \pm 5.3	69 \pm 2.5	67 ^b \pm 2.2	0.99
Glu	85 \pm 2.0	89 ^a \pm 2.6	89 \pm 3.6	86 \pm 3.8	82 \pm 1.3	81 ^b \pm 1.6	0.99
Gly	72 ^a \pm 4.4	75 ^a \pm 4.8	76 \pm 7.8	72 \pm 7.0	60 ^b \pm 2.8	59 ^b \pm 2.9	0.97
Ile	77 \pm 3.6	80 ^a \pm 4.8	82 \pm 6.4	75 \pm 7.0	69 \pm 2.4	65 ^b \pm 2.9	0.98
Leu	78 \pm 3.3	84 ^a \pm 4.2	83 \pm 6.0	79 \pm 6.2	74 \pm 2.2	73 ^b \pm 2.6	0.99
Lys	84 ^a \pm 3.8	83 ^a \pm 4.9	83 \pm 6.8	76 \pm 7.1	70 ^b \pm 2.5	66 ^b \pm 3.0	0.98
Met	87 ^a \pm 3.3	92 ^a \pm 3.1	87 \pm 5.9	86 \pm 4.6	76 ^{b,x} \pm 2.2	80 ^{b,y} \pm 1.9	0.99
Phe	85 ^x \pm 2.4	79 ^y \pm 3.2	88 ^x \pm 4.3	75 ^y \pm 4.7	83 ^x \pm 1.6	73 ^y \pm 2.0	0.99
Ser	79 \pm 3.1	79 \pm 4.3	83 \pm 5.6	74 \pm 6.3	77 ^x \pm 2.1	70 ^y \pm 2.7	0.99
Thr	78 ^a \pm 4.5	77 ^a \pm 5.0	82 \pm 8.1	73 \pm 7.4	66 ^b \pm 3.0	64 ^b \pm 3.1	0.97
Val	77 ^a \pm 4.1	77 ^a \pm 4.7	80 \pm 7.2	72 \pm 6.9	66 ^b \pm 2.6	62 ^b \pm 2.9	0.98

^{a,b}Amino acids not sharing a common superscript are significantly different between species within protein source, $P < 0.05$.

^{x,y}Amino acids not sharing a common superscript are significantly different between protein sources within species, $P < 0.05$.

out of the 5 AA with the highest DC in broilers and turkeys, 4 were present in the group of the 5 highest digestible AA in ducks.

The DC of GE from the BD could not be detected in turkeys due to a shortage in sampled material. The effects of both species ($P = 0.043$) and diet ($P < 0.001$) on the DC of AA were significant, and a significant interaction between species and diet was detected ($P < 0.001$). The DC of GE was 79% in broilers and 86% in ducks (Table 6). The replacement of cornstarch with oilseed meal caused a reduction in the GE DC of the diet. This effect was significant in broilers and ducks on the highest level of inclusion of SBM or RSM.

DISCUSSION

Amino acid DC at the terminal ileum has been extensively studied in recent years, especially with broilers (Ravindran et al., 1998, 1999; Short et al., 1999; Wiseman et al., 2003; Rodehutsord et al., 2004; Kluth et al., 2005a). Studies were also conducted with Pekin ducks (Martin et al., 1998) and turkeys (Yi et al., 1996). Systematic comparisons with mixed diets based on barley, wheat, and SBM indicated that digestibilities are different between broilers and waterfowl (Jamroz et al., 2001, 2002) yet pro-

vided no information about the potential relevance of species-specific endogenous AA losses for these differences. Mean digestibilities for all AA on d 14, 28, and 42 were 70, 73, and 73% in broilers, respectively, and 44, 62, and 60% in ducks (Jamroz et al., 2002). The present study confirmed that differences exist between broilers and ducks. The approach we used is based on the linear relationship that exists between the variable intake and digested amounts of N and individual AA, either at the fecal or ileal level (Mitchell and Bert, 1954; Bielora et al., 1985; Gruhn and Zander, 1989; Short et al., 1999; Rodehutsord et al., 2004). When the quantitative data on the intake and digested amounts are used for regression analysis, the calculated slopes can be considered as partial digestibilities for the protein under study, without any need for a correction of basal endogenous losses (Rodehutsord et al., 2004). The latter are contained in the intercept estimates of the respective regressions. For this reason, neither the differences in feed intake found among species nor the related differences in basal endogenous AA loss can be considered the cause of differences in partial digestibilities. Because the slopes were significantly different for several AA, especially from RSM (Table 4), it can be concluded that basal endogenous AA losses were not the primary reason for the differences

Table 5. Ranking of digestibilities determined for amino acids in soybean meal (SBM) and rapeseed meal (RSM)

Item	Amino acids
SBM	
Broiler	Met > Phe = Glu > Arg = Lys > Ser > Leu = Thr > Ile = Val > Asp = Ala > Cys > Gly
Turkeys	Glu > Phe > Met > Arg > Lys = Ser = Leu > Thr = Ile > Ala > Val = Asp > Gly > Cys
Ducks	Phe > Glu > Ser > Met = Arg > Leu > Lys = Asp > Ile = Cys > Ala > Thr = Val > Gly
RSM	
Broiler	Met > Glu > Arg > Leu > Lys > Ala > Ile > Phe = Ser > Thr = Val > Asp = Cys > Gly
Turkeys	Met = Glu > Arg = Leu > Lys > Ala = Ile = Phe > Ser > Thr = Val = Asp = Gly > Cys
Ducks	Glu > Met > Leu = Phe > Arg > Ser > Cys > Lys = Ala > Ile > Thr > Val > Asp > Gly

Table 6. Content and digestibility (DC) of gross energy (GE) in the experimental diets (Mean ± SD)

Item	Broilers						Turkeys						Ducks					
	BD ¹		SBM		RSM		BD		SBM		RSM		BD		SBM		RSM	
	0	150	150	300	150	300	0	150	150	300	150	300	0	150	150	300	150	300
GE (MJ/kg)	16.8	17.3	17.3	17.6	17.1	17.5	16.8	17.3	17.6	17.6	17.1	17.5	16.8	17.3	17.3	17.6	17.1	17.5
DC of GE (%)	79 ^a ± 5.5	77 ^{ac} ± 0.8	73 ^{bc} ± 2.2	70 ^b ± 1.9	70 ^b ± 1.9	72 ^b ± 1.4	0	77 ^a ± 3.1	74 ^{ab} ± 8.6	75 ^a ± 2.6	70 ^b ± 2.5	86 ^c ± 1.0	71 ^c ± 4.3	75 ^{bc} ± 2.0	77 ^b ± 1.1	72 ^{bc} ± 3.7	77 ^b ± 1.1	72 ^{bc} ± 3.7

^{a-c}Means within species not sharing a common superscript are significantly different ($P \leq 0.05$)

¹BD = basal diet; SBM = soybean meal; RSM = rapeseed meal.

²Could not be determined due to limitation of digesta sample size.

found in digestibilities between broilers and ducks. Differences in specific endogenous losses among the species may be relevant, but these could not be considered with the chosen approach. The studies by Jamroz et al. (2004) indicate that the differences in the development of the digestive tract might be the cause of the species' differences in DC. They found that the relative length of the small intestine (in relation to $BW^{0.67}$) is higher in broilers than in ducks. Estimates made from Figure 2 and Table 2 of Applegate et al. (2005) indicate that the length of jejunum + ileum in relation to BW, measured on d 7 posthatch, is greater in turkeys than in ducks. In the same study, however, Applegate et al. (2005) found a higher relative mass of jejunum + ileum in ducks than in turkeys and viewed this difference as a reason for the higher growth rate in ducks. Based on our findings, differences in AA DC should not be considered a cause of the differences in the 3 species' growth rate because ducks had the lowest DC.

The overall level of AA DC in ducks was higher in the studies of Adeola (2005) and Nyachoti et al. (2004) than in the present study. However, these authors used older ducks and a different assay; they calculated the DC by excreta analyses. The effects of postileal fermentation and the feeding level on AA DC account, in major part, for the differences between the present study and those of Adeola (2005) and Nyachoti et al. (2004).

The average DC in 28- to 42-d-old broilers of the AA Arg, Ile, Leu, Lys, Met, Phe, Thr, and Val from SBM was 82 (Pérez et al., 1993), 84 (Ravindran et al., 1999), and 88% (Bryden and Li, 2004). The corresponding average from the present broiler study was 81%. On the other hand, the average DC of the indicated AA for RSM was higher in the present study (82%) than the 78% value reported by Ravindran et al. (1999) and equal to the value reported by Bryden and Li (2004). One may consider these differences as indicative of differences in DC among different origins of the same raw material. However, as long as the methodological details of prececal DC studies are poorly standardized (age of birds, CP level in the diet, consideration of endogenous AA loss, length of the sampled intestine section, etc.), the results of different studies will remain difficult to compare in regard to the ingredient under study (Rodehutscord and Mosenthin, 2005). When data for RSM obtained with broilers and a similar experimental approach were compared [as in the present study and Rodehutscord et al. (2004)], the DC was equal or similar (no more than 2 percentage units difference) for 9 out of 14 analyzed AA. Larger differences were noted for Leu, Met, Phe, Thr (each 4 percentage units), and cystine (8 percentage units). Kluth et al. (2005a) used the same regression approach to study differences in DC among 4 cultivars of *Pisum sativum* and found that 1 variety had significantly lower DC than the other 3. Pea lines with a high activity of trypsin inhibitors had lower AA DC than lines with low activity (Wiseman et al., 2003). There is some evidence, therefore, that AA digestibilities vary not only among different feedstuffs, but also among different batches of the same feedstuff.

In 4-wk-old turkeys, Palander et al. (2004) found differences in the CP DC between SBM (80%) and RSM (66%). In the present study, a lower CP DC was also found for RSM (78%) than for SBM (85%), although this was statistically insignificant (Table 4). Digestibilities for AA in turkeys were reported from studies investigating the effects of supplementing the enzyme phytase (Yi et al., 1996; Wendt and Rodehutsord, 2004). The range in AA DC reported in these studies was similar to the present study.

It can be concluded that there are differences in AA DC among poultry species. The underlying mechanisms and reasons still require clarification. However, the application of data obtained with broilers in feed formulation for turkeys and ducks is not justified. Ducks digested AA from both oilseed meals to a lesser extent than broilers and turkeys. Data indicated that the magnitude and direction of differences in AA DC between broilers and turkeys depends on the raw material. The ranking in DC of individual AA was very similar between broilers and turkeys, but differences exist between ducks and the 2 other species.

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