Ensiling Techniques for Shrimp By-Products and their Nutritive Value for Pigs

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ABSTRACT : An experiment was performed to evaluate different methods for preserving shrimp by-products and to determine their chemical composition. In the first experiment three ratios of shrimp by-product (SBP) to molasses (6:1, 4:1 and 3:1, wet weight), and to cassava root meal (3:1, 2:1 and 1:1, wet weight of shrimp by-product and air-dry weight of cassava root meal) were investigated. The pH of the SBP ensiled with molasses at a ratio of 3:1, and with cassava root meal at a ratio of 1:1, decreased during the first week to below 4.5 and remained low up to day 56 of ensiling, whereas the pH of the mixtures with higher ratios of SBP remained above 7.0, and the material deteriorated rapidly. The dry matter decreased initially in all treatments but then increased slightly from day 28 in the treatment where shrimp by-product was ensiled with cassava root meal at a ratio of 1:1. The crude protein (CP) and ammonia-N (NH_3-N) contents of the preserved shrimp by-product material ensiled with molasses at a ratio of 3:1 increased significantly one week after ensiling. The CP content then remained constant, while the NH_3-N concentration continued to increase up to 56 days after ensiling. When SBP was ensiled with cassava root meal at a ratio of 1:1 the CP content of the silage increased significantly up to 21 days after ensiling and then decreased back to the original level after 56 days, whereas NH_3-N increased markedly up to 14 days and then remained fairly constant up to 56 days. However, the NH_3-N content was significantly higher when SBP was ensiled with cassava root meal than with molasses. A balance experiment was carried out, arranged as a double Latin-square and including 6 F1 (Large White x Mong Cai) castrates fed randomly one of three diets based on cassava root meal, rice bran, and fish meal (FM) or shrimp by-product ensiled with molasses (SBEMO) or with cassava root meal (SBECA) as the main protein source. Apparent organic matter and CP digestibilities were significantly ($p<0.001$) higher for the fish meal diet than for the two shrimp by-product diets, although CP digestibility in SBEMO and SBECA was similar ($p>0.05$). N-retention was significantly higher for the fish meal diet than for the SBEMO diet, which in turn was significantly higher than for the SBECA diet ($p<0.01$). It can be concluded that shrimp by-product can be preserved by ensiling with molasses at a ratio of 3:1 or with cassava root meal at a ratio of 1:1. Nutrient digestibility and N-retention of diets based on these shrimp by-product silages were lower than for similar diets based on fish meal, probably due to their high chitin content and inferior amino acid balance. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 9 : 1278-1284*)

Key Words : Shrimp By-Product, Silage, N-Retention, Digestibility, Growing Pigs

INTRODUCTION

In recent years, shrimp production for export has increased rapidly in Vietnam, resulting in large quantities of by-product from the shrimp processing industry, amounting to 42 thousand tons in 1994 (Le et al., 1995). The by-product from shrimp processing consists of the head and shell, and is estimated to make up about fifty percent of the total raw fresh material (Le et al., 1995; Balogun and Akegejo-Samsons, 1992).

The traditional method to preserve shrimp by-product is salt-based ensiling (Evers and Carroll, 1998). However, the high concentration of salt in the silage limits its use for feeding animals. Alternatively, shrimp by-product is preserved in the dry season by sun drying to produce shrimp by-product meal, although as the shrimps are mainly harvested in the rainy season in Central Vietnam sun drying is difficult to apply as a preservation method (Ngoan and An, 1999).

Ensiling with carbohydrate-rich materials may be a more suitable fermentative process (Lien et al., 1994; Perez, 1995). Ensiling does not depend on weather conditions, produces a palatable feed and prevents proteolysis. A concern when making silage from shrimp by-product is that it has a high content of protein and water and a low soluble carbohydrates content, thus excluding ensiling unless materials high in fermentable carbohydrates are added (McDonald, 1981). Cassava root meal and in particular molasses, which are locally available throughout the year in Vietnam, are rich in soluble carbohydrates and are therefore potential additives in silage making (An, 1999).

The amino acid balance of shrimp by-product is similar to that of krill meal (Rehbein, 1981) and fish meal, although absolute lysine levels are lower than in fish meal (Watkins et al., 1982), and reduced digestibility due to the high content of chitin would

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further decrease available lysine.

The purpose of these experiments was to identify appropriate preservation methods of shrimp by-product by ensiling with different ratios of sugar cane molasses or cassava root meal, and to determine the nutritive value of the most promising silage by growing pigs.

MATERIALS AND METHODS

Ensiling of shrimp by-product

Shrimp by-products were supplied by the Seafood Processing Factory in Hue City in Central Vietnam, which produces 200-300 tons of shrimp by-products each year (Ngoan and An, 1999). At the factory, shrimps are processed by boiling in water prior to removing the head and the shell. These by-products were collected, ground to pass through a 5-mm screen, and mixed with different proportions of sugar cane C molasses with 55 degrees Brix (percentage of soluble solids) or cassava root meal. The ratios of shrimp by-product to molasses were 6:1, 4:1 and 3:1 on a wet weight basis, and to cassava root meal 3:1, 2:1 and 1:1 (wet weight of shrimp by-product and air-dry weight of cassava root meal). The mixtures were placed in 2 L plastic bags and were sealed to prevent air contamination. The bags were put in buckets and stored at room temperature (20 to 30℃). Samples of shrimp by-product ensiled with molasses or with cassava root meal were taken at 21 days of ensiling, and the chemical composition of the silages, shrimp by-product, molasses and cassava root meal are shown in table 1.

The silages were ground carefully in a mixer and triple sub-samples for dry matter (DM), pH, crude protein (CP) and ammonia-nitrogen (NH_3-N) determination were taken at day 0, 7, 14, 21, 28 and 56 after ensiling.

Balance trial

Animals, experimental design, diets and feeding. Six F1 crossbred castrates (Large White x Mong Cai) of 35 kg initial live weight were used in the balance trial. The three experimental diets were formulated to be isonitrogenous, but were not balanced for amino acids and included fish meal or shrimp by-product ensiled with molasses (3:1 on a wet weight basis) or with cassava root meal (1:1, wet weight of shrimp by-product to air dry weight of cassava root meal). The diets based on the shrimp by-products were mixed daily from 3 weeks after ensiling until the end of the trial. The trial was designed as a double 3×3 Latin-square and lasted 45 days, divided into three experimental periods. Each experimental period consisted of 10 days of adaptation to the diet followed by 5 days of faeces and urine collection. Diet formulation and chemical composition of the dietary ingredients are shown in table 2. The pigs were given three equal meals per day (at 07:00, 12:00 and 18:00 h) and any refusals were collected and weighed. The feed level during collection was set slightly below the maximum level consumed during the preliminary period. The pigs were weighed at the start of each experimental period and the feed allowance was adjusted accordingly.

Sample collection. During the collection period, faeces and urine were collected and weighed daily at 08:00 and 19:00 h, and stored at 4℃. At the end of each experimental period, faeces were mixed and representative sub-samples were taken, dried in an oven at 60 to 65℃ for 48 hours and ground prior to chemical analysis. Sub-samples of urine were taken, to which 50 ml of 10% HCl had been added, and were stored at -10℃.

Chemical analysis

The chemical composition of the silage, feed,

Table 1. Dry matter content (%) and chemical composition (% of dry matter) of the dietary ingredients and contents of some essential amino acids (% of dry matter)

Ingredients[1]	Dry matter	Chemical composition				Essential amino acids			
		Crude protein	Ether extract	Chitin	Ash	Lysine	Methio -nine	Threo -nine	Phenyl -alanine
Rice bran	85.2	12.4	17.9	-	7.0	0.7	0.4	0.6	0.8
Fresh shrimp by-product	30.2	35.2	4.3	16.1	30.0	2.6	1.1	1.6	2.0
Shrimp by-product ensiled with									
molasses	33.0	26.3	2.9	10.6	21.0	1.7	0.7	0.9	1.3
cassava root meal	37.9	13.4	4.6	8.2	9.5	0.8	0.1	0.5	0.5
Molasses	47.0	1.1	-	-	3.4	-	-	-	-
Fish meal	84.2	46.4	6.5	-	30.5	4.6	1.8	2.5	2.7
Cassava root meal	87.2	2.9	0.6	-	2.4	0.2	-	0.1	0.1

[1] Samples of shrimp by-product ensiled with molasses with ratios of 3:1 on wet weight basis or 66:34% on a dry matter basis; and shrimp by-product ensiled with cassava root meal with ratios of 1:1 a wet weight of fresh shrimp by-product to air-dry weight of cassava root meal or 26:74% on a dry matter basis were taken at 21 days of ensiling.

faeces and urine was determined using the following Association of Official Analytical Chemists (AOAC) methods (1984). Dry matter (DM) was measured by drying fresh samples at 100℃ for 24 hours. Total nitrogen (N) was determined on fresh samples by the Kjeldahl method and CP was calculated from total nitrogen (N×6.25). Ether extract (EE) was determined by Soxhlet extraction without prior acid hydrolysis. Crude fibre (CF) was determined conventionally and chitin was determined according to the ADF method modified by Stelmock et al. (1985). The ammonia nitrogen (NH_3-N) in the sample was determined by distillation with water and MgO, collection in 0.3% H_3BO_3 and then titration with standard 0.1 N H_2SO_4. Total ash was the residue after ashing the samples at 550 to 600℃. The pH was determined in the liquid obtained by pressing fresh samples of the silage. Amino acids were analysed according to Spackman et al. (1958) on an ion-exchange column using a 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). All samples were analysed in triplicate.

Statistical analysis

Analysis of variance was performed using the general linear model (GLM) procedure of Minitab version 12 (1998). Results are presented as least squares means with their standard error.

RESULTS

Chemical and amino acid composition of fresh shrimp by-product

Proximate analysis of fresh shrimp by-product indicated a crude protein content of 35.2% and chitin of 16.1%, which was high compared with shrimp by-product ensiled with molasses (10.6%) or with cassava root meal (8.2%). In addition, the contents of lysine, methionine and threonine were 33, 30 and 15% lower, respectively, than those of fish meal (table 1).

Effect of molasses ratio on ensiled shrimp by-products

At molasses to shrimp by-product ratios of 6:1 and 4:1, the pH of the silage fell slightly after 7 days, and then increased to the initial value. NH_3-N concentrations increased substantially in the 14 days after ensiling, when the unpleasant smell and dark color of the material indicated deterioration and further measurements were not taken (table 3). However, the pH of the silage with a ratio of shrimp by-product to molasses of 3:1 fell to around 4.5 after 7 days, and only increased non significantly up to 56 days of ensiling. DM content fell by around 4 percentage units, while the CP content, after increasing during the first 7 days, remained at this level up to 56 days. NH_3-N concentrations increased significantly after 7 days of ensiling, and continued to increase for the rest of the period of ensiling. All treatments showed a gradual decrease in DM content with time of storage.

Effect of cassava root meal ratio on ensiled shrimp by-product

With ratios of shrimp by-product to cassava root meal of 3:1 and 2:1, the pH fell only slightly, but not significantly, after 7 days, before increasing to its original value after 14 days. NH_3-N concentrations increased rapidly (table 4), and the material was obviously spoiled after 14 days when measurements were discontinued. However, for the shrimp by-product ensiled with cassava root meal 1:1, pH fell to 4.2 after 7 days, and remained at this level up to 56 days. DM content fell after 14 days and then gradually increased to its original level after 56 days, while CP concentration increased after 21 days, before falling back to its initial level after 56 days.

Amino acid contents of fresh and ensiled shrimp by-products

The contents of lysine, methionine, threonine and phenylalanine in shrimp by-product ensiled with molasses or with cassava root meal were lower than those of the fresh shrimp by-product (table 1). The lowest content of methionine was found in shrimp by-product ensiled with cassava root meal (0.1 g/100 g DM).

Apparent digestibility and N-utilization of ensiled shrimp by-products

Dry matter and crude protein intakes were similar for all treatments ($p>0.05$), but there were significant differences ($p<0.05$) in crude fiber and chitin intake between the fish meal diet and the diets with ensiled shrimp by-products (table 2). Apparent OM and CP digestibilities were significantly higher ($p<0.001$) for the fish meal diet, and OM digestibilities were higher for the diet with shrimp by-product ensiled with molasses than for the diet with shrimp by-product ensiled with cassava root meal (table 5).

N-retention for the fish meal diet was 13.1 g/day, or 71% of N-digested, which was significantly ($p<0.05$) higher than for the shrimp by-product ensiled with molasses diet, with the lowest N-retention values of 8.4 g/day or 49% of N-digested found for the shrimp by-product ensiled with cassava root meal diet (table 5).

Table 2. Ingredient and chemical composition (% of dry matter) of the experimental diets and contents of some essential amino acids (% of dry matter), and mean daily intake (g per day)

	Diets			SEM
	Fish meal	Shrimp by-product ensiled with		
		Cassava	Molasses	
Ingredients				
Cassava root meal	68.0	15.0	55.0	
Rice bran	16.0	15.0	15.0	
Fishmeal	16.0	-	-	
Shrimp by-product ensiled with cassava	-	70.0	-	
Shrimp by-product ensiled with molasses	-	-	30.0	
Chemical composition				
Crude protein	11.4	11.7	11.3	
Crude fiber	4.5	1.3	3.5	
Chitin	-	5.7	3.2	
Ether extract	4.3	6.0	3.9	
Total ash	7.6	8.1	8.7	
Amino acid content				
Lysine	1.1	0.8	0.8	
Methionine	0.4	0.2	0.3	
Threonine	0.6	0.2	0.5	
Phenylalanine	0.7	0.5	0.6	
Daily intake				
Dry matter	1,247	1,227	1,207	94.4
Crude protein	142	143	137	10.8
Crude fiber+chitin	56[a]	86[b]	80[b]	8.7
Ash	92	87	93	4.03
Lysine	12.1[a]	8.8[b]	8.7[b]	0.71
Methionine	4.3[a]	1.6[b]	3.3[a]	0.09
Threonine	6.9[a]	5.5[b]	4.8[b]	0.13
Phenylalanine	7.7[a]	5.6[b]	6.7[ab]	0.43

[a,b,c] Values within rows with differing superscript letters are significantly different ($p<0.05$).

DISCUSSION

The composition of shrimp by-product varies with the proportion of shrimp heads to shells and the type of processing. The fresh shrimp by-product used in these studies contained 35.2% CP and 16.1% chitin, values that were similar to shrimp by-products collected by Watkins et al. (1982), but lower than the values reported by Evers and Carroll (1996). The reduction of the lysine, methionine, threonine and phenylalanine contents of ensiled shrimp by-products compared with the fresh material was due to the inclusion of molasses (34% on a DM basis) or cassava root meal (74% on a DM basis), both of which have low contents of protein and amino acids (Göhl, 1993).

The results from the present study show that ratios of 3:1 and 1:1 of shrimp by-product to molasses and cassava root meal, respectively, were adequate to preserve the shrimp by-product. Evers and Carroll (1996) also found that with increasing ratios of liquid and dry molasses to shrimp by-products, the pH, CP and NH_3-N decreased whereas DM increased. Hall and de Silva (1994) considered cassava root meal to be the best additive for silage making, as cassava stimulates lactic acid fermentation to produce a very low pH. Although a low pH was obtained in the treatment shrimp by-product ensiled with cassava root meal 1:1 in the present study, the content of NH_3-N in this treatment was considerably higher than in treatment shrimp by-product ensiled with molasses 3:1. This indicates a more extensive protein degradation when cassava root meal was used as a silage additive, while the increase was relatively low in the treatment shrimp by-product ensiled with molasses 3:1, in which the final product was successfully preserved. Negative effects on the quality of shrimp by-product silage are reflected by the NH_3-N concentration, which has been

Table 3. Effect of shrimp by-product to molasses ratio on pH, dry matter (DM, %), crude protein (CP, %) and ammonia N (NH_3-N, % of total N) in ensiled shrimp by-product

Parameter	Treatment[1]	Days 0	7	14	21	28	56	SEM	p
pH	SBEMO 6:1	8.5	7.6	8.7	-	-	-	0.09	0.001
	SBEMO 4:1	8.3	7.6	8.1	-	-	-	0.07	0.002
	SBEMO 3:1	8.0[a]	4.5[b]	4.5[b]	4.6[b]	4.6[b]	4.8[b]	0.09	0.001
DM	SBEMO 6:1	31.6[a]	27.4[b]	26.6[c]	-	-	-	0.09	0.001
	SBEMO 4:1	33.2[a]	30.0[b]	29.6[b]	-	-	-	0.09	0.001
	SBEMO 3:1	32.4[a]	29.5[b]	29.1[b]	28.9[b]	28.3[bc]	28.0[c]	0.18	0.001
CP	SBEMO 6:1	29.1	29.2	29.3	-	-	-	0.57	0.977
	SBEMO 4:1	25.3	25.4	25.0	-	-	-	0.19	0.337
	SBEMO 3:1	23.2[a]	26.4[b]	26.6[b]	28.2[b]	28.3[b]	27.9[b]	0.42	0.001
NH_3-N	SBEMO 6:1	1.2[a]	14.2[b]	20.8[c]	-	-	-	0.40	0.001
	SBEMO 4:1	1.0[a]	7.2[b]	8.6[c]	-	-	-	0.14	0.001
	SBEMO 3:1	1.5[a]	3.4[b]	4.1[c]	4.4[c]	4.5[c]	6.5[d]	0.12	0.001

[1] SBEMO 6:1, etc.: Ratios of shrimp by-product to molasses as fresh weight.
[a,b,c] Values within rows with differing superscript letters are significantly different ($p<0.05$).

shown to increase markedly in the first week of ensiling (Vantana and Rosario, 1983), as was also found in our experiments in all treatments. Ammonia can be formed by the action of deaminase, which is suspected of remaining active in shrimps after the brining process (Whitaker, 1978). Another possible explanation could be the action of contaminating microorganisms that can grow in the initial phase of fermentation (Vantana and Rosario, 1983). Molasses and cassava root meal are rich in sugars and starch, respectively, while shrimp by-product is rich in protein. An appropriate ratio between shrimp by-product and sugar cane molasses or cassava root meal could thus create a suitable balance of protein and readily fermentable starch or sugars that would facilitate the fermentation process. However, the starch fraction may be only partly utilized by the lactic acid bacteria because of the lack of enzymes capable of

Table 4. Effect of shrimp by-product to cassava root meal ratio on pH, dry matter (DM, %), crude protein (CP, %) and ammonia N (NH_3-N, % of total N) in ensiled shrimp by-product

Parameter	Treatment[1]	Days 0	7	14	21	28	56	SEM	p
pH	SBECA 3:1	8.4	7.6	8.2	-	-	-	0.07	0.001
	SBECA 2:1	8.4	7.5	8.1	-	-	-	0.12	0.004
	SBECA 1:1	8.2[a]	4.2[b]	4.1[b]	4.1[b]	4.2[b]	4.3[b]	0.08	0.001
DM	SBECA 3:1	29.6[a]	26.3[b]	25.3[c]	-	-	-	0.14	0.001
	SBECA 2:1	31.5[a]	27.0[b]	25.6[c]	-	-	-	0.26	0.001
	SBECA 1:1	36.6[a]	35.0[b]	33.9[c]	34.2[c]	37.9[d]	36.2[a]	0.54	0.001
CP	SBECA 3:1	29.9	30.9	28.7	-	-	-	0.56	0.109
	SBECA 2:1	19.1	21.2	19.5	-	-	-	0.56	0.072
	SBECA 1:1	12.4[a]	12.0[a]	13.1[b]	14.0[c]	13.4[b]	12.1[a]	0.10	0.001
NH_3-N	SBECA 3:1	1.3	31.4	39.1	-	-	-	0.76	0.001
	SBECA 2:1	1.8	29.3	35.1	-	-	-	0.33	0.001
	SBECA 1:1	2.1[a]	10.9[b]	12.5[c]	11.9[bc]	11.0[b]	13.2[c]	0.25	0.001

[1] SBECA 3:1, etc.: Ratios of shrimp by-product to cassava root meal on a fresh weight and air-dry weight basis, respectively.
[a,b,c] See footnote in table 3.

breaking down the α-glucosidic linkages (McDonald et al., 1991). Therefore only a minor part of the starch may be available because of low acid hydrolysis (Spörndly, 1986; Pettersson, 1988). Thus, when the content of available starch is too low in the silage, the lactic acid bacteria are replaced by Clostridia, Enterobacteria, Bacilli, yeasts and moulds. This will result in an unacceptable quality of the silage (McDonald, 1981), as was found in this study when the ratio of shrimp by-product was 2:1 or higher in the cassava root meal silage or 4:1 and higher when molasses was used.

The optimum level of molasses in the present study was 34% (DM basis), whereas more than double this proportion of cassava root meal (74% of DM) was required, probably because the carbohydrate in the cassava root meal is found mainly as starch, which is less soluble than the sugars that dominate in molasses. Dominguez (1988), also recommended the addition of 30% molasses (DM basis) in fish and shrimp by-product silage, and Perez (1995) found that a mixture (50:50 w/w fresh weight) of sugar cane molasses and ground fish by-product only required ten days to reach a pH of 4.5. Samuels et al. (1992) also reported that fish and crab processing by-products could be successfully ensiled when ground and ensiled with maize stovers or wheat straw with addition of dry molasses. In contrast, Evers and Carroll (1996) carried out an experiment on fresh shrimp by-product with 0, 10, 15, 20 and 25% dry molasses added and with the use of bacteria inoculants. They found that with a molasses level of 25% the pH had only decreased marginally (from 7.7 to 6.8) by day 6, which was too high for successful preservation.

The increase in CP content after ensiling measured in our study could be a consequence of losses of carbohydrates by the fermentation process and the volatile fatty acids produced during ensiling (Lien et al., 1994).

The inclusion of ensiled shrimp by-products in the diets significantly reduced the OM and CP digestibilities compared to the fish meal diet, probably due to chitin, which is considered chemically as cellulose (Stryer, 1981; van Ornum, 1992). In the present study the inclusion of shrimp by-product silages in the diets for growing pigs resulted in a high chitin content, 1.5 times higher in shrimp by-product ensiled with cassava root meal and shrimp by-product ensiled with molasses than in the fish meal diet. An increase in the rate of passage of digesta can be hypothesized as reducing overall nutrient digestibility, while an additional explanation for the low CP digestibility is that chitin itself, containing approximately 6.9% nitrogen (Stephens et al., 1976), might not be totally digested in the pig gastrointestinal tract. The decline of CP digestibility in the present study is supported by the results of Mohan and Sivaraman (1993), who reported that the inclusion of 13.5% dry prawn waste in the diets for growing pigs reduced significantly CP digestibility. Rehbein (1981) also found that meal made from krill, a shrimp-like organism from the Antarctic, was poorly digested, probably as a result of the chitin in the meal. In our study, the OM digestibilities in the diet with the shrimp by-product ensiled with sugar cane molasses were higher than in with the cassava root meal diet, probably as a result of the lower soluble carbohydrate content of cassava root meal compared to molasses.

There was a significantly higher daily N-retention on the fish meal diet compared to the two ensiled shrimp by-product diets, which could be explained by the higher intake of digestible nitrogen in combination with a higher intake of digestible organic matter. Also, when expressed as a percentage of digestible N-intake, N-retention on the shrimp by-product diets was lower than on the fish meal diet. This could be related to the lower contents of lysine, methionine, threonine and phenylalanine in the shrimp by-product diets. Further, the low N-retention of the digestible N on the diet with shrimp by-product ensiled with cassava root meal was most likely a result of the very low methionine content in this silage.

IMPLICATIONS

It can be concluded from the present studies that shrimp by-product can be successfully preserved for at least 8 weeks by ensiling with sugar cane molasses at a ratio of 3:1 (wet weight) or with cassava root meal at a ratio of 1:1 (wet weight of shrimp by-product to air-dry weight of cassava root meal). However, the proportion of cassava root meal required (74% on a

Table 5. Apparent digestibility of organic matter and crude protein of fish meal and shrimp by-product ensiled with molasses or with cassava root meal in cassava-based diets, and utilization of dietary nitrogen

	Diets				
	Fish meal	Shrimp by-product ensiled with		SEM	p
		Cassava	Molasses		
Digestibility, %					
Organic matter	91[a]	82[c]	86[b]	0.8	0.001
Crude protein	81[a]	75[b]	75[b]	0.8	0.001
N intake, g/day	22.7	22.9	21.9	1.7	0.125
N digested, g/day	18.4[a]	17.2[b]	16.4[b]	1.2	0.031
N retained					
g/day	13.1[a]	8.4[c]	10.2[b]	1.4	0.013
% of N digested	71[a]	49[c]	62[b]	2.1	0.005

[a,b,c] Values within rows with differing superscript letters are significantly different.

dry matter basis) resulted in a crude protein concentration of only 13.4% in the silage, which would necessitate the inclusion of a protein supplement in diets for growing pigs. Nutrient digestibility and N-retention of diets based on these ensiled shrimp by-products were lower than for similar diets based on fish meal, but the products could still be economically attractive to pig producers because of their low price. Due to low ammonia-N concentration and high N-retention of the diet based on shrimp by-product ensiled with molasses, the use of molasses (over 30% on a DM basis) for shrimp by-product silage can be recommended.

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