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Digestibility by growing pigs of amino acids in canola meal from North America and 00-rapeseed meal and 00-rapeseed expellers from Europe[1]

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ABSTRACT: The digestibility of CP and AA by growing pigs in coproducts from canola and 00-rapeseed may be influenced by the variety of seeds that was grown and the processing method used to extract the oil from the seeds. Therefore, the objective of this experiment was to determine the apparent ileal digestibility (AID) and the standardized ileal digestibility (SID) of CP and AA in canola meal, 00-rapeseed meal, and 00-rapeseed expellers fed to growing pigs. Canola meal and 00-rapeseed meal are the coproducts produced after the residual oil has been solvent extracted from canola seeds and 00-rapeseeds, respectively, whereas 00-rapeseed expellers is the coproduct from 00-rapeseeds that have been only expeller pressed. Twenty-three barrows (initial BW: 28.8 ± 2.64 kg) that had a T-cannula installed in the distal ileum were allotted to a 9 × 23 Youden square design with 9 periods and 23 dietary treatments. The 23 diets included 7 diets based on the 7 samples of canola meal, 10 diets based on the 10 samples of 00-rapeseed meal, 5 diets based on the 5 samples of 00-rapeseed expellers, and a N-free diet. Each source of canola or rapeseed coproducts was used as the only source of CP and AA in 1 diet. The SID of CP and all AA except Val, Cys, and Glu were not different between canola meal and 00-rapeseed meal, but 00-rapeseed expellers had greater ($P < 0.01$) SID of CP and all AA except Thr, Trp, and Gly than 00-rapeseed meal, which possibly is due to heat damage in 00-rapeseed meal. For Lys, Met, Thr, and Trp, SID values of 70.6%, 84.5%, 73.0%, and 82.6%, and 71.9%, 84.6%, 72.6%, and 82.6% were obtained in canola meal and rapeseed meal, respectively, whereas values in 00-rapeseed expellers were 74.7%, 87.1%, 74.0%, and 83.4%. The SID for most AA was different ($P < 0.05$) among the 7 sources of canola meal, among the 10 sources of 00-rapeseed meal, and among the 5 sources of 00-rapeseed expellers. The concentration of standardized ileal digestible indispensable AA in canola and 00-rapeseed coproducts can be predicted from the concentration of the corresponding AA with only a low to moderate correlation ($r^2 = 0.206$ to 0.655). In conclusion, AA digestibility is not different between canola meal and 00-rapeseed meal, but 00-rapeseed expellers have greater digestibility of most AA than 00-rapeseed meal. Prediction equations may not always adequately estimate the concentration of indispensable AA and standardized ileal digestible indispensable AA in canola and 00-rapeseed coproducts.

Key words: amino acids, canola meal, digestibility, pig, 00-rapeseed expellers, 00-rapeseed meal

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INTRODUCTION

Varieties of *Brassica napus* with low levels of erucic acid (<2%) in the oil and low concentrations of glucosinolates (<30 μmol/g) in the defatted coproducts have been selected (Thomas, 2005; Newkirk, 2009). Varieties that meet these characteristics are called "canola" in North America and Australia, but they are called "zero-zero," "double-zero," or "double-low" rapeseeds in Europe (Shahidi, 1990; Spragg and Mailer, 2007; Newkirk, 2009). Canola meal, 00-rapeseed meal, and 00-rapeseed expellers are the coproducts generated if oil has been extracted or expelled from canola or 00-rapeseeds, respectively. The meals and expellers may be used as a protein source in animal diets because they have high concentrations of CP and AA and relatively low concentrations of fiber and glucosinolates (Bell, 1993; Spragg and Mailer, 2007; Newkirk, 2011). Because of greater concentrations of residual oil, the

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concentration of DE and ME is usually greater in expellers than in meals (Sauvant et al., 2004; NRC, 2012).

The digestibility of CP and AA in canola meal may vary depending on the age of pigs (Stein et al., 1999a, 2001), the variety of canola or 00-rapeseed, and the processing method used to remove the oil (Fan et al., 1996; Woyengo et al., 2010; Trindade Neto et al., 2012). In many feed databases, canola and 00-rapeseed coproducts are considered the same ingredients (Sauvant et al., 2004; NRC, 2012), but we are not aware of data demonstrating that there are no differences between canola and 00-rapeseed coproducts. Therefore, the objectives of this experiment were 1) to determine the variation in the digestibility of CP and AA among sources of canola and 00-rapeseed coproducts, 2) to compare the digestibility of CP and AA between canola meal and 00-rapeseed meal and between 00-rapeseed meal and 00-rapeseed expellers, and 3) to develop prediction equations to estimate concentrations of indispensable AA or digestible indispensable AA in canola and 00-rapeseed coproducts.

MATERIALS AND METHODS

Animals, Experimental Design, and Housing

The experiment was approved by the Institutional Animal Care and Use Committee at the University of Illinois (Urbana, IL). Twenty-three growing barrows (initial BW: 28.8 ± 2.64 kg; G-Performer boars × F-25 females, Genetiporc, Alexandria, MN) were allotted to a 9 × 23 Youden square design with 9 periods and 23 diets. There were 9 replications for each treatment. Pigs had a T-cannula surgically inserted in the distal ileum using the method described by Stein et al. (1998) and were housed individually in 1.2 × 1.5 m pens in an environmentally controlled room. A feeder and a nipple drinker were installed in each pen, and pens had smooth side walls and fully slated tri-bar floors.

Ingredients, Diets, and Feeding

Seven samples of canola meal were obtained from solvent-extraction crushing plants in North America, with 4 samples being sourced from Canada and 3 samples from the United States. Ten samples of 00-rapeseed meal were obtained from solvent-extraction crushing plants in central and western Europe, and 5 samples of 00-rapeseed expellers were obtained from mechanical-press crushing plants in western Europe (Table 1).

Twenty-three diets were prepared (Tables 2 and 3); 7 diets contained each of the 7 samples of canola meal, 10 diets contained each of the 10 samples of 00-rapeseed meal, 5 diets contained each of the 5 samples of 00-rapeseed expellers, and 1 diet was a N-free diet that was used to estimate the basal ileal endogenous losses of AA. Canola and 00-rapeseed coproducts were the only AA-containing ingredients in the diets. All diets contained 0.5% chromic oxide as an indigestible marker. Vitamins and minerals were included in all diets to meet or exceed requirements for growing pigs (NRC, 1998).

Experimental diets were fed to the pigs at a daily level of 3 times the estimated maintenance requirement for energy (i.e., 106 kcal ME per kg $BW^{0.75}$; NRC, 1998). The daily feed allotments were divided into 2 equal meals and fed at 0700 and 1700 h. Water was available at all times throughout the experiment.

Data and Sample Collection

Individual pig weights were obtained at the beginning of the experiment and at the end of each period, and the amount of feed supplied to each pig each day was measured. The initial 5 d of each period was considered an adaptation period to the diet, which was assumed to be sufficient because the diets were similar in composition. Ileal digesta were collected for 8 h on d 6 and 7. A plastic bag was attached to the cannula barrel using a cable tie, and digesta flowing into the bag were collected. Bags were removed whenever they were filled with digesta or at least every 30 min. No acid was added in the plastic bags before collection because the samples were immediately frozen at -20°C to prevent bacterial degradation of the AA in the digesta. On the completion of 1 experimental period, animals were deprived of feed overnight to avoid possible mixing between diets, and the following morning, a new experimental diet was offered.

Chemical Analysis

At the conclusion of the experiment, ileal samples were thawed and pooled within animal and diet, and a subsample was collected for chemical analysis. A sample of each diet and of each source of canola meal, 00-rapeseed meal, and 00-rapeseed expellers was collected as well. Digesta samples were lyophilized and finely ground through a 1-mm screen in a Wiley Mill (model 4; Thomas Scientific, Swedesboro, NJ) before chemical analysis. Ingredients, diets, and ileal digesta samples were analyzed for DM (method 930.15; AOAC International, 2007), CP by combustion (method 990.03; AOAC International, 2007), which was determined on an Elementar Rapid N-cube Protein/Nitrogen Apparatus (Elementar Americas Inc., Mt. Laurel, NJ), and AA (method 982.30 E [A, B, and C]; AOAC International, 2007). Diets were also analyzed for acid hydrolyzed ether extract (**AEE**), which was determined by acid hydrolysis using 3*N* HCl (Sanderson, 1986) followed by crude fat extraction with petroleum ether (method 954.02;

Table 1. Concentration (%) of DM, acid hydrolyzed ether extract (AEE), CP, and AA in canola meal, 00-rapeseed meal, and 00-rapeseed expellers, as-fed basis

				Indispensable AA										Dispensable AA							
Item	DM	AEE	CP	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val	Ala	Asp	Cys	Glu	Gly	Pro	Ser	Tyr
Canola meal																					
1	90.47	4.31	39.35	2.35	1.07	1.57	2.71	2.22	0.74	1.53	1.54	0.49	2.04	1.66	2.71	0.89	6.12	1.92	2.24	1.29	1.06
2	89.17	3.80	36.74	2.03	0.93	1.40	2.40	1.95	0.67	1.37	1.38	0.41	1.83	1.49	2.37	0.76	5.27	1.71	1.96	1.13	0.96
3	90.18	3.01	39.77	2.24	1.02	1.53	2.65	2.06	0.72	1.49	1.52	0.47	1.98	1.62	2.65	0.84	5.88	1.88	2.18	1.28	1.03
4	89.81	4.44	38.08	2.12	0.98	1.47	2.52	2.03	0.69	1.41	1.49	0.45	1.92	1.57	2.54	0.82	5.49	1.79	2.08	1.23	1.01
5	90.40	3.79	36.70	1.96	0.93	1.38	2.40	1.82	0.63	1.34	1.38	0.42	1.81	1.48	2.37	0.77	5.27	1.70	1.96	1.16	0.92
6	89.44	3.58	37.56	2.14	1.00	1.51	2.60	1.98	0.73	1.45	1.53	0.41	1.95	1.63	2.58	0.84	5.73	1.86	2.10	1.36	1.00
7	89.90	3.71	36.59	2.11	0.97	1.43	2.51	1.88	0.68	1.40	1.49	0.45	1.86	1.57	2.50	0.80	5.70	1.80	2.06	1.37	0.98
Average	89.91	3.81	37.83	2.14	0.99	1.47	2.54	1.99	0.69	1.43	1.48	0.44	1.91	1.57	2.53	0.82	5.64	1.81	2.08	1.26	0.99
CV, %	0.54	12.46	3.45	6.04	5.07	4.79	4.69	3.68	5.57	4.70	4.61	6.99	4.39	4.40	5.14	5.49	5.59	4.63	5.01	7.33	4.66
00-rapeseed meal																					
1	89.09	3.58	36.35	1.98	0.91	1.38	2.39	1.91	0.67	1.34	1.46	0.40	1.83	1.51	2.48	0.74	5.16	1.74	1.96	1.21	0.97
2	90.31	4.19	38.02	2.17	0.99	1.51	2.59	2.05	0.71	1.48	1.53	0.45	1.97	1.59	2.70	0.81	5.71	1.86	2.11	1.28	1.01
3	88.08	3.47	37.52	2.22	1.01	1.52	2.60	2.14	0.72	1.50	1.52	0.48	1.98	1.59	2.71	0.82	5.67	1.86	2.11	1.26	1.03
4	89.09	5.25	35.64	2.03	0.95	1.45	2.43	1.97	0.67	1.37	1.44	0.42	1.88	1.52	2.49	0.80	5.33	1.77	2.00	1.16	0.94
5	90.01	5.91	32.85	1.72	0.81	1.22	2.04	1.65	0.57	1.15	1.25	0.34	1.60	1.33	2.11	0.68	4.51	1.54	1.62	1.06	0.84
6	88.01	3.61	36.52	2.07	0.94	1.42	2.49	1.98	0.70	1.41	1.52	0.44	1.86	1.55	2.62	0.76	5.42	1.79	2.04	1.29	1.00
7	88.56	3.72	37.11	2.08	0.96	1.41	2.45	2.06	0.69	1.39	1.46	0.42	1.86	1.51	2.47	0.81	5.34	1.76	2.01	1.19	0.99
8	89.02	3.68	37.30	1.93	0.9	1.41	2.37	1.85	0.63	1.35	1.41	0.45	1.84	1.47	2.51	0.69	5.09	1.71	1.9	1.13	0.93
9	88.64	2.71	35.63	2.00	0.91	1.35	2.40	1.91	0.71	1.35	1.52	0.38	1.77	1.51	2.44	0.80	5.59	1.75	1.98	1.31	1.01
10	88.89	3.01	37.07	1.97	0.91	1.41	2.39	1.88	0.64	1.35	1.42	0.44	1.84	1.48	2.53	0.73	5.1	1.71	1.93	1.16	0.94
Average	88.97	3.91	36.40	2.02	0.93	1.41	2.42	1.94	0.67	1.37	1.45	0.42	1.84	1.51	2.51	0.76	5.29	1.75	1.97	1.21	0.97
CV, %	0.83	24.99	4.03	6.83	5.99	6.00	6.40	4.63	6.95	6.95	5.81	9.58	5.77	4.90	6.72	6.83	6.71	5.17	7.09	6.63	5.77
00-rapeseed expellers																					
1	89.88	10.79	36.13	2.08	0.94	1.41	2.42	2.07	0.68	1.38	1.42	0.43	1.86	1.49	2.56	0.82	5.51	1.73	2.00	1.27	0.95
2	89.86	12.99	34.51	2.06	0.94	1.39	2.36	2.09	0.67	1.35	1.43	0.39	1.82	1.47	2.52	0.79	5.33	1.71	1.99	1.27	0.94
3	91.23	13.84	36.22	1.89	0.86	1.34	2.24	1.83	0.60	1.29	1.34	0.39	1.74	1.39	2.40	0.70	4.76	1.61	1.83	1.11	0.89
4	95.15	11.70	35.21	1.98	0.90	1.37	2.35	1.88	0.64	1.34	1.42	0.43	1.80	1.47	2.44	0.75	5.06	1.69	1.9	1.18	0.95
5	93.04	8.27	35.82	1.86	0.87	1.34	2.26	1.63	0.63	1.28	1.35	0.43	1.74	1.41	2.31	0.70	4.97	1.64	1.86	1.10	0.89
Average	91.83	11.52	35.58	1.97	0.90	1.37	2.33	1.90	0.64	1.33	1.39	0.41	1.79	1.45	2.45	0.75	5.13	1.68	1.92	1.19	0.92
CV, %	2.47	18.76	2.02	4.99	4.19	2.25	3.21	10.81	5.01	3.16	3.11	5.34	2.91	2.99	4.04	7.14	5.78	2.96	3.98	6.94	3.40

Table 2. Ingredient composition (%) of experimental diets, as-fed basis

Item	Canola meal	00-rapeseed meal	00-rapeseed expellers	Corn-starch	Soybean oil[1]	Sucrose	Solka-Floc[2]	Limestone	Monocalcium phosphate	Chromic oxide	Salt	Vitamin-mineral premix[3]
Canola meal												
1	40.40	—	—	43.59	3.40	10.00	—	0.72	0.69	0.50	0.40	0.30
2	43.30	—	—	40.46	3.70	10.00	—	0.69	0.65	0.50	0.40	0.30
3	40.00	—	—	43.58	3.80	10.00	—	0.73	0.69	0.50	0.40	0.30
4	41.80	—	—	42.13	3.50	10.00	—	0.70	0.67	0.50	0.40	0.30
5	43.40	—	—	40.56	3.50	10.00	—	0.69	0.65	0.50	0.40	0.30
6	42.40	—	—	41.24	3.80	10.00	—	0.70	0.66	0.50	0.40	0.30
7	41.50	—	—	42.22	3.70	10.00	—	0.71	0.67	0.50	0.40	0.30
00-rapeseed meal												
1	—	43.80	—	39.87	3.80	10.00	—	0.69	0.64	0.50	0.40	0.30
2	—	41.80	—	42.23	3.40	10.00	—	0.71	0.66	0.50	0.40	0.30
3	—	42.50	—	41.14	3.80	10.00	—	0.70	0.66	0.50	0.40	0.30
4	—	44.80	—	39.70	3.00	10.00	—	0.68	0.62	0.50	0.40	0.30
5	—	48.50	—	36.59	2.50	10.00	—	0.64	0.57	0.50	0.40	0.30
6	—	45.20	—	38.47	3.80	10.00	—	0.68	0.65	0.50	0.40	0.30
7	—	42.90	—	40.85	3.70	10.00	—	0.69	0.66	0.50	0.40	0.30
8	—	42.70	—	41.05	3.70	10.00	—	0.69	0.66	0.50	0.40	0.30
9	—	44.70	—	38.80	4.00	10.00	—	0.66	0.64	0.50	0.40	0.30
10	—	42.90	—	40.55	4.00	10.00	—	0.69	0.66	0.50	0.40	0.30
00-rapeseed expellers												
1	—	—	44.10	42.88	0.50	10.00	—	0.69	0.63	0.50	0.40	0.30
2	—	—	46.20	41.33	—	10.00	—	0.66	0.61	0.50	0.40	0.30
3	—	—	44.00	43.48	—	10.00	—	0.69	0.63	0.50	0.40	0.30
4	—	—	45.20	42.31	—	10.00	—	0.67	0.62	0.50	0.40	0.30
5	—	—	44.50	41.19	1.80	10.00	—	0.68	0.63	0.50	0.40	0.30
N free	—	—	—	77.42	5.00	10.00	4.00	1.14	1.24	0.50	0.40	0.30

[1]The concentration of soybean oil was adjusted to achieve the same concentration of acid hydrolyzed ether extract in all diets.

[2]Fiber Sales and Development Corp., Urbana, OH.

[3]Provided the following quantities of vitamins and microminerals per kilogram of complete diet: vitamin A as retinyl acetate, 11,136 IU; vitamin D_3 as cholecalciferol, 2,208 IU; vitamin E as DL-alpha-tocopheryl acetate, 66 IU; vitamin K as menadione dimethylprimidinol bisulfite, 1.42 mg; thiamin as thiamine mononitrate, 0.24 mg; riboflavin, 6.59 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B12, 0.03 mg; d-pantothenic acid as d-calcium pantothenate, 23.5 mg; niacin, 44.1 mg; folic acid, 1.59 mg; biotin, 0.44 mg; Cu as copper sulfate and copper chloride, 20 mg; Fe as ferrous sulfate, 126 mg; I as ethylenediamine dihydriodide, 1.26 mg; Mn as manganese sulfate, 60.2 mg; Se as sodium selenite and selenium yeast, 0.3 mg; and Zn as zinc sulfate, 125.1 mg.

AOAC International, 2007) on a Soxtec 2050 Automated Analyzer (FOSS North America, Eden Prairie, MN). All diets and ileal digesta samples were analyzed for Cr (method 990.08; AOAC International, 2007).

Calculations and Statistic Analysis

Values for apparent ileal digestibility (**AID**), endogenous losses, and standardized ileal digestibility (**SID**) of CP and AA in the diets containing canola meal, 00-rapeseed meal, or 00-rapeseed expellers were calculated (Stein et al., 2007). Because canola meal, 00-rapeseed meal, and 00-rapeseed expellers were the only AA-containing ingredients in the diet, the AID and SID for AA in each diet also represent the AID and SID of the canola or 00-rapeseed product that was included in the diet.

Data were analyzed using PROC MIXED of SAS (SAS Inst. Inc., Cary, NC). The presence of outliers was tested using the UNIVARIATE procedure of SAS. The differences among sources of canola meal, 00-rapeseed meal, or 00-rapeseed expellers were analyzed using source as a fixed effect and period as a random effect. The mean values for each ingredient were calculated using the LSMEANS statement. To compare the differences between canola meal and 00-rapeseed meal, the model included continent as a fixed effect and pig and period as random effects. To compare the differences between 00-rapeseed meal and 00-rapeseed expellers, the model included processing method as a fixed effect and pig and period as random effects. The pig was the experimental unit, and significance among means was assessed at an α level of 0.05. Equations to predict the concentration of standardized ileal digestible AA from CP or the concentration of each corresponding AA in canola meal, 00-rapeseed meal, and 00-rapeseed expellers were developed using PROC REG in SAS.

Table 3. Analyzed composition (%) of experimental diets, as-fed basis

				Indispensable AA										Dispensable AA							
Item	DM	AEE[1]	CP	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val	Ala	Asp	Cys	Glu	Gly	Pro	Ser	Tyr
Canola meal																					
1	90.1	2.78	15.3	0.86	0.40	0.59	1.02	0.83	0.27	0.58	0.59	0.21	0.77	0.64	1.02	0.34	2.40	0.73	0.84	0.52	0.37
2	89.2	3.66	15.1	0.88	0.41	0.61	1.07	0.85	0.28	0.60	0.63	0.19	0.80	0.67	1.05	0.35	2.42	0.76	0.87	0.55	0.40
3	89.6	4.08	15.1	0.85	0.39	0.59	1.02	0.80	0.27	0.57	0.59	0.20	0.77	0.63	1.04	0.33	2.34	0.73	0.84	0.50	0.37
4	87.9	4.47	15.0	0.86	0.40	0.61	1.04	0.83	0.27	0.59	0.62	0.20	0.80	0.66	1.05	0.35	2.36	0.75	0.86	0.53	0.38
5	90.8	2.80	15.1	0.87	0.41	0.61	1.07	0.81	0.27	0.60	0.63	0.20	0.80	0.67	1.06	0.35	2.48	0.77	0.88	0.56	0.38
6	87.7	2.47	15.2	0.86	0.40	0.60	1.05	0.80	0.28	0.59	0.62	0.19	0.79	0.66	1.04	0.33	2.40	0.76	0.86	0.55	0.38
7	91.3	4.35	15.4	0.85	0.39	0.58	1.03	0.76	0.27	0.57	0.61	0.20	0.76	0.65	1.02	0.32	2.34	0.74	0.85	0.53	0.37
Average	89.5	3.52	15.2	0.86	0.40	0.60	1.04	0.81	0.27	0.58	0.61	0.20	0.78	0.65	1.04	0.34	2.39	0.75	0.86	0.53	0.38
00-rapeseed meal																					
1	89.8	4.73	15.1	0.84	0.39	0.60	1.03	0.80	0.27	0.58	0.62	0.20	0.79	0.66	1.07	0.32	2.31	0.76	0.83	0.54	0.40
2	89.8	3.34	15.3	0.85	0.39	0.60	1.02	0.81	0.26	0.59	0.59	0.20	0.79	0.63	1.06	0.31	2.34	0.74	0.83	0.50	0.38
3	89.5	2.33	15.5	0.89	0.40	0.60	1.05	0.85	0.28	0.60	0.63	0.21	0.78	0.66	1.10	0.33	2.38	0.76	0.85	0.57	0.39
4	87.1	2.96	15.5	0.88	0.41	0.59	1.07	0.85	0.28	0.59	0.66	0.19	0.78	0.68	1.10	0.34	2.44	0.78	0.88	0.59	0.41
5	87.0	3.88	15.1	0.88	0.41	0.61	1.05	0.85	0.28	0.58	0.66	0.17	0.81	0.70	1.10	0.34	2.39	0.80	0.87	0.59	0.40
6	88.1	2.81	15.3	0.86	0.39	0.60	1.04	0.82	0.27	0.59	0.63	0.21	0.79	0.66	1.09	0.32	2.33	0.75	0.84	0.55	0.39
7	91.0	4.28	15.2	0.88	0.41	0.61	1.06	0.89	0.28	0.60	0.64	0.20	0.79	0.66	1.07	0.35	2.37	0.76	0.88	0.55	0.38
8	91.3	3.87	15.2	0.90	0.41	0.62	1.11	0.84	0.28	0.62	0.68	0.20	0.82	0.69	1.17	0.31	2.45	0.80	0.89	0.59	0.42
9	91.7	4.10	15.1	0.83	0.40	0.58	1.02	0.81	0.27	0.57	0.63	0.21	0.77	0.65	1.01	0.33	2.31	0.75	0.85	0.54	0.38
10	91.0	4.68	15.3	0.89	0.41	0.61	1.09	0.84	0.28	0.61	0.66	0.19	0.80	0.68	1.15	0.32	2.39	0.78	0.88	0.59	0.40
Average	89.6	3.70	15.3	0.87	0.40	0.60	1.05	0.84	0.28	0.59	0.64	0.20	0.79	0.67	1.09	0.33	2.37	0.77	0.86	0.56	0.40
00-rapeseed expellers																					
1	88.9	4.75	15.3	0.90	0.42	0.62	1.07	0.91	0.28	0.61	0.63	0.20	0.83	0.66	1.13	0.34	2.52	0.77	0.85	0.57	0.40
2	85.3	5.27	15.1	0.88	0.40	0.59	1.02	0.89	0.27	0.58	0.62	0.19	0.78	0.64	1.09	0.34	2.36	0.74	0.83	0.54	0.39
3	88.2	5.38	15.4	0.78	0.35	0.54	0.93	0.75	0.25	0.53	0.56	0.18	0.71	0.58	0.99	0.29	2.08	0.67	0.75	0.49	0.35
4	89.8	4.68	15.2	0.89	0.41	0.61	1.07	0.85	0.28	0.60	0.65	0.20	0.81	0.68	1.11	0.34	2.42	0.78	0.87	0.57	0.39
5	87.1	4.70	15.2	0.83	0.38	0.57	1.01	0.71	0.25	0.57	0.62	0.20	0.76	0.65	1.04	0.32	2.30	0.74	0.83	0.54	0.37
Average	87.9	4.96	15.2	0.86	0.39	0.59	1.02	0.82	0.27	0.58	0.61	0.19	0.78	0.64	1.07	0.33	2.33	0.74	0.83	0.54	0.38
N free	91.9	1.05	0.41	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.04	0.03	0.02	0.02	0.01	0.06	0.01	0.01	0.01	0.01

[1]AEE = acid hydrolyzed ether extract.

RESULTS AND DISCUSSION

Ingredient Composition

Concentrations of indispensable and dispensable AA in canola and 00-rapeseed meals (Table 1) are in agreement with values for canola meal and rapeseed meal reported by Sauvant et al. (2004), Spragg and Mailer (2007), de Blas et al. (2010), Philippine Society of Animal Nutritionists (2010), Woyengo et al. (2010), Rostagno et al. (2011), and NRC (2012). However, the concentrations of indispensable and dispensable AA in 00-rapeseed expellers were less than the values for canola expellers reported by Spragg and Mailer (2007), Seneviratne et al. (2010), and Woyengo et al. (2010). The CV for CP and most AA in canola meal, 00-rapeseed meal, and 00-rapeseed expellers ranged from 2 to 5%, which indicates that variations in the concentrations of CP and most AA among sources of canola meal, 00-rapeseed meal, and 00-rapeseed expellers are relatively small. However, the CV for Trp in canola meal was 6.99%, the CV for Met, Phe, and Trp in 00-rapeseed meal was 6.95 to 9.58%, and the CV for Lys was 10.81% in 00-rapeseed expellers. These variations may be a result of differences in the concentration of these AA in the canola seeds and 00-rapeseeds that were used in the production of the meals and expellers. Differences in seed conditioning before pressing and efficiency of oil extraction among crushing plants may also affect the concentration of CP and AA in the canola and rapeseed meals that were used in this experiment (Spragg and Mailer, 2007).

Digestibility of CP and AA

Differences were observed in the AID and SID of CP and all AA among the 7 sources of canola meal that were used ($P < 0.05$; Tables 4 and 5). Differences were also observed in values for AID and SID of CP and all AA except Ile, Leu, Thr, Val, and Tyr among the 10 sources of 00-rapeseed meal ($P < 0.05$). However, the AID and SID of CP were not different among the 5 sources of 00-rapeseed expellers, but the AID and SID of all AA except Ala, Asp, Cys, Glu, and Gly were different ($P < 0.05$) among the 5 sources of 00-rapeseed expellers.

The differences in the AID and SID of CP and AA within sources of canola meal, 00-rapeseed meal, and 00-rapeseed expellers that were observed indicate that there is some variation in the digestibility of CP and AA among sources of canola meal, 00-rapeseed meal, and 00-rapeseed expellers. For most AA, the differences were 5 to 10% units. The reasons for these differences may be that the canola and rapeseed coproducts that were used in this experiment were produced from seeds that originated from different genetic selections, were

Table 4. Apparent ileal digestibility (%) of CP and AA in canola meal, 00-rapeseed meal, and 00-rapeseed expellers by growing pigs[1]

		Indispensable AA											Dispensable AA								
Item	CP	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val	Mean	Ala	Asp	Cys	Glu	Gly	Ser	Tyr	Mean	All
Canola meal																					
1	64.6	78.0	77.3	70.1	73.0	70.9	81.1	71.6	63.7	78.5	66.6	72.1	67.2	64.5	71.4	79.8	56.6	65.5	68.7	71.0	71.4
2	68.5	83.7	80.6	75.5	78.6	74.0	85.3	77.8	69.1	77.8	72.1	76.9	73.7	70.5	74.0	83.3	64.1	71.0	73.2	75.7	76.2
3	63.0	78.1	77.0	69.9	74.5	67.4	80.8	73.3	63.9	76.4	66.8	72.0	65.6	65.2	69.8	78.3	55.9	66.9	69.8	69.9	70.7
4	62.5	80.9	78.2	70.7	74.8	66.0	81.5	73.1	64.1	77.5	67.4	72.5	67.6	65.5	69.0	80.6	55.6	67.4	67.2	71.4	71.7
5	65.3	82.4	80.3	74.8	78.5	67.7	84.2	77.6	67.9	78.4	71.1	76.0	70.8	69.0	71.4	82.3	59.2	70.5	71.2	74.0	74.8
6	61.0	77.4	75.2	68.3	71.6	64.8	80.0	69.9	62.2	71.6	64.7	69.8	64.8	60.7	65.6	76.7	52.9	64.1	67.2	67.7	69.4
7	62.2	79.5	76.5	70.4	75.0	60.8	82.2	73.8	63.8	77.0	66.9	71.6	65.7	63.5	65.3	78.7	51.5	66.0	67.7	69.2	70.2
Average	63.9	80.0	77.9	71.4	75.1	67.4	82.2	73.9	65.0	76.7	67.9	73.0	67.9	65.6	69.5	80.0	56.5	67.3	69.3	71.3	72.1
CV, %	3.92	3.01	2.54	3.77	3.48	6.30	2.34	3.95	3.88	3.11	3.91	3.47	4.75	5.03	4.57	2.89	7.37	3.80	3.27	3.89	3.47
SEM[2]	1.63	1.23	1.03	1.40	1.35	2.31	1.07	1.44	1.60	1.55	1.47	1.31	1.75	1.72	1.57	1.11	2.98	1.57	1.45	1.44	1.34
P-value[2]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01
00-rapeseed meal																					
1	62.7	78.1	77.3	70.4	74.2	65.4	82.1	73.2	63.1	76.6	66.3	71.6	68.1	64.1	65.2	78.0	54.6	64.1	68.1	69.1	70.3
2	63.9	80.1	76.8	70.2	73.4	67.4	80.9	72.9	62.0	76.5	66.5	71.8	67.2	65.0	65.1	78.4	55.7	63.1	67.4	69.6	70.6

Continued

Table 4. (cont.)

Item	CP	Indispensable AA											Dispensable AA								All
		Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val	Mean	Ala	Asp	Cys	Glu	Gly	Ser	Tyr	Mean	
3	65.9	79.5	78.3	71.1	74.5	72.8	82.1	73.2	65.6	78.1	67.0	73.4	69.5	67.7	70.5	80.0	59.1	68.0	69.4	72.1	72.6
4	65.7	82.4	79.2	71.9	76.9	70.2	84.0	75.4	66.9	76.3	67.9	74.4	71.1	68.2	66.7	80.0	58.5	69.3	70.4	72.1	73.2
5	65.7	82.6	79.4	72.7	76.6	70.6	83.6	74.4	68.3	77.5	69.6	74.8	72.0	69.6	69.7	80.9	61.4	70.5	69.9	73.3	74.2
6	62.4	78.5	75.6	68.6	73.1	66.5	80.0	71.9	62.1	78.4	65.7	71.5	66.8	65.2	64.5	77.1	55.6	65.9	67.1	68.8	69.8
7	66.6	83.4	79.9	73.0	76.3	74.3	83.6	74.7	66.4	76.1	68.6	75.1	72.4	69.8	72.4	82.0	62.6	69.1	68.8	74.5	74.7
8	60.6	78.2	76.1	69.4	73.8	65.3	80.7	72.6	64.8	73.8	65.9	71.3	67.1	64.4	63.1	77.5	53.0	66.9	68.6	68.9	70.0
9	61.8	79.4	77.3	70.6	74.9	65.9	82.9	73.7	63.5	78.3	66.3	72.2	67.3	63.6	64.3	78.5	51.6	64.7	67.8	68.8	70.4
10	65.4	81.9	78.4	72.6	76.6	69.8	83.1	75.3	67.3	74.9	68.6	74.3	71.8	68.9	67.8	79.8	60.5	70.1	69.9	72.5	73.4
Average	64.1	80.4	77.8	71.0	75.0	68.8	82.3	73.7	65.0	76.7	67.2	73.0	69.3	66.7	66.9	79.2	57.3	67.2	68.7	71.0	71.9
CV, %	3.24	2.48	1.86	2.08	1.93	4.64	1.68	1.60	3.46	1.96	2.00	2.07	3.31	3.64	4.59	1.98	6.47	3.92	1.66	3.04	2.62
SEM[3]	1.41	1.25	1.02	1.32	1.19	1.40	0.97	1.32	1.40	1.70	1.32	1.18	1.49	1.54	2.16	1.09	2.61	1.47	1.41	1.38	1.24
P-value[3]	0.03	<0.01	<0.01	0.14	0.07	<0.01	0.01	0.37	<0.01	0.05	0.21	0.05	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	0.22	<0.01	0.01
00-rapeseed expellers																					
1	67.1	82.0	80.1	72.5	76.1	75.4	83.4	75.6	65.3	75.9	69.2	75.1	71.6	70.9	72.4	81.9	59.6	68.6	70.1	74.2	74.5
2	67.0	84.1	80.5	70.0	74.0	75.2	84.1	74.5	63.7	75.4	66.4	74.2	71.2	72.2	67.1	82.2	56.8	65.7	68.3	73.2	73.5
3	69.5	82.8	78.4	72.3	76.9	70.3	84.2	75.2	64.6	77.6	68.2	74.3	71.1	70.1	68.7	81.1	57.5	67.4	68.7	72.8	73.5
4	65.9	81.7	79.4	74.0	78.6	70.0	85.1	77.0	67.6	77.5	70.5	76.6	72.8	73.5	67.8	82.8	52.7	69.5	69.7	72.8	74.0
5	68.4	85.1	79.8	77.1	81.6	67.1	86.8	81.7	69.7	80.9	73.4	77.7	74.9	72.4	69.6	84.0	60.3	71.8	74.1	75.6	76.6
Average	67.6	83.1	79.6	73.2	77.4	71.6	84.7	76.8	66.2	77.5	69.5	75.6	72.3	71.8	69.1	82.4	57.4	68.6	70.2	73.7	74.4
CV, %	2.06	1.73	1.01	3.58	3.68	5.03	1.55	3.76	3.69	2.78	3.78	2.02	2.20	1.86	2.98	1.32	5.21	3.33	3.29	1.62	1.73
SEM[4]	1.83	1.13	0.98	1.12	1.08	1.63	1.02	1.10	1.54	1.71	1.39	1.02	1.53	1.45	2.53	0.89	3.55	1.59	1.53	1.32	1.16
P-value[4]	0.13	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.02	<0.01	0.03	0.08	0.40	0.17	0.22	0.33	<0.01	<0.01	0.36	0.23
Canola meal vs. 00-rapeseed meal																					
SEM	1.07	0.94	0.77	1.08	0.91	1.27	0.88	1.00	1.16	1.70	1.14	0.95	1.26	1.19	1.14	0.81	1.97	1.12	1.06	1.07	1.01
P-value	0.52	0.86	0.58	0.15	0.40	0.32	0.57	0.29	0.46	0.46	0.04	0.45	0.45	0.45	<0.01	0.03	0.63	0.29	0.08	0.21	0.19
00-rapeseed meal vs. 00-rapeseed expellers																					
SEM	1.01	0.91	0.62	0.89	0.75	1.13	0.80	0.80	1.05	1.65	0.89	0.75	0.98	1.03	1.15	0.68	2.15	1.07	0.91	1.00	0.88
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.12	0.15	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.91	0.06	0.03	<0.01	<0.01

[1]Data are least squares means of 9 observations for all treatments.

[2]Comparison of the 7 sources of canola meal.

[3]Comparison of the 10 sources of 00-rapeseed meal.

[4]Comparison of the 5 sources of 00-rapeseed expellers.

grown in different environments, and had oil extracted using different processes (Fan et al., 1996; Barthet and Daun, 2011; Trindade Neto et al., 2012). All of these factors may influence the concentrations of CP and AA in seeds, meals, or expellers, and it is possible that the AID and SID of CP and AA also were influenced.

The AID and SID of CP in canola meal were not different from the AID of CP in 00-rapeseed meal, but the AID and SID of CP in 00-rapeseed expellers were greater ($P < 0.01$) than in 00-rapeseed meal. The AID and SID of all AA in canola meal were also not different from values for 00-rapeseed meal with the exception that the AID and SID of Val, Cys, and Glu in canola meal were greater ($P < 0.05$) than in 00-rapeseed meal. However, the AID and SID of most AA in 00-rapeseed expellers were greater ($P < 0.01$) than in 00-rapeseed meal, but for Thr, Trp, Gly, Pro, and Ser, no differences were observed for AID, and for Thr, Trp, and Gly, no differences between 00-rapeseed meal and 00-rapeseed expellers were observed for SID values.

The AID and SID values for CP and most AA in canola meal and 00-rapeseed meal that were calculated in this experiment are in agreement with the values for canola meal reported by NRC (2012). Values for AID and SID of CP and AA in both canola meal and 00-rapeseed meal that were calculated in this experiment are also within the large range of values previously reported (Sauvant et al.; 2004; Stein et al., 2005; de Blas et al., 2010; Woyengo et al., 2010; Grageola et al., 2013; Messerschmidt et al., 2014).

The observation that the AID and SID for CP and most AA in canola meal and 00-rapeseed meal were not different is likely a result of the fact that canola and 00-rapeseeds are both selected from *B. napus*. Although mostly separate and independent breeding programs were used in North America and Europe to select varieties of canola and rapeseed with low concentration of erucic acids and glucosinolates, the chemical composition of the seeds was likely not changed, which is the reason the nutrient composition in the meals produced from canola and 00-rapeseed is not different.

In the present experiment, inclusion of canola meal, 00-rapeseed meal, and 00-rapeseed expellers was adjusted to a level that was expected to result in diets containing 15% CP. Diet analyses indicated that all diets contained between 15.0% and 15.5% CP. Concentration of AEE in diets influences the SID of AA because a greater concentration of AEE reduces the rate of passage for digesta in the intestinal tract, which results in increased absorption of AA (Cervantes-Pahm and Stein, 2008; Kil and Stein, 2011). The increased concentration of AEE in 00-rapeseed expellers compared with 00-rapeseed meal was therefore expected to result in increased SID of AA in 00-rapeseed expellers. To eliminate this effect, diets were balanced

Table 5. Standardized ileal digestibility (%) of CP and AA in canola meal, 00-rapeseed meal, and 00-rapeseed expellers by growing pigs[1,2]

		Indispensable AA											Dispensable AA								
Item	CP	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val	Mean	Ala	Asp	Cys	Glu	Gly	Ser	Tyr	Mean	All
Canola meal																					
1	75.3	84.4	81.5	74.7	77.3	74.0	83.5	76.0	72.1	84.1	73.2	77.2	75.3	70.9	75.1	83.2	78.4	74.2	74.4	78.2	77.6
2	79.2	89.9	84.7	79.9	82.6	77.0	87.6	81.9	76.8	83.9	78.4	81.8	81.4	76.7	77.6	86.7	84.9	79.1	78.5	82.6	82.1
3	73.8	84.5	81.2	74.5	78.8	70.6	83.2	77.6	72.2	82.3	73.4	77.2	73.8	71.5	73.6	81.8	77.8	75.8	74.1	77.1	77.0
4	73.0	87.1	82.2	75.1	78.8	69.1	83.8	77.3	71.8	83.3	73.6	77.4	75.1	71.6	72.5	83.9	75.9	75.3	72.7	78.1	77.6
5	76.2	88.8	84.4	79.3	82.6	70.9	86.6	81.9	75.8	84.3	77.5	81.0	78.6	75.2	75.1	85.7	80.2	78.6	76.8	81.0	80.8
6	71.4	83.6	79.2	72.7	75.6	68.0	82.2	74.1	69.9	77.6	70.9	74.8	72.4	66.8	69.3	80.0	73.5	72.2	72.6	74.7	75.3
7	72.9	86.0	80.9	75.1	79.3	64.3	84.6	78.3	72.0	83.0	73.7	76.9	73.8	70.1	69.3	82.3	76.0	74.5	73.5	76.6	76.6
Average	74.5	86.3	82.0	75.9	79.3	70.6	84.5	78.2	73.0	82.6	74.4	78.0	75.8	71.8	73.2	83.4	78.1	75.7	74.7	78.3	78.1
CV, %	3.49	2.76	2.39	3.51	3.26	5.82	2.29	3.70	3.35	2.82	3.53	3.16	4.16	4.56	4.23	2.76	4.71	3.24	2.95	3.42	3.09
SEM[3]	1.63	1.23	1.03	1.40	1.35	2.31	1.07	1.44	1.60	1.55	1.47	1.31	1.72	1.57	1.11	2.98	1.57	1.45	1.72	1.44	1.34
P-value[3]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01
00-rapeseed meal																					
1	73.4	84.6	81.5	75.0	78.5	68.6	84.4	77.5	70.9	82.5	72.7	76.7	75.9	70.2	69.1	81.5	75.7	72.5	73.5	76.2	76.4
2	74.5	86.6	81.1	74.7	77.7	70.6	83.3	77.2	70.3	82.4	72.9	76.9	75.4	71.2	69.1	82.0	77.3	72.0	73.1	76.8	76.8

Continued

Table 5. (cont.)

Item	CP	Indispensable AA										Dispensable AA								All
		Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val	Mean	Ala	Asp	Cys	Glu	Gly	Ser	Tyr	Mean	
3	76.3	85.7	82.5	75.7	78.7	75.8	84.4	77.4	73.3	83.6	73.5	78.3	77.4	73.6	74.3	83.4	80.1	75.9	74.8	79.1	78.6
4	75.9	88.4	83.2	76.3	80.9	73.2	86.2	79.5	74.1	82.3	74.2	79.2	78.5	74.0	70.2	83.3	78.4	76.8	75.4	78.8	79.0
5	76.1	88.6	83.4	77.0	80.6	73.5	85.8	78.6	75.5	84.2	75.6	79.6	79.2	75.3	73.3	84.2	80.6	77.9	75.0	80.0	80.0
6	72.9	84.7	79.8	73.0	77.2	69.6	82.3	76.1	69.8	83.9	72.0	76.4	74.6	71.1	68.3	80.5	76.5	73.8	73.1	75.8	75.8
7	77.4	89.7	84.0	77.5	80.5	77.3	86.0	78.9	74.2	82.0	75.1	80.1	80.3	76.0	76.0	85.6	83.8	77.4	74.4	81.6	80.8
8	71.4	84.3	80.2	73.9	77.9	68.4	83.0	76.7	72.2	79.8	72.2	76.2	74.7	70.1	67.2	80.9	73.4	74.6	73.7	75.7	75.9
9	72.8	86.2	81.6	75.4	79.3	69.1	85.3	78.2	71.5	84.0	73.0	77.4	75.4	70.2	68.2	82.1	73.3	73.1	73.5	76.2	76.7
10	76.2	88.2	82.6	77.1	80.7	73.0	85.5	79.4	74.8	81.1	75.0	79.3	79.4	74.7	71.7	83.3	81.3	77.8	75.3	79.4	79.4
Average	74.7	86.7	82.0	75.5	79.2	71.9	84.6	78.0	72.6	82.6	73.6	78.0	77.1	72.6	70.7	82.7	78.0	75.2	74.2	78.0	77.9
CV, %	2.64	2.21	1.69	1.93	1.76	4.34	1.62	1.48	2.75	1.70	1.74	1.87	2.78	3.19	4.17	1.90	4.42	3.01	1.22	2.66	2.34
SEM[4]	1.41	1.25	1.02	1.32	1.19	1.40	0.97	1.32	1.40	1.70	1.32	1.18	1.49	1.54	2.16	1.09	2.62	1.47	1.41	1.38	1.24
P-value[4]	0.05	0.012	<0.01	0.14	0.09	<0.01	0.02	0.35	0.01	0.07	0.30	0.07	0.01	0.01	<0.01	0.03	0.01	<0.01	0.30	<0.01	0.02
00-rapeseed expellers																					
1	77.6	88.0	84.1	76.9	80.1	78.2	85.6	79.7	73.1	81.7	75.3	79.8	79.3	76.6	76.0	85.1	80.2	76.5	75.3	80.9	80.3
2	77.2	90.0	84.5	74.4	78.1	77.9	86.4	78.6	71.3	81.3	72.6	78.9	78.9	77.9	70.6	85.5	77.4	73.6	73.5	79.9	79.3
3	79.9	89.7	83.0	77.3	81.5	73.7	86.7	79.9	73.2	84.0	75.2	79.8	79.9	76.6	72.9	85.0	81.0	76.3	74.7	80.6	80.2
4	76.6	87.8	83.5	78.5	82.7	73.0	87.4	81.2	75.2	83.4	76.8	81.5	80.4	79.3	71.4	86.2	73.1	77.4	75.1	79.7	79.9
5	78.8	91.4	84.1	81.7	85.8	70.6	89.3	86.0	77.4	86.6	79.8	82.8	82.7	78.5	73.4	87.5	81.1	79.9	79.7	82.7	82.7
Average	78.0	89.4	83.8	77.7	81.6	74.7	87.1	81.1	74.0	83.4	75.9	80.6	80.2	77.8	72.9	85.9	78.6	76.7	75.6	80.8	80.5
CV, %	1.70	1.68	0.70	3.42	3.54	4.40	1.61	3.58	3.15	2.54	3.47	1.94	1.86	1.53	2.86	1.20	4.33	2.95	3.12	1.47	1.62
SEM[5]	1.83	1.13	0.98	1.12	1.08	1.63	1.02	1.10	1.57	1.71	1.39	1.02	1.53	1.45	2.53	0.89	3.55	1.59	1.53	1.32	1.16
P-value[5]	0.17	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.03	0.09	0.56	0.20	0.32	0.31	<0.01	<0.01	0.44	0.26
Canola meal vs. 00-rapeseed meal																					
SEM	1.06	0.93	0.76	1.07	0.91	1.26	0.87	0.99	1.15	1.7	1.06	0.94	1.25	1.18	1.13	0.81	1.95	1.1	1.09	1.06	1.00
P-value	0.35	0.88	0.60	0.15	0.39	0.39	0.56	0.27	0.20	0.47	0.03	0.39	0.50	0.68	<0.01	0.04	0.42	0.13	0.08	0.18	0.16
00-rapeseed meal vs. 00-rapeseed expellers																					
SEM	1.00	0.91	0.62	0.89	0.75	1.12	0.8	0.8	1.04	1.65	0.89	0.75	0.97	1.02	1.15	0.68	2.15	1.06	0.89	1.00	0.88
P-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	0.16	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.68	0.04	0.03	<0.01	<0.01

[1]Values for standardized ileal digestibility were calculated by correcting values for apparent ileal digestibility for basal ileal endogenous losses. Basal ileal endogenous losses were determined (g/kg DMI) as CP, 18.01; Arg, 0.61; His, 0.19; Ile, 0.30; Leu, 0.49; Lys, 0.29; Met, 0.07; Phe, 0.28; Thr, 0.55; Trp, 0.13; Val, 0.56; Ala, 0.57; Asp, 0.73; Cys, 0.14; Glu, 0.92; Gly, 1.78; Ser, 0.50; Tyr, 0.24; total indispensable AA, 3.46; total dispensable AA, 4.30; total AA, 8.34.

[2]Data are least squares means of 9 observations for all treatments.

[3]Comparison of the 7 sources of canola meal.

[4]Comparison of the 10 sources of 00-rapeseed meal.

[5]Comparison of the 5 sources of 00-rapeseed expellers.

Table 6. Prediction equation for the concentration (%) of AA from the concentration (%) of CP in canola meal, 00-rapeseed meal, and 00-rapeseed expellers

Dependent variable[1]	Prediction equation	SE		*P*-value				
		Intercept	Estimate	Intercept	Estimate	r^2	RMSE	*P*-value
Total AA	2.011 + 0.390(CP)	3.265	0.080	0.545	<0.01	0.541	0.819	<0.01
Indispensable AA								
Arg	0.003 + 0.056(CP)	0.451	0.011	0.99	<0.01	0.559	0.113	<0.01
His	0.047 + 0.024(CP)	0.187	0.005	0.802	<0.01	0.588	0.047	<0.01
Ile	0.071 + 0.037(CP)	0.218	0.005	0.748	<0.01	0.705	0.055	<0.01
Leu	0.003 + 0.066(CP)	0.437	0.011	0.995	<0.01	0.657	0.109	<0.01
Lys	-0.154 + 0.057(CP)	0.528	0.013	0.774	<0.01	0.490	0.132	<0.01
Met	0.039 + 0.017(CP)	0.157	0.004	0.805	<0.01	0.505	0.039	<0.01
Phe	-0.024 + 0.038(CP)	0.246	0.006	0.921	<0.01	0.667	0.062	<0.01
Thr	0.345 + 0.031(CP)	0.280	0.007	0.233	<0.01	0.502	0.070	<0.01
Trp	-0.037 + 0.012(CP)	0.113	0.003	0.744	<0.01	0.507	0.028	<0.01
Val	0.151 + 0.047(CP)	0.266	0.006	0.577	<0.01	0.720	0.067	<0.01
Total	0.468 + 0.387(CP)	2.616	0.064	0.860	<0.01	0.643	0.656	<0.01

[1]The dependent variables are concentrations (%) of AA.

for concentration of AEE by adjusting the inclusion of soybean oil, and all diets were formulated to contain 6% AEE. However, even with this adjustment in oil concentration, the AID and SID for CP and most AA in 00-rapeseed expellers was greater ($P < 0.05$) than in 00-rapeseed meal. This observation is in agreement with Woyengo et al. (2010), who observed that SID of N, Arg, Ile, Leu, Phe, Glu, and Pro in canola expellers were greater than in canola meal. The greater AID and SID in the expellers may be a result of heat damage to some of the sources of 00-rapeseed meal that were used because Maillard reactions may occur during the desolventizing and toasting stages after oil extraction (Jensen et al., 1995; Newkirk et al., 2003; Klein-Hessling, 2007). In the desolventizing and toasting steps, temperature is increased, and steam is added to the meal, which negatively affects the AID and SID of CP and AA in canola or rapeseed meals (Newkirk et al., 2003; Klein-Hessling, 2007; Almeida et al., 2014). However, because oil is expelled from 00-rapeseed expellers without the use of a solvent, the desolventizing step is not needed in the production of 00-rapeseed expellers, which eliminates the risk of heat damage during this step. In the production of both meal and expellers, seed conditioning may also cause some CP or AA damage because heat or steam is used. The fact that SEM values for the SID of Lys in 00-rapeseed meal was much greater than SEM values for the SID of other AA also indicates that some of the meals may have been heat damaged because Lys is the AA that is most negatively affected by the Maillard reaction (González-Vega and Stein, 2012; Almeida et al., 2014). The SEM of the SID of Lys in canola meal and 00-rapeseed meal were greater than in 00-rapeseed expellers, indicating that the level of heat damage in some of the sources of canola meal and 00-rapeseed meal may be greater than in 00-rapeseed expellers.

The SID of Thr is expected to be less than the SID of other indispensable AA because the concentration of Thr in endogenous losses of protein is greater than the concentration of other indispensable AA (Stein et al., 1999b). This result was observed for 00-rapeseed expellers, but for canola meal and 00-rapeseed meal, the average SID of Lys was less than the SID of Thr and all other indispensable AA. This further indicates that some of the canola meals and 00-rapeseed meals may have been heat damaged because the SID of Lys is reduced if feed ingredients are heat damaged (Fontaine et al., 2007; González-Vega et al., 2011; Almeida et al., 2014).

One of the characteristics of canola and rapeseed protein is that it is relatively high in the sulfur-containing AA (Newkirk, 2011). As an example, dehulled soybean meal (47.73% CP) contains approximately 0.66% Met and 1.36% Met + Cys (NRC, 2012). However, despite the lower concentrations of CP (35.6% to 37.8%) in canola and 00-rapeseed coproducts, concentrations of Met and Met + Cys were 0.69% and 1.51% in canola meal, 0.67% and 1.43% in 00-rapeseed meal, and 0.64% and 1.39% in 00-rapeseed expellers used in this experiment. Thus, diets containing canola or 00-rapeseed protein usually have relatively high concentrations of the sulfur-containing AA. The fact that the SID of Met is greater than the SID of all other indispensable AA, except Arg, in canola meal, 00-rapeseed meal, and 00-rapeseed expellers further indicates that canola and rapeseed protein are rich sources of digestible Met in diets fed to pigs. In contrast, soybean meal contains approximately 2.96% Lys and 0.66% Trp (NRC, 2012), whereas concentrations of Lys and Trp in canola meal, 00-rapeseed meal, and 00-rapeseed expellers used in this experiment were 1.99% and 0.44%, 1.94% and 0.42%, and 1.90% and 0.41%, respectively. Therefore, diets containing

Table 7. Prediction equation for the concentration (%) of standardized ileal digestible CP or AA from the concentration (%) of CP in canola meal, 00-rapeseed meal, and 00-rapeseed expellers

Dependent variable[1]	Prediction equation	SE		*P*-value		r^2	RMSE	*P*-value
		Intercept	Estimate	Intercept	Estimate			
CP	4.844 + 0.632(CP)	3.354	0.083	0.150	<0.01	0.228	2.053	<0.01
Indispensable AA								
Arg	1.010 + 0.087(CP)	0.441	0.011	<0.05	<0.01	0.245	0.270	<0.01
His	0.313 + 0.041(CP)	0.181	0.004	0.086	<0.01	0.300	0.111	<0.01
Ile	0.537 + 0.055(CP)	0.255	0.006	<0.05	<0.01	0.277	0.156	<0.01
Leu	1.199 + 0.092(CP)	0.440	0.011	<0.01	<0.05	0.271	0.266	<0.05
Lys	0.060 + 0.087(CP)	0.675	0.017	0.929	0.053	0.123	0.413	0.053
Met	0.514 + 0.023(CP)	0.135	0.003	<0.01	<0.01	0.198	0.083	<0.01
Phe	0.695 + 0.051(CP)	0.271	0.007	<0.05	<0.01	0.228	0.166	<0.01
Thr	1.217 + 0.036(CP)	0.281	0.007	<0.01	<0.01	0.122	0.172	<0.01
Trp	-0.180 + 0.027(CP)	0.124	0.003	0.148	<0.01	0.279	0.076	<0.01
Val	0.720 + 0.069(CP)	0.351	0.009	<0.05	<0.01	0.242	0.215	<0.01
Total	5.368 + 0.495(CP)	2.290	0.057	<0.05	<0.01	0.280	1.402	<0.01

[1]The dependent variables are concentrations (%) of standardized ileal digestible CP or AA.

canola or rapeseed protein are more likely to be limiting in Lys and Trp than diets containing soy protein. In addition to these differences in composition, both soybean meal and canola and rapeseed coproducts may contain antinutritional factors that may reduce AA digestibility. However, whereas the trypsin inhibitors in soybean meal can easily be inhibited by toasting the meals, the glucosinolates in canola and 00-rapeseed coproducts cannot be inhibited by heat.

Prediction Equations

Regression analyses indicated that the concentration of CP can be used to predict the concentration of total AA and indispensable AA with a moderate coefficient of determination ($P < 0.01$; $r^2 = 0.502$ to 0.720; Table 6). In many feed formulation programs, the concentration of individual AA is automatically adjusted as a consequence of changes in CP. The present data indicate that the concentrations of individual AA are not always linearly related to the concentration of CP. The concentration of CP can be used to estimate the concentration of indispensable AA in canola and 00-rapeseed meal only with moderate accuracy. The concentrations of standardized ileal digestible CP or indispensable AA in canola and 00-rapeseed coproducts can also be predicted from the concentration of CP and corresponding AA ($P < 0.01$; Tables 7 and 8) with only a low to moderate correlation ($r^2 = 0.122$ to 0.300 and 0.206 to 0.655, respectively). This observation indicates that the standardized

Table 8. Prediction equation for the concentration (%) of standardized ileal digestible AA from the concentration (%) of each AA in canola meal, 00-rapeseed meal, and 00-rapeseed expellers

Dependent variable[1]	Prediction equation	SE		*P*-value		r^2	RMSE	*P*-value
		Intercept	Estimate	Intercept	Estimate			
Indispensable AA								
Arg	0.403 + 0.693(Arg)	0.093	0.041	<0.01	<0.01	0.592	0.086	<0.01
His	0.092 + 0.735(His)	0.040	0.039	0.024	<0.01	0.649	0.034	<0.01
Ile	0.316 + 0.559(Ile)	0.084	0.053	<0.01	<0.01	0.358	0.064	<0.01
Leu	0.645 + 0.557(Leu)	0.124	0.046	<0.01	<0.01	0.430	0.102	<0.01
Lys	-0.389 + 0.906(Lys)	0.127	0.059	<0.01	<0.01	0.546	0.129	<0.01
Met	0.123 + 0.064(Met)	0.226	0.035	<0.01	<0.01	0.655	0.024	<0.01
Phe	0.357 + 0.551(Phe)	0.078	0.051	<0.01	<0.01	0.370	0.065	<0.01
Thr	0.461 + 0.440(Thr)	0.099	0.062	<0.01	<0.01	0.206	0.071	<0.01
Trp	0.003 + 0.820(Trp)	0.021	0.045	0.085	<0.01	0.631	0.023	<0.01
Val	0.401 + 0.546(Val)	0.125	0.061	<0.01	<0.01	0.290	0.090	<0.01
Total	2.513 + 0.606(Total)	0.624	0.044	<0.001	<0.01	0.487	0.514	<0.01

[1]The dependent variables are concentrations (%) of standardized ileal digestible AA.

ileal digestible CP and indispensable AA are not always linearly related to the concentration of CP and individual indispensable AA in canola and 00-rapeseed ingredients.

Conclusions

The AID and SID for CP and most AA in canola meal and 00-rapeseed meal were not different. However, 00-rapeseed expellers had greater AID and SID for CP and most AA than 00-rapeseed meal, which may be a result of less heat damage during processing to 00-rapeseed expellers than to 00-rapeseed meal. Thus, the protein quality of the 00-rapeseed expellers used in this experiment is greater than that of 00-rapeseed meal. The differences in the AID and SID for CP and AA within sources of canola meal and within sources of 00-rapeseed coproducts that were observed may be a result of differences in varieties, growing conditions, seed conditioning, and oil extraction procedures. The results of this experiment also indicate that the concentration of CP and indispensable AA cannot always be used to accurately estimate the SID of indispensable AA in canola and 00-rapeseed coproducts.

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