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FLORIDA SEA GRANT COLLEGE

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Potential Utilization of Scallop Viscera Silage for Solid Waste Management and as a Feedstuff for Swine[1]

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INTRODUCTION

Waste management has been identified as a major problem which will threaten the economic security of Florida's seafood industry within the next ten years (1). One of the primary concerns is treatment and disposal of solid wastes resulting from seafood processing. For example, an adverse consequence of the rapid increase in scallop processing has been the emergence of a solid waste disposal problem. Average mechanical scallop processing yields about 70% shell, 23% viscera and 7% edible meat (2). The wet viscera portion represents a putrescent disposal problem.

Utilization of scallop viscera as silage, much like that developed for waste fish and fish offal (3,4), could represent a practical solid waste treatment option which offers the additional benefit of a protein feed supplement for production of swine. Silage made with fish is a semi-liquid product made from whole fish and (or) fish parts liquefied by the action of

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naturally occurring indigenous enzymes in the fish aided by the addition of organic acids or acidifying bacteria. The final product is preserved by low acidity and does not have objectionable odors or require refrigerated storage.

The development of swine feed ingredients that have potential to reduce feed costs that disadvantage the Florida swine producer is needed. Feed costs represent 40 to 70% of the cost of swine production (5). Thus it is hypothesized that viscera from Florida scallop processing will produce a silage that can be used as a protein feed supplement for swine production. Specifically, the objectives of this study were 1) to determine if solid wastes resulting from scallop processing can be ensiled and 2) to evaluate the feeding value of scallop viscera silage and its effect on resulting carcass quality when included in diets for growing-finishing swine.

MATERIALS AND METHODS

The viscera was collected as needed after mechanical shucking of the scallop shellfish at Southern Seafood, Inc., Port Canaveral, FL. The viscera was refrigerated as soon as possible after shucking and transported to the Food Science Department of the University of Florida in insulated containers. A representative viscera sample was collected, frozen and later analyzed. For analyses this sample was freeze-dried, ground and sent to a commercial laboratory[6] to determine the quantity of crude protein, amino acids, crude fat (ether extract), total mineral matter (ash), calcium, phosphorus, potassium, sodium, cloride, magnesium, copper, iodine, iron, manganese, selenium and zinc.

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[6]Woodson-Tenent Laboratories, Inc., Memphis, TN.

Recommended AOAC (6) procedures were used except for the amino acid tryptophan in which the procedure described by Spies (7) was used. In addition, levels of cadmium, arsenic and mercury were also determined (6).

Ensiling trials. Three ensiling trials were conducted. The first involved formic acid addition, the second involved bacterial fermentation and the third was a repeat of formic acid addition. Trial 1 was done with one batch of viscera and trials 2 and 3 were done simultaneously with another batch. Before ensiling, the wet viscera was minced using a pressure belt system fish debonder[7] with a 5 mm head. For the formic acid addition trials, 3 1/2% (w/w) of formic acid (92%) was mixed with minced viscera. The bacteria fermentation trial involved the use of a commercial[8] preparation of lactic acid producing bacteria with an available carbohydrate source - 10% added molasses, mixed with the minced viscera. Before mixing with the viscera-molasses mix, the bacteria was prepared as recommended by the manufacturer[8] and added at a rate of 2.2 ml bacteria preparation per kg of viscera-molasses mixture.

In each of the three ensiling trials, eight, 8 kg lots of viscera silage were prepared. After mixing, the silages were placed in 3 mil plastic bags and sealed. These bags were placed in plastic containers and stored at room temperature (22 to 27° C). Before sealing, four pooled day 0 samples were collected

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[7]Baader, model 694, North American Corp., New Bedford, MA.

[8]Stabisil, Triple F Feeds, Inc., Des Moines, IA.

from all containers within the three trials, and frozen for future analyses. On each of days 3, 7, 14, and 28 after the start of ensiling, two containers were opened and two representative samples were obtained from each container. These samples were also frozen for future analyses.

For analyses, two of the four samples collected (one from each container) in each trial on each day were thawed, and dry matter content and pH were determined using conventional procedures. For the second formic acid ensiling trial only, soluble nitrogen was also determined using the procedure as described by Haard et al. (8). Also for the second formic acid trial only, the other two samples collected on each day were freeze-dried and ground. These samples were analyzed for crude protein, ether extract, ash, and amino acids as described above.

Swine feeding trial. For the feeding trial, the formic acid ensiling procedure was used to ensile the scallop viscera. The ensiling procedure used was similar to that outlined above except larger, 16 kg lots were prepared. The silage was used after 7 or 14 days of storage at 22 to 30° C. A total of three different batches of silage were prepared. Duplicate samples of the silages were taken before sealing and after opening for each batch, frozen and saved for future analyses. One sample of each batch at each collection time was analyzed for dry matter and pH as described above and the other was freeze-dried and ground. The freeze-dried samples were analyzed for crude protein, amino acids, ether extract, and ash as described before.

The swine feeding trial used pigs that were finished to market size (growing-finishing swine)and was conducted at the

Marianna AREC Swine Unit. Forty-eight crossbred pigs, with an average initial weight of 29 kg, were divided among four dietary treatments. The four treatments consisted of corn-based diets with three diets each containing a different level of viscera silage - 4, 8, and 12%, and a control diet with no added silage. The pigs were allotted by sex, litter origin and initial weight into pens of four pigs each. Each pen was assigned a treatment at random within each of three replicates (blocks). Pigs were housed in a semi-enclosed building in 2 x 4.5 m pens with solid concrete floors. Each pen was equipped with an automatic watering device.

All diets were formulated following NRC (9) guidelines. The diets were adjusted (air-dry basis) to contain 0.75% lysine during the growing phase (29 to 56 kg body weight) and 0.60% lysine during the finishing phase (56 to 102 kg). The viscera silage was assumed to contain 6% lysine (dry matter basis) and 75% moisture; NRC (9) lysine and dry matter values were used for soybean meal and corn. Composition of experimental diets is given in tables 1 and 2. A 50% propionic acid additive[9] was added at a rate of 0.5% of diet to prevent spoilage of the mixed diets, especially those containing silage. Feed was available to the pigs at all times in self feeders and the amount of feed fed to each pen was recorded. Samples of diets were taken, frozen and saved for future analyses. The diets were analyzed for dry matter, crude protein, ether extract, crude fiber and ash as described before.

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[9]Monoprop, Antitox Corp., Buford, GA.

At pig weights of about 40 to 45 kg and again at 75 to 80 kg, apparent dry matter and crude protein digestibilities of the experimental diets were determined by using chromic oxide, an indigestible indicator, added at a rate of 0.2% to the experimental diets. Pigs were adjusted to the diets containing the indicator for 5 days after which daily "grab" fecal samples were collected from at least three pigs per pen for each of four consecutive days and frozen for subsequent analyses. This procedure was done with all three replicates. For analysis, the fecal samples were dried, ground, pooled by pen and a sample taken. Both feed and fecal samples were analyzed for chromic oxide (10), crude protein (6) and dry matter (6), and the apparent digestibilities were calculated.

When pigs averaged 102 kg, the feeding phase was terminated. All pigs from each pen were trucked to the University of Florida Meats Lab in Gainesville, and slaughtered for carcass, fatty acid and sensory evaluations. After chilling, each carcass was evaluated for fat firmness, backfat thickness, amount of lean, and loin eye size, color, marbling and firmness using standard procedures (11). A section of the loin (7th to 10th rib) was obtained, frozen and saved for sensory analysis.

For fatty acid analysis, the subcutaneous fat (all layers) was removed opposite the eighth to tenth rib area, vacuum packed and frozen. Preparation and analysis was the same as that described in Myer et al. (12). Fatty acid analysis was done on samples from two representative pigs per pen only.

For sensory analysis, the loin section was divided into chops 2.5 cm thick. The chops were thawed for 18 hr at 2 to 4°

C, broiled to an internal temperature of 75° C and evaluated using a trained sensory panel following recommended AMSA procedures (13). The sensory panel evaluated the chops for juiciness (8 = extremely juicy, 1 = extremely dry), overall tenderness (8 = extremely tender, 1 = extremely tough) and off-flavor (6 = none detected, 1 = extremely intense off-flavor). Loin chops for Warner-Bratzler shear analysis were also thawed for 18 hr at 2 to 4° C and broiled to an internal temperature of 75° C (13). After chops were cooled to 21° C, as many cores (1.27 cm diameter) as possible were removed parallel to fiber orientation from two chops and sheared on a Warner-Bratzler shearing device[10] for tenderness analysis.

Performance (average daily gain, average daily feed intake and feed-to-gain ratio) and apparent digestibility data were determined on a per pen basis. Carcass, fatty acid and sensory evaluation data were determined on a per pig basis. Data were analyzed by analysis of variance for randomized-complete-block trial.

RESULTS AND DISCUSSION

Composition of scallop viscera. The nutrient composition of scallop viscera is given in table 3. On a moisture free basis, the viscera was found to be quite high in protein. This viscera was also high in the essential amino acid lysine---usually the most limiting component in the protein of grain-soybean meal-based diets for swine. The viscera also had high levels of the other essential amino acids with the possible exception of tryptophan. While the level of tryptophan was relatively high in

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[10]G. R. Electric Co., Manhattan, KS.

the viscera, in relation to the other essential amino acids, it was fairly low. Corn-based diets for swine are usually second limiting in tryptophan after lysine (9).

Scallop viscera was found to be relatively low in fat content. This may be beneficial as a high content of fat (oil) of marine origin in the diet for swine may give a 'fishy' taint to the pork (14). This has been reported previously when pigs were fed diets containing high levels of fish silage having a high fat (oil) content (3,4).

Levels of the heavy metals arsenic, cadmium and mercury in the viscera are also presented in table 3. Of the three metals, cadmium was found to be relatively high. Cadmium toxicity may be a potential problem for swine if the viscera is used at high levels in the diet and fed over a long period of time. To prevent toxicity to the pig and to minimize carryover into the pork, it is generally recommended that the cadmium content of swine diets not exceed 0.5 ppm (15). Fortunately, the cadmium content of cereal grains and soybean meal is very low, often less than 0.1 ppm (15). Thus, viscera can be included in the diet up to a level of 4% (dry basis) without exceeding the 0.5 ppm safety limit. At the 4% level in a typical corn-soybean meal-based diet, the viscera could contribute about 25 to 40% of the total dietary lysine.

Ensiling trials. Of the two ensiling procedures evaluated, formic acid addition proved to be the most successful. The formic acid silages reached a safe pH of 3.3 to 3.7 immediately (table 4) and no objectionable odor was noted on any sampling day. The formic silages progressively became more liquid much

like that previously reported for formic acid treated fish silages (3,4,8). On the other hand, problems were encountered with the bacteria treated silages. The pH initially dropped within 7 days to a safe level of 4.2 indicating that the bacteria were converting the available carbohydrate to lactic acid. However, excessive gas formation occurred causing the seals to be broken and subsequently the silages spoiled. The cause of the gas production is unknown be may be due to the indigenous bacteria and (or) yeasts on the viscera. Van Wyk et al. (16) reported problems encountered with gas production by yeasts in bacteria fermentation ensiling trials with fish processing wastes. This gas production did not occur with the formic acid silages in our trials.

Because of the success with formic acid addition, more detailed nutrient composition was desired and obtained on samples from the second formic acid ensiling trial (trial 3) and is presented in table 5. Nutrient analyses of the silages indicated that on a dry matter basis, the silages were quite high in crude protein much like that observed in the freeze-dried sample of raw viscera (table 3). The content of lysine was also quite high. There was a 7 1/2 fold increase in soluble nitrogen from day 0 to day 28, indicating some breakdown of amino acids and other nitrogen containing compounds. This increase in soluble nitrogen was most apparent in the initial days of the ensiling process. A similar finding has been observed with fish silages (8). However, only minimal nutrient deterioration was noted even after 28 days. Of the essential amino acids, tryptophan and histidine are thought to be the least stable in formic acid treated fish

silages (3). In our trial there was a trend for some degradation of these two amino acids with time; however, the losses were not any greater than that observed for the other amino acids. Because of the slight trend of increased nutrient deterioration from 14 to 28 days observed in our trials, maximum nutrient concentration in formic acid-treated viscera silage appeared to occur between 3 to 14 days after the start of ensiling process at room temperature.

Swine Feeding Trial. Nutrient composition of the formic acid silages at the start and after ensiling is presented in table 6. Nutrient compositions of the other two major dietary components, corn and soybean meal, are also presented in table 6. The viscera silages used in the feeding trial were lower in crude protein and amino acids than the silages in the ensiling trials (dry matter basis). The reasons for these differences are not known. However, the viscera used in the ensiling trials and swine feeding trials were obtained at different times of the year---fall for ensiling trials vs spring for the feeding trial. In addition, the viscera used for the ensiling trials was collected during a period when scallops were relatively plentiful whereas the viscera for the feeding trial was obtained during a period when scallops were relatively scarce.

Performance summary of the growing-finishing trial is presented in table 7. The addition of formic acid scallop viscera silage at 4, 8 or 12% of the diet did not influence ($P>.10$) pig growth rate as measured by average daily gain. This lack of an effect on average daily gain was noted in both the grower and finisher phases. However, the addition of viscera

silage to the diet had a linear detrimental effect ($P<.05$) on feed-to-gain ratio; slightly more feed was required per unit of gain over the entire growing-finishing period as the level of viscera silage in the diet increased. This detrimental effect on feed-to-gain was noted in both the grower ($P<.05$) and finisher ($P<.10$) phases. The reason for this detrimental effect may be due to the decreasing level of analyzed crude protein in the diets as the content of viscera increased (tables 1 and 2). Thus at the higher viscera levels, the diets may have been marginally deficient in amino acids (protein), in particular lysine, which could result in higher feed-to-gain ratios. The diets were formulated to be of similar protein content. The reason for the decrease with increasing viscera level in the diets may be due to lower than expected protein (amino acid) and higher than expected moisture content of the viscera silages (table 6). Comparisons of protein consumed-to-gain ratios, which would correct for these differences in dietary protein, indicated no difference ($P>.10$) due to the addition of viscera silage to the diet (table 7). This lack of a difference was true for both grower and finisher phases. This finding would indicate that the protein nutritive value of the diets containing either 4, 8 or 12% viscera silage were similar to the diet containing no viscera silage.

Apparent digestibilities of dry matter and crude protein of the grower and finisher diets used in the growing-finishing swine trial are presented in table 8. The addition of 4, 8 or 12% viscera silage to the diet had no effect ($P>.10$) on dry matter or crude protein digestibility of either the grower or finisher

diets. This lack of an effect on dry matter or, especially crude protein digestibility, agrees with the similarity of daily gain and protein-to-gain ratios observed in the feeding phase. Thus, it appears that the protein nutritive value of the viscera silage for swine when fed at levels of up to 12% of the diet is comparable to the protein nutritive value of a soybean meal-corn based diet. This finding is in agreement with that usually observed with fish silages fed to swine (3).

Summary of carcass characteristics is presented in table 9. The addition of scallop viscera silage to the diet had no effect on resulting carcass backfat thickness, length, loin eye area or percentage of the four main lean cuts. Likewise, there were no differences in backfat fatty acid composition which are summarized in table 10. This latter finding was expected since the level of fat (oil) in viscera silage was quite low (table 6).

Meat quality and compositional characteristics of the loin and sensory characteristics of broiled loin chops is summarized in table 11. Loin lean color, firmness, texture, and fat and moisture contents were not affected ($P>.10$) by dietary treatment. Marbling score, however, did show a slight but linear increase ($P<.10$), indicating increased visible marbling, as the amount of viscera increased in the diet. The reason for this increase is not known.

The consumption of viscera silage by the pigs had no effect ($P>.10$) on palatability characteristics of broiled loin chops as determined by a trained sensory panel (table 11). The values indicated that the chops were acceptable in tenderness and had no

detectable off-flavor. The consumption of the viscera silage also had no effect on shear force value of the loin chop or on average cooking losses. The lack of differences in palatability indicated no problem existed with the pork having a "fishy" taint, a problem that has been observed previously with pigs fed high levels of fish silage (3,4). The "fishy" taint is due to the relatively high fat (oil) content of the fish silages. Fish oil and oil from many other marine animals is high in unique long chain unsaturated fatty acids and some of these fatty acids can show up in the pork fat, thus giving the pork a "fishy" taste (14). Again the reason for lack of differences is probably due to the low oil content of the viscera silage. The lack of differences observed in backfat fatty acid composition further supports this finding.

CONCLUSION

The ensiling of wet scallop viscera with formic acid and its utilization as a supplemental protein source for swine diets may offer a practical means of disposal of the viscera. In our initial trial, the viscera silage supported good growth when included at levels of 4, 8 or 12% in corn-soybean meal-based diets. The pork from these pigs was found by a trained sensory panel to be acceptable.

It should be reemphasized that the viscera silage was quite high in moisture content. This high moisture level would limit its use in most swine feeding systems used in the United States. In the 12% diet used in our swine trial, the viscera contributed only 3% of the dietary dry matter and just 14% of the total

dietary protein. The rest of the dietary protein was provided by the soybean meal and corn. Thus to really be effective, viscera silage would best be suited in liquid swine feeding systems in which higher levels could be used.

SUMMARY

A study was conducted to determine if solid wastes resulting from scallop processing can be ensiled (preserved and stabilized) and to evaluate the feeding value of this silage and its effect on resulting carcass quality when included in diets for growing-finishing swine. The viscera, on a moisture-free basis, was found to be quite high in protein (80 to 90%) and in all of the essential amino acids except possibly tryptophan. The viscera was rather low in fat (oil) content; however, it contained a very high level of moisture (74 to 82%). The viscera was successfully ensiled by mixing 3 1/2% (w/w) formic acid with minced wet viscera and placing the mixture in airtight containers. Only minimal nutrient deterioration was noted in the silage after 28 days of sealed storage at room temperature. The addition of 4, 8 or 12% silage in diets for growing-finishing swine (29 to 102 kg) resulted in no detrimental effect on growth, feed intake or protein utilization. The inclusion of viscera silage in the diets also had no detrimental effect on resulting carcass composition, backfat fatty acid composition or on the palatability of broiled loin chops as determined by a trained taste panel. Thus the ensiling of wet scallop viscera with formic acid and its subsequent utilization as a protein feed supplement for swine diets may offer a practical means of disposal of the viscera.

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TABLE 1. PERCENTAGE COMPOSITION OF GROWER DIETS (SWINE TRIAL)

Ingredient	Amount of viscera silage in diet, % 0	4	8	12
Viscera silage[a]	--	4.00	8.00	12.00
Ground corn	78.55	77.05	75.55	74.05
Soybean meal (48%)	18.00	15.50	13.00	10.50
Constants[b]	3.45	3.45	3.45	3.45
	100.00	100.00	100.00	100.00
Calculated composition[c]:				
Dry matter	88	85	83	80
Lysine	0.75	0.73	0.71	0.69
Lysine (dry matter basis)	0.85	0.86	0.86	0.86
Calcium	0.72	?	?	?
Phosphorus	0.56	?	?	?
Analyzed composition[d]:				
Dry matter	89.8	87.3	85.3	83.0
Crude protein	17.4	16.6	15.6	15.0
Crude protein (dry matter basis)	19.4	19.0	18.3	18.0
Crude fat	3.1	3.0	2.9	2.7
Crude fiber	2.2	2.2	2.1	2.3
Ash	4.4	4.4	4.4	4.0

[a]Formic acid treated viscera silage.

[b]Provided the following to the diet: dicalcium phosphate, 1.25%; calcium carbonate, 1.00%; salt, 0.30%; vitamin premix, 0.20%; trace mineral premix, 0.05%; antibiotic premix, 0.15%; and mold inhibitor (50% propionic acid), 0.50%. Vitamin premix provided the following per kilogram of diet: vitamin A, 4400 IU; vitamin D_3, 700 IU; vitamin E, 18 IU; vitamin K activity, 2.6 mg; riboflavin, 3.5 mg; d-pantothenic acid, 14 mg; niacin, 18 mg; choline chloride, 440 mg; vitamin B_{12}, 18 µg; and selenium, 0.09 mg. Trace mineral prexmix provided the following per kilogram of diet: zinc, 100 mg; iron, 50 mg; manganese, 22 mg; copper, 5 mg; and iodine, 0.8 mg. Antibiotic premix provided 55 mg nitrofurazone per kilogram of diet.

[c]Calculated using National Research Council table values (1979) with viscera silage containing 6.0% lysine (DM basis) and 75% moisture.

[d]Average of analysis of two separate samples.

TABLE 2. PERCENTAGE COMPOSITION OF FINISHER DIETS (SWINE TRIAL)

Ingredient	Amount of viscera silage in diet, % 0	4	8	12
Viscera silage[a]	--	4.00	8.00	12.00
Ground corn	84.00	82.33	80.67	79.00
Soybean meal (48%)	13.00	10.67	8.33	6.00
Constants[b]	3.00	3.00	3.00	3.00
	100.00	100.00	100.00	100.00
Calculated composition[c]:				
Dry matter	88	85	83	80
Lysine	0.61	0.59	0.57	0.56
Lysine (dry matter basis)	0.69	0.69	0.69	0.70
Calcium	0.61	?	?	?
Phosphorus	0.53	?	?	?
Analyzed composition[d]:				
Dry matter	88.0	86.0	83.9	82.0
Crude protein	14.2	13.7	13.0	12.4
Crude protein (dry matter basis)	16.1	15.9	15.5	15.2
Crude fat	3.1	3.0	2.9	2.7
Crude fiber	2.2	2.5	2.5	2.2
Ash	4.1	4.0	3.8	3.7

[a]Formic acid treated viscera silage.

[b]Provided the following to the diet: dicalcium phosphate, 1.20%; calcium carbonate, 0.80%; salt, 0.30%; vitamin premix, 0.15%; trace mineral premix, 0.05%; and mold inhibitor (50% propionic acid), 0.50%. Vitamin premix provided the following per kilogram of diet: vitamin A, 3300 IU; vitamin D_3, 525 IU; vitamin E, 14 IU; vitamin K activity, 2.0 mg; riboflavin, 2.6 mg; d-pantothenic acid, 10 mg; niacin, 14 mg; choline chloride, 330 mg; vitamin B_{12}, 14 µg; and selenium, 0.07 mg. Trace mineral prexmix provided the following per kilogram of diet: zinc, 100 mg; iron, 50 mg; manganese, 22 mg; copper, 5 mg; and iodine, 0.8 mg.

[c]Calculated using National Research Council table values (1979) with viscera silage containing 6.0% lysine (DM basis) and 75% moisture.

[d]Average of analysis of three separate samples.

TABLE 3. NUTRIENT AND HEAVY METAL COMPOSITION OF SCALLOP VISCERA - DRY MATTER BASIS[a]

Item	Amount/units
Crude protein (N × 6.25)	83.9%
Crude fat	3.5%
Total mineral matter (ash)	9.4%
Calcium	2.5%
Phosphorus	0.80%
Potassium	0.25%
Sodium	0.54%
Chloride	0.66%
Magnesium	0.27%
Copper	6 ppm
Iodine	<20 ppm
Iron	190 ppm
Manganese	13 ppm
Selenium	2.4 ppm
Zinc	85 ppm
Essential amino acids:	
Lysine	6.34%
Tryptophan	0.48%
Threonine	3.44%
Methionine	2.30%
Isoleucine	3.98%
Leucine	6.07%
Valine	3.19%
Histidine	3.67%
Phenylalanine	3.12%
Arginine	7.97%
Non-essential amino acids:	
Cystine	1.17%
Tyrosine	3.95%
Aspartic acid	6.59%
Serine	1.25%
Glutamic acid	12.55%
Proline	4.51%
Alanine	6.77%
Hydroxyproline	1.95%
Heavy metals:	
Arsenic	5 ppm
Cadmium	10 ppm
Mercury	<0.3 ppm

[a]Fresh scallop viscera contains 75 to 85% water.

TABLE 4. MOISTURE CONTENT AND pH OF SCALLOP VISCERA SILAGES (ENSILING TRIALS)

Item		Trial 1 Formic acid silage	Trial 2 Bacteria silage	Trial 3 Formic acid silage
Day[a] 0	pH	3.7	6.8	3.3
	Moisture, %	84.9	77.8	82.2
Day 3	pH	3.7	4.6	3.4
	Moisture, %	83.4	77.0	80.4
Day 7	pH	3.6	4.4	3.4
	Moisture, %	83.6	75.8	79.8
Day 14	pH	3.8	4.2	3.5
	Moisture, %	85.4	77.0	80.3
Day 28	pH	3.8	4.2	3.6
	Moisture, %	84.4	75.0	80.0

[a]Day sample collected after start of ensiling.

TABLE 5. PERCENTAGE COMPOSITION OF FORMIC ACID TREATED SCALLOP VISCERA SILAGE - DRY MATTER BASIS (ENSILING TRIAL 3)

Item	Sampling day 0	3	7	14	28
Crude protein	91.9	92.3	91.7	91.8	89.2
Crude fat	1.2	1.4	1.8	1.8	1.6
Ash	4.6	4.7	4.8	5.0	4.7
Selected amino acids:					
Lysine	5.90	6.24	5.78	5.53	5.42
Tryptophan	.49	.50	.55	.60	.48
Threonine	3.69	3.74	3.70	3.48	3.52
Methionine	2.22	2.69	2.77	2.57	2.39
Cystine/2	.83	.82	.82	.75	.69
Histidine	1.51	1.57	1.46	1.41	1.35
Soluble N, mg/g[a]	4	15	21	27	30

[a]20% dry matter basis.

TABLE 6. COMPOSITION OF FORMIC ACID TREATED VISCERA SILAGES AND OTHER DIETARY INGREDIENTS USED IN SWINE FEEDING TRIAL.

Item	Viscera silages: Start Mean[a]	Viscera silages: Start Range	Viscera silages: When used Mean[a]	Viscera silages: When used Range	Soybean meal (48%)[c]	Corn[c]
Dry matter, %	21.0	16.4-23.9	18.5	15.5-21.1	89.6	88.4
pH	3.8	3.4-4.2	3.8	3.4-4.1	NA[d]	NA
Composition, % (dry matter basis):						
Crude protein	76.2	69.0-82.3	77.7	71.0-83.7	57.1	10.4
Crude fat	1.9	1.8-2.1	2.4	2.2-2.6	1.0	4.0
Ash	14.4	9.6-19.8	14.2	9.8-19.4	8.0	1.5
Lysine	4.78	4.31-5.14	5.16	4.36-5.73	3.26	0.36
Tryptophan	0.49	0.43-0.56	0.54	0.47-0.60	0.72	0.08
Threonine	3.56	3.08-4.11	3.61	3.21-3.92	2.53	0.48
Methionine	2.17	1.82-2.41	2.25	1.89-2.53	0.94	0.17
Cystine	0.83	0.67-0.96	0.88	6.77-0.94	0.82	0.15
Histidine	1.80	1.69-2.00	1.70	1.55-1.91	1.78	0.35

[a]Average of three analyses - each representing a different batch.

[b]Average of five analyses - two separate samples of the first batch (for grower diets), two separate samples of the second batch (for finisher diets) and one of the third batch (finisher diets).

[c]Average of analyses of two separate samples (one used for grower diets and the other for finisher diets).

[d]Not applicable.

TABLE 7. PERFORMANCE OF GROWING-FINISHING SWINE FED DIETS CONTAINING SCALLOP VISCERA SILAGE[a].

Item[b]	Amount of viscera silage in diet, % 0	4	8	12	SE[c]
Grower phase (29 to 56 kg)					
Avg. daily gain, kg	0.84	0.90	0.90	0.85	.03
Avg. daily feed intake, kg	2.09	2.27	2.28	2.26	.07
Feed/unit gain[d], kg/kg	2.49	2.53	2.52	2.67	.05
Protein consumed/unit gain, kg/kg	0.43	0.43	0.41	0.43	.01
Finisher phase (56 to 102 kg)					
Avg. daily gain, kg	0.91	0.90	0.91	0.86	.03
Avg. daily feed intake, kg	2.99	2.90	3.04	2.94	.08
Feed/unit gain[e], kg/kg	3.33	3.27	3.40	3.45	.05
Protein consumed/unit gain, kg/kg	0.47	0.46	0.47	0.46	.01
Overall (29 to 102 kg)					
Avg. daily gain, kg	0.89	0.90	0.91	0.86	.03
Avg. daily feed intake, kg	2.65	2.66	2.77	2.68	.07
Feed/unit gain[d], kg/kg	3.03	2.99	3.08	3.16	.03
Protein consumed/unit gain, kg/kg	0.46	0.45	0.45	0.45	.01

[a]Three pens per treatment with four pigs per pen.

[b]Feed consumption of the diets were adjusted to a constant dry matter intake - that of the 0% diet.

[c]$n = 3$.

[d]Linear effect ($P<.05$).

[e]Linear effect ($P<.10$).

TABLE 8. APPARENT DIGESTIBILITY COEFFICIENTS (%) OF SWINE DIETS CONTAINING SCALLOP VISCERA SILAGE[a].

Item	Amount of viscera silage in diet, % 0	4	8	12	SE[b]
Grower diets:					
Dry matter	82.9	82.0	82.1	82.7	0.3
Crude protein	76.6	75.7	76.3	75.6	0.5
Finisher diets:					
Dry matter	84.9	84.8	84.9	84.8	0.2
Crude protein	77.7	78.0	78.6	77.6	0.5

[a]Indicator method; five day adjustment followed by four day collection period. Three pens per treatment with four pigs per pen, collections from at least three pigs per pen each collection day; approximate pig weights, 35 to 45 kg - grower and 70 to 80 kg - finisher.

[b]n = 3.

TABLE 9. CARCASS CHARACTERISTICS FROM GROWING-FINISHING SWINE FED DIETS CONTAINING SCALLOP VISCERA SILAGEa.

Item	Amount of viscera silage in diet, % 0	4	8	12	SE
Avg. backfat[b], cm	3.1	3.1	3.0	3.2	0.1
Carcass length[b], cm	82	80	80	79	0.2
Loin eye area[b], cm^2	29	29	28	30	1.3
Four lean cuts, %	59	60	59	59	0.7

[a]Each mean is based on information from 12 animals.

[b]Adjusted to 100 kg.

TABLE 10. BACKFAT FATTY ACID COMPOSITION AND CARCASS FAT FIRMNESS OF SWINE THAT CONSUMED DIETS CONTAINING SCALLOP VISCERA SILAGE[a].

Item	Amount of viscera silage in diet, % 0	4	8	12	SE
Saturated fatty acids, %					
C12	3	3	3	3	0.1
C14	5	5	5	4	0.1
C16	24	24	24	24	0.4
C18	13	13	13	13	0.3
Unsaturaded fatty acids, %					
C16:1	4	4	4	4	0.1
C18:1	36	37	37	37	0.4
C18:2	10	10	10	10	0.4
C20:1	2	2	2	2	0.1
Unsat'd:sat'd ratio[b]	1.2	1.2	1.2	1.2	0.1
Fat firmness score[c]	1.3	1.6	1.5	1.6	0.2

[a]Each mean is based on the information from six animals.

[b]Ratio of C16:1 - C20:1 to C12 - C18 fatty acids reported here.

[c]Scores: 1 = firm; 2 = slightly firm; 3 = slightly soft; 4 = soft, oily.

Table 11. QUALITATIVE COMPOSITIONAL AND SENSORY CHARACTERISTICS AND SHEAR FORCE VALUES OF LOIN CHOPS FROM SWINE THAT CONSUMED DIETS CONTAINING SCALLOP VISCERA SILAGE[a].

Item	Amount of viscera silage in diet, % 0	4	8	12	SE
Marbling score[b,i]	2.3	2.5	2.7	2.8	0.2
Lean color score[c]	2.6	2.9	2.9	2.8	0.2
Lean firmness score[d]	3.0	2.5	2.7	2.7	0.2
Lean texture score[e]	2.8	2.5	2.4	2.6	0.2
Fat, %	4.0	4.5	4.2	4.6	0.3
Moisture, %	73.2	72.8	73.4	73.2	0.4
Sensory scores of broiled chops:					
Overall tenderness[f]	6.7	6.3	6.5	6.7	0.2
Juiciness[g]	5.4	5.3	5.4	5.6	0.2
Off-flavor[h]	5.6	5.6	5.7	5.6	0.1
Shear force, kg/1.2 cm	3.6	3.8	3.4	3.4	0.2
Cooking loss, %	34.9	33.9	33.9	34.7	1.1

[a]Each mean is based on information from 12 animals.

[b]Scores: 1 to 5; 2 = slight; 3 = small.

[c]Scores: 1 to 5; 2 = gray; 3 = light pink.

[d]Scores: 1 to 5; 2 = firm; 3 = slightly firm.

[e]Scores: 1 to 5; 2 = fine; 3 = slightly fine.

[f]Scores: 1 to 8; 6 = moderately tender; 7 = tender.

[g]Scores: 1 to 8; 5 = slightly juicy; 6 = moderately juicy.

[h]Scores: 1 to 6; 5 = just detectable, threshold; 6 = none detected.

[i]Linear effect ($P<.10$).