Ileal and Total Tract Digestibility in Growing Pigs Fed Cassava Root Meal and Rice Bran Diets With Inclusion of Fish Meal and Fresh or Ensiled Shrimp By-Products

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ABSTRACT : The digestibility of organic matter (OM), crude protein (CP), ether extract and amino acids of a cassava root meal and rice bran diet, without (Basal) and with inclusion of fish meal (FM) or fresh (FSB) or ensiled (ESB) shrimp by-product in growing pigs (Large White×Mong Cai) fitted with post-valve T-caecum (PVTC) cannulas was studied in a 4×4 change-over experiment. Significantly higher ileal digestibility of OM in the basal and FM diets and lower ileal digestibility of CP in the basal and ESB diets were found ($p<0.05$). Total tract digestibilities of OM and CP of diet ESB were lower ($p<0.05$) than in the other diets. The apparent ileal digestibilities of most amino acids were higher ($p<0.05$) in diets FM, FSB and ESB than in the basal diet. There was no difference ($p>0.05$) in the ileal digestibility of individual amino acids between diets FM, FSB and ESB, except for threonine, alanine and glycine. The estimated apparent ileal digestibility of individual amino acids in ensiled shrimp by-product was lower ($p<0.05$) than in fresh shrimp by-product and fish meal.
In conclusion, as a result of the reduced daily intake of the diets containing shrimp by-products and lower ileal and total tract digestibility of both fresh and ensiled shrimp by-products complete replacement of fish meal cannot be recommended. The ensiled shrimp by-product was inferior nutritionally compared with fresh shrimp by-product. However, lower daily feed intakes of both the FSB and ESB diets suggest that the replacement should only be made partially, in order not to reduce the overall performance. *(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 2 : 216-223)*

Key Words : Pigs, Digestibility, Fish Meal, Shrimp By-Product, Amino Acids

INTRODUCTION

Fish meal and shrimp by-products, from the fish and shrimp industries, respectively, are important animal protein sources in Vietnam. It was estimated that in 1998 over 80 thousand tons of shrimp by-product and 300 thousand tons of fish meal were produced (General Statistics Office, 1999). Shrimp by-products are considered to be a valuable protein source for animals (Barratt and Montano, 1986) and in terms of quantity it is the second most important animal protein-rich by-product after fish meal in Vietnam (Ngoan and An, 1999).

Shrimp by-product, consisting of the head and shell, is characterized not only by a high concentration of crude protein (CP) and minerals, but also by a high content of chitin (Evers and Carroll, 1996; Göhl, 1998). The high CP concentration, and reasonably good balance of essential amino acids (Watkins et al., 1982; Ngoan et al., 2000a), makes shrimp by-product a potential candidate as an alternative to conventional protein feeds in diets for pigs. Recently, Ngoan et al. (2000b) showed that the high content of chitin can reduce the total tract digestibility of CP in shrimp by-product and this may limit its use as a protein supplement. Also, earlier studies have indicated a negative effect of chitin on the total tract digestibility of CP (Mohan and Sivaraman, 1993). Moreover, in order to assess the availability of amino acids in pigs, digestibility measurements should be made at the terminal ileum, rather than at the total tract level, due to the modifying action of the microflora in the large intestine (Zebrowska, 1973). Also, previous studies (Sauer and Ozimek, 1986; Köhler et al., 1991) have shown that the ileal analysis method is the preferred method for the determination of amino acid digestibility in feedstuffs for pigs. Knowledge of the digestible amino acid content of shrimp by-products may lead to more accurate formulation of pig diets. To our knowledge, no published data are available on the ileal digestibility of individual amino acids in shrimp by-products.

The present study was therefore initiated to provide information on the total tract and ileal digestibility of major nutrient components and the ileal digestibility of the individual amino acids in growing pigs given a cassava root meal and rice bran-based diet with inclusion of fish meal or fresh and ensiled shrimp by-products.

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MATERIALS AND METHODS

Animals and experimental design

Two castrated male and two intact female crossbred pigs (Large White × Mong Cai) with an average live weight of 35 (SD 3.7) kg at the start and 57 (SD 5.1) kg at the termination of the experiment were used. The pigs were surgically fitted with post-valve T-caecum (PVTC) cannulas (Van Leeuwen et al., 1991) to allow collection of ileal digesta.

The four experimental diets were introduced to the pigs two weeks post-surgery and were fed according to a 4×4 Latin Square design (table 1). The experimental periods were 12 days, comprising 5 days of adaptation to each diet followed by 4 days of collection of faeces, one day of collection of ileal digesta, one day of rest and finally a second day of collection of ileal digesta. The pigs were housed individually in 3 m^2 pens, and during digesta collection were restricted to a limited space within the pen.

Diets and feeding

All ingredients used in the different diets throughout the experiment originated from the same batches (table 1). The basal diet was based on cassava root meal and rice bran (at a ratio of 1:1) and the three test diets included the basal diet and fish meal or fresh or ensiled shrimp by-products at concentrations to make the experimental diets isonitrogenous (namely FM, FSB and ESB diets, respectively). All diets were supplemented with a standard mixture of vitamins, minerals and trace elements according to requirements given by NRC (1988). Chromium oxide was included in the diet as a digestibility marker.

The fish meal was mixed carefully with the basal diet before each feeding occasion. The fresh shrimp by-product was collected from the Seafood Processing Factory in Hue City in central Vietnam at 5-day intervals, ground and stored at 0 to -4℃, and then mixed daily with the basal diet. Ensiled shrimp by-product was made on three occasions by mixing ground fresh shrimp by-product with molasses at a ratio of 3:1 (wet weight basis), and the mixture was then placed in a plastic jar and sealed to prevent air contamination. The ensiled shrimp by-product was mixed daily with the basal diet. The feeding level during the collection period was set slightly below the maximum level consumed during the adaptation period.

Table 1. Ingredient and chemical composition (% of DM) of the experimental diets, and mean daily feed intake (kg/day)

	Diet[1]			
	Basal	FM	FSB	ESB
Ingredients				
Cassava root meal	48.65	38.22	39.21	27.65
Rice bran	48.65	38.22	39.21	27.62
Fish meal	-	22.92	-	-
Fresh shrimp by-product	-	-	20.92	-
Ensiled shrimp by-product	-	-	-	44.15
Dicalcium phosphate	0.45	-	-	-
Chromic oxide	0.45	0.34	0.36	0.25
Limestone	1.50	-	-	-
Vitamin and mineral premix[2]	0.30	0.30	0.30	0.30
Chemical composition				
Organic matter	95.21	89.52	86.14	85.51
Crude protein	7.30	16.32	15.40	15.32
Ether extract	9.05	8.60	8.20	6.43
Calcium	0.87	1.36	2.42	3.51
Phosphorus	0.98	1.19	1.00	0.98
Mean daily intake				
Dry matter	1.67[a]	1.64[a]	1.19[ab]	0.75[b]
Crude protein	0.12[c]	0.27[a]	0.18[b]	0.12[c]

[1] FM: fish meal diet; FSB and ESB: fresh and ensiled shrimp by-product diets.

[2] Supplied per kilogram of diet: 6,000 IU vitamin A; 1,150 IU vitamin D_3; 0.4 IU vitamin E; 0.3 mg thiamin; 0.15 mg riboflavin; 2 mg vitamin B5; 0.6 mg vitamin B6; 0.35 mg folic acid; 1 mg vitamin C; 20 mg biotin; 100 mg iron; 135 mg zinc; 40 mg copper; 67.5 mg manganese; 0.9 mg iodine; 0.1 mg cobalt; 0.06 mg selenium; 7.5 mg lysine; 10 mg methionine.

[a,b,c] Means with different superscripts within rows are significantly different ($p<0.05$).

The pigs were given two equal meals per day (6:00 and 18:00 h), and water was available *ad libitum*.

Sample collection and calculations

Faeces were collected daily and stored at 4℃, and at the end of each experimental period samples were pooled and mixed. Sub-samples were taken and dried at 60℃ prior to chemical analysis. Ileal digesta samples were quantitatively collected for one hour every second hour during a 12 h collection period, making in total 12 samples for each experimental period. Samples were collected in chilled plastic jars, which were emptied into a container placed in crushed ice. The digesta samples were weighed, homogenized and immediately frozen (-20℃) hourly after collection. At the end of the collection period, the samples were thawed, mixed, sub-sampled and dried at 60℃. Oven-drying digesta and fecal samples at low temperature was considered to be an acceptable method, as Karn (1991) found that N values obtained with freeze-dried and oven-dried samples (at 50℃) were identical.

The apparent ileal and total tract digestibilities were calculated from the individual ratios of components to marker in the diet at the respective site of sampling. The digestibility coefficients of nutrients in fish meal and shrimp by-products were estimated by the difference method, using the average digestibility values obtained in the basal diet and individual digestibility values in each of the experimental diets.

Chemical analysis

Nitrogen determinations on faeces and digesta were made on fresh samples, while the other analyses on feed, faeces and digesta were performed on air-dry samples. All samples were analyzed in duplicate.

The chemical composition was determined according to standard methods (AOAC, 1984). Dry matter (DM) was measured by drying fresh samples at 100℃ for 24 hours. Total nitrogen (N) was determined by the Kjeldahl method and crude protein (CP) was calculated from total nitrogen (N*6.25). Ether extract (EE) was determined by Soxhlet extraction without prior acid hydrolysis. Ash was the residue after ashing the samples at 550 to 600℃. Chromium oxide in feed, faeces and ileal digesta was determined according to Fenton and Fenton (1979). Amino acids were analyzed according to Spackman et al. (1958) on an ion-exchange column using an HPLC. Samples were hydrolyzed for 24 hours at 110℃ with 6 mol/l HCl containing 2 g/l reagent grade phenol and 5000 nmol norleucine (internal standard) in evacuated and sealed ignition tubes. Half-cystine and methionine were determined as cysteic acid and methionine sulphone, respectively, with separate samples hydrolyzed for 24 hours as described above following oxidation with performic acid overnight at 0℃ (Moore, 1963).

Statistical analysis

Analyses of variance were performed according to a 4×4 Latin-Square design using the General Linear Model (GLM) procedure (Minitab Version 12, 1998). Pair-wise comparisons with a confidence level of 95 were used to determine the effects of dietary treatment between groups. Results are presented as least squares means with their pooled standard errors.

RESULTS

Diet composition and feed intake

The basal and FM diets were consumed without any problem, but on the FSB and ESB diets pigs consumed only 72 and 45%, respectively, of the DM intake of the basal diet (table 1). This was also lower than for pigs on the FM diet ($p<0.05$). Due to differences in CP concentration and DM intake the daily intake of CP differed among diets ($p<0.05$), with animals on the FM diet having the highest, and those on the ESB and basal diets having the lowest daily CP intake (table 1). Total essential amino acid (EAA) concentration was approximately 50% of total amino acids in all diets and was the highest on the basal diet (table 2).

Digestibility of organic matter, crude protein and ether extract

At the ileal level the highest ($p<0.05$) organic matter (OM) digestibility was found for the basal and FM diets. The two shrimp by-product diets were significantly less digestible ($p<0.05$) than the basal and FM diets (table 3). The digestibility values obtained for CP in the basal and ESB diets were lower ($p<0.05$) than for the other diets. There were no differences in the ileal digestibility of EE between diets ($p>0.05$).

At the total tract level the ESB diet had a lower OM digestibility ($p<0.05$) than the other three diets (table 3). The FM and FSB diets had higher CP digestibility ($p<0.05$) than the basal and ESB diets. However, there were no differences in the total tract digestibility of EE between diets ($p>0.05$).

At both the ileal and total tract level the digestibilities of OM and CP for the fresh and ensiled shrimp by-products were lower than those for the fish meal ($p<0.05$). No significant difference in digestibility of EE between protein sources was found ($p>0.05$).

Ileal digestibility of amino acids

Generally, the ileal digestibilities of most amino acids were lower in the basal diet than in the other

Table 2. Amino acid composition of the experimental diets (g per 100 g DM and g per 16 g N)

	Diet[1]							
	g per 100 g dry matter				g per 16 g N			
	Basal	FM	FSB	ESB	Basal	FM	FSB	ESB
Essential amino acids (EAA)								
Arginine	0.70	0.92	1.01	0.84	9.59	5.64	6.56	5.48
Isoleucine	0.29	0.80	0.78	0.85	3.97	4.90	5.06	5.55
Leucine	0.55	1.06	0.83	0.73	7.53	6.50	5.39	4.77
Lysine	0.37	1.06	0.84	0.93	5.07	6.50	5.45	6.07
Histidine	0.17	0.32	0.30	0.27	2.33	1.96	1.95	1.76
Methionine+Cystine	0.15	0.41	0.34	0.39	2.05	2.51	2.21	2.55
Phenylalanine	0.36	0.73	0.70	0.75	4.93	4.47	4.55	4.90
Threonine	0.29	0.62	0.56	0.52	3.97	3.80	3.64	3.39
Tyrosine	0.34	0.64	0.56	0.54	4.66	3.92	3.64	3.52
Valine	0.40	0.79	0.71	0.74	5.48	4.84	4.61	4.83
Total EAA	3.62	7.35	6.63	6.56	49.59	45.04	43.05	42.82
Non-essential amino acids								
Alanine	0.45	0.96	0.79	0.92	6.16	5.88	5.13	6.01
Aspartic acid	0.57	1.44	1.45	1.46	7.81	8.82	9.42	9.53
Glutamic acid	1.09	2.25	2.03	2.01	14.93	13.79	13.18	13.12
Glycine	0.33	0.82	0.70	0.64	4.52	5.02	4.55	4.18
Proline	0.26	0.65	0.69	0.88	3.56	3.98	4.48	5.74
Serine	0.34	0.73	0.71	0.56	4.66	4.47	4.61	3.66
Sum of amino acids (SAA)	6.66	14.20	13.00	13.03	91.23	87.01	84.42	85.05
EAA : SAA	0.54	0.52	0.51	0.50	0.54	0.52	0.51	0.50

[1] See abbreviations in table 1.

Table 3. Apparent ileal and total tract digestibility (%) of the experimental diets and dietary ingredients

	Diet[1]						Feed				
	Basal	FM	FSB	ESB	SEM	p	Fish meal	Fresh shrimp by-product	Ensiled shrimp by-product	SEM	p
Ileal digestibility											
Organic matter	79.8[a]	78.7[ab]	77.4[b]	76.8[b]	1.22	0.013	75.0[a]	68.4[b]	71.2[b]	1.54	0.021
Crude protein	72.5[a]	75.6[a]	75.3[b]	72.8[a]	1.38	0.004	86.0[a]	75.4[b]	73.2[b]	2.12	0.032
Ether extract	78.3	77.9	76.8	75.7	2.06	0.198	76.6	71.2	72.4	4.32	0.176
Total tract digestibility											
Organic matter	86.8[a]	85.2[a]	84.3[a]	81.2[b]	1.77	0.007	79.8[a]	74.9[b]	74.1[b]	2.11	0.011
Crude protein	73.7[a]	77.5[b]	76.2[b]	74.2[a]	2.53	0.033	90.2[a]	75.6[b]	74.8[c]	1.98	0.001
ether extract	80.1	80.8	79.7	78.9	2.13	0.040	83.1	78.2	77.4	4.61	0.121

[1] See abbreviations in table 1.
[a,b,c] Means with different superscripts within rows are significantly different (p<0.05).

three diets (p<0.05). Except for threonine, alanine and glycine there were no differences (p>0.05) in the ileal digestibility of individual amino acids between diets FM, FSB and ESB. In contrast, the calculated ileal digestibility of all individual amino acids in fish meal and fresh shrimp by-product was significantly higher than in ensiled shrimp by-product (p<0.05) (table 4). Fish meal and fresh shrimp by-product had the same ileal digestibility value of individual EAA, except for phenylalanine, tyrosine, aspartic acid, glutamic acid, and glycine. The latter were lower in the fish meal than in fresh shrimp by-product (p<0.05).

The calculated ileal digestible amino acid composition of fish meal, fresh shrimp by-product and ensiled shrimp by-product is shown in table 5. The same ileal digestible composition of individual amino acids in the

Table 4. Apparent ileal amino acid digestibility (%) of the experimental diets and calculated ileal amino acid digestibility (%) of the dietary protein sources

	Diet[1]					Feed			
	Basal	FM	FSB	ESB	SEM	Fish meal	Fresh shrimp by-product	Ensiled shrimp by-product	SEM
Essential amino acid									
Arginine	75.7[a]	78.6[b]	78.1[b]	77.1[b]	0.38	81.0[a]	83.1[a]	76.1[b]	1.52
Isoleucine	72.7[a]	74.4[b]	73.7[ab]	73.3[ab]	0.71	83.4[a]	88.5[a]	78.9[b]	1.34
Leucine	73.2[a]	75.9[b]	75.3[b]	74.8[b]	0.37	83.8[a]	85.0[a]	76.4[b]	0.98
Lysine	73.6[a]	76.7[b]	75.8[b]	75.8[b]	0.38	85.0[a]	88.3[a]	76.8[b]	1.23
Histidine	72.9[a]	75.6[b]	74.6[b]	74.4[b]	0.07	81.4[a]	81.6[a]	75.0[b]	1.15
Methionine+Cystine	69.2[a]	74.9[b]	72.5[b]	73.3[b]	0.51	94.2[a]	90.4[a]	78.4[b]	2.11
Phenylalanine	69.9[a]	72.5[b]	72.8[b]	69.8[b]	0.61	81.3[b]	89.0[a]	69.7[c]	1.93
Threonine	68.8[a]	71.2[b]	72.4[b]	66.6[a]	0.68	86.3[a]	90.4[a]	76.5[b]	2.11
Tyrosine	70.8[a]	75.8[b]	75.3[b]	74.4[b]	1.71	72.6[b]	83.1[a]	61.3[c]	2.36
Valine	72.2[a]	75.5[b]	74.5[b]	74.2[b]	0.81	86.7[a]	88.3[a]	76.7[b]	1.68
Non-essential amino acid									
Alanine	72.5[a]	75:1[b]	70.5[c]	69.9[c]	0.91	83.9[a]	65.7[b]	66.6[b]	0.94
Aspartic acid	70.8[a]	74.6[b]	74.5[b]	74.0[b]	0.96	87.5[b]	94.2[a]	78.0[c]	2.31
Glutamic acid	73.2[a]	76.9[b]	76.8[b]	75.9[b]	0.32	82.7[b]	87.7[a]	76.8[c]	1.71
Glycine	65.1[a]	71.8[b]	67.6[a]	69.9[cb]	0.68	85.7[b]	92.5[a]	73.9[c]	2.23
Proline	71.2[a]	74.5[b]	74.5[b]	74.2[b]	1.70	94.5[a]	81.9[b]	75.9[c]	1.93
Serine	73.2[a]	75.9[b]	75.5[b]	74.1[b]	0.64	85.0[a]	89.3[a]	75.2[b]	2.68

[1] See abbreviations in table 1.

[a,b,c] Means with different superscripts within rows are significantly different ($p<0.05$).

Table 5. Relative ratios of apparent ileal digestible essential amino acids to lysine in fish meal and fresh and ensiled shrimp by-products and in the NRC (1998) requirements for growing-finishing pigs

	Feed			Requirement	
	Fish meal	Fresh shrimp by-product	Ensiled shrimp by-product	20-50 kg	20-80 kg
Arginine	87	78	61	40	36
Isoleucine	121	103	99	55	56
Leucine	99	69	58	104	105
Lysine	100	100	100	100	100
Histidine	28	28	24	32	33
Methionine+cystine	63	41	43	57	59
Phenylalanine	76	77	69	60	61
Threonine	68	62	49	60	61
Phenylalanine+tyrosine	127	127	107	94	95
Valine	89	72	72	66	67

fish meal and fresh shrimp by-product was found for lysine, histidine, phenylalanine and tyrosine. For the other EAA, the values in fresh shrimp by-product were 0.90 (arginine), 0.84 (isoleucine), 0.69 (leucine), 0.65 (methionine+cystine), 0.91 (threonine) and 0.80 (valine) of those in fish meal. Lower values were found of the ileal digestible composition of most amino acids in the ensiled shrimp by-product than those in the other feeds. However, the ratio of digestible EAA to total digestible amino acids was on average 49 % and did not differ ($p>0.05$) between the feeds studied.

DISCUSSION

The total tract digestibilities of OM and CP in the FM and ESB diets were comparable with earlier data on similar diets fed to intact pigs (Ngoan et al., 2000b). As shown by Lindberg (1997), the total tract digestibility of nutrients should be expected to be comparable in intact pigs and PVTC-cannulated pigs. The proportion of OM digested prior to the hindgut was comparable in the basal, FM and FSB diets (0.92), while a higher proportion was found (0.95) for the ESB diet. This could be explained by the inclusion of molasses in this diet, originating from the ensiled shrimp by-product.

The ileal digestibility values of individual EAA in the fish meal and the fresh shrimp by-product in the present study were comparable to data on different fish meal sources, while the ileal digestibilities of CP were lower than those in fish meal (NRC, 1998). In agreement with other studies (Knabe et al., 1989; Sauer et al., 1991), the ileal digestibilities of arginine and lysine in the experimental diets were usually high, whereas those of threonine and glycine were relatively low. As discussed by Sauer and Fan (1993), the low ileal digestibility of threonine and glycine may partly result from their relatively high concentration in endogenous secretions. Studies by De Lange et al. (1989) and Furuya and Kaji (1989) have shown a relatively high content of threonine and glycine in digesta collected from the distal ileum of growing pigs fed protein-free diets. In addition, the low ileal digestibility of threonine may also result from its relatively low rate of absorption (Sauer et al., 1993).

The low ileal digestibility of CP and most of the amino acids in the basal diet can be explained by the low CP level (7% CP) compared with the other diets (15% CP), and could be due to a higher contribution of endogenous excretions in the ileal digesta. Fan et al. (1994) found that increasing levels of CP in corn starch and soybean meal diets (4 to 24% CP) fed to growing pigs quadratically increased the ileal digestibility of CP and individual amino acids. Also, Furuya and Kaji (1989) reported that the apparent ileal digestibilities of all individual amino acids measured at 16% CP were higher than those at 8% CP. Consequently, a higher endogenous excretion on the basal diet in the present study should have resulted in an underestimation of ileal digestibility of CP and amino acids in fish meal and shrimp by-products.

The ileal digestibility of CP and amino acids in the ESB diet may have been affected by the low DM intake on this diet (42 g/kg $BW^{0.75}$), compared with the other diets (70 to 95 g/kg $BW^{0.75}$). As shown by Hess and Sève (1999), the daily basal endogenous ileal amino acids and N losses should be expected to be proportional to the DM intake above 70 g/kg $BW^{0.75}$, while this may not be true at lower levels of DM intake. Thus, the low ileal digestibility of individual amino acids on the ESB diet may partly be explained by a low DM intake on this diet. Thus, using the difference method the estimated CP and amino acid digestibility of the ensiled shrimp by-product would have been reduced by the lower DM intakes.

Low daily feed intake for pigs fed the ESB diet in the present study is in agreement with the results of a previous experiment (Ngoan et al., 2000b) and with the result of Lien et al. (1994), who found a lower daily feed intake in pigs fed a diet including 10% of shrimp by-product and blood ensiled with molasses than those fed the control diet. Also, Mohan and Sivaraman (1993) reported that the inclusion of 6 and 12% of dry prawn waste meal in the diets of growing pigs resulted in a decrease in daily feed intake of 37 and 39%, respectively. These results indicate acceptability and palatability problems when including even relatively low levels of shrimp waste. One explanation could be that the high calcium concentration made the diets less palatable, and there appears to be an optimum dietary calcium content below or above which intake is depressed (Forbes, 1995). Accordingly, Mahan and Petter (1982) found that when the contents of calcium and phosphorus of feed for sows were increased from 6 and 5 g per kg to 8 and 6 g per kg, respectively, there was an increase in feed intake but this then decreased again when they were increased further to 9 g calcium and 7 g phosphorus per kg of feed. Also, Watkins et al. (1982) reported a lower weight gain by male mink on a high shrimp meal diet that appeared to result from an excessive calcium intake. The calcium content in the fresh and ensiled shrimp by-product diets in the present study was 24.2 and 35.1 g per kg DM, respectively, which were higher than in the fish meal diet (11.9 g per kg). Another explanation for the reduction in feed intake may be a low acceptability of the fermented diet, which may be spoilt by high temperatures (25.9±2.3℃) and humidity (81.6±3.4%) during the day. It was observed that the intakes from animals in the ESB group were very low on the hottest days, as compared to the intake of the other diets. Additionally, Ly and Castro (1984) suggested that lower voluntary feed intake of molasses diets was due to an excessive ingestion

Recommendations for pig diet formulations based on ileal digestible amino acids have been proposed in several countries (Rhône-Poulenc Animal Nutrition, 1989; NRC, 1998). The content of apparent ileal digestible CP was markedly lower in ensiled shrimp by-product than in fish meal (0.47) and fresh shrimp by-product (0.54), while the difference between the latter was smaller (0.86; table 5). When compared with the EAA-profile of the dietary requirements for apparent ileal digestible EAA for growing-finishing pigs (NRC, 1998), fish meal, as well as fresh shrimp by-product, will provide in excess of the needs for most EAA except for leucine, histidine and methionine+cystine. In particular for fresh shrimp by-product, the latter three amino acids become limiting. In addition, the ensiled shrimp by-product will only supply 55 to 56% of leucine, 73 to 75% histidine, 73 to 75% methionine+cystine and 80 to 82% threonine for growing-finishing pigs.

CONCLUSION

Lower daily feed intake and ileal and total tract digestibility on the fresh and ensiled shrimp by-product diets suggest that the replacement of fish meal with fresh and ensiled shrimp by-products should only be made partially, in order not to reduce the overall performance. In addition, the ensiled shrimp by-product was nutritionally inferior compared with the fresh shrimp by-product, and had a large negative effect on daily feed intake, and should thus be only used to a limited extent to replace fish meal.

Further research is needed on the performance of pigs in order to assess the overall feed value of shrimp by-product.

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