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Validation of a mathematical model to explain variation in apparent ileal amino acid digestibility of diets fed to pigs

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ABSTRACT

Variation in apparent ileal digestibility of amino acids within the same diet is partly related to the amino acid composition of feed protein and endogenous protein. Mathematical model which estimate the apparent ileal amino acid digestibility coefficients, based on apparent ileal digestibility coefficients of the diet protein and the amino acid composition of the diet protein as factors, has been described in literature. In the present study, apparent ileal amino acid digestibilities of pigs fed eighteen different diets with a wide range of different protein sources were determined and the mathematical model from the literature was validated.

Results of the validation showed that the mathematical model explained 60-94% of the variation in apparent ileal amino acid digestibility of sixteen diets. However, variations for diets with *Phaseolus* beans and meat and bone meal as protein sources were explained by only 45 and 27%, respectively. Standard error of prediction (SEP) was about 2-3 times higher as compared to the standard error of the mean (SEM) of the determinations between animals.

For most of the feedstuffs, the factors of the model explain the main part of the variation in apparent amino acid digestibility ($R^2 \geq 0.60$). If the explained part of the variation in apparent amino acid digestibility is small, $R^2 < 0.50$, other factors which are not included in the model have major effects on apparent digestiblity of the amino acids.

KEY WORDS: pigs, ileal digestibility, amino acids, mathematical model

INTRODUCTION

Variation in apparent ileal digestibility of amino acids has been studied previously by mathematical analysis of a data base using apparent ileal amino acid digestibility values from the literature (van Leeuwen et al., 1993a). For each amino acid an equation was calculated with the digestibility of crude protein and the amino acid content in the feedstuff as a factor. In this data base, results of different feedstuffs, experimental design and analytical techniques were included.

The aim of the present study was to validate the model of the mathematical study (van Leeuwen et al., 1993a). The apparent ileal amino acid digestibility of 18 diets with different protein sources were determined and apparent digestibility values were predicted by the model. Comparing the predicted and measured values the model was validated.

MATERIAL AND METHODS

Experimental design

Digestibility experiment. Twelve crossbred barrows [(Dutch Landrace x Yorkshire) x Finnish Landrace] were surgically fitted with Post Valve T-Caecum (PVTC) cannulae according to van Leeuwen et al. (1991) and kept in smooth walled metabolic cages. The cages were placed in an environmentally controlled barn with air temperature of 19-21^{0}C. From 7.00-21.00 h the experimental room was illuminated, during the night the lights were dimmed.

After a recovery period of 10 days experimental diets were fed at a level of 2.6 times the requirement of metabolizable energy for maintenance (420 kJ/BW$^{0.75}$). Water was mixed with the feed (2.5:1) just prior to feeding. The pigs were fed equal amounts of feed at 8.00 and 16.00 h during the adaptation period and at 8.00 and 20.00 h from 2 days prior and during the collection periods. In a change-over design apparent ileal crude protein (CP) and amino acid digestibilities were determined using six animals at a body weight ranging from 46 to 94 kg. Digesta was collected during three successive days over a period from 08.00 to 20.00 h. Details of the experimental procedure and the experimental protocol have been described elsewhere (van Leeuwen et al., 1996).

The experiment was approved by the TNO Committee for Animal Welfare.

Diets. Eighteen diets, containing at least 14.1% crude protein (CP), were formulated using 18 feedstuffs as the only or main protein source. The 18 feedstuffs were derived from the next three product groups:

1. cereals and by-products of cereals: wheat, barley, maize, wheat gluten, wheat bran and maize gluten feed
2. legume seeds: peas, faba beans with low tannin (LT) and with high tannin (HT) content, lupins, toasted full fat soya beans and toasted *Phaseolus* beans
3. protein rich products of vegetable and animal origin: soyabean meal, rapeseed meal, sunflower meal, fish meal, casein and meat and bone meal.

In diets containing a feedstuff with a low protein content wheat gluten meal was included, additionally. Amino acid contents of the diets were balanced for the requirements (CVB, 1994) and if necessary supplemented with crystalline amino acids. Details of diet composition and analytical results have been described elsewhere (van Leeuwen et al., 1996).

Analytical procedures

Prior to chemical analysis, feedstuffs, diets and freeze-dried digesta were ground through a 1 mm screen using a Retsch AM 1 grinder. Nitrogen (N) was analyzed by the Kjeldahl method in a semi-automatic Kjellfoss apparatus (Foss Electroic, Denmark). The amino acids were analysed after hydrolysis (22 h, 6N HCl; except Trp) using a Beckman's Amino Acid Analyzer 6300 equipped with a 12 cm Na-column. Met and Cys were determined after oxidation with performic acid and peroxide before hydrolysis (Moore, 1963). Samples for Trp determination were hydrolized with BaOH according to Eggum (1968).

Calculations

The apparent ileal CP and amino acid digestibility coefficients of the diets were determined using chromic oxide as a digestibility marker (van Leeuwen et al., 1996). The crystalline amino acids included were assumed to be completely absorbed. Moreover, apparent ileal amino acid digestibilities were predicted using calculation model (Table 1), with the apparent ileal CP digestibility of the diet and the reciprocal of the amino acid content in the dietary protein as factors.

Statistical analysis

Differences between predicted and determined values were evaluated by calculating:
- standard error of the mean (SEM), differences in determined apparent digestibility between animals for CP and each amino acid (SPSS, 1988)
- correlation coefficient (R^2) and standard error of prediction (SEP), differences between determined and predicted amino acid digestibility coefficient for each diet (SPSS, 1988).

TABLE 1

Model to predict apparent ileal digestibility of amino acids (Y, % units) with apparent ileal digestibility of crude protein (X_1, % units) and the reciprocal of the amino acid content (AA) in the protein of the diet (X_2, g AA/100 g CP) as factors. $Y = a X_1 + b X_2 + C$ (van Leeuwen et al., 1993a)

	a	b	C
		Indispensable amino acids	
Arg	0.650	−33.91	42.2
His	0.850	−9.08	19.7
Ile	0.804	−11.68	21.1
Leu	0.700	−68.28	37.4
Lys	1.022	−55.08	11.5
Met	0.623	−17.80	46.1
Phe	0.752	−22.00	29.6
Thr	0.984	−45.36	9.5
Trp	1.127	−8.31	−4.0
Val	0.825	−19.66	18.5
		Dispensable amino acids	
Ala	0.911	−60.83	19.7
Asp	0.957	−78.00	12.8
Cys	1.100	−17.65	−0.1
Glu	0.642	−152.67	44.7
Gly	1.268	−44.14	−17.8
Pro	0.907	−63.10	18.6
Ser	0.824	−15.00	18.2
Tyr	0.889	−20.15	18.5

RESULTS

The results of the CP (N x 6.25) and amino acid analysis are presented in Table 2. Tables 3 to 5 give coefficients for the apparent ileal digestibility CP and amino acids (Experimental digestibility coefficients (DC), in % units) measured for eighteen diets with the standard errors of the means (SEM). The Tables 3 to 5 also include values of the amino acid digestibility coefficients predicted with the model (Model DC, in % units), the correlation coefficients (R^2) between experimental and model DC's and the standard error of prediction (SEP).

Correlation coefficients (R^2) were $\geqslant 0.60$, with the exception of the *Phaseolus* beans/ wheat-gluten diet (diet d3, $R^2 = 0.45$) and the meat and bone meal diet (diet f3, $R^2 = 0.27$). Standard errors for predicted values were < 5.4 units, with the exception of diet d3 (SEP = 7.1) and diet f3 (SEP = 7.0). The accuracy of prediction for these two diets is therefore worse compared to the other sixteen diets which, is in agreement with the low correlation coefficients.

TABLE 2

Crude protein (CP, in %) and amino acid contents (g/100 g CP) in the diets

Diet	a1	a2	a3	b1	b2	b3	c1	c2	c3	d1	d2	d3	e1	e2	e3	f1	f2	f3
CP (N x 6.25)	16.0	15.3	16.0	15.3	15.2	14.7	16.6	17.0	16.7	16.0	14.8	16.1	17.1	16.6	14.5	16.2	16.0	14.1
Indispensable amino acids																		
Arg	4.5	4.4	4.3	3.5	4.7	4.1	8.4	10.0	9.1	10.9	7.8	5.1	7.5	5.5	8.2	5.9	3.8	6.3
His	2.3	2.2	2.5	2.1	2.3	2.6	2.5	2.7	2.8	2.8	2.7	2.6	2.7	2.7	2.4	3.5	3.1	3.1
Ile	3.7	3.6	3.8	3.7	3.6	3.4	4.2	4.3	4.3	4.2	4.6	4.5	4.9	4.1	4.2	4.4	5.5	2.8
Leu	7.2	7.0	10.0	7.3	6.9	9.1	7.2	7.8	7.8	7.2	7.9	8.2	8.1	7.3	6.5	7.7	10.3	7.9
Lys	2.4	2.7	2.4	1.7	2.4	2.4	7.1	6.5	7.0	4.9	6.4	4.5	6.4	5.3	3.6	7.9	8.5	5.7
Met	1.7	1.8	1.9	1.6	1.7	1.7	1.1	0.7	0.7	0.9	1.6	1.4	1.5	2.0	2.3	2.7	3.0	1.6
Phe	5.0	5.5	6.0	5.2	4.8	5.3	4.7	4.4	4.6	4.3	5.2	6.0	5.6	4.2	4.6	4.6	5.6	4.4
Thr	3.0	3.3	3.3	2.6	2.8	3.4	3.8	3.8	3.9	3.5	4.1	3.7	4.1	4.5	3.9	4.4	4.7	3.8
Trp	1.0	1.1	0.9	0.9	1.1	0.6	0.9	0.8	0.9	0.8	1.2	1.0	1.3	1.3	1.2	1.2	1.3	1.0
Val	4.2	4.5	4.4	3.9	4.2	4.3	5.1	5.1	5.0	4.3	4.6	4.7	5.2	5.2	4.8	5.0	7.2	5.4
Dispensable amino acids																		
Ala	3.3	3.5	5.1	2.7	3.2	5.8	4.4	4.3	4.5	3.6	4.5	3.7	4.6	4.6	4.3	6.4	3.3	7.3
Asp	4.6	5.0	5.4	3.4	4.6	5.7	11.1	12.0	12.1	10.8	11.8	8.0	12.1	7.8	9.3	9.5	7.7	9.3
Cys	2.3	2.2	2.2	2.0	2.0	2.2	1.6	1.2	1.3	1.2	1.5	1.6	1.4	2.1	1.8	1.0	0.6	1.4
Glu	35.2	31.2	31.1	41.5	34.6	23.7	18.2	19.1	19.4	23.1	20.0	29.9	20.3	18.1	21.7	14.0	25.7	13.2
Gly	3.8	3.9	3.7	3.3	3.9	3.9	4.3	4.4	4.5	4.3	4.4	3.8	4.4	5.3	5.7	6.6	2.1	10.5
Pro	10.8	11.1	10.6	12.4	10.5	9.5	4.5	4.4	4.4	4.4	5.1	9.2	5.5	6.1	4.3	4.2	11.3	7.3
Ser	4.8	4.5	5.0	4.9	4.8	4.4	4.7	5.0	5.1	5.0	5.2	5.6	5.2	4.5	4.4	4.1	6.1	4.8
Tyr	3.2	3.2	3.8	3.3	3.1	3.4	3.3	3.4	3.5	3.7	3.7	3.6	3.8	3.2	2.5	3.2	5.7	2.5

Protein source: a1 = Wheat + wheat gluten; a2 = Barley + wheat gluten; a3 = Maize + wheat gluten; b1 = Wheat gluten; b2 = Whean bran + w.gl.; b3 = Maize gl. feed + w.gl.; c1 = Peas; c2 = Faba beans LT; c3 = Faba beans HT; d1 = Lupins; d2 = Soya beans; d3 = *Phaseolus* beans + w.gl.; e1 = Soyabean meal; c2 = Rapeseed meal; e3 = Sunflower meal; f1 = Fish meal; f2 = Casein; f3 = Meat and bone meal

TABLE 3

Apparent crude protein (CP) and ileal amino acid digestibility coefficients (DC, in % units) of six diets with cereals and by products of cereals as protein source; values predicted with the model [Model DC; $Y = a X^1 + b X^2 + C$ (see Table 1)] and values determined in the experiment. Experimental DC

Diets	a1			a2			a3			b1			b2			b3		
Protein source	Wheat/ wheat gluten			Barley/wheat gluten			Maize/wheat gluten			Wheat gluten			Wheat bran/ wheat gluten			Maize gluten feed/ wheat gluten		
	model	experimental		model	experimental		model	experimental		model	experimental		model	experimental		model	experimental	
	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM
CP (N x 6.25)	–	86.3	0.8	–	77.9	1.0	–	82.9	1.4	–	92.3	0.5	–	83.6	0.9	–	61.8	1.3
Indispensable amino acids																		
Arg	90.7	88.1	0.6	85.2	83.1	0.7	88.2	87.7	1.0	92.5	92.6	0.5	89.4	88.9	0.9	74.1	74.0	0.7
His	89.0	90.1	1.2	81.8	83.0	0.7	86.5	86.9	1.1	93.9	93.8	0.4	86.8	84.9	1.1	68.8	68.9	1.5
Ile	87.3	87.4	0.7	80.5	78.8	1.0	84.7	84.9	1.3	92.2	93.6	0.5	85.1	82.8	0.9	67.4	67.8	1.3
Leu	88.3	89.3	0.5	82.2	82.9	0.9	88.7	89.2	1.0	92.7	94.8	0.4	86.0	85.2	0.9	73.1	78.6	0.9
Lys	77.1	82.9	0.9	71.1	71.3	1.5	73.1	73.4	2.1	74.3	84.2	1.2	74.1	70.3	2.9	52.0	50.6	2.4
Met	89.5	86.2	0.7	84.5	77.7	1.1	88.6	86.8	1.1	92.3	93.2	0.4	87.7	85.5	1.0	74.1	72.6	0.9
Phe	90.1	85.6	0.9	84.2	79.4	1.1	88.3	85.8	1.2	94.8	91.3	0.4	87.9	82.4	1.1	71.9	76.6	0.9
Thr	79.1	77.9	1.4	72.5	69.1	1.6	77.5	74.5	2.1	83.2	83.6	0.9	75.8	69.7	1.8	56.9	52.5	1.6
Trp	85.1	82.6	1.1	76.5	75.9	1.2	80.2	81.7	1.4	90.7	89.1	0.8	82.5	82.7	1.2	51.7	55.8	1.3
Val	85.0	84.5	0.8	78.4	76.7	1.1	82.5	82.7	1.4	89.6	91.0	0.6	82.9	78.8	1.3	64.9	65.1	1.3
Dispensable amino acids																		
Ala	79.7	79.5	1.2	73.2	68.5	1.7	83.4	82.4	1.6	81.0	87.2	1.1	77.1	71.2	1.9	65.4	71.8	1.2
Asp	78.6	77.5	1.2	71.8	65.0	1.8	77.6	75.8	1.9	78.0	81.9	1.3	75.7	71.1	1.9	58.2	55.2	1.6
Cys	86.9	83.9	0.7	77.4	76.1	1.1	83.1	81.6	1.5	92.8	90.7	0.6	83.1	82.4	1.3	59.8	56.9	1.4
Glu	95.7	95.4	0.2	89.8	90.9	0.4	93.0	93.1	0.6	100.3	98.0	0.2	94.0	94.1	0.5	77.9	80.8	0.8
Gly	80.0	79.1	1.2	69.8	69.8	1.2	75.4	74.8	2.2	86.0	86.4	0.9	76.9	73.7	1.8	49.3	46.8	2.1
Pro	91.0	93.5	0.4	83.6	88.4	0.6	87.8	90.0	1.0	97.2	96.0	0.4	88.4	91.9	0.7	68.0	70.6	1.5
Ser	86.2	87.5	0.7	79.1	78.9	0.9	83.6	84.9	1.2	91.2	92.8	0.4	84.0	84.1	1.2	65.7	68.0	1.2
Tyr	88.9	88.2	0.6	81.5	81.9	0.8	86.9	87.1	1.0	94.5	93.3	0.5	86.3	82.9	0.9	67.4	73.5	0.9
R^2	0.79		–	0.83		–	0.94		–	0.84		–	0.92		–	0.91		–
SEP	2.4		–	3.2		–	1.4		–	3.2		–	3.3		–	3.5		–

DISCUSSION

Several studies showed distinct differences in apparent ileal amino acid digestibility between different feedstuffs (Żebrowska et al., 1978; Buraczewska et al., 1987) and between the same kind of feedstuff (Gdala et al., 1992). A mathematical study showed that a large part of the variation in apparent ileal digestibility between amino acids could be explained by factors in the mathematical model (van Leeuwen et al., 1993a). The model, based on apparent protein digestibility and the amino acid contents in the feedstuff protein, explained 60 to 81% of the variation. A validation of the model with a small number of feedstuffs confirmed this observation (van Leeuwen et al., 1993b).

In the present study, the data of apparent amino acid digestibility of 18 diets containing proteins of different origin provided a more general validation of the model. Results showed that for 16 of the 18 diets R^2 between predicted and determined apparent digestibility of the amino acids was $\geqslant 0.6$.

A part of the unexplained variation is due to differences between the animals, however, generally the SEP was 2 to 3 times higher than the SEM. Köhler et al. (1991) and Hennig et al. (1991) showed distinct differences in apparent amino acid digestibility due to digesta collection techniques. So the procedure for digesta collection is also source of error. The model were calculated on the data base with data derived from different collection techniques. In present digestibility experiment one technique for digesta collection was used.

Also analytical errors in the determination of amino acid contents are a source of error. Distinct differences between the amino acid content of the same sample analyzed by different laboratories have been shown (A.J.M. Jansman, personal communication; Bütikofer, 1993). The effect of a systematic analytical error in the level of an amino acid content in the diet and digesta has only a minor effect on the experimentaly determined digestibility coefficient. An under- or overestimation of the amino acid content in the feedstuff is compensated by the same bias error of analysis in digesta. However, model values are directly related to only the amino acid content in the feedstuff protein. As a result a higher SEP compared to the SEM is related to experimental and analytical techniques. There are other limitations of the model which are to be discussed on the following points.

Low amino acid levels in the protein of some feedstuffs

Large deviation in the amino acid content in a particular feedstuff protein compared to the levels in the majority of the feedstuffs included in the data base which was used to calculate the model, decrease accuracy of the prediction. This can be illustrated by the results of diet b1 (Table 3), with wheat gluten as a protein

TABLE 4

Apparent crude protein (CP) and ileal amino acid digestibility coefficients (DC, in % units) of six diets with legume seeds as protein source; values predicted with the model [Model DC; Y= $aX^1 + bX^2 + C$ (see Table 1)] and values determined in the experiment. Experimental DC

Diets	c1			c2			c3			d1			d2			d3		
Protein source	Peas			Faba beans, low tannins			Faba beans high tannins			Lupins			Soya beans			*Phaseolus* beans/ wheat gluten		
	model	experimental		model	experimental		model	experimental		model	experimental		model	experimental		model	experimental	
	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM
CP (N x 6.25)	–	75.3	1.4	–	72.8	1.0	–	67.8	0.8	–	77.6	2.5	–	73.3	1.3	–	66.3	1.7
Indispensable amino acids																		
Arg	87.1	89.5	0.7	86.1	89.8	0.7	82.6	83.0	0.6	89.6	91.7	1.1	85.5	83.4	1.1	78.7	73.1	0.9
His	80.1	81.7	1.0	78.2	78.5	0.7	74.1	76.2	0.5	82.4	82.4	2.6	78.6	77.5	1.2	72.5	69.3	1.1
Ile	78.8	77.8	1.2	76.9	71.0	1.7	72.9	69.6	0.5	80.8	77.5	2.9	77.5	73.4	1.4	71.8	64.4	1.2
Leu	80.6	77.7	1.2	79.6	74.2	1.7	76.2	72.8	0.6	82.3	80.4	2.6	80.1	75.5	1.7	75.5	68.6	1.1
Lys	80.7	83.8	1.1	77.4	78.5	1.9	72.9	77.6	0.6	79.6	80.6	2.2	77.8	81.5	1.2	66.9	67.3	1.2
Met	76.3	68.3	2.1	66.0	52.2	2.8	63.9	46.7	1.7	74.3	65.9	4.1	80.7	77.6	0.8	74.9	71.3	1.1
Phe	81.6	75.9	1.4	79.4	69.2	1.6	75.8	71.0	0.6	82.8	75.3	3.4	80.5	70.9	1.6	75.8	61.5	1.6
Thr	71.6	70.5	1.5	69.2	66.6	1.7	64.7	65.8	0.5	72.9	71.4	3.7	70.6	67.9	1.7	62.4	57.3	1.8
Trp	71.1	62.0	2.5	67.3	63.0	2.1	62.7	61.8	0.9	72.7	70.9	2.9	71.8	76.6	1.3	62.1	62.4	2.6
Val	76.7	75.5	1.3	74.7	70.3	1.7	70.5	69.0	0.3	77.9	75.0	3.1	74.7	68.9	1.6	69.0	61.1	1.6
Dispensable amino acids																		
Ala	74.5	72.9	1.5	71.7	67.1	2.0	67.8	65.9	0.8	73.4	68.5	4.2	72.9	70.0	1.6	63.7	59.7	1.9
Asp	77.8	77.3	1.2	76.0	78.2	1.3	71.2	75.3	0.8	79.9	78.6	2.9	76.3	74.0	1.4	66.6	49.3	1.9
Cys	71.8	67.6	1.8	65.7	59.0	2.2	60.7	54.1	0.5	71.1	71.0	3.3	68.8	66.7	1.9	61.8	68.4	1.6
Glu	84.6	82.4	1.4	83.4	80.9	1.6	80.4	80.8	0.4	87.9	86.9	1.8	84.1	79.0	1.2	82.2	82.5	0.7
Gly	67.3	67.8	1.8	64.5	64.4	1.6	58.4	60.4	0.8	70.4	74.7	3.2	65.2	64.4	2.2	54.8	55.4	2.7
Pro	72.8	74.8	1.5	70.2	70.5	1.6	65.7	67.4	0.7	74.5	78.1	2.7	72.7	73.0	1.8	71.9	79.8	1.2
Ser	77.0	74.2	1.3	75.2	72.5	1.7	71.1	70.6	0.4	79.1	78.6	2.8	75.7	72.8	1.4	70.2	66.9	1.3
Tyr	79.2	78.2	1.2	77.2	71.8	1.5	73.0	72.2	0.4	82.1	80.2	2.6	78.3	76.8	1.2	71.8	67.9	1.3
R^2	0.76		–	0.77		–	0.72		–	0.73		–	0.64		–	0.45		–
SEM	3.7		–	5.4		–	5.0		–	3.5		–	3.9		–	7.1–		

TABLE 5

Apparent crude protein (CP) and ileal amino acid digestibility coefficients (DC, in % units) of six diets with crude protein rich feedstuffs as protein source; values predicted with the model [Model DC; Y = $aX^1 + bX^2 + C$ (see Table 1)] and values determined in the experiment. Experimental DC

Diets	e1			e2			e3			f1			f2			f3		
Protein source	Soyabean meal			Rapeseed meal			Sunflower meal			Fish meal			Casein			Meat and bone meal		
	model	experimental		model	experimental		model	experimental		model	experimental		model	experimental		model	experimental	
	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM	DC	DC	SEM
CP (N x 6.25)	–	79.6	1.5	–	57.4	2.7	–	72.3	1.5	–	77.8	0.7	–	93.3	0.2	–	61.0	1.8
Indispensable amino acids																		
Arg	89.4	90.9	0.6	73.3	76.8	1.2	85.1	88.6	0.6	87.1	90.6	0.3	93.8	95.7	0.2	76.5	78.1	1.0
His	84.0	84.6	1.2	65.1	70.4	2.5	77.4	77.7	1.6	83.3	84.3	0.6	96.1	96.4	0.2	68.6	64.9	1.5
Ile	82.7	84.0	1.5	64.4	59.5	2.3	76.5	76.0	2.0	81.0	86.1	0.7	94.0	94.1	0.4	66.0	62.3	2.0
Leu	84.6	84.0	1.4	68.3	65.5	2.7	77.5	76.7	1.6	83.1	88.2	0.6	96.1	96.9	0.1	71.4	67.9	1.2
Lys	84.2	87.9	1.3	59.8	58.6	3.4	69.9	75.0	1.9	84.1	87.4	0.5	100.3	96.8	0.1	64.3	66.1	1.3
Met	84.1	86.2	1.2	73.0	72.8	2.0	83.5	84.7	1.0	88.0	88.7	0.3	98.4	97.1	0.1	72.6	63.8	1.8
Phe	85.5	79.3	1.3	67.5	64.9	3.1	79.2	72.4	1.9	83.3	83.0	0.9	95.8	95.0	0.3	70.4	62.9	1.5
Thr	76.8	77.2	1.7	55.9	52.9	3.3	68.9	67.6	1.7	75.7	80.0	0.9	91.7	89.6	0.3	57.6	57.2	1.8
Trp	79.3	83.8	1.3	54.5	60.8	2.6	70.5	76.4	1.2	76.5	83.5	0.6	94.6	93.1	0.3	56.6	70.0	1.5
Val	80.4	82.1	1.6	62.0	57.2	2.7	74.0	72.7	1.9	78.8	85.0	0.8	92.7	94.4	0.3	65.1	64.5	1.4
Dispensable amino acids																		
Ala	79.0	79.8	2.1	58.6	60.0	3.5	71.5	73.8	1.8	81.2	86.3	0.6	86.3	90.8	0.3	67.0	70.4	1.3
Asp	82.5	82.1	1.2	57.7	51.3	2.9	73.6	73.8	1.6	79.1	66.2	1.1	92.0	93.0	0.2	62.8	48.3	2.1
Cys	75.0	70.6	2.1	54.5	50.3	4.0	69.8	67.6	1.6	67.5	65.3	1.7	74.8	79.1	0.5	54.4	43.9	2.5
Glu	88.3	85.5	1.7	73.1	71.3	2.6	84.1	85.6	1.2	83.8	85.7	0.6	98.6	94.6	0.5	72.3	63.9	1.6
Gly	73.1	73.0	2.4	46.6	52.9	3.7	66.2	60.3	2.2	74.2	76.4	0.8	78.9	82.0	0.9	55.3	66.0	2.0
Pro	79.2	83.2	1.4	60.2	56.1	3.5	69.5	72.8	1.6	74.2	79.3	0.6	97.6	95.7	0.2	65.3	67.2	1.7
Ser	80.9	82.8	1.3	62.1	58.2	3.3	74.4	70.1	1.5	78.6	79.5	0.8	92.6	88.3	1.0	65.3	61.3	1.7
Tyr	84.0	84.9	1.3	63.1	67.3	2.2	74.6	75.3	1.4	81.5	86.7	0.6	97.9	97.3	0.1	64.8	64.1	1.6
R^2	0.69		–	0.72		–	0.74		–	0.60		–	0.88		–	0.27		–
SEP	2.7		–	4.1		–	3.3		–	5.0		–	2.5		–	7.0 –		

source. The analyzed Lys content of the feedstuff was 1.7 g/100 g CP (Table 2) which is relatively low in comparison with other feedstuffs. Although, this Lys content was in agreement with the Lys content of wheat gluten reported in the literature (CVB, 1994). The experimentally determined Lys digestibility value was 84.2 where as the predicted model value was 74.3 % units. So the low predictive value of Lys digestibility in the wheat gluten diet was presumably related to the low Lys content.

Low digestibility of a particular amino acid in a particular feedstuff

Apparent CP ileal digestibility coefficient of a regular batch of meat and bone meal is about 70% units (CVB, 1994; van Leeuwen et al., 1993a). CP digestibility of the meat and bone meal diet used in the present experiment was 61.0% units (Table 5). Comparing the amino acid composition of regular batches of meat and bone meal with the batch used in the present experiment shows a striking difference in Cys content. The Cys of pure meat and bone meal and the batch from in the experiment were 0.9 and 1.4 g Cys per 100 g CP, respectively. The high Cys content in the meat and bone meal may indicate its contamination with keratinous protein of feather meal in the level of about 4.5 g Cys/100 g CP (CVB, 1994). Microscopical observation confirmed the assumption that the meat and bone meal was contaminated with hydrolized feather meal (about 7%). Additionally, some hulls from soya, maize, and sunflower were also identified (5%). CP digestibility of the feather meal and the seed hulls would be relatively low (CVB, 1994) and explains the low CP digestibility of the experimental batch of meat and bone meal. Moreover, Moran et al. (1966) suggests that low digestibility of Cys in keratinous protein is related to the cystine disulphide bonds. So, it seems clear why the low digestibility of the cystine was not predicted by the model (DC experimental Cys, 43.9% units, DC model Cys, 54.4% units). Met, Phe, Asp, Glu were also much less digestible as compared to the values predicted while the opposite was found for Trp and Gly. The discrepancies in digestibility of the Phe, Trp, Asp and Gly were also observed for other protein rich feedstuffs.

The apparent Met and Cys digestibility coefficients of the diets using peas, faba beans and lupins used as the only protein source, measured experimentally were generally much lower when compared to the model values. Gdala et al. (1992) studied the relationship between CP digestibility and amino acid digestibility in peas. They concluded that the degree of accuracy to predict Met and Cys was much lower in comparison to the relationship found for Lys and Thr. Sarwar et al. (1985) suggested that lower Met digestibility of legume seeds is related to steric hindrance in peptides. This lowers the Met availability from these feedstuffs.

Variation in the amount of endogenous excretion and amino acid composition of the endogenous nitrogen compounds

The factors of the general model explain the main part of variation in the apparent amino acid digestibilities within feedstuffs. A prerequisite is that the amino acid composition and amount of endogenous protein is rather constant. Huisman (1990) determined high endogenous CP losses in piglets fed a *Phaseolus vulgaris* diet and Kik et al. (1989 a,b) observed damages of the intestinal epithelium of piglets fed similar diets with *Phaseolus* beans. These observations indicate an increased tissue turnover and increased amino acid losses of these specific mucosal proteins. The increased turnover of the intestinal tissues due to antinutritional factors in beans of *Phaseolus vulgaris* may have changes the amount and composition of the endogenous protein and therefore only a minor part of the variation ($R^2=0.45$) could be explained by the model.

In conclusion, for most of the feedstuffs, the factors of the model explain the main part of the variation in apparent amino acid digestibilities within the same feedstuff ($R^2 \geqslant 0.60$). This implies that the model can be used for practical application to predict apparent ileal digestibility of amino acids in feedstuffs.

A large unexplained part of the variation in apparent amino acid digestibilities ($R^2<0.50$) means that factors which are not included in the model would have a major effect on apparent amino acid digestibilities. It should be taken into consideration that a very low content of a particular amino acid in the protein of a feedstuff and effects of antinutritional factors will decrease the accuracy of the predictions.

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STRESZCZENIE

Ocena przydatności modelu matematycznego do szacowania zmienności pozornej strawności aminokwasów dawek pokarmowych, oznaczonej do końca jelita cienkiego

Zmienność współczynników strawności aminokwasów przy skarmianiu tej samej diety zależy w znacznym stopniu od składu aminokwasowego białka paszy i białka endogennego. Model matematyczny określający współczynniki strawności aminokwasów do końca jelita cienkiego w oparciu o takie czynniki, jak współczynniki strawności pozornej do końca jelita cienkiego białka paszy i skład aminokwasowy białka paszy, jest już opisany w literaturze.

W prezentowanej pracy oszacowano pozorną strawność aminokwasów do końca jelita cienkiego świń, którym podawano 18 różnych diet zawierających bardzo zróżnicowane źródła białka i zweryfikowano przydatność modelu matematycznego opisanego w literaturze.

Stwierdzono, że przy zastosowaniu zaproponowanego modelu matematycznego obejmuje on 60-94% zmienności pozornej strawności aminokwasów do końca jelita cienkiego szesnastu diet. Jednakże przy skarmianiu diet z nasionami fasoli oraz mączki mięsno-kostnej, jako źródłami białka, wartości te są niższe i wynoszą 45 i 27%, odpowiednio. Standardowy błąd przewidywania (SEP) był 2-3 razy większy w porównaniu z błędem standardowym średniej (SEM) oznaczeń w obrębie zwierząt.

Dla większości pasz parametry modelu wyjaśniają większą część zmienności w pozornej strawności aminokwasów ($R^2 \geqslant 0,60$). Jeżeli przewidywana część zmienności w pozornej strawności aminokwasów jest mała, $R^2 < 0,50$, inne czynniki – nie zawarte w modelu – wpływają głównie na pozorną strawność aminokwasów.