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Studies on the Preparation of Fish Silage

I. Effect of quality of Raw Material and Type of Acid

By

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Introduction

The acid ensilage of fish to produce a protein supplement for feeding to animals is not a new process. The basic technology was developed more than 50 years ago and substantial quantities are produced in countries such as Denmark and Poland, mainly for feeding to pigs. In recent years, however, there has been renewed interest in fish silage as it represents a means of utilizing waste fish and offal in situations where conventional fish meal production is inappropriate. The process is particularly suitable for Asian conditions since it can be adapted for use as a cottage industry in the villages or as a large-scale commercial enterprise. In order to produce fish silage only a minimal amount of training and equipment is required. There is no need for refrigeration and no pollution or effluent problem.

Fish silage is prepared by mixing ground or minced fish with an acid. The enzymes naturally occurring in the fish break down the proteins into smaller soluble units while the acid helps speed up their activity and prevents bacterial spoilage. The acid used may be an inorganic acid such as hydrochloric or an organic acid, such as formic or propionic. Alternatively, a lactic acid–producing organism and a carbohydrate source can be added. In the latter case the acid produced by fermentation is then responsible for the preservation. If an inorganic acid is used it is necessary to neutralise the silage before it is fed to animals.

When correctly prepared fish silage is a grey viscous liquid and has only a slight oily or malty odour. It can be used in the wet form as a pig feed or alternatively, silage can be dried together with a filler material such as rice bran and the product used as a protein supplement for chicken or as a fish feed.

The prospects for fish silage in Sri Lanka (and 7 other Indo-Pacific Fisheries Commission countries) has recently been reviewed by Disney (1979) and Sumner (1977). These references also contain comprehensive bibliographies relating to work on fish silage. In his review of the prospects for fish silage in Sri Lanka Disney refers to unpublished data produced by the Institute of Fish Technology, Sri Lanka which indicates that the production of fish silage in Sri Lanka is likely to be highly profitable. However, he points out that there is an urgent need to resolve any outstanding technical problems and to verify the economic feasibility in practice. To this end a research programme is being undertaken jointly by the Institute of Fish Technology, Colombo and the Veterinary Research Institute, Peradeniya.

The present paper is the first of a series and describes an experiment in which silver belly (*Leiognathus splendens*) of different initial quality were taken and silages produced using different concentrations of hydrochloric and formic acid. The quality and storage life of the various

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preparations is reported. Future papers in the series will give details of a study to determine the feasibility of producing silage from prawn waste, a study to determine the economics of producing silage in Sri Lanka and of experimental feeding trials in which silage was fed to broiler and layer chicken. Trials to be undertaken together with a firm in Mannar using a commercial silage unit capable of producing 300 tonnes of silage per year will also be reported.

Materials and Methods

Fish Samples

Silver belly (*Leiognathus splendens*) caught as a by-catch during prawn trawling near Mannar Island in May 1978 were used. Batch one (15 kg.) designated " good quality", was kept at ambient temperature (28°C) for 3 hours after capture and then iced. Batch two (15 kg.) designated " bad quality " was kept at ambient temperature for 12 hours after capture and then iced. Both good and bad quality batches of fish were kept in ice for 12 hours before being processed into silage.

Preparation of Silage

Three types of silage were produced, hydrochloric acid silage, formic acid silage and silage made with both hydrochloric and formic acid. Table 1 gives the concentrations of acids used for each type of silage. The fish samples were comminuted in an electric mincer and 750g of mince was mixed mechanically with the appropriate acid for 10 minutes. The silages were stored in 2-litre plastic containers. The strength of the hydrochloric acid used was 12N and the formic acid was a 90% (w/v) solution.

For the formic acid silages the required concentration of acid was added at the beginning of the experiment and, although the pH was monitored, no further acid was added during storage. For the hydrochloric acid silages the pH was brought down initially to the required level and, if required, further acid was added daily to maintain the pH. Generally the pH became relatively stable after the first 12 days. The procedure for production of silage containing hydrochloric acid and formic acid was similar to that used for silage made from hydrochloric acid alone. The concentrations of hydrochloric acid shown in Table 1 are the total amounts added.

Water Content

Samples (2g) were dried in a convection oven at 105°C for 24 hours. The weight loss was taken to be due to evaporation of water.

Ash Content

The residue from the water content determination was ashed in a muffle furnace at 600°C for 24 hours.

Fat Content

This was determined by the methanol/chloroform extraction procedure of Bligh and Dyer 1959).

Crude Protein Content

The micro-kjeldahl procedure was used and analyses were made on 0.2g samples (Pearson, 1970). Total nitrogen was converted to crude protein by multiplying by a factor of 6.25.

Total volatile bases (TVB) and trimethylamine (TMA) determination

Protein nitrogen in a 25g sample of material was precipitated by reducing the pH to 5.2 with a HC l and heating to 70°C. The TVB and TMA content of the non-protein nitrogen fraction was determined using the Conway micro-diffusion method (Beatty and Gibbons, 1937).

PH

This was measured directly using a Radiometer 26 pH and a glass electrode.

Results

The proximate composition of the iced silver belly samples is given in Table 2 along with the TVB and TMA values. The results are the means of duplicate determinations.

When first produced, the silages made from the good quality fish were very rubbery in texture whereas those made from bad quality fish were much more paste-like in consistency. This occurred regardless of the type or concentration of acid used. Two to three days after production both batches of silage were liquid.

The appearance and odour of the various silages at 30, 50 and 115 days after production is given in Tables 3 and 4. For the good-quality fish silages, only the sample acidified with hydrochloric acid to pH 2.5 kept for 115 days (and is still in an acceptable condition after 290 days). Six out of the eleven samples however, did keep well for shorter periods. For the bad quality fish silages, all the samples kept for 30 days but again, only the sample acidified to pH 2.5 kept for 115 days. Generally the samples became unacceptable due to putrid off-odours and appearance of moulds or maggots. The change in pH during the first 41 days of storage in the silages made from formic acid is given in table 5. There was an increase in pH in all the samples. Only in the silages made from good-quality fish with 1.5% and 2% formic acid, and possibly in the silage from bad-quality fish with 2% formic acid was the rise excessive.

DISCUSSION

There was no appreciable difference between the proximate composition of the good and bad quality batches of fish. The TVB and TMA results indicate that the description of the samples was indeed correct, ie. the samples stored for 3 hours at 28°C were of good quality and those stored for 12 hours were of bad quality. For temperate water fish, eg cod, a TVB value of 30 to 40 mg/100g and a TMA value of 10 to 15mg/100g is taken to indicate that the fish is unsuitable for human food. (Connell 1975).

The difference in initial texture of the silage made from good and bad quality samples of fish must reflect a difference in the physical nature of the structural proteins in the samples. It is reasonable to assume that a much greater degree of degradation of these proteins had occurred in fish held for 12 hours at 28°C compared with fish held at 28°C for only 3 hours. In practice, the initial rubbery texture of silages prepared from good quality fish meant that it was extremely difficult to evenly distribute the acid throughout the sample. After 2 to 3 days when the silages made from both good and bad quality fish had liquefied, mixing was no longer a problem.

Generally the silages prepared from bad-quality fish remained in an acceptable condition for longer than those prepared from good-quality fish. This is the opposite of what might be expected and must reflect the ease with which the acid may be distributed throughout the silages during the first few days after production.

For silage produced with formic acid it appears that a slight rise in pH during storage is to be expected and will not seriously affect the quality. However, large rises in pH of the silages indicate putrifaction and should be avoided by increasing the concentration of formic acid and /or ensuring more even mixing.

In Sri Lanka the main use for fish silage is as a poultry feed. For this purpose it is necessary to have the product in a dried form. In this experiment only the silages in which the pH was reduced to 2.5 or below kept for 115 days. However, all of the silages from the bad quality fish and six of those produced from good quality fish kept for 30 days. In practice a storage life for wet silage of one month should be sufficient time to allow it to be mixed with a cheap filler material, such as rice bran or maize meal, and sun dried. Once the moisture content of the silage/carbohydrate mixture has been reduced to below 10 %it may then be stored for several months without loss of quality.

Conclusions

1. Silage produced from silver belly held for up to 3 hours at 28°C, initially has a rubbery texture An even distribution of acid in such material is difficult to achieve and this may reduce the storage life of the product. Silage produced from fish held at 28°C for 12 hours has more of a paste-like consistency and mixing is less of a problem.

2. Silages prepared from silver belly held for 3 or 12 hours at 28°C and in which the pH has been reduced to 2.5 or below by addition of hydrochloric acid will remain in an acceptable condition for at least 115 days.

3. Silages which keep for at least 30 days can be produced from silver belly held for 3 or 12 hours at 28°C by (*a*) reducing the pH to 3.0 by addition of hydrochloric acid, (*b*) adding 0.5%formic acid and reducing the pH to 3.5 with hydrochloric acid or (*c*) adding 2.5% formic acid.

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TABLE 1

ACID CONCENTRATIONS USED TO PREPARE SILAGE SAMPLES

Formic acid % *w/w*	*Hydrochloric Acid* *pH* *	*Hydrochloric Acid* % *w/w*
(*a*) Good quality silver belly :		
—	2.5	10
—	3.0	5
—	3.5	6
1.5	—	—
2.0	—	—
2.5	—	—
0.5	3.0	6
0.5	3.5	4
0.5	4.0	3
1.0	3.5	4
1.0	4.0	2
(*b*) Bad quality silver belly :		
—	2.0	10
—	2.5	10
—	3.0	6
2.0	—	—
2.5	—	—
3.0	—	—
3.5	—	—
0.5	2.5	8
0.5	3.0	7
0.5	3.5	5
1.0	3.0	7
1.0	3.5	4
1.0	4.0	3

* For silages containing hydrochloric acid, the acid was added until the desired pH was obtained.

TABLE 2

CHEMICAL COMPOSITION OF GOOD QUALITY AND BAD QUALITY SILVER BELLY

Sample	*Water* % (*w/w*)	*Ash* % (*w/w*)	*Fat* % (*w/w*)	*Crude Protein* % (*w/w*)	*TVB* *mg*/100*g*	*TMA* *mg*/100*g*
Good Quality	74.1	5.0	2.9	18.6	13.6	7.9
Bad Quality	73.5	5.4	3.7	19.2	140.0	27.9

TABLE 3

APPEARANCE AND ODOUR OF SILAGE MADE FROM GOOD QUALITY SILVER BELLY

Sample	*Days of Storage*		
	30	*50*	*115*
(*a*) *HCl*			
pH 2.5	Normal	Normal	Normal
pH 3.0	Normal	Mould	Discarded
pH 3.5	Putrid	Discarded	Discarded
(*b*) *Formic Acid*			
1.5%	Putrid	Discarded	Discarded
2.0%	Putrid	Discarded	Discarded
2.5%	Normal	Putrid/Maggots	Discarded
(*c*) *HCl and Formic Acid*			
pH 3.0–0.5%	Normal	Normal	Mould
pH 3.5–0.5%	Normal	Putrid	Discarded
pH 4.0–0.5%	Putrid	Discarded	Discarded
pH 3.5–1.0%	Normal	Putrid	Discarded
pH 4.0–1.0%	Mould/Off odour	Cheesy odour	Discarded

N.B.—Normal means a grey viscous liquid with a slight oily or malty odour.

TABLE 4

APPEARANCE AND ODOUR OF SILAGE MADE FROM BAD QUALITY SILVER BELLY

Sample	*Days of Storage*		
	30	*50*	*115*
(*a*) *HCl*			
pH 2.0	Normal	Normal	Normal
pH 2.5	Normal	Normal	Normal
pH 3.0	Normal	Slightly putrid	Putrid
(*b*) *Formic Acid*			
2.0%	Normal	Mould	Discarded
2.5%	Normal	Maggots	Discarded
3.0%	Normal	Maggots	Discarded
3.5%	Normal	Mould	Maggots/Off odour
(*c*) *HCl and Formic Acid*			
pH 2.5–0.5%	Normal	Normal	Normal
pH 3.0–0.5%	Normal	Mould	Discarded
pH 3.5–0.5%	Normal	Mould	Discarded
pH 3.0–1.0%	Normal	Mould	Discarded
pH 3.5–1.0%	Normal	Mould	Discarded
pH 4.0–1.0%	Normal	Mould/Gas	Discarded

N.B.—Normal means a grey viscous liquid with a slight oily or malty odour.

TABLE 5

pH OF FORMIC ACID SILAGES

Formic Acid added to Silage	*Days of Storage*						
	1	2	4	8	14	19	41
(*a*) Good quality Silver Belly Silages							
1.5%	4.4	4.5	4.6	4.5	5.8	7.0	8.0
2.0%	4.2	4.3	4.3	4.3	4.9	6.5	7.3
2.5%	4.0	4.0	4.1	4.0	3.9	4.2	4.5
(*b*) Bad quality Silver Belly Silages							
2.0%	4.1	4.1	4.4	4.2	4.4	4.4	5.1
2.5%	3.8	4.2	4.1	4.0	4.0	4.2	4.7
3.0%	3.7	3.9	3.9	3.8	4.0	4.0	4.3
3.5%	3.7	3.8	3.7	3.8	3.7	4.0	4.0