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THE USE OF FORMIC ACID PREPARED FISH SILAGE MADE FROM SHRIMP BY-CATCH IN THE DIETS OF FATTENING PIGS

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The growth and performance of crossbred Yorkshire x Duroc x Hampshire pigs fed 3 levels of fish silage in their diets were compared with those of similar pigs fed a control diet containing local fish meal. The silage, produced using formic acid (85%) at a concentration of 3.5% (v/w of minced fish), was fed at 3 levels calculated to supply 5,10 and 15% dry matter from the silage. In the control diet 10% dry matter was supplied from fish meal. All diets were balanced nutritionally. The performance of all pigs on trial was considered satisfactory. Pigs fed silage had **significantly greater** daily liveweight gains than pigs fed the control diet ($P < 0.05$), but there were no significant differences between the groups fed silage. All the pig carcasses were marketed commercially and no reports of unacceptable qualities were noted or reported to the company concerned.

Key words: shrimp by-catch, ensilage, formic acid, pig feeding.

During commercial shrimping operations, large quantites of fish and other marine organisms are caught incidentally in the trawl nets. This by-catch is generally discarded at sea and represents a considerable wastage of fishery resources. Mexican shrimp by-catch comprises a complex mixture of small demersal fish(Young and Romero 1979). Although considerable progress has been made with respect to the development of food products for human consumption from this material (Young 1980), in some circumstances recovery of by-catch as human food may be problematical due to handling difficulties and sporadic supply of raw materials. Thus attention has been devoted to the use of by-catch for the preparation of an acid-ensiled animal feed raw material. Acid preservation using mineral acids was first proposed in Sweden in the 1940s though subsequent developments reviewed by Tatterson and Windsor(1974),and Disney et al (1977) favour the use of organic acid such as formic acid, since they permit the preservation of materials at higher pHs and do not need to be neutralised before feeding to livestock.

The fish silage process has been studied in many countries of the world (Petersen 1953; McBride et al 1961 ; Krishnaswamy et al 1965; Disney et al 1978b and Disney 1979) and would appear to have practical applications, especially in circumstances where supplies of raw materials are available, fuel costs are high and maintenance and management of conventional processing is difficult.

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Preliminary studies have demonstrated that mixed by-catch fish, when minced, may be readily liquified by treatment with a minimum concentration of 2.5% (v/w) formic acid (Crean et al 1975). Such treatment lowers the pH of the mixture to 3.5 - 4.5 encouraging enzymatic breakdown of the fish protein and preventing spoilage bacteria from becoming active. Having demonstrated the feasibility of preparing liquid silage from shrimp by-catch fish, information was required on the suitability of the product as a component of feeds for monogastric animals. Since México imports significant quantities of oil seed cake and fish meal for animal feed purposes, the increased use of locally produced protein feed would contribute to a saving of foreign exchange.

The silage product may be prepared in a liquid or dried form (Disney et al 1978 a), although liquid feeding systems can have advantages over dry feeding methods, including reduced labour costs and improved performance (Bostocci et al 1976) in addition to reduced processing costs. It is therefore logical to consider the use of wet silage in liquid feeding systems.

In experiments carried out by other workers, pigs fed diets containing silages produced from both oily and non-oily fish have achieved satisfactory levels of performance, but problems with taint can arise from oily fish. In order to prevent taint from fish oils Carpenter (1971) recommended that the level of these oils in pig diets should not exceed 1% . This limit was corroborated by the work of Smith (1977) when herring silage, containing about 40% oil in the dry matter did not cause taint when included at 2.4% of dry matter in the diet, but it was noted at 5.1%. No taint problems were observed by Disney et al (1978b) when this limit of oil inclusion was also observed in experiments on the utilisation of formic acid preserved tuna offal by growing pigs.

Materials and Methods

Preparation of silage: Silage was prepared from shrimp by-catch collected from shrimping vessels based at Guaymas, Sonora, Mexico. The fish was firstly separated from crustacean, elasmobranch, poriferan, echinoderm, molluscan and toxic fish species, and then washed.

Mincing of the fish was effected through a 10mm screen using a Paoli 25 HP mincer. Formic acid (85%) was added to the minced fish at a concentration of 3.5% (v/w of minced fish) and the mixture was stirred regularly during the following 24 hour period using a wooden paddle. After standing for 4 days the end product was stored in high density polyethylene drums ready for transportation to the feeding trial site.

Preparation of feeds: The feeding trial was designed to establish the response of growing pigs to diets containing silage at 0, 5, 10 and 15 % of the dry matter content of the final diet. The amount of wet silage required to provide these levels was calculated accordingly from the measured DM content of the silage. In the 0% diet, local fish meal was included to supply the same amount of fish protein as the 10% silage diet.

The remainder of the diets were formulated to the UK Agricultural Research Council's recommendations on nutrient requirements for growing pigs (ARC 1967) using milo (sorghum), extracted soya bean meal, wheat feed, limestone, calcium orthophosphate and salt (NaCl).

A vitamin trace element premix was included in all diets.

In the fish silage treatments the levels of L-tocopherol (vitamin E) and thiamine were added at twice normal levels. Additional vitamin E was provided because of the known metabolic antagonism between certain fish oils and L-tocopherol There have also been suggestions that higher intakes of anti-oxidants may assist in stabilising the carcass fat which could be beneficial in this situation. Additional thiamine was provided because it is recognised that many fish contain thiaminases, and the extent to which these are inactivated during the silage making process has not been fully quantified.

Method of feeding: Twenty castrated male and 20 female crossbred Duroc x Yorkshire x Hampshire pigs of approximately 20 kg liveweight were selected for the trial and separated by weight into 8 pens of 5 pigs of similar sex and weaning weight. The pens were arranged alternately male and female along the pig house. The diets were allocated to pens such that the various treatments were as widely distributed throughout the pens as possible and were fed with water so that the final water to dry matter ratio was approximately 1:1.

The pigs were group weighed once a week and the weight of food provided for the following seven days calculated using a feeding scale designed to supply the same quantities of nutrients as proposed by the ARC (ARC 1967).

The pigs were fed once a day and records kept of food consumption and group mean weight until each pig reached 90 kg liveweight. As each pig reached this weight, it was individually weighed, sent for slaughter and marketing by local commercial outlets.

Statistical analysis was carried out using analysis of variance and differences between treatments carried out by least significant differences.

Results

Composition of silage and diets: The proximate composition of fish silage is shown in Table 1 and the amino acid composition in Table 2. As

Table 1:
Composition of fish silage (Guaymas)

Moisture content of fresh material	73.3%
Composition of dry matter	Percentages
Dry matter	91.3
Crude protein	67.0
Ash	21.0
Ether extract	5.6
Calcium	4.7
Phosphorus (total)	2.6
Salt (NaCl)	2.7
Digestible energy (calculated)	13.25 MJ/kg

Table 2:
Amino acid composition of the fish silage (Guaymas)

Amino acids as g/16g nitrogen	
Aspartic acid	8.9
Threonine	4.0
Serine	4.4
Glutamic acid	12.6
Proline	5.6
Glycine	8.3
Alanine	6.2
Valine	4.3
Cystine	1.2
Methionine	2.2
Isoleucine	3.9
Leucine	6.6
Tyrosine	2.9
Phenylalanine	4.1
Lysine	7.8
Histidine	1.9
Arginine	7.0

would be expected the composition of the dry matter is similar to fish meal. Digestible energy value of the silage was calculated using the equation proposed by Morgan et al (1975).

Formulations and Analyses of diets: The formulations and analyses of diets are shown in Tables 3 and 4. From these it can be seen that the crude protein, lysine, threonine and digestible energy content of the 15% fish silage diet,are slightly higher than for the other diets. It was not possible to r[illegible]e the levels of these nutrients to those of the other diets due to the high nutrient content of fish silage and the limited range of other raw materials available.

Pig growth performance: The growth, food consumption and feed conversion efficiencies of the pigs are shown in Table 5. From this it can be seen that the daily liveweight gains of pigs fed the silage were greater than those fed the diet without fish silage ($P < 0.05$) and that

Table 3:
Diet formulations (with fish silage as percentages of air dry material (ADM))

Ingredients	Fish silage inclusion rate (%) 0	5	10	15
Fish silage	0.00	5.00	10.00	15.00
Ext soya meal (46% CP)	3.85	9.15	1.90	0.00
Sorghum	59.40	60.80	64.35	81.70
Wheatfeed	24.80	23.00	22.50	0.00
Fish meal (57% CP)	10.70	0.00	0.00	0.00
Salt (NaCl)	0.01	0.19	0.06	0.02
Limestone	1.03	1.26	1.00	0.10
Orthophosphate (20% Ca, 20% P)	0.00	0.61	0.00	0.30
Premix (Vit and Min)*	0.20	0.20	0.20	0.20

* Premix (vitamin and mineral) supplied the following per kilogram: Vitamin A - 3 m.i.u., Vitamin D_2 - 0.5 m.i.u., Vitamin E - 1000 i.u., Vitamin K - 1g, Riboflavin - 2g, Niacin - 10g, D.L.Calcium pantothenates - 6g, Choline Chloride - 100g, Vitamin B_{12} - 12mg, BHT - (antioxidant) - 40g, Iron - 30g, Manganese - 15g, Zinc - 40g, Iodine - 0.2g, Copper - 4g, Selenium - 0.05g

Table 4:
Calculated analysis of diets including fish silage (as percentage ADM)

Nutrients	Fish silage inclusion rate (%) 0	5	10	15
Crude protein	18.00	18.00	18.00	18.50
Ether extract	3.25	2.96	3.20	3.67
Crude fibre	3.74	3.84	3.47	2.38
Digestible energy (MJ/kg)	12.73	12.73	12.73	13.03
Lysine	0.89	0.84	0.88	1.00
Methionine and Cystine	0.63	0.61	0.62	0.67
Threonine	0.66	0.65	0.66	0.71
Calcium	0.90	0.92	0.90	0.90
Phosphorus	0.72	0.70	0.67	0.69
Salt (NaCl)	0.40	0.40	0.40	0.40

Table 5:

Growth, feed conversion efficiencies and food consumption of pigs

Parameter means	0% silage	5% silage	10% silage	15% silage
Initial weight (kg) (group mean)	21.2	21.9	21.5	21.4
Final weight (kg)	94.3 ± 7.6	97.3 ± 10.1	95.0 ± 7.9	94.5 ± 11.0
Daily liveweight gain (g)	519 ± 54.0[a]	603 ± 81.5[b]	615 ± 6.7[b]	615 ± 93.1[b]
Food consumption (kg) (air dry matter)	298.2	282.0	265.3	249.3
Food conversion efficiencies (kg food consumed/kg liveweight gain)	4.08	3.74	3.61	3.41

a,b Values in each parameter bearing different letter subscripts differ at the 5% significance level

the efficiencies of food conversion increased as the content of fish silage in the diet increased. There was, however, no significant difference between the daily liveweight gains of animals fed silage.

The health of all animals on trial was good throughout the study period and no palatibility problems were noted. One pig died during the trial, but this was from causes unrelated to the trial. The carcasses of all other pigs passed commercial scrutiny and were marketed without problems.

Discussion

From this trial it can be seen that the fish by-catch from the shrimp fishing industry can be successfully made into fish silage, which in turn can be successfully fed up to 15% of the dry matter of the pig diets. The pigs fed silage, in fact had superior growth rate and food conversion efficiencies than those fed fish meal. Since all diets were nutritionally balanced and the comparison of fish materials was based on the supply of fish crude protein, it can be concluded that the difference in performances reflects the greater availability of nutrients in the silage than in the fish meal. This is in agreement with the work of Smith (1977). However, since the fishmeal was made from sardines and the silage from fish component of by-catch, part of the variation could be an effect of protein origin as well as of processing.

Carpenter (1971) suggested that no more than 1% fish oil should be permitted in fattening pig diets or tainting of the meat could result. With this limitation in mind, it would appear that levels of inclusion of the silage greater than 15% (which supplied 0.85% fish oil) are very near to the upper limit for the use of this material in growing pig diets. This point is emphasised by the inability to produce a diet containing 15% fish silage to the same nutrient specifications as the 0% fish diet, due to the high nutrient density of this material.

As well as fish species, shrimp by-catch contains molluscan and crustacean species which if successfully ensiled could be used in pig diets. Obviously this possibility should be examined, though ensilage of this material will be complicated by the neutralizing effect of the high calcium content of these components.

One of the main problems of producing balanced diets for pigs and poultry in developing countries is the low nutritional value of many of the locally available raw materials. However, in many developing countries there are large quantities of uneconomic fish species such as in shrimp by-catch, which although not available in sufficiently large quantities to make fish meal, could economically be made into fish silage of high nutrient density. In these situations the use of fish silage with its high nutrient concentration could be of special value permitting the preparation of balanced diets using other local materials of low nutritional value.

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