THE PREDICTION OF AMINO ACID DIGESTIBILITIES IN COMPLETE BARLEY-CANOLA MEAL DIETS FOR SWINE

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ABSTRACT

The present studies were carried out to determine if amino acid (AA) digestibilities determined from canola meal (CM) and barley, when only these ingredients supplied the dietary AA, could be used to predict the digestibilities of AA in a diet consisting of a mixture of barley and CM. Experiment 1. Eight crossbred barrows, 38-43 kg, were surgically fitted with ileocecal re-entrant cannulas. Following a 21 day recuperation period, they were fed a diet (15.3% crude protein; CP) consisting of 16.9% CM, 79.5% barley and 4% of a vitamin-mineral mixture. Experiment 2. Four crossbred barrows, 35-40 kg, were surgically fitted with ileocecal re-entrant cannulas. Following a 21 day recuperation period they were fed a diet (10.8% CP) consisting of 96% barley (from the same batch as in experiment 1) and 4% of a vitamin-mineral mixture. Experiment 3. Four crossbred barrows, 38-42 kg, were fitted with ileocecal re-entrant cannulas. Following a 14 day recuperation period, they were fed a semi-purified diet (14.9% CP) consisting of 38.7% CM (from the same batch as in experiment 1), 42.6% cornstarch, 10% dextrose, 2.5% alphafloc, 3% fat and 3.2% of a vitamin-mineral mixture. Chromic oxide was used as the digestibility marker. The pigs received 1500-1600 g of each diet per day. Ileal digesta and feces were collected following an adaptation period to the diet of at least 6 days. The AA digestibilities determined directly from the barley-CM diet compared reasonably well with those calculated from results obtained when only barley or CM supplied the dietary AA. Differences between predicted and actual AA digestibilities for the indispensable AA, based on the ileal analysis method, ranged from 10.9 units (threonine) to 0.4 units (lysine), with a mean difference of 4.0 percentage units (P>0.05). Differences between predicted and actual AA digestibilities, based on the fecal analysis method, ranged from 0.1 units (histidine) to 2.4 units (threonine) with a mean difference of 1.5 percentage units (P>0.05). The present results indicate that AA digestibilities determined on individual feed ingredients, as far as CM and barley are concerned, can be used to predict the digestibility of AA in a diet consisting of a mixture of these ingredients.

INTRODUCTION

Additivity of the digestible protein and amino acid supply, determined in single ingredients, is a crucial consideration in the formulation of diets for pigs. However, there may be associative effects i.e. whereby the digestible supply of amino acids in a mixture of feedstuffs is not equal to the sum of the supply based on the digestibilities determined in the single ingredients and the proportion of these in the complete diets. Associative effects have been demonstrated in ruminants and in non-ruminant herbivores. There is no information on associative effects between feed ingredients in swine. Studies were carried out to determine if there were interactions, with respect to the digestible amino acid supply, between barley and canola meal. These feedstuffs were selected as they make up a large proportion of the ingredients used in diets for swine in Canada. The amino acid digestibilities were determined according to the ileal analysis method in which the digestibilities are calculated based on the intake and amount of each amino acid passing through the distal ileum. The ileal analysis method should be considered as further improvement of the fecal analysis method. The fecal analysis method, which measures the amount of each amino acid consumed and excreted in feces, does not account for the modifying effect of the microflora, in the large intestine (Zebrowska, 1973).

MATERIALS AND METHODS

Experiment 1.

Eight barrows (Lacombe x Yorkshire), ranging in weight from 38 to 43 kg, were surgically fitted with ileocecal re-entrant cannulas according to the technique developed by Easter and Tanksley (1973). The cannulas (12 mm id) were made from polyvinylchloride plastisol as described by Sauer (1976). After surgery, the pigs were allowed a 21 day recuperation period during which time they were fed a 16% crude protein grower diet that consisted of 31.5% wheat, 50% barley, 15% soybean meal and 3.5% of a vitamin-mineral mixture.

The barrows were housed in stainless steel metabolism cages that allowed separate quantitative collection of urine and feces. They were fed a barley-based diet (table 1) formulated to contain 15% crude protein by supplementation with canola meal (meal derived from a low-glucosinolate variety of rapeseed). Prior to mixing, the ingredients were ground through a 1-mm mesh screen. Vitamins and minerals were included according to NRC (1979). Chromic oxide (0.5%) was added as a marker for the determination of the digestibilities of the nutrients that were measured. The test period lasted 12 days. Each pig was given 800 g diet twice daily, at 0800 h and 1600 h. Water was supplied ad libitum. Feces were collected from 0800 h on day 10 to 0800 h on day 12 of each test period. Ileal digesta were collected from 0800 h to 2000 h on day 12. The procedures involved in the collection of digesta and feces were previously described by Sauer (1976).

Experiment 2.

Four barrows (Lacombe x Yorkshire), ranging in weight from 35 to 40 kg, were fitted with ileocecal re-entrant cannulas to determine the ileal and fecal AA digestibilities in a diet where barley supplied the sole source of dietary protein (table 1). The barrows were fed 800 g of diet at 0800 h and 2000 h. The barley that was used in this experiment was obtained from the same batch of barley as in experiment 1. Ileal digesta were collected from 0800 h to 2000 h on day 11 following the start of the experiment. Feces were collected from 0800 h on day 9 to 0800 h on day 11.

Experiment 3.

Four barrows (Yorkshire x Lacombe), ranging in weight from 38 to 42 kg were fitted with ileocecal re-entrant cannulas to determine the ileal and fecal AA digestibilities in a diet in which canola meal supplied the sole source of dietary protein (table 1). The barrows were fed a cornstarch-based diet containing canola meal which was obtained from the same batch of canola meal as in experiment 1. The diet contained 2.5% Alphafloc to minimize problems associated with the passing of hard feces (i.e. rectal prolapse) which had been observed previously in pigs fed purified-type diets (Sauer, 1976). Dextrose was included in this diet at a level of 10% to possibly improve the palatability. The test period lasted 7 days. The barrows were fed a slurry of 500 g diet and 1.5 litres water three times daily at 0600, 1400 and 2200 h. Feces were collected from 0600 h on day 6 to 0600 h on day 7. Ileal digesta were collected from 0600 to 1400 h on day 7.

Surgical techniques, pre- and post-surgery care, cannula design, housing of pigs, feeding and collection procedures were similar in experiments 2 and 3 to those decribed or referred to under experiment 1..

Analytical and Statistical Procedures.

At the conclusion of these experiments feed, feces and digesta were freeze-dried and ground in a Wiley mill through a 0.8-mm mesh screen. Analyses for nitrogen and dry matter were carried out according to AOAC (1975) methods. Chromic oxide was determined according to Fenton and Fenton (1979). Amino acid analyses were carried out using a Beckman 121 amino acid analyzer following hydrolysis for 24 h with 6 N HCl. Analysis of variance was carried out according to procedures described by Steel and Torrie (1960).

RESULTS AND DISCUSSION

The protein content and AA composition of the experimental diets are shown in table 2. The ileal digestibilities for the nine indispensable AA averaged 71.4% for the barley-canola meal diet (table 3). Arginine had the highest ileal digestibility of the indispensable AA (77.8%). The ileal digestibility of threonine was the lowest of the indispensable AA (57.9%). The fecal digestibilities of the nine indispensable AA measured were higher than the ileal digestibilities and averaged 80.1% for the barley-canola meal diet. The fecal digestibility of arginine was the highest of the indispensable AA (87.3%). The fecal digestibility of threonine was the lowest of the indispensable AA in the barley-canola meal diet (73.8%).

Differences between fecal and ileal AA digestibilities were larger than ten percentage units for arginine, histidine, threonine and valine of the indispensable AA and for aspartic acid, glycine, serine and proline of the dispensable AA. Differences between ileal and fecal AA digestibilities were of a small magnitude for lysine and methionine (table 3). The present results agree very well with those obtained by Zebrowska (1973), Sauer et al. (1977), and Taverner and Farrell (1981), who reported relatively large differences between ileal and fecal AA digestibilities for threonine and relatively small differences for lysine and methionine.

When barley was fed as the sole protein source, the ileal digestibility of the nine indispensable AA averaged 73.8% (table 4). Of the indispensable AA, the ileal digestibility was lowest for lysine (66.2%), followed by valine (69.0%). The apparent ileal AA digestibilities were highest for arginine (79.4%) and phenylalanine (78.9%). The fecal digestibility of the nine indispensable AA averaged 80.6%. Of the indispensable AA, the fecal digestibility was highest for phenylalanine (86.0%) and lowest for lysine (73.3%). The differences between the apparent ileal and fecal AA digestibilities in barley ranged from 6.0 percentage units (leucine) to 9.1 percentage units (valine) for the indispensable AA and from 5.3 percentage units (glutamic acid) to 11.2 percentage units (glycine) for the dispensable AA (table 4). The ileal and fecal digestibilities of AA in barley obtained in the present studies compare reasonably well with those obtained in previous studies (Sauer et al., 1981).

When canola meal was fed as the sole source of dietary protein, the ileal digestibility of the nine indispensable AA averaged 76.2% (table 5). Of the indispensable AA the ileal digestibility of valine was the lowest (66.7%), followed by threonine (67.8%). Apparent ileal AA digestibilities were highest for methionine (82.3%) followed by arginine (81.5%). The fecal digestibilities of the nine indispensable AA averaged 81.6%. Of the indispensable AA, the fecal digestibility of threonine was the lowest (78.0%) followed by valine and isoleucine (78.2%). Arginine had the highest fecal digestibility (89.0%) followed by histidine (85.2%).

Differences between apparent ileal and fecal digestibilities for canola meal ranged from -1.3 percentage units for methionine to 11.5 percentage units for valine for the indispensable AA and from 2.7 percentage units for alanine to 21.0 percentage units for proline for the dispensable AA (table 5).

AA digestibilities for the barley-canola meal diet compare very well with those calculated from data obtained when only barley or canola meal supplied the dietary AA. Differences between the predicted and directly determined AA digestibilities for the indispensable AA, based on the ileal analysis method, ranged from 10.9 percentage units (threonine) to 0.4 percentage units (lysine), with a mean difference of 4.0 percentage units (table 6). Taking into consideration all the possible sources of error in the determination of AA digestibilities, which were pointed out by Just (1980), these differences are of a small magnitude. Differences between predicted and directly determined digestibilities for the indispensable AA, based on the fecal analysis method, ranged from 0.1 percentage units (histidine) to 2.4 percentage units (threonine) with a mean difference of 1.5 percentage units (table 7).

The present results indicate that AA digestibilities determined in individual feedstuffs can be used to predict the digestibility of AA in a diet consisting of a mixture of the protein sources. Similar findings were reported by Eggum and Jacobsen (1976) and Meier et al. (1975). However, a wider array of different feed ingredients must be examined to ensure that there are no associative effects between other feedstuffs.

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TABLE 1. FORMULATION OF EXPERIMENTAL DIETS.

	Experiment 1	Experiment 2	Experiment 3
Diets	Barley-Canola meal	Barley	Canola meal
Canola meal	16.9	-	38.7
Barley	79.5	96.0	-
Cornstarch	-	-	42.6
Dextrose	-	-	10.0
Alphafloc[1]	-	-	2.5
Soybean oil	-	-	3.0
Calcium carbonate	1.0	1.25	0.5
Calcium phosphate	0.6	0.75	0.7
Trace mineralized salt[2]	0.5	0.5	0.5
Vitamin-mineral premix[3]	1.0	1.0	1.0
Chromic oxide	0.5	0.5	0.5

[1]Brown Company, Berlin, NH, 03570.

[2]Supplied by Windsor Salt Co., Toronto, Canada. Composition (percentage): NaCl, 96.5; ZnO, 0.40; $FeCO_3$, 0.16; MnO, 0.12; CuO, 0.033; Ca $(IO_3)_2$, 0.007; CoO, 0.004.

[3]Contributed the following nutrients/kg of diet: Zn, 100 mg; Cu, 10 mg; Mn, 20 mg; Fe, 150 mg; Se, 0.1 mg; vitamin A, 1,300 IU; vitamin D_3 150 IU; vitamin E, 11 IU; menadione, 2 mg; biotin, 0.1 mg; folic acid, 0.6 mg; niacin, 12 mg; pantothenic acid, 11 mg; pyridoxine, 1.1 mg; riboflavin, 2.2 mg; thiamine, 1.1 mg; vitamin B_{12}, µg; and choline chloride, 55 mg.

TABLE 2. PROTEIN CONTENT AND AMINO ACID COMPOSITION OF THE EXPERIMENTAL DIETS[1].

Diets	Experiment 1 Barley-Canola meal	Experiment 2 Barley	Experiment 3 Canola meal
Crude protein (%)	15.3	10.8	14.9
Dry matter (%)	91.8	88.50	91.6
Indispensable Amino Acids (%)			
Arginine	0.78	0.53	0.90
Histidine	0.33	0.24	0.42
Isoleucine	0.56	0.39	0.60
Leucine	1.05	0.75	1.07
Lysine	0.68	0.40	0.87
Methionine	0.24	0.15	0.35
Phenylalanine	0.71	0.54	0.60
Threonine	0.57	0.38	0.68
Valine	0.80	0.54	0.78
Dispensable Amino Acids (%)			
Alanine	0.63	0.45	0.67
Aspartic acid	1.01	0.64	1.06
Cysteine	0.17	0.11	0.15
Glutamic acid	3.16	2.44	2.61
Glycine	0.66	0.44	0.72
Proline	1.27	1.27	0.93
Serine	0.64	0.46	0.63
Tyrosine	0.38	0.24	0.30

[1]As is.

TABLE 3. APPARENT ILEAL AND FECAL DIGESTIBILITIES[1] OF AMINO ACIDS IN THE BARLEY-CANOLA MEAL DIET.

Location	Ileum	Feces	SEM[2]
Dry matter (%)	58.6a	74.8b	0.8
Crude protein (%)	67.8a	79.9b	1.4
Indispensable Amino Acids (%)			
Arginine	77.8a	87.8b	1.7
Histidine	72.8a	84.1b	1.2
Isoleucine	71.4a	79.1b	1.3
Leucine	72.9a	81.5b	1.2
Lysine	70.0a	76.1b	2.0
Methionine	76.8	76.2	1.9
Phenylalanine	74.2a	83.1b	1.2
Threonine	57.9a	73.8b	2.3
Valine	69.1a	79.9b	1.7
Dispensable Amino Acids (%)			
Alanine	62.6a	72.0b	2.1
Aspartic acid	62.3a	75.3b	3.2
Cysteine	87.7a	96.9b	1.4
Glutamic acid	83.8a	90.9b	1.4
Glycine	56.5a	77.2b	2.3
Proline	75.8a	88.8b	1.1
Serine	64.4a	79.4b	1.4
Tyrosine	70.9a	79.7b	1.6

[1]Means in the same row with different letters are significantly different ($P<0.05$).

[2]Standard error of the mean.

TABLE 4. APPARENT ILEAL AND FECAL DIGESTIBILITIES[1] OF AMINO ACIDS IN BARLEY.

Location	Ileum	Feces	SEM[2]
Dry matter (%)	69.7a	82.6b	1.1
Crude protein (%)	76.4a	83.2b	1.4
Indispensable Amino Acids (%)			
Arginine	78.3a	85.9b	1.2
Histidine	77.9a	85.4b	1.2
Isoleucine	73.5	80.5	2.3
Leucine	77.9a	83.9b	1.5
Lysine	65.6	73.3	3.2
Methionine	69.1	76.0	3.9
Phenylalanine	78.6a	86.0b	1.9
Threonine	68.7	76.8	2.2
Valine	68.9a	78.0b	1.8
Dispensable Amino Acids (%)			
Alanine	66.4	76.0	2.8
Aspartic acid	66.8	75.6	2.8
Cysteine	92.2	99.6	3.7
Glutamic acid	84.9a	90.2b	1.2
Glycine	66.8a	78.0b	1.8
Proline	83.9a	90.5b	1.6
Serine	75.1a	83.1b	1.3
Tyrosine	74.9	81.4	2.2

[1]Means followed by different letters are significantly different ($P<0.05$).

[2]Standard error of the mean.

TABLE 5. APPARENT ILEAL AND FECAL DIGESTIBILITIES[1] OF AMINO ACIDS IN CANOLA MEAL.

Location	Ileum	Feces	SEM[2]
Dry matter (%)	69.5a	82.2b	0.91
Crude protein (%)	70.0a	79.5b	0.98
Indispensable Amino Acids (%)			
Arginine	81.5	89.0	2.77
Histidine	79.8	85.2	1.77
Isoleucine	76.2	78.2	1.52
Leucine	79.2	82.0	1.36
Lysine	75.0a	82.0b	1.58
Methionine	82.3	81.0	1.36
Phenylalanine	77.5	81.0	2.24
Threonine	67.8a	78.0b	1.61
Valine	66.7a	78.2b	1.95
Dispensable Amino Acids (%)			
Alanine	76.3	79.0	1.51
Aspartic acid	71.4a	78.1b	1.60
Cysteine	88.0	95.2	3.60
Glutamic acid	84.0a	89.0b	0.79
Glycine	66.0a	82.5b	1.57
Proline	62.5a	83.5b	3.67
Serine	69.0a	80.2b	1.48
Tyrosine	71.0	74.0	1.73

[1]Means followed by different letters are significantly different ($P<0.05$).

[2]Standard error of the mean.

TABLE 6. PREDICTED AND DIRECTLY DETERMINED ILEAL DIGESTIBILITIES OF AMINO ACIDS IN THE BARLEY-CANOLA MEAL DIET.

	Barley		Canola meal		Barley-Canola meal		Digestibility	
	Total	Digestible	Total	Digestible	Total	Digestible	Predicted	Directly
Indispensable								
Arginine	0.44	0.35	0.39	0.32	0.83	0.67	80.7	77.8
Histidine	0.20	0.16	0.18	0.14	0.38	0.30	78.9	72.8
Isoleucine	0.33	0.24	0.26	0.20	0.59	0.44	74.5	71.4
Leucine	0.62	0.48	0.47	0.37	1.09	0.85	77.9	72.9
Lysine	0.33	0.22	0.38	0.28	0.68	0.50	70.4	70.0
Methionine	0.13	0.09	0.15	0.12	0.28	0.21	75.0	76.8
Phenylalanine	0.44	0.35	0.26	0.20	0.70	0.55	78.5	74.2
Threonine	0.32	0.22	0.29	0.20	0.61	0.42	68.8	57.9
Valine	0.44	0.30	0.34	0.23	0.78	0.53	67.9	69.1
Dispensable								
Alanine	0.37	0.25	0.29	0.22	0.66	0.47	71.2	62.6
Aspartic acid	0.53	0.36	0.46	0.33	0.99	0.69	69.7	62.3
Cysteine	0.09	0.08	0.06	0.05	0.15	0.13	86.7	87.7
Glutamic acid	2.02	1.71	1.14	0.95	3.16	2.66	84.2	83.8
Glycine	0.37	0.25	0.32	0.21	0.69	0.46	66.6	56.5
Proline	1.05	0.89	0.40	0.25	1.45	1.14	78.6	75.8
Serine	0.38	0.29	0.28	0.19	0.66	0.48	72.7	64.4
Tyrosine	0.20	0.15	0.13	0.09	0.33	0.24	72.7	70.9

TABLE 7. PREDICTED AND DIRECTLY DETERMINED FECAL DIGESTIBILITIES OF AMINO ACIDS IN THE BARLEY-CANOLA MEAL DIET.

	Barley		Canola meal		Barley-Canola meal		Digestibility	
	Total	Digestible	Total	Digestible	Total	Digestible	Predicted	Directly
Indispensable								
Arginine	0.44	0.38	0.39	0.35	0.83	0.73	87.9	87.3
Histidine	0.20	0.17	0.18	0.15	0.38	0.32	84.2	84.1
Isoleucine	0.33	0.27	0.26	0.20	0.59	0.47	79.7	79.1
Leucine	0.62	0.52	0.47	0.38	1.09	0.90	82.5	81.5
Lysine	0.33	0.24	0.38	0.31	0.68	0.55	77.5	76.1
Methionine	0.13	0.10	0.15	0.12	0.28	0.22	78.6	76.2
Phenylalanine	0.44	0.38	0.26	0.21	0.70	0.59	84.3	83.1
Threonine	0.32	0.25	0.29	0.23	0.61	0.48	78.7	73.8
Valine	0.44	0.34	0.34	0.27	0.78	0.61	78.2	79.9
Dispensable								
Alanine	0.37	0.28	0.29	0.23	0.66	0.51	77.2	72.0
Aspartic acid	0.53	0.40	0.46	0.36	0.99	0.76	76.8	75.3
Cysteine	0.09	0.06	0.08	0.05	0.15	0.15	100.0	96.9
Glutamic acid	2.02	1.82	1.14	1.01	3.16	2.96	93.6	90.9
Glycine	0.37	0.29	0.32	0.26	0.69	0.55	79.7	77.2
Proline	1.05	0.95	0.40	0.33	1.45	1.28	88.3	88.8
Serine	0.38	0.32	0.28	0.22	0.66	0.54	81.8	79.4
Tyrosine	0.20	0.16	0.13	0.10	0.33	0.26	78.8	79.7