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THE UTILIZATION OF FISH WASTE AS SILAGE

Final Report: The Utilisation of Fish Waste as Silage.

Project Summary.

This project, with funding of $19,400, was carried out from July, 1981-June, 1983. Delays were incurred in carrying out and reporting of feeding trials where silage was fed to pigs, poultry and fish.

Date from feeding trials are now available and, accordingly, a final report is submitted.

The project had, as its main aims, the construction of a low-cost ensiling plant; the manufacture and chemical evaluation of a range of silages and the feeding of these silages to a range of farmed animals.
The aims were substantially achieved. As well, advice was given on ensiling methods to more than 40 enquiries and visits were made (with funding outside the present grant) to Tasmania and the Northern Territory to advise on ensiling operations.

Areas Covered and Major Findings.

1. Construction of a Low-Cost Silage Plant.

At prices obtaining during the early part of the study an imported plant cost in excess of A$20,000. A suitable plant capable of ensiling around 1 tonne/day was constructed for around A$2,500.
Around 50 silages were prepared using locally-available species, and their chemical composition determined. Generally, silages were suitable for incorporation into animal feed, with fat content (high fat content has been associated with fishy taint in pork and chicken meat) averaging around 5% of the dry matter.

A basic production cost for silage around A$50/tonne was calculated, though these costs could be radically streamlined were commercial production undertaken.

2. Feeding trials.

The value of silage as a feeding supplement for pigs, broiler chickens and chinook salmon was assessed using feeding units located at, respectively, Melbourne University, Victorian Department of Agriculture, Animal Research Institute, Werribee and the Snobs Creek Research Station of the Victorian Fisheries and Wildlife Division.

In these trials silage-based feeds were compared with conventional feeding meals throughout the growing period of the animals and an assessment made of the cost-effectiveness of incorporating silage into the diet. As well, the health of animals was monitored closely.

2.1 Pig Feeding Trials.

Pigs fed silage-based diets exhibited superior weight gain and feed conversion ratio compared with conventional feed based on soybean meal. At the highest level of silage incorporation taste panelists were able to distinguish flavour differences compared with pigs fed solely on soybean meal. At lower levels of silage incorporation no flavour differences were detected by panelists, similarly with pigs withdrawn from high silage prior to slaughter. Savings by utilising silage were calculated at around A$5/head, a considerable saving for a large, 2,000 head pig herd.

Two major drawbacks have surrounded the feeding of silage to pigs. Firstly, the problem of tainted pig meat which results from feeding silage too high in fat. It was found in the present work that smallgoods prepared from a pig fed a high fat silage diet, and which had pork chops considered "fishy" by panelists, were acceptable. For example, bacon, Polish salami, Milano salami and Strasbourg were all perfectly acceptable both to trained taste panelists and to untrained consumers.

Secondly, the perceived threat of viral disease in pig herds, introduced by Sealion virus thought to be present in silage, was found to be groundless; Dr. Stoddart, an authority on this virus was adamant that this virus would be inactivated by the ensiling process.

2.2. Broiler Chicken Trials.

Broilers fed silage diets had higher liveweight gains compared with those fed a control diet based on fish meal. Costs per unit of protein were around A$0.50/kg protein compared with around A$1.00/kg protein for fish meal pointing to commercial viability for silage.

Two major problems associated with silage feeding, namely, leg weakness and fishy taint were not found in the present study.

2.3 Fish Feeding Trials.

Silage based meals were inferior to control diet for chinook salmon in terms both of liveweight gain and of feed conversion ratio.

In the present study poor digestibility of silage meals affected performance and it is considered that blending of silage into a moist pellet would have been more appropriate.

Conclusion.

Silage can be cheaply manufactured on a commercial scale using the plant designed in the present study. Taint, caused by high fat levels need not be a problem for pigmeat utilisation if this is processed as smallgoods. Considerable savings are apparent for pig and broiler chicken farmers prepared to incorporate fish silage into diets.

Publications.

To date, aspects of the work have been published in several forms:

1. Shum, S.K., Brown,N. and Sumner, J.L. (1984). Problems and prospects for fish silage utilisation in Singapore. Proceedings of the Third Symposium on the Environment. Singapore, March, 1984.

2. Brown,N. and Sumner, J.L. (1984). Fish silage. Proceedings of the IPFC Symposium, Melbourne, October, 1984.

3. Brown, N., Sumner, J.L. and Dunkin, A. (1984). Fish silage - can it be converted to profit? Australian Fisheries, November, 47-49.

4. Johnson, R., Brown, N., Eason, P. and Sumner, J.L. The nutritional quality of fish silage for broiler chickens. Journal of the Science of food and agriculture (submitted for publication).

Copies of the above are attached.

As well, aspects of the study have been published as part of two theses

Davis, M. An investigation into the effects of fish silage tainted pork in smallgoods production. Undergraduate thesis for B.appl. Sci. (Food Science and Technology) degree, December, 1983.

Brown, N. The Evaluation of Fish Waste as Silage. Master of Applied Science thesis, Royal Melbourne Institute of Technology, March, 1985.

A copy of Mr. Davis' thesis has been deposited with the Fishing Industry Research Committee. A copy of Mr. Brown's thesis will also be deposited following its examination.

PROBLEMS AND PROSPECTS OF FISH SILAGE UTILISATION IN SINGAPORE.

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PROBLEMS AND PROSPECTS OF FISH SILAGE UTILISATION IN SINGAPORE

Introduction

Fish protein is an important ingredient widely used in the formulation of animal feed. Traditionally, this protein has been obtained from fish meal, a dehydrated form of minced fish. However the activities of the OPEC in the increase of oil prices and of environmentalists with their antipollution requirements have made the manufacture of fish meal increasingly difficult. Fish silage, a low-energy, pollution-free process represents an attractive, alternative source.

Though widely used in Europe and Scandinavia, fish silage has not yet been widely accepted in Asia. Lately, however a number of feasibility studies in this region has shown that fish silage can be used for poultry, pigs and fresh water fish feeding.

This paper concentrates on the possibility of using fish silage as a supplement in pig feed formulation.

What is fish silage?

The Ensiling Process

A total landing of 3.8 millon tonnes of marine fish were reported in the Southeast Asian region in 1978. About 26.9% (1.0 million tonnes) comprised by-catch (trash fish) which were discarded at sea or converted to animal feed (Table 1). A considerable increase in the by-catch landing, especially from shrimp trawling has been reported from most Southeast Asian countries in recent years, ranging from 40% to 70% of the total fish landed (JICA, 1978). It was estimated that 5 million tonnes of fish by-catch may be discarded annually at sea in the tropics (Allsopp, 1977).

Table 1 Landings (metric tons) of marine fish, mixed species and by-catch in the Southeast Asian region(1978)

Country	Annual landings	Mixed species	By-catch	% by-catch
Indonesia	1,227,386	182,516	-	-
Malaysia	626,912	33,157	161,889	25.8
Philippines	77,512	13,903	4,789	6.2
Singapore	15,635	1,225	2,986	19.1
Thailand	1,837,807	95,746	847,421	46.1
Total	3,785,252	326,547	1,017,085	-

Source: Fishery Statistical Bulletin for South China Sea Area 1978 (SEAFDEC, 1980).

Two FAO feasibility studies were conducted by J.L.Sumner (1978b) and J. Disney (1979) respectively on the production of fish silage in the Asia Pacific Region at about the same period. Collaborative studies have since been made in several Asean countries including Philippines, Indonesia, Malaysia ,Thailand, Sri Lanka and Singapore.

In the manufacture of silage, whole fish or fish waste, comprising whole non-commercial fish frames, heads and offal or crustacean processing waste, is ground or mixed with acid which prevents the growth of spoilage bacteria (acid silage). Either inorganic or organic acids such as formic and propionic acids can be used. Alternatively lactic acid production can be encouraged by mixing a carbohydrate source with ground fish and inducing fermentation (fermented silage). Subsequent liquefaction is brought about by the activity of proteolytic enzymes naturally present in the fish.

Fish silage contains 60 - 80 % moisture. Typical chemical composition of fish silage as indicated is shown in Table 2.

Table 2 Analysis of silage made from Australian fish species

	Acid Silage		Fermented Silage	
	Mean*	Range	Mean**	Range
Dry matter (%)	29.2	(18.8-38.7)	33.6	(29.6-39.1)
Ash (%)	5.3	(1.9- 9.8)	6.7	(4.6-12.8)
Fat(%)	5.0	(0.6-15.6)	6.4	(1.9-14.2)
Protein (%)	16.4	(11.6-23.7)	14.4	(11.9-16.8)

* 35 acid silages analysed
** 13 fermented silages analysed

While fish silage has a very similar chemical composition to that of fish meal, it has an advantage over fish meal as shown in its pepsin degestibility (Flores 1973) Table 3.

Table 3 Comparison between the results of pepsin digestability of fish meal and fish silage

Samples	Pepsin digestability % protein	Solubility % protein	%NPU of total protein
	Average	Average	Average
Fish silage	1.1	18.3	36.9
Fish meal	1.8	15.8	33.3

Feed trials by Batterham and Gorman(1980) showed that the addition of fish silage into grower feed for pigs resulted in a significant increase in growth rate and a significantly decreased feed conversion ratio during the 20-45 kg growth range. These authors suggested that the superior performance of pigs fed with fish silage may indicate the presence of an unidentified growth factor in the silage .

In a recently completed feeding trial carried out at the University of Melbourne Pig Centre (Brown, Dunkin and Sumner, unpublished) 48 large white pigs, individually penned, were fed either a control diet with soybean meal, or one of three diets in which soybean was replaced with silage (Table 4). Pigs were taken from 20 kg to 50 kg liveweight when half were sacrificed; of the remainder, 12 pigs continued to the 90 kg stage on a non-silage diet while a further 12 pigs had a silage-based diet to the 70 kg stage when they too were transferred to a non-silage diet. At 90 kg all pigs were sacrificed.

Table 4 Composition of Diets

Ingredients (kg air dry basis)	Treatments 1	2	3	4
Barley	83.0	83.0	83.0	83.0
Salt	0.25	0.25	0.25	0.25
Vitamin/min. premix	0.25	0.25	0.25	0.25
Di-calcium Phosphate	2.5	2.0	1.5	1.0
Soybean Meal	14.0	9.3	4.7	0
Silage	0	13.8	27.7	41.5
Total	100.0	108.6	117.4	126.0

Growth response from 20-50 kg was superior on a silage-based diets ($p<0.05$) (Table 5) both in terms of Feed Conversion Ratio (FCR) and daily weight gain. Over the complete growth range (20-90kg) there was no significant difference in performance between the diets. For 50 kg pigs, which typically are slaughtered for pork meat in Australia, there was no difference in the dressing percentage at slaughter, or in the percentage of lean meat in the ham, between the control and silage diets.

Table 5 Growth Results

RESPONSE 20-50KG.

	Treatment 1	2	3	4	SIGNIF.
F.C.R.	2.40	2.33	2.31	2.31	*
Gain (G/Day)	627	641	648	650	*
Dressing (%)	72.6	73.0	74.0	74.0	NS
Lean in ham (%)	65.7	66.5	66.3	67.7	NS

* P<0.05
NS :Not significant

RESPONSE 20-90 KG

	Treatment 1	2	3	4	
F.C.R..	2.60	2.54	2.51	2.59	NS
Gain (G/DAY)	785	800	816	795	NS

One finding in previous studies (Sumner, 1978a) was that a silage-based diet could lead to pork meat which tasted fishy, the result of a diet too rich in fish oil. In the present study taste panelists were required to compare, in a triangle test, pork chops taken from either a control or a silage-fed; pig panelists were asked to correctly identify the single sample (either control or silage-fed pork) and, for those correctly selected, to gauge the degree of difference between samples and to exercise a preference. Penalists were able to correctly identify only the diet in which all of the soybean had been replaced by silage (Table 6), this pork sample being moderately different to control which was considered preferable to the silage-fed pork. The main flavour scores for silage-fed pork were "Meaty", followed by "Bland" with "Fishy" being only a slightly-perceived flavour (Table 7).

Table 6 Taste Panel Results

Growth Period 20-50 kg

Treatment	%Correct	Signif.	Degree of Difference	Prefer.
2	35	NS	SLIGHT	NS
3	41	NS	SL.-MOD.	CONTROL**
4	48	***	MODERATE	CONTROL**

NS : NOT SIGNIFICANT
** P=0.01
*** P=0.001

Table 7 Main flavour Scores

Treatment	Flavour Scores		
	Fishy	Bland	Meaty
2	0.1	1.4	1.6
3	0.4	0.8	1.6
4	0.6	1.2	1.5

0=NONE
1=SLIGHT
2=MODERATE

For pigs carried on to the 90 kg stage taste panelists were able to detect a difference only in pork from pigs fed on high silage to the 70 kg stage, though there was no difference in preference between the control and silage-fed pork.

Silage proved an economical addendum to pig diets (Table 8) with significant savings on diet cost/pig, both to the 50kg and 70 kg stages.

Table 8 Feed Costs
(Figures in Australian dollars)
(A$1.00=S$2.00 approx)

1. Relative Costs of diets

Treatment :	1	2	3	4
Costs :	222	214	206	198

A$/tonne (equivalent nutrients)

2. Costs of 20-50 kg Growth Period

Treatment :	1	2	3	4
Cost :	16.30	15.30	14.50	13.90

A$/pig

3. Costs of 20-90 kg Growth Period

Control	: 40.80
Treatment 3, withdrawn at 70 kg	: 37.20
Treatment 4, withdrawn at 50 kg	: 39.60

A$/pig 3-6 pigs treatment.

Fish silage in its physical form creates problems because:

(a) It has a high liquid content that makes it bulky. High transport costs will thus limit its use chiefly to production units near to fish processing plants and to pig farms.

(b) Porkers, in practice, are fed dry meal on an ad libitum (free choice) basis by means of self-feeders. The high liquid content of fish silage will make difficult its mixture with a meal ration and the method of feeding.

(c) so-called 'fish off-flavour ' in pork requires that the level at which it is to be included to suit local tastes should be carefully determined.

(d) Van Wyk *et al* , (1977) conducted trials to establish, among other things, a suitable feeding method. He concluded that the best method of feeding appeared to be measured amounts of fish silage per pig per day, supplied in separate troughs as a supplement to the dry feed mixture which is fed *ad lib.* This method might not be suitable for automatic handling systems. Its implications on additional labour costs should also be further studied.

Fish silage or Fish meal

Organic acid ensilage appear the most suitable process in our environment. Major cost factor in the production of silage would then depend on the raw material and on the organic acids costs , since the process is neither labour nor energy intensive. Fish silage prepared this way was also found to be free from pathogens such as *Salmonella spp.*, *Shigella spp.* and *Vibrio. cholerae*

The value of silage can be expressed as equivalents of other feeding meals in terms of nitrogen content. This comparison is shown in Table 9.

Table 9 Value of Silage in Singapore

Description	S$ per tonne	N-Content	Silage Equivelent $
Fish meal	1,140	55%	720.00
Soya Bean	725	44%	576.00
Meat Meal	1,075	45%	589.00

Assume Fish waste cost at S$150 per tonne
Formic acid at 3 %
Propionic acid at 1 %

Equipment

Major equipment requirements have been reviewed by Raa and Gildberg (1982). The automatic and semi-automatic processes reviewed are reproduced as Figs 1 to 3. Generally costs for such a fish meal process of similar size.

The attraction of fish silage is that it can be produced manually or semi-manually in small scale production. A typical small scale ensiling plant comprising 2 x 10 tonnes glass fiber tanks; a heavy duty meat mincer and a modified submersible sludge pump for materials recycling and transfer is estimated at S$10,000. Processed silage could be stored in plastic drums or hoppers until further use.

By-catch landing is avaliable in small quantities and is sold at S$150 to S$350 per tonne. The main user is a fish meal processing Company with an annual consumption of about 4,400 tonnes.

Further survey on waste materials available showed that:

1. Trash fish or by-catch are specifically brought in by contract to the fish meal processing company.

2. A number of fish processing companies whose operations range from canning, processed chilled frozen sea food to fish ball manufactures have wastes amounting to 2,000 to 3,000 tonnes a year.

3. It has been estimated that there are about 350 licensed fish ball/fish cake processors . These processors range from stall holders in the markets to small factories in housing estimates. Fish frames and offals from them can be collected and put to better use.

4. Of late there has been considerable interest in aqua-farming and fish farmers have been buying trash fish to use them as fish food.

Prospects and problems in the pig farming industry

Pig rearing is the most important livestock activity in Singapore. It has an annual output of more than 900,000 porkers in 1982 amounting to an ex-farm value of S$250 million.

Using 6% fish silage as fish meal replacement in growth ration, the estimated 2,500 tonnes of fish waste available could be used to feed about 15% of the pig population during the grower period. (Table 11)

Table 11 Sample calculation

Estimated Requirement fFor Fish Silage In Pig Feed

Basis of assumption:-

1) 1 pig consumes 2 kg. feed/day
2) 6% of feed composition is silage
3) Each pig is fed on growth ration for 150 days

Then :

Silage requirement per pig per day
= (2.0 x 6)/100 kg = 0.12 kg

Total requirement per pig fed on grower feed
= 0.12 x 150 kg = 18 kg

If 2,500 tonnes fish silage is available,
Number of pigs able to be fed
= 2,500,000/18
= 139,000 pigs

% pig population (139,000/900,000) x 100 = 15.4 %

Recent trends and developments should however, be taken into consideration when suggesting the introduction of silage in the local pig farming industry:

1. Pig feeding practice have recently been converted to dry feed. An additional process will be required to blend silage with dry feed. Alternatively Ad libitum or free choice feeding may be used.

2. Blending of silage with dry feed may not be compatible with automated feed systems.

3. Pig farmers are currently heavily committed to waste disposal systems and may not be inclined to experiment into other feed alternatives.

Fish Silage can be easily utilized in Singapore for the following reasons:

1. it is an efficient means of using waste materials

2. farms are relatively close to the source and transportation is not the major consideration

3. farms are centralised and pooling of facilities among the neighbourhood is possible

4. Free choice feeding in separate troughs as a supplement to dry feed mixture has been suggested. This would appear suitable for the smaller farms where feeding is not automated.

Other developments

Sinoda <u>et</u> <u>al</u> (1978) found that about 79.3% of the by-catch sampled from the Kangar Fish Market in Singapore could be considered as suitable for human consumption. Since then there has since been further research by SEAFDEC/MFRD, Tan S M <u>et</u> <u>al</u> (1980-1982) reported the formulating an extensive programme for research and development in post-harvest fish technology. An ongoing project involves the utilisation of by-catch as a raw material for the production of traditional fish jelly products for human consumption in the region.

Such efforts should be viewed as complementary to the fish silage alternative aimed to make use of the valuable food material which would otherwise be wasted.

Conclusion and recommendation

Fish silage appears an attractive alternative to fish meal and other protein feed supplements. Its attraction lies in its better performance, as an energy saving process and as an efficient ways of utilizing waste materials.

It can incorporated into feeds ranging from 6 - 30% as feed supplement. In view of the limited supply of raw materials incorporation should only be confined a few medium sized farms. A blend of dry feed and separate trough feeding could be implemented and adoption appears favourable in these non automated farms.

Farmer resistance may be appreciable at present because of competing priorities in pig waste disposal.

The best course of action in realising the long term objective appears to be in the continued evaluation in the feeding of silage and in the study of farm management involving the use of silage under local conditions.

Acknowledgement

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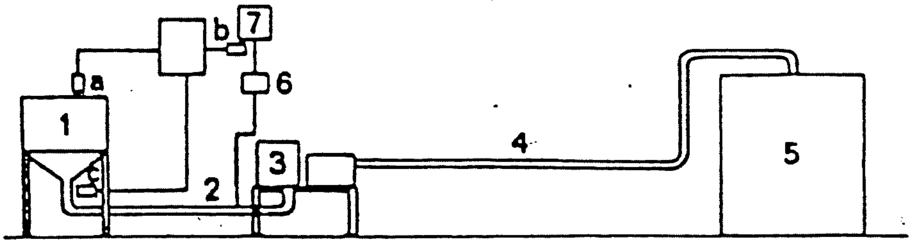

FIGURE 1. Layout of the automatic silaging process. (After Stormo, B. and Strøm, T., Ensilering av Fiskeslo, report from the Institute of Fishery Technology Research, Tromsø, Norway, 1978, 40. With permission.)

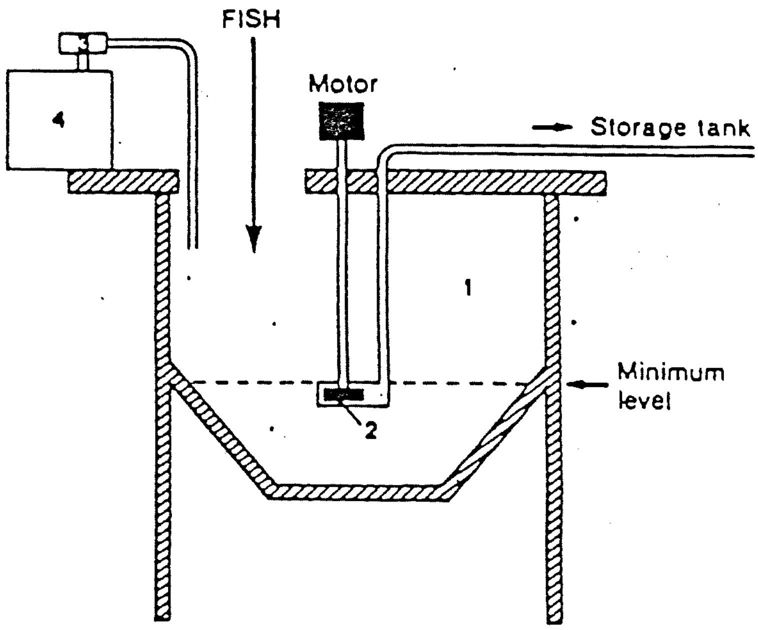

FIGURE 2. Semiautomatic silage plant. (From Anon., *Liquid Fish Protein. The Bio-Add Process for Liquid Fish Protein Production*, B.P. Nutrition (U.K.), Stepfield, Witham, Essex, U.K. With permission.)

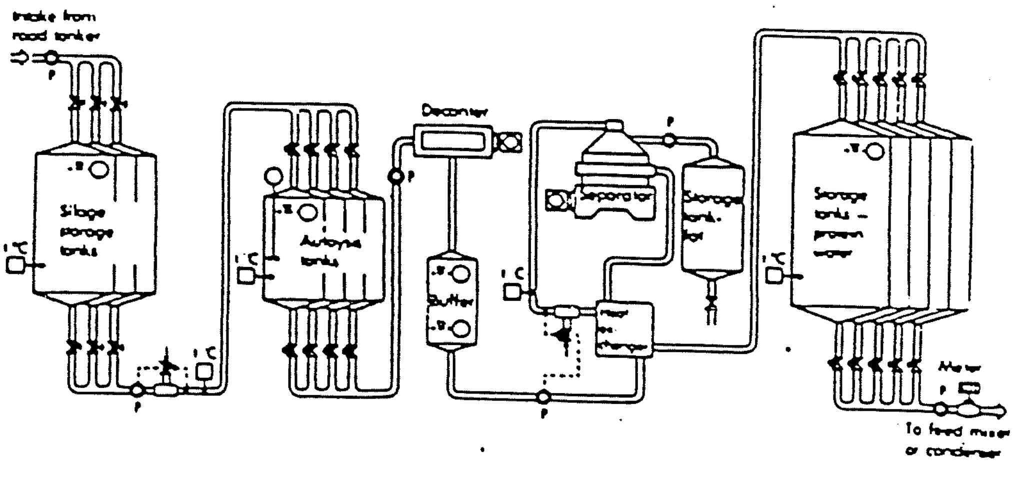

FIGURE 3. Flowsheet of a silage processing plant. (From Anon., From Pollutant to Resource. Fish Offal to Compound Feeds, report from Hamjern A/S, Hamar, Norway, 1979, 14. With permission.)

Source: CRC Critical Reviews in Food Science and Nutrition - April 1982

FISH SILAGE

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1. Introduction

Fish silage is a brown, stable liquid stock feed prepared by acidifying whole fish or waste from fish processing. During manufacture fish are minced, acidified and stored until endogenous enzymes cause liquefaction of tissue. Acidification may be effected by direct acid addition to the mince (acid silage) or by generation of acid in the mince through fermentation of added carbohydrate (fermented silage). Although utilized as a major source of protein for animals in many countries, manufacture of fish silage in Australia is, at present, very much in its infancy with small amounts utilized as pig feed and as a foliar fertilizer.

In the present study, composition of acid and fermented silages prepared from filletting waste generated in the Melbourne area was determined and the nutritional value of silage, manufactured from local fish waste, for pigs, chickens and farmed fish assessed.

2. Materials and Methods

Preparation of Silages

All silages were prepared from fish filletting waste obtained from fish processors. Waste was refrigerated (4 C) or frozen (-40 C) until minced through a 2 mm plate and ensiled. Acid silages were prepared by addition of 3.5L formic acid per 100 kg of mince and fermented silage by addition of 12-15 kg of molasses and 5L of starter culture (L.plantarum) per 100 kg of mince. Batches ranged in size from 5 to 2000kg and silages were stored at room temperature (20-25 C) or incubated at 30 C.

For incorporation in the diets of chickens and fish, silage was mixed with wheat bran (either 80 kg silage/20 kg bran or 85 kg silage/15 kg bran) and dried in an experimental batch dehydrator (6h at temperature < 70 C). Dried silage meals were ground (2mm plate) and stored in airtight containers prior to mixing with other feed ingredients. Acid silage meals (ASM) and fermented silage meals (FSM) were prepared.

Pig Digestibility Trials

Two feeding trials were conducted to determine digestibility by pigs of the dry matter, gross energy and nitrogen of acid and fermented silages prepared from mixed filletting waste. Coefficients of apparent digestibility were determined as the amount of nutrient ingested over a period of time by pigs, minus the amount voided in the faeces over that time expressed as a percentage of the nutrient ingested. Large White pigs of similar weight were housed in metabolism cages for a fixed period of time (5-7d) during which faeces was collected. Pigs were fed diets of barley in which silage was included at levels of 20 or 25% of the dry matter and on conclusion of feeding, digestibility coefficients were calculated. Digestibility coefficients were also determined for the barley meal and coefficients for silage determined by difference.

During the first trial the digestibility of nutrients in an acid silage stored for 6 months prior to feeding was determined. During the second trial digestibility of nutrients in acid and fermented silages prepared from similar raw materials and stored (30 C) for 2 weeks prior to feeding was determined.

Pig Feeding Trial

A controlled pig feeding trial was conducted during which 48 Large White pigs were raised from 20 to 50 or 20 to 90 kg liveweight. Four treatment diets were formulated; treatment 1 was a control diet utilizing soyabean meal as the entire source of supplementary protein. In the remaining diets soyabean meal was progressively substituted by acid fish silage, silage being the entire source of supplementary protein in the diet of treatment 4. Formulation and chemical composition of diets are presented in Table 1. Diets were designed to contain equivalent amounts of protein, lysine and digestible energy.

On attaining 50 kg live weight 6 pigs/treatment were slaughtered and the meat produced subjected to taste panel analyses (triangle test and preference test) to determine the presence of taint. All remaining animals (6 pigs/treatment) were slaughtered on reaching 90 kg although 2 stages of withdrawal of silage from diets were practiced in order to assess effect on flavour quality of meat produced. At 50 kg, 3 pigs/treatments were placed on the diet lacking silage (treatment 1) and at 70 kg remaining animals were placed on the diet lacking silage.

Chicken Feeding Trial

Eight treatment diets were formulated to assess the nutritional value of acid silage meal (ASM) and fermented silage meal (FSM) in the diets of male broiler chickens. The formulation and chemical composition of the diets are presented in Tables 2 and 3. Treatment 1 was a control diet utilizing soyabean meal as the major source of supplementary protein, and treatment 2 was a further control diet in which the majority of the soyabean meal of the diet of treatment 1 was replaced by fishmeal (5%). Remaining treatment diets incorporated ASM or FSM substituting for soyabean meal to a maximum level of inclusion of 10%. Broilers were raised for 42d on the treatment diets. On conclusion of feeding selected birds were slaughtered and meat produced subjected to taste panel analyses to assess any flavour alteration.

Fish Feeding Trial

The nutritive value of acid silage meal (ASM) in the diet of chinook salmon (*Oncorhynchus tshawytscha*) was assessed. Four treatment diets were formulated in which fish meal, the major source of supplementary protein in the control diet (treatment 1) was progressively substituted by ASM to a maximum level of inclusion of 30%. The formulation and chemical composition of the diets are presented in Table 4. Fish (initial weight 1.29g) were held in 16 pens with 740 fish/treatment and were fed the diets for 52d.

3. Results

Analysis of the composition of a range of silages prepared from fish filletting waste generated in the Melbourne area indicated large variation in protein, fat ash and dry matter contents, depending on source of offal. The average and ranges of values are presented in Table 5. In general, fermented silages were higher in dry matter and ash contents but lower in protein and fat contents than acid silages prepared from similar raw materials, this being an effect of substrate addition. Most silages contained high levels of oil (>3%).

Coefficients of apparent digestibility (Table 6) for pigs, as determined during the digestibility trials, indicated acid and fermented silages were very digestible (>80%) in terms of dry matter and gross energy while the nitrogen in silages was highly digestible (96-97%). Little difference in digestibility of nutrients was found between an acid silage stored for 6 months (trial 1) or two weeks prior to feeding (trial 2) or between acid and fermented silages prepared from similar raw material (trial 2).

Results showing the performance of animals during the pig feeding trial are presented in Table 7. Statistical analysis indicated that during the 20-50 kg phase of growth, animals fed diets of treatments 2,3 and 4 exhibited superior gain to those of animals fed the control diet (treatment 1). The superior performance by animals fed diets incorporating silage was reflected in the data for feed conversion of animals during this phase. There was no significant difference between treatments for animal performance during the 20-90 kg phase of growth.

Taste panel analysis indicated that of the pigs slaughtered at 50 kg, meat from animals fed the diet of treatment 4 was found to be significantly different in flavour to that of meat from animals fed the control diet (treatment 1) containing no silage and that the difference was detrimental. Meat from animals fed diets of treatments 2 and 3 and slaughtered at 50 kg was not significantly different in flavour from that of control animals. Of the meat from animals slaughtered at 90 kg, that of pigs fed the diet of treatment 4 withdrawn at 70 kg was found to be significantly different in flavour from that of control animals, however, withdrawal of the treatment 4 diet at 50 kg allowed sufficient time for reduction of off-flavours in meat. Meat from pigs fed the diet of treatment 3 and slaughtered at 50 or 90 kg was found to be not significantly different in flavour to that of control animals.

Results showing the performance of broilers during the chicken feeding trial are presented in Table 8. No significant difference was found between treatments for gain or feed conversion during any period of growth. Taste panel analyses conducted on meat from birds slaughtered after 42 d of feeding indicated that meat from animals fed diets of treatments 2 (5% fishmeal), 5 (10% ASM) and 8 (10% FSM) was not significantly different in flavour to that of animals fed the control diet lacking a protein supplement derived from fish.

In Table 9 are presented the results for performance of salmon during the fish feeding trial. Although no significant difference was found between treatments for growth performance, a trend showing poorer gain and feed conversion by fish with increasing levels of inclusion of ASM was observed. Significant differences between treatments would be expected with prolonged feeding of the diets.

4. Discussion

Variation in composition of silages prepared from different filletting wastes indicates the necessity of routine analysis of silages by manufacturers/farmers to assure proper management of animal diets. Manufacture of silage from waste of a single species does not ensure a constant product as chemical composition, particularly fat content, has been found to vary seasonally (Gaiger 1978).

The dry matter, gross energy and nitrogen of silages were very digestible to pigs. Digestibility of nitrogen was higher than that of commonly used protein supplements, which have apparent digestibility coefficients of nitrogen in the range 78-90% (Leche _et al._ 1982).

Feeding trials indicated fish silage can be successfully incorporated in the diet of pigs, chickens and fish.

The significantly improved performance of pigs fed diets incorporating silage compared with animals fed the diet utilizing soyabean meal as the entire source of supplementary protein was most probably a reflection of greater availability of lysine in fish silage compared with soyabean meal. Chance and unidentified growth factors have also been postulated as causes when silage has produced superior growth in previous work (Batterham _et al._ 1983). Feeding of a diet containing 2.5% fish oil (dry-matter basis, treatment 4) produced unacceptible flavour alteration in meat from animals slaughtered at 50 kg liveweight, but such flavour alteration was not significant in meat from animals slaughtered at 90 kg if silage was withdrawn from the diet at 30 kg. Withdrawal at 70 kg was not sufficient to eliminate taint from meat of treatment 4 animals when slaughtered at 90 kg. Feeding the diet containing 1.6% fish oil (dry-matter basis, treatment 3) resulted in the production of meat of flavour not significantly different to that of control animals when animals were slaughtered at 50 kg or when silage was withdrawn at 70 kg and animals slaughtered at 90 kg. This indicates that greater than 1% fish oil, regarded as the maximum level before taint is produced (Barlow and Pike 1977), may be included in the diet of swine providing diets are fed for short periods or adequate withdrawal of silage from diets is practiced prior to slaughter.

ASM and FSM were successfully incorporated in the diet of broilers to a maximum inclusion of 10%. No toxicity of feeds incorporating silages was observed although the short periods of storage of silage and silage meals (10-14d), and the use of fish waste of good quality for silage production, may have prevented generation of harmful levels of toxic constituents previously found when feeding dried silage meals (Kompiang et al. 1979, Disney et al. 1978). No evidence of leg weakness or vitamin deficiency in birds was observed.

The poor response of chinook salmon to ASM was disappointing although inferior performance of fish fed diets utilizing dried silage meals has been previously reported and attributed to low digestibility of meals (Hardy et al. 1984). In the present study, poorer digestibility by fish of ASM compared with the fish meal and the slightly lower protein content of the diets incorporating silage may have produced the tendency towards poorer performance of fish. Preparation of moist pellets by blending of wet silage with dry binder meal have been found to be very acceptible to fish producing good growth (Asgard and Austreng 1981) and clearly warrants further investigation.

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Table 1. Formulation and chemical composition (% dry-matter basis) of treatment diets fed to Large White pigs during silage feeding trial

	Treatment diet			
	1	2	3	4
Formulation:				
Barley	82.7	83.6	84.5	85.5
Salt	0.27	0.27	0.28	0.28
Vitamin premix	0.27	0.27	0.28	0.28
Dicalcium phosphate	2.70	2.19	1.66	1.12
Soyabean meal	14.1	9.23	4.84	–
Acid silage	–	4.17	8.44	12.8
Chemical composition:[a]				
Crude protein	17.4	17.5	17.6	17.7
Fat	2.1	2.9	3.6	4.4
Digestible energy (MJ/kg)	14.8	14.9	15.0	15.1
Calcium	0.92	1.01	1.10	1.18
Phosphorus	0.90	0.89	0.89	0.89
Lysine	0.95	0.96	0.97	0.98

[a] diets of treatments 1,2,3 and 4 contained 88.9, 80.9, 74.0 and 68.2% dry matter, respectively

Table 2. Formulation and chemical composition (%) of starter diets fed to male broiler chickens between 1 and 21 d of age.

	Treatment diets							
	1	2	3	4	5	6	7	8
Formulation:								
Common [a]	83.04	83.04	83.04	83.04	83.04	83.04	83.04	83.04
Soyabean meal	12.75	3.55	10.65	8.56	4.39	10.92	9.00	5.20
Fishmeal	—	5.00	—	—	—	—	—	—
ASM	—	—	2.50	5.00	10.00	—	—	—
FSM	—	—	—	—	—	2.50	5.00	10.00
Tallow	2.58	4.00	2.31	2.01	1.50	2.22	1.82	1.20
Dicalcium phosphate	0.95	0.42	0.71	0.48	—	0.70	0.59	0.13
Sodium chloride	0.26	0.21	0.23	0.21	0.15	0.20	0.18	0.08
Limestone	0.13	—	—	—	—	0.15	0.06	—
Methionine	0.25	0.18	0.25	0.23	0.21	0.24	0.25	0.23
Lysine	—	—	—	—	—	0.03	0.06	0.12
Rice hulls	0.04	3.60	0.31	0.47	0.71	—	—	—
Chemical composition:								
Dry matter	87.5	87.8	88.9	88.1	88.4	88.6	88.2	88.5
Crude protein	21.1	20.9	21.9	21.0	21.3	21.7	20.9	21.3
Ether extract	7.3	8.2	7.7	6.8	7.7	7.5	7.5	7.9
Ash	4.9	5.1	4.8	4.5	4.5	4.7	4.5	4.5

[a] common ingredients were as follows (%): wheat 53.0, sorghum 10.0, meat and bone meal 8.0, whole sunflower seeds 5.0, blood meal 2.54, cottonseed meal 4.0, vitamin premix 0.5.

Table 3. Formulation and chemical composition (%) of finisher diets fed to male broiler chickens between 22 and 42 d of age

	Treatment diets							
	1	2	3	4	5	6	7	8
Formulation:								
Common [a]	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
soyabean meal	12.75	4.64	10.65	8.56	4.39	10.92	9.00	5.47
Fish meal	—	5.00	—	—	—	—	—	—
ASM	—	—	2.50	5.00	10.00	—	—	—
FSM	—	—	—	—	—	2.50	5.00	10.00
Tallow	5.11	6.13	4.84	4.54	4.03	4.75	4.42	3.76
Dicalcium phosphate	0.89	0.36	0.67	0.42	—	0.66	0.54	0.13
Sodium chloride	0.28	0.23	0.25	0.23	0.17	0.23	0.20	0.10
Limestone	0.24	0.20	0.20	0.16	—	0.20	0.08	—
Methionine	0.23	0.16	0.23	0.21	0.19	0.22	0.23	0.21
Lysine	—	—	—	—	—	0.05	0.07	0.14
Rice hulls	0.50	3.28	0.66	0.88	1.22	0.47	0.46	0.19
Chemical composition:								
Dry matter	86.3	88.8	88.1	88.4	88.2	88.5	88.1	88.7
Crude protein	19.1	19.6	19.7	19.0	19.3	19.7	19.5	19.3
Ether extract	7.1	7.6	7.3	7.9	7.7	7.5	7.5	0.8
Ash	4.6	4.8	4.8	5.1	4.7	4.3	4.6	4.1

[a] common ingredients were as follows (%): wheat 50.5, sorghum 15.0, meat and bone meal 8.0, whole sunflower seeds 3.0, cottonseed meal 3.0, vitamin premix 0.5.

Table 4. Formulation and chemical composition (%) of treatment diets fed to chinook salmon (*Oncorhynchus tshawytscha*) during silage feeding trial

	Treatment diet			
	1	2	3	4
Formulation:				
Common ingredients [a]	42.1	42.1	42.1	42.1
Fishmeal	40.0	35.9	32.0	27.9
ASM	-	10.0	20.0	30.0
Wheat bran	12.8	8.5	4.3	-
Rice hulls	5.1	3.5	1.6	-
Chemical composition:				
Dry matter	90.2	89.9	89.3	88.7
Crude protein	49.8	48.9	48.7	48.0
Gross energy (MJ/kg)	18.7	18.6	18.8	18.7
Calcium	2.34	2.33	2.47	2.49
Phosphorus	1.77	1.74	1.80	1.74

[a] common ingredients were as follows (%): meat and bone meal 8.0, soyabean meal 7.5, blood meal 7.0, skim milk powder 5.0, cottonseed meal 5.0, corn gluten 3.6, salt 2.0, linseed oil 2.0, cod liver oil 1.0, vitamin premix 1.0

Table 5. Composition (% wet-weight basis) of acid and fermented silages [a]

	Acid silage		Fermented silage	
	Mean	Range	Mean	Range
Dry matter	29.2	18.8-38.7	33.6	29.6-39.1
Crude protein	16.4	11.6-23.7	14.4	11.9-16.8
Fat	5.0	0.6-15.6	6.4	1.9-14.2
Ash	5.3	1.9- 9.8	6.7	4.6-12.8

[a] 35 acid silages and 13 fermented silages were prepared

Table 6. Coefficients of apparent digestibilty (%) determined for silages during pig digestibility trials

Trial	Type of silage	Coefficient of digestibility (%)		
		Dry matter	Gross energy	Nitrogen
1	acid	80	87	96
2	acid	82	88	97
	fermented	84	88	97

Table 7. Performance of Large White pigs during silage feeding trial

	Treatment			
	1	2	3	4
(a) 20-50 kg phase of growth				
Liveweight gain (g/d)	627a	641b	648b	651b
FCR (g feed/g gain)	2.13a	2.05b	2.00bc	1.98c
(b) 20-90 kg phase of growth				
(i) silage withdrawn at 50 kg				
Liveweight gain (g/d)	772	789	802	775
FCR (g feed/g gain)	2.33	2.29	2.24	2.34
(ii) silage withdrawn at 70 kg				
Liveweight gain (g/d)	798	813	830	815
FCR (g feed /g gain)	2.28	2.20	2.15	2.19

within a parameter, differing subscripts indicate significant difference between treatments

Table 8. Performance of male broiler chickens raised during silage feeding trial[a]

	Treatment diet							
	1	2	3	4	5	6	7	8
(a) 0-21d period of growth								
Liveweight gain (g/d)	674	642	653	652	676	657	661	650
FCR (g feed/g gain)	1.65	1.65	1.77	1.70	1.69	1.64	1.64	1.66
(b) 22-42 period of growth								
Liveweight gain (g/d)	1186	1053	1187	1115	1146	1176	1136	1204
FCR (g feed/g gain)	3.07	2.97	2.98	2.96	3.05	2.99	2.84	2.82
(c) 0-42d period of growth								
Liveweight gain (g/d)	1859	1694	1841	1763	1822	1833	1796	1854
FCR (g feed/g gain)	2.51	2.41	2.55	2.45	2.52	2.46	2.37	2.36

[a] no significant difference between treatments for gain or feed conversion ratios

Table 9. Performance of chinook salmon during silage feeding trial [a]

	Treatment			
	1	2	3	4
Liveweight gain (g/100 fish)	180	174	163	159
FCR (g feed/g gain)	1.35	1.41	1.50	1.52

[a] no significant difference between treatments for gain or feed conversion ratios

Fish silage — can it be converted to profit?

by Nick Brown, John Sumner and Tony Dunkin

Nick Brown and John Sumner are, respectively, technical officer and principal lecturer in the Food Technology Unit, Royal Melbourne Institute of Technology (RMIT). Tony Dunkin is a senior lecturer in animal production at the School of Agriculture and Forestry, University of Melbourne.

FISH silage can be made easily in Australia, but can it be made as a profit? That is obviously the key question to be answered before likely commercial manufacturers examine more seriously this technique of utilising fish waste.

In 1981 an article in *Australian Fisheries* ('*Fish silage holds promise for fishermen and farmers*' by Batterham and Gorman, *AF*, December 1981) concluded that '. . . fish silage is comparatively easy to produce, and is a suitable feed for pigs. The product is available and a potential market exists. Between the two lies the question: how much will it cost? At a time when fishermen everywhere are trying to increase the efficiency of their operation and make maximum use of the catch, it would seem worthwhile to do a few sums on fish silage.'

Now, following a three-year study at the Royal Melbourne Institute of Technology's Food Technology Unit, funded by a FIRTA grant, a number of key questions on the economics and utilisation of fish silage have been answered.

The results of the study will be presented as a series of articles in *Australian Fisheries*. This first article examines the production and economics of fish silage.

Production stages

Fish waste (frames, heads, guts or trash fish) may be converted into silage by either of two processes: by adding acid, such as sulphuric acid or formic acid (a process known as acid silage) or by fermenting the waste with molasses (fermented silage). Both products can be used as stock feed, though they have slightly different compositions.

Production of both forms of silage has some common processing steps (see flow diagram), initial stages including weighing the waste, grinding and transferring to the silage tank.

Weighing is necessary because acid addition (for acid silage) and molasses addition (for fermented silage) are linked with the quantity of raw material to be ensiled. Acidification is best carried out with formic acid, 3.5 kg being added to each 100-kg batch of ground fish waste. Other useful acids, like sulphuric acid, require neutralisation before feeding to stock. By contrast, formic acid-based silage can be fed direct.

Grinding the waste is necessary to reduce the particle size so that the acid (or molasses) can be mixed intimately. Failure to mix properly results in formation of pockets of putrefied fish within the silage. This not only reduces the food value of the silage but may harm the growth of the animals to which it is fed.

Grinding can be achieved with a butcher's mincer or with a hammer mill, the latter being especially necessary for grinding shark, where the skin becomes wrapped around the worm of the grinder.

The mince is then bulked into a tank which, since it is used for mixing and storing silage, must be acid-resistant. Either plastic, fibreglass or concrete tanks can be used and obsolete stainless steel tanks from a dairy factory may prove economical. Tanks can be either free-standing or sunk into the ground.

Once the fish is in the tank the acid, or molasses, is weighed or measured into the tank. For acic silage gloves and goggles are ad visable to prevent burns from the formic acid.

Acid and mince are now mixec thoroughly, a cheap, effective mixe being a chopper pump, such as : sewage pump, which can be lowere into the silage tank. During pumpin the silage is shredded by cutters a the entrance to the chopper pump size reduction both speeding up th ensiling process and reducing th risk of putrefacation.

The mix is then expelled into bulk storage tank or into drum which should be resistant to acid fc the period the silage is likely to t stored.

'Mono' pumps are useful i pumping silage, one such syster the 'Mutrator', being in commerci use.

The degree of mincing is impc tant — a coarse mince being easi to deal with than a very fine minc which toughens when acid is add making pumping difficult. Also it advisable to have some liquifi silage from a previous batch in t tank to allow for more effecti mixing.

Acidified mix is now subjected regular pumping, which speeds liquifaction, a period of one to fc days being normal, depending the raw material and the te perature (the warmer the weatl the more rapid the silage mar facture).

Finally liquid silage is pump into drums (200-litre) that are pla lined, and which serve both

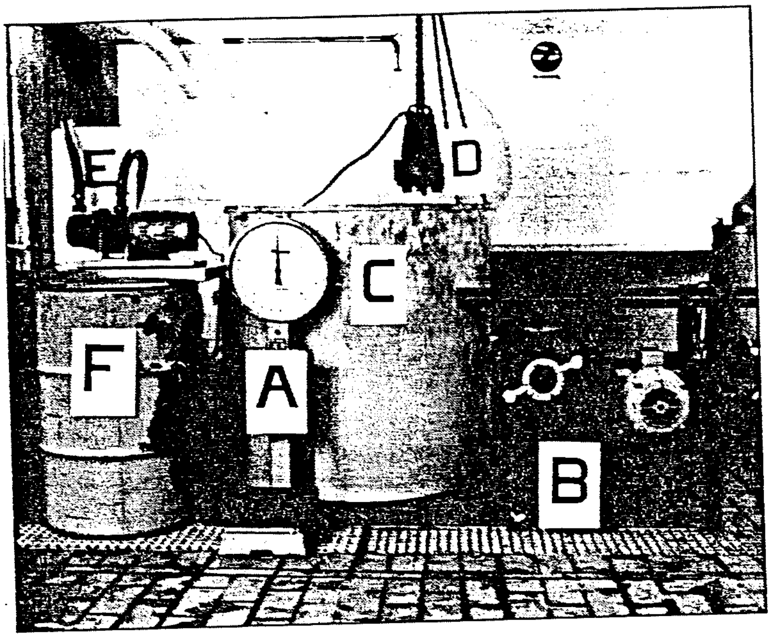

Figure 1. Silage production plant.

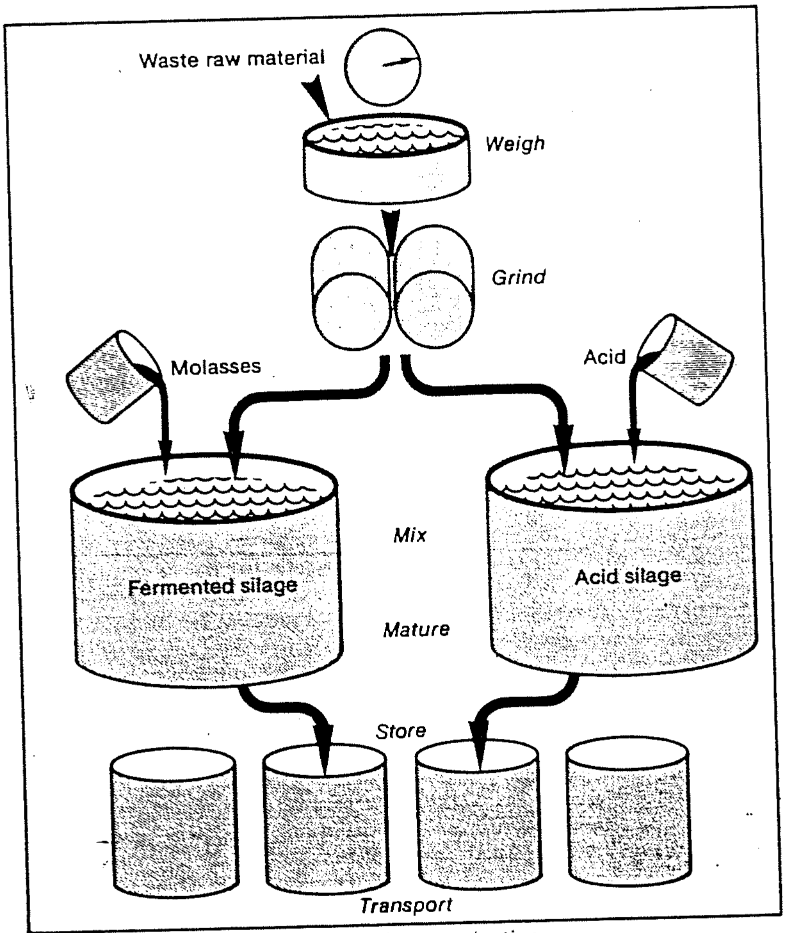

Figure 2. Process flow diagram of silage production.

transport and for storage at the farm.

A typical silage set-up is shown in Figure 1, the main components being scales (A), mincer (B), plastic ensiling tank (C), chopper (sewage) pump (D), 'mono' pump (optional) (E) and plastic-lined 200-litre tank (F).

Costings for a similar plant are presented in Table 1, from which it can be seen that a silage plant capable of handling about 800 kg of waste a day costs about $2500. For larger-scale production, costs increase, depending on the size of mincer purchased plus the price of larger silage tanks and more plastic-lined tanks for storage of the final product.

The RMIT silage plant is radically cheaper than a commercial plant available from British Petroleum Nutrition (UK) Ltd, which would cost more than $20 000 in Australia for a throughput of one tonne a day.

Costs of producing silage

Costs are estimated for acid silage because these represent maximum production costs. Fermented silage, based on molasses addition, could prove radically cheaper.

Basic production costs, set out in Table 2, are about $54 a tonne. (This assumes an effective grinding and pumping system is used; otherwise labour costs increase.) The major cost, formic acid at the 3.5 per cent level, may be trimmed considerably

Table 1. Basic costs of a plant capable of producing 800 kg a day of silage.

Item	*Cost ($)*
Scales (used)	350
Mincer (used)	650
Tank (900-l, new)	450
Sewage pump (new)	750
Drums (200-l x 5, reconditioned)	75
Pipes, safety equipment	225
	2500

Table 2. Basic production costs for silage.*

	$/tonne of silage
Labour (2 hours at $8.60/h)	18
Acid (3.5% formic acid)	34
Overheads (electricity, water, etc.)	2
	54

* Based on figures for March, 1984.

once the processor gains expertise in the process and knowledge of the stability of his particular silage. Stable silage, made with 2.5 per cent formic acid, reduces costs to about $45 a tonne.

Raw material, depending on the particular operation, must be either added to, or subtracted from, basic production costs.

For example Company A, with an outlet for fish waste as pet food, at $100 a tonne in frozen blocks, would have to carry out a feasibility study to determine whether silage manufacture would be more profitable.

However Company B, currently eliminating waste 'free' by dumping in an estuary, actually may save by ensiling (Table 3) due to the hidden costs of macerating waste.

For Company C, which currently pays a fee to dump fish at a local tip, there are considerable savings in ensiling waste (Table 3).

Thus any processor considering converting waste into silage should analyse raw-materials costs or savings. As a final feasibility step the processor should canvas local pig, poultry or fish farmers with a view to fixing the value of silage. The more 'local' the farmer the better, because transport costs are also a factor.

Value of fish silage

Fish silage will be valued by a farmer of pigs, poultry or fish on a number of criteria: how much nitrogen will be supplied; will the nitrogen be 'good quality'; how much energy will be available; is the material easy to store and to mix with other feed ingredients; is there any residue left after feeding which will require cleaning?

Table 3. Costs for dumping waste which could become raw materials for silage.

	Cost ($/tonne waste)
Company B	
(discharge into estuary)	
Labour (2 h at $8.60 h)	18
Macerator operating costs	5
	23
Company C	
(dumps at local tip)	
Tipping fee	3
Labour (2 h at $8.60 h)	18
Transport costs	8
	29

Table 4. Composition of acid and fermented silages.

	Acid silage		*Fermented silage*	
	*Mean**	*Range*	*Mean***	*Range*
% Dry matter	29.2	(18.8-38.7)	33.6	(29.6-39.1)
% Ash	5.3	(1.9-9.8)	6.7	(4.6-12.8)
% Fat	5.0	(0.6-15.6)	6.4	(1.9-14.2)
% Protein	16.4	(11.6-23.7)	14.4	(11.9-16.8)

* A total of 35 acid silages were made.
** A total of 13 fermented silages were made.

The nutritional value of silage is summarised in Table 4, from which it can be seen that acid silages averaged 16.4 per cent protein, 29.2 per cent dry matter, 5.3 per cent ash and 5 per cent fat. Molasses silages, by comparison, were lower in protein (14.4 per cent), and higher in dry matter (33.6 per cent) ash (6.7 per cent) and fat (6.4 per cent).

A pig farmer would see a typical acid silage in terms of supplying his stock with around 160 kg of protein per tonne of silage, which would give about 10.9 kg of the key amino acid, lysine. The dry matter and fat would supply to the pig around 4.7 megajoules of digestible energy per kilogram of silage.

Such values for both protein and energy are lower than competing feed meals currently used by pig farmers, so the price of silage will be less. (The prices of competing protein meals are in Table 5.)

While vegetable protein supplements, like soyabean and lupins, are relatively stable in price, animal protein meals fluctuate greatly: fish meal from $650 to $810 a tonne, meat and bone meal from $300 to $400, and blood meal from $550 to $650. By contrast fish silage should be marketable at a stable price, which would enhance its value to farmers.

On the other hand should the price of silage be linked with that of other feeds, in the same way that currencies are linked? If so the relative cost of competing protein supplements, calculated on how much protein and lysine is supplied, is promising (Table 6). On a protein and lysine basis, silage selling for $100 a tonne competes well with other protein sources.

Table 5. Prices of protein rich concentrates used to supplement animal diets ($/tonne).

Meal	*Protein (%)*	*Prices $ during 1983* Average	Range
Meat and bone meal	50	350	300-400
Blood	85	595	550-650
Fish	72	740	650-810
Soyabean	44	415	400-430
Peanut	46	350	—
Sunflower	32	265	225-280
Linseed	33	305	285-310
Rapeseed	34	300	295-300
Lupin	30	215	150-250

Table 6. Cost of competing protein supplements on a protein and lysine basis.

Supplement	*Cost ($) per tonne of:* Protein	Lysine
Silage*	660	9 170
Meat and bone	690	12 500
Blood	760	8 750
Fish	1 060	14 800
Soyabean	920	15 370
Rapeseed	830	15 790
Lupins	740	16 540

* Based on a typical acid silage, priced at $100 a tonne.

The future for fish silage is as a protein supplement. In Europe more than 60 000 t a year are produced for use in the pig, cattle, fish and fur industries. In Australia, at $100 a tonne (depending on actual composition), it would provide profit to fishermen, ensiler and farmer.

In the acceptance of silage by Australian farmers the demonstration of its potential and economics under local conditions is of critical importance. The next article on fish silage will examine its performance in pig-feeding trials, and its influence on the quality of the pork meat and smallgoods.

The nutritional quality of fish silage in broiler chicken diets.

by

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Summary

Fish waste was ensiled by acification with formic acid and by fermentation with a bacterial starter culture and molasses. The resulting liquified products were mixed with wheat bran (85:15 w/w silage:bran) and dried (70°C) to produce acid silage meal (ASM) and fermented silage meal (FSM). ASM and FSM were incorporated into wheat-based diets at levels of 25, 50 and 100 g/kg at the expense of soyabean meal. There were two control diets, the first containing soyabean meal as the predominant protein supplement and the second in which commercially available fish meal was added at 50 g/kg at the expense of the soyabean meal. Diets, which were formulated to be nutritionally adequate for broiler chickens, were essentially isonitrogenous and were made isoenergetic by variation in the level of animal fat (tallow). Starter diets (13.25 MJ ME/kg, 12 g/kg lysine) were fed from day-old to 21d of age and finisher diets (13.25 MJ ME/kg, 9.5 g/kg lysine) were fed from 22 to 42d of age. Treatment groups consisted of six replicates each of five birds. Birds were reared in raised-wire cages, and feed intake, liveweight and mortality were recorded over 7d periods.

There were no significant effects of dietary inclusion of either ASM and FSM for broiler chickens relative to the control diets on any of the production parameters measured. However FSM contained lower levels of crude protein and amino acids relative to ASM. The recovery of amino acids relative to the total crude protein content of FSM was only 78.7%, presumably due to the formation of Maillard reaction products during the drying process.

Key words: Fish silage, broiler chickens, amino acids.

1. Introduction

Fish or fish waste may be ensiled to produce a usable animal feed by processes which require less technology than that for the production of fish meal (see review by Raa and Gildberg, 1982). There is little information on the nutritional value of fish silage for broiler chickens. McNaughton et al. (1978) and Kompiang et al. (1980a) reported no adverse effects due to inclusion of dried fish silage on the growth of broiler chickens. However there are reports that fish silage products induce high mortality, increase the incidence of leg disorders and depress the growth performance of broiler chickens (e.g., Kompiang et al., 1980b).

The present study was carried out to examine the nutritive value and nutritional quality for broiler chickens of dried fish silage produced by two different ensiling techniques: by acidification with formic acid and by fermentation with starter culture and molasses.

2. Experimental

2.1 Silage preparation

Fish silages were prepared from mixed filletting waste obtained from fish processers in the Melbourne area. Waste was minced (2mm screen), mixed and divided into two batches for preparation of acid silage and fermented silage. Acid silage was prepared by addition of formic acid (3.5L/100kg waste) and fermented silage by initiation of fermentation through addition of molasses and an active culture of L. plantarum (12hg and 5L/100hg waste, respectively). Silages were incubated in plastic containers at 30±1°C for a period of 10d after which acid silage meal (ASM) and fermented silage meal (FSM) were prepared. Silage (85kg) was mixed with wheat bran (15kg) and dried in a batch dehydrater (6h at temperature <70°C), and the resulting meal ground (2mm screen) and stored in airtight plastic drums. The chemical composition of ASM and FSM is given in Table 1.

2.2 Diets

Diets with proximate analyses are shown in Tables 2 and 3. Nutrient specifications as described by the ARC (1975) and by the SCA (1983) were used in the starter (1-21d growth period) and finisher (22-42d growth period) diets. Starter diets contained the following nutrient specifications. Apparent metabolisable energy (AME, MJ/kg), 13.25; crude protein (Nx6.25), 210 to 220 g/kg; total lysine, 12 g/kg; calcium, 11.5 g/kg; available phosphorus, 6.3 g/kg; sodium, 2.0 g/kg; potassium, 7.5 g/kg; magnesium, 2.0 g/kg; chloride, 2.5 g/kg. Finisher diets contained the following nutrient specifications: AME, 13.25 MJ/kg; crude protein, 190 to 200 g/kg; total lysine, 9.5 g/kg, calcium, 11.4 g/kg; available phosphorus, 6.1 g/kg and the same mineral levels as for the starter diets.

There were two control diets, one which contained predominantly soyabean meal as the source of supplemental protein (diet 1) and another in which the majority of the soyabean meal was replaced by fish meal (diet 2). ASM or FSM were incorporated into diet 1 at the expense of soyabean meal at three levels, 25 g/kg, 50 g/kg and 100 g/kg. All diets were pelleted and were prepared immediately prior to commencement of the relevant growth period.

2.3 Birds and their management

Two hundred and forty day-old, male, broiler chickens were wing-banded and randomly allocated to the eight dietary treatments. Each treatment had six replications with five birds per replication. During the starter phase birds were housed in two brooder units each of 24 cages (910mmx380mmx210mm). Temperature during the first 7d period was 35°C and was gradually decreased thereafter such that at 21d of age it was 25°C. Illumination was constant, and food and water were freely available. During the finisher phase from 22 to 42d birds were housed in raised wire cages (910mmx780mmx450mm). Temperature was uncontrolled during this phase. Mean (±SD) maximum and minimum temperatures were 18.1 (±2.6) and 10.6 (±2.4), respectively.

2.4 Measurements

Liveweights were measured at day-old, 21d and 42d. Birds were starved for 16h prior to measurement of liveweight at 42d of age. Feed intake was recorded over 7d intervals. Mortality was measured and cause of death diagnosed. Dressed carcass percentage was measured at 42d of age. One bird with liveweight closest to the average for that treatment was selected from each replicate (6 birds/ treatment) for treatments 3 to 8. Two birds were similarly selected from each replicate (12 birds/treatments) for treatments 1 and 2. Birds were starved overnight (approximately 20h), weighed, slaughtered and bled for 5 min prior to carcass preparation. After chilling in cold water (12°C, 30 minutes) carcasses were drained (30 min), weighed, sealed in impermeable film under vacuum and stored at -40°C until required for sensory analysis.

Taste panel assays were conducted to assess the degree of flavour difference beween meat from birds fed diets utilizing a supplement derived from fish (treatments 2, 5 and 8) and meat from birds fed the diet of treatment 1 (control diet incorporating soyabean meal as the major source of supplementary protein).

A triangle test ( ) was used as the basis for assessment of difference in flavour. Carcasses were thawed overnight (16h, 4°C), sealed in two layers of aluminium foil, enclosed in an oven bag and

cooked in a gas oven at 200°C for approx. 150 min. Breast or leg meat was served warm (40°C) to panelists and at least 60 assessments were conducted for each comparison of meat samples.

2.5 Chemical and statistical analyses

Proximate analyses were carried out on the diets and ingredients according to procedures given by the Association of Official Agricultural Chemists (1970)., Amino acids were hydrolysed by the method of Finlayson (1965) and determined by ion exchange chromatography by the method of Spackman et al. (1958) using a Kontron Liquimat 3 amino acid analyser. Treatment comparisons were tested by two-way analysis of variance (Steel and Torrie, 1980).

3. Results and Discussion

Results for growth, mortality and dressed carcass percentage are given in Table 4. There was no significant effects of inclusion of either ASM or FSM up to a level of 10% in the diet on any of the parameters measured. Liveweight and liveweight gain tended to be lower for birds that received the control diet (diet 2) which contained fish meal (50 g/kg of diet). However pellet stability was markedly reduced in this diet, probably due to higher tallow levels of 40 g/kg in the starter diet and 61 g/kg in the finisher diet, which casued appreciable pellet breakdown after allocation to the birds. Feed intake of birds on diet 2 was therefore depressed, particularly in the 21 to 42d period when the finisher diet was fed. This effect was significant ($P<0.05$) when compared with the feed intake of birds on diet 1, the soyabean meal control diet during the period 21-42d and 0-42d of age. The feed conversion ratio (FCR, g feed/g liveweight gain) averaged 2.45 for all groups over the 42 day growth period. This was higher than would be expected for broiler chickens due to the elevated FCR°s during the finisher period. However the average temperature during the finisher period was about 14°C, considerably lower than the ideal range of 20 to 30°C for maximum efficiency of feed utilization by broiler chickens (Hurwitz et al 1980). No significant difference in flavour was found ($p>0.05$) between meat from birds fed diets of treatments 2, 5 or 8, and that of animals fed the diet of treatment 1.

The present study demonstrated that, with appropriate precautions in the preparation and handling of the fish prior to ensilation, fish silage can be incorporated into nuritionally balanced diets for broiler chickens without detrimental effects on growth performance or carcass taste. Although a maximum inclusion level of 100 g/kg was studied, other studies (Rattagool et al., 1980 b and c) would indicate that higher inclusion levels are possible with appropriate dietary alterations to maintain nutrient levels. For example Rattagool et al (1980b) found that a level of 300 g/kg of fish silage did not depress the liveweight of broiler chickens relative to controls although feed efficiency was reduced. This latter effect may have been due to certain amino acid or other nutrient imbalances. Levels of inclusion of a dried fish silage product similar to those used in the present studies would therefore seem to pose no problems for broiler chickens (Kompiang et al., 1980a ; Rattagool et al., 1980a), McNaughton et al. (1978) found that the incorporation of fish silage into diets for broiler chickens actually improved the growth and feed efficiency.

Factors such as freshness of the raw material and length and conditions of storage may be important (Raa and Gilberg, 1982) but spoilage of the fish prior to ensilation did not influence the nutritional quality of the silage product for broiler chickens (Rattagool et al., 1980a). Recent work on the use of acid fish silage for growing pigs (Batterham, 1983) substantiate the results of the present study.

The major problem with high inclusion levels of fish products for poultry and pigs is in carcass tainting. Dean et al (1969) found that flavour differences could be detected between birds fed 3% and 9% fish meal in skin and breast meat but not until an inclusion level of 14% in thigh meat. The fat level in fish products has been considered as the most important factor in the incidence of tainting (Dean et al 1969; Fry et al 1965; Opstvedt, 1971) and Fry et al (1965) suggested a maximum level of fish oil of 1 to 1.5% in broiler diets. Off-flavours attributed to fish products have been associated with accumulation in meat tissues of polyenoric marine fatty acids (Opstvedt, 1971). In the present study with a maximum incorporation level of 100 g/kg fish silage (ASM and FSM) the level of fish oil in the diets would have been approximately 15 g/kg. This level of fish oil did not lead to to downgrading by taste panelists. However, trimethylamine (TMA) content of fish products is also an important consideration (Butler and Fenwick 1984). TMA levels in acid fish silage have been reported to be low (0-11 mg of N/100g) (Backoff, 1976) although these levels can be influenced by freshness of the fish prior to ensilation (Rattagool et al., 1980).

Although there were no effects on the nutritive value for chickens of the two types of fish silage (ASM or FSM) used in the present study, there were important alterations in amino acid levels due to the ensilation process. FSM contained lower levels of crude protein and of most amino acids relative to ASM. Since the same mixed batch of fish and fish waste was used to produce both types of fish silage these changes can be directly attributable to the ensilation technique. Fermented silage has a lower protein content than acid silage due to a greater dilution with substrates (James et al., 1977). Importantly the recovery of amino acids relative to the total crude protein content was markedly lower for FSM than for ASM (78.7% compared with 98.7%). All amino acids were reduced in the FSM relative to ASM except for alanine and phenyalanine (see Table 1). Presumably the reduction in amino acid content was due to reactions between α-amino groups and excess sugar aldehyde groups, so called Maillard reactions (Hurrell and Carpenter, 1977). However the extent of the changes signify the occurrence of advanced stages of Maillard reactions, which was unexpected given the mild nature of the drying process used in the meal preparation (see Materials and Methods). This premise also relies upon there being excess sugar in the fish silage after liquification. Kompiang et al (1980) found high levels of sugar remained 7d after preparation of fermented silage using 15kg molasses/100kg fish. In the present study the silage meals were dried at approximately 70°C on metal trays. Possibly the surface temperature of the trays may have been higher than this, leading to the formation of Maillard reaction products. Additionally, although the total protein solubilization of the fish has been found to be greater with formic acid digestion, free amino acid levels were higher with the fermentation procedure (James et al., 1977). In the presence of excess sugar, this effect may have enhanced the formation of Maillard reaction products. Rayner and Fox (1978) reported that beef muscle stored with glucose at 40°C for 12d suffered a 47% reduction in total lysine content. Similarly, beef muscle heated at 121°C for 15 min in the presence of glucose suffered a 68% reduction in total lysine content.

The alterations in amino acid content in FSM would result in a product with limited commercial value for poultry diets relative to ASM. The cost of manufacture of acid fish silage and fermented fish silage was approximately $A64 and $A55/tonne respectively. Assuming wheat bran to cost $A160/tonne then ASM and FSM would cost $A200 and $A165/tonne respectively, not including drying costs. Cost per unit of protein was therefore $A0.54 and $A0.51/kg protein for ASM and FSM respectively. Fish meal costs about $A1.00/kg protein and meat and bone meal costs about $A0.74/kg protein. Given the considerable quantities of waste fish on a world basis (Raa and Gilberg, 1982) the manufacture of fish silage for poultry diets using appropriate techniques would probably be commercially viable in many situations.

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Table 1. Chemical composition of acid silage meal (ASM) and fermented silage meal (FSM).

Constituent (g/kg)	ASM	FSM
Dry matter	936	925
Crude protein (Nx6.25)	371	323
Ether extract	210	203
Apparent metabolisable energy (AME, MJ/kg)+	13.7	13.3
Calcium	26.9	25.8
Total phosphorus	16.6	13.4
Sodium	4.0	3.9
Chloride	5.3	9.9
Lysine	25.1	10.9
Methionine	9.3	6.6
Cystine + Cysteine	3.7	2.5
Leucine	23.4	12.4
Isoleucine	14.0	11.2
Arginine	23.7	9.8
Threonine	16.1	7.8
Histidine	8.6	4.9
Valine	17.0	14.6
Phenyalanine	14.8	38.2
Tyrosine	10.8	5.2
Tryptophan	4.7	4.7
Glutamic acid	48.0	21.1

\+ Determined by the 'rapid' method of Farrell (1978) using adult cockerels and a 42h collection period.

Table 2. Composition (g/kg) of starter diets fed to male broiler chickens between 1 and 21d.

Ingredient	Diets 1	2	3	4	5	6	7	8
Common+	830.4	830.4	830.4	830.4	830.4	830.4	830.4	830.4
Soyabean meal	127.5	35.5	106.5	85.6	43.9	109.2	90.0	52.0
Fish meal	-	50.0	-	-	-	-	-	-
ASM[1]	-	-	25.0	50.0	100.0	-	-	-
FSM[2]	-	-	-	-	-	25.0	50.0	100.0
Tallow	25.8	40.0	23.1	20.1	15.0	22.2	18.2	12.0
Dicalcium phosphate	9.5	4.2	7.1	4.8	-	7.0	5.9	1.3
Sodium chloride	2.6	2.1	2.3	2.1	1.5	2.0	1.8	0.8
Limestone	1.3	-	-	-	-	1.5	0.5	-
Methionine	2.5	1.8	2.5	2.3	2.1	2.4	2.5	2.3
Lysine-HCl	-	-	-	-	-	0.3	0.6	1.2
Rice hulls	0.4	36.0	3.1	4.7	7.1	-	-	-
<u>Composition</u> (determined)								
Dry matter	875	878	889	881	884	886	882	865
Crude protein (Nx6.25)	221	209	219	210	213	217	209	213
Ether extract	73	82	77	68	77	75	75	79
Ash	49	51	48	45	45	47	45	45

\+ Common ingredients were as follows (g/kg): wheat 530, sorghum 100, meat and bone meal 80, whole sunflower seeds 50, blood meal 25.4, cottonseed meal 40, vitamin and mineral premix 5. The vitamin and mineral premix was based on NRC(1977) recommendations and was described by Johnson and Karunajeewa (1983).

1 Acid silage meal.

2 Fermented silage meal.

Table 3. Composition (g/kg) of finisher diets fed to male broiler chickens between 22 and 42d.

Ingredient	Diets 1	2	3	4	5	6	7	8
Common+	800	800	800	800	800	800	800	800
Soyabean meal	127.5	46.4	106.5	85.6	43.9	109.2	90.0	54.7
Fish meal	-	50.0	-	-	-	-	-	-
ASM[1]	-	-	25.0	50.0	100.0	-	-	-
FSM[2]	-	-	-	-	-	25.0	50.0	100.0
Tallow	51.1	61.3	48.4	45.4	40.3	47.5	44.2	37.6
Dicalcium phosphate	8.9	3.6	6.7	4.2	-	6.6	5.4	1.3
Sodium chloride	2.8	2.3	2.5	2.3	1.7	2.3	2.0	1.0
Limestone	2.4	2.0	2.0	1.6	-	2.0	0.8	-
Methionine	2.3	1.6	2.3	2.1	1.9	2.2	2.3	2.1
Lysine-HCl	-	-	-	-	-	0.5	0.7	1.4
Rice hulls	5.0	32.8	6.6	8.8	12.2	4.7	4.6	1.9
Composition (determined)								
Dry matter	863	888	881	884	882	885	881	887
Crude protein (Nx6.25)	191	196	197	190	193	197	195	193
Ether extract	71	76	73	79	77	75	75	80
Ash	46	48	48	51	47	43	46	41

\+ Common ingredients were as follows (g/kg): wheat 505, sorghum 150, meat and bone meal 80, whole sunflower seeds 30, cottonseed meal 30, vitamin and mineral premix 5. The vitamin and mineral premix was based on NRC(1977) recommendations and was described by Johnson and Karunajeewa (1983).

Notes 1 and 2 - See Table 2.

Table 4. Growth performance, mortality and dressed carcass content of male broiler chickens which received two different types of fish silage.

Parameter	Diet+ 1	2	3	4	5	6	7	8	signif.[1]	
Feed intake (g/bird):										
0-21d	52.7	50.4	55.0	52.6	54.2	51.3	51.6	51.2	1.2	NS
21-42d	171.6	146.3	168.6	156.4	165.7	166.6	151.7	161.8	6.7	NS
0-42d	111.2	96.5	111.7	102.5	109.2	106.5	100.9	104.3	4.0	NS
Liveweight (g):										
21d	716	684	696	693	718	699	703	692	13	NS
42d	1901	1737	1883	1808	1864	1874	1838	1896	57	NS
Liveweight gain (g/bird):										
0-21d	674	642	653	652	676	657	661	650	13	NS
21-42d	1186	1053	1187	1115	1146	1176	1136	1204	53	NS
0-42d	1859	1694	1841	1763	1822	1833	1796	1854	57	NS
Feed conversion (g feed/g gain):										
0-21d	1.65	1.65	1.77	1.70	1.69	1.64	1.64	1.66	0.04	NS
21-42d	3.07	2.97	2.98	2.96	3.05	2.99	2.84	2.82	0.13	NS
0-42d	2.51	2.41	2.55	2.45	2.52	2.46	2.37	2.36	0.09	NS
Mortality (%):										
0-21d	0	3.3	0	6.7	3.3	6.7	0	10.0		
21-42d	10.0	10.3	3.3	7.1	3.4	3.6	6.7	3.7		
0-42d	10.0	13.3	3.3	13.3	6.7	10.0	6.7	13.3		
Dressed carcass (% of liveweight):	67.5	68.5	67.2	67.9	68.3	68.4	67.6	66.6	2.28	NS

\+ See Tables 2 and 3 for description of diets.

1 Standard error of the mean (SEM) and significance of treatment differences; NS is not significant (P>0.05).