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Fish silage: the protein solution

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Fish silage: the protein solution

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SUMMARY

Fish silage is a source of high quality protein plus minerals for animal feeding. It is easily made and in cases where it is produced in relatively small quantities, no special equipment is needed.

The nutrient content of fish silage is approximately the same as that of fish meal and it is a versatile feedstuff which can be used by a number of animal species. Probably its greatest use is in the feeding of fur-bearing animals, especially mink. It is also used as a feed supplement for farm livestock such as pigs and cattle.

Fish silage, or liquid fish protein, is the product obtained when fish processing wastes are ground and acid is added to prevent spoilage. Enzymes present in the raw material break down the tissue protein and liquefy it. The liquefied product can then be used in animal feeds.

Fish silage is easily made and provides the most economical method for storage of fish wastes. In addition, a fish silage production setup is easily scaled to any size of operation and is environmentally sound.

RESUME

Le poisson ensilé est une source de minéraux et de protéines de haute valeur biologique convenant à l'alimentation des animaux. Ce produit est facile à préparer et, lorsqu'il n'est produit qu'en quantités relativement faibles, sa fabrication ne nécessite aucun équipement spécial.

Le poisson ensilé a une valeur nutritive à peu près équivalente à celle de la farine de poisson; c'est un aliment polyvalent qui peut être servi à diverses espèces animales. Son utilisation la plus importante est sans doute l'alimentation des animaux à fourrure, en particulier le vison. Il peut également être utilisé comme complément alimentaire pour le bétail, notamment les porcs et les bovins.

Le poisson ensilé, aussi appelé "protéines de poisson liquéfiées", est le produit résultant du broyage des déchets de transformation du poisson auxquels on a ajouté un acide comme agent de conservation. Les enzymes présentes dans le produit cru causent la dégradation et la liquéfaction des protéines tissulaires. Le produit liquéfié peut ensuite être utilisé pour l'alimentation animale.

Le poisson ensilé se prépare facilement et constitue la méthode la plus économique de stocker les déchets de poisson. En outre, la fabrication de ce produit peut facilement être adaptée à des exploitations de taille diverse et ne présente aucun danger pour l'environnement.

PREFACE

In Canada there is a growing interest in the production and use of fish silage. Economic pressures, more stringent environmental regulations and the need for protein sources all contribute to this increased interest. Although fish silage has been used commonly in Scandanavia for several decades, it is not used widely elsewhere.

Fish silage offers an environmentally safe method for disposal of processing wastes (offals), enables smaller processors to meet environmental control regulations and converts a liability into an asset.

This bulletin outlines the up-to-date knowledge about the nutritional value, potential uses and production of fish silage. Other, more technical sources of information are cited in the bibliography.

The authors welcome any comments or suggestions and will attempt to answer requests for further information.

FISH SILAGE

THE PROTEIN SOLUTION

Sometimes it's called liquid fish protein or LFP. But it's most commonly known as fish silage - the liquefied product obtained from a mixture of ground whole fish and/or fish waste.

Unlike silage from forage crops where the preservative acids are a byproduct of fermentation, fish silage is usually made by combining fish wastes with acid from an outside source. However, the anaerobic production of lactic acid caused by adding soluble carbohydrates (like molasses) to the ground fish is an alternate method for fish silage making.

WHAT IS FISH SILAGE?

Generally, fish silage is the product obtained when fish processing wastes and non-edible fish are ground and acid is then added to the mixture. The acids prevent spoilage. In the acidified mixture the enzymes present in the raw material break down the tissue protein and liquefy it.

WHO MAKES IT?

Historically, the practice of using acids to preserve fish wastes was first used in the 1930's in Sweden, and fish silage has been used in neighbouring Denmark since the 1940's. Fish silage industries now exist in Denmark, Norway and Poland, with lesser amounts being produced in several other countries. But there is little, if any, fish silage production outside Europe.

WHY MAKE FISH SILAGE?

- It's a versatile feedstuff
- It's economical
- It's easily made
- Long term storage is safe and easy
- It's an environmentally sound way to dispose of fish wastes

There are, as you can see, many good reasons for the sudden, increased interest in fish silage. To be more specific:

- Fish silage is a suitable protein source for mink, foxes, pigs, cattle, sheep, furbearing animals and fish.

- Fish silage can be produced where the supply of raw fish materials is too low or too infrequent to support fish meal production. As well, a fish silage production unit can be sized according to the supply of raw material. Fish silage uses materials which could otherwise create pollution. The disposal of fish waste products like heads and frames, and internal organs by the traditional offshore or off-wharf dumping methods causes environmental problems.

- It's easy. The three basic steps in fish silage production are grinding, acidifying and storing - no matter how big or small an operation may be.

- A fish silage production unit costs far less than a fish meal production unit.

- Producing fish silage instead of fish meal requires one-tenth the amount of energy.

- Fish silage keeps well. It can be stored for extended periods of time without becoming spoiled or rancid.

- Fish silage is the cheapest way to store fish wastes.

Therefore, fish silage production provides an attractive alternative, especially for smaller fish processing operations where fish meal production is too costly to consider but environmental regulations must be followed. Silage-making converts fish wastes into a valuable resource.

WHICH PRODUCTS GO INTO THE MAKING OF FISH SILAGE?

The raw materials used for fish silage-making may consist of whole, inedible or undersized fish, heads and frames from filleting operations as well as internal organs (viscera). It is estimated that these materials account for about sixty percent of the landed catch. Several acids, or combinations of acids (see Table 2), may be used as preservatives. The time required to break down the tissue proteins can vary from a few hours to several weeks, depending largely upon temperature. After the fish silage is liquefied the oil may be removed, depending on the quantity of oil the mixture contains and the type of animal to which the product will be fed.

Fish silage is a relatively stable material which may be stored for a period of a year or more without any obvious deterioration. In fact, Danish workers report that a quantity of fish silage which was mistakenly stored for a period of six years showed no visible signs of spoilage when discovered!

NUTRITIONAL COMPOSITION OF FISH SILAGE

Fish silage contains several valuable nutrients. However, the amounts of these nutrients can vary as Table 1 indicates.

Table 1. Nutrient Composition of Fish Silages

Type of Silage	Dry Matter	Crude Protein	Crude Fat	Calcium	Phosphorus
	%	% DM Basis			
Cod, offal[1]	26	48.5	--	3.6	2.1
Cod, offal[1]	28	56.1	--	3.6	2.4
White fish offal[1]	18	59.9	2.6	3.3	2.0
Sole, heads and frames[1]	24	48.3	--	--	--
Cod viscera[2]	30.4	40.8	53.3	--	--
Cod viscera, de-oiled[2]	17.9	55.9	1.1	--	--
White fish offal[3]	21.2	70.3	3.1	3.8	1.9
Herring offal[3]	33.2	42.7	43.9	2.1	1.6
Herring offal, de-oiled[3]	--	76.1	--	3.7	2.9
Herring silage[4]	27.3	48.3	28.2	3.5	1.8

[1] From fish silage samples analysed at Charlottetown Research Station.

[2] Smith, P. and Adamson, A. H. 1976. Proceedings Torry Research Station, Symposium on Fish Silage. Aberdeen. pp III:1-9.

[3] Strom, Terje and Eggum, Bjorn. 1981. J. Sci. Fd. Agric. 32:115-120.

[4] Whittemore, C. T. and Taylor, A. G. 1976. J. Sci. Fd. Agric. 27:239-243.

PROTEIN

Protein is essential to the growth and repair of living tissue. It is, therefore, important that the protein fed to animals be readily digested.

Protein contained in fish silage is largely in a soluble, degraded form. As a result of the enzyme-related autolysis which occurs, the silage contains a high level of free amino acids. The amino acid composition of fish silage closely resembles that of fish meal made from the same type of raw material. Fish silage is a good source of essential amino acids.

Although there can be some loss of the amino acid tryptophan and possibly histidine as well during storage of the acid silage, most amino acids remain stable in the acidic silage. Some amino acids tend to be less soluble than others, and these are found in the insoluble sludge portion. If the fish silage is not de-sludged nor held at a high temperature to hasten breakdown, amino acid deficits are not likely to be encountered in the animal feeds.

Because of its similarity to fish meal in terms of protein quality and amino acid content, fish silage should be especially useful in balancing the diets of non-ruminant animals. Although the high level of protein quality is not needed by ruminant animals, its low cost may make the feeding of fish silage to ruminants economically worthwhile in situations where the product is readily available.

MINERALS

Fish silage can be a good source of minerals. However, silage made from viscera is lower in mineral content than silage made from whole fish or heads and frames. Appreciable amounts of calcium and phosphorus plus lesser amounts of other elements will be supplied by fish silage.

Since the silage is acidic and most of the material liquified, a large portion of the minerals should be readily available to animals.

Levels of calcium and phosphorus contained in several silages are shown in Table 1.

VITAMINS

In diets supplemented with fish silage, vitamin E deficiency may result indirectly from the destruction of this sensitive vitamin by oxidized oils. There may also be some destruction of vitamin A. It is therefore imperative that one of the antioxidants mentioned earlier be added to the silage. However, since vitamins A, D and E are inexpensive and frequently added to animal diets, this deficiency is not likely to occur unless mixed feeds are stored for an extended period.

Thiamine (vitamin B_1) in the diet may be destroyed by the enzyme thiaminase, which is present in certain species of fish, most often those of fresh water origin. Although thiamine deficiency in animals has been suspected in certain cases, no response was noted when thiamine was added to the diets of these animals.

This poses a problem which may become more prevalent if fish silage comes into common usage in livestock feed.

PUTTING FISH SILAGE TO WORK

Fish silage provides a relatively high quality crude protein for the supplementation of animal feeds. As we said earlier, it is most useful in the diets of monogastric (single stomached) animals like pigs, poultry, fur-bearing animals and fish.

With ruminants such as cattle and sheep, there is less need for this high quality animal protein. However, given the rapid fluctuations in the costs of other protein supplements, fish silage often offers a thrifty alternative.

Here are some guidelines to follow when using fish silage as an animal feed supplement.

MINK AND FOXES - In Scandanavian countries where a large amount of fish silage is produced, fur animals are fed wet diets rather than dry feeding which is becoming more popular in Canada. These wet diets are prepared at "off-farm" plants known as Central Kitchens. There the necessary ingredients are combined and the prepared diet is transported to the fur ranch several times weekly or daily during the growing season when consumption is high.

The amount of fish silage used in fur animal diets is limited as both foxes and mink are sensitive to diets with a low pH. Mink can tolerate a pH of about 5.5 in the mixed diet while foxes are more sensitive and can tolerate a pH of about 5.8. Usually, about 10% fish silage is used in the mixed diet. However, the amount may be increased during the growing period to a maximum of 30% by weight. It is usually removed from the diet during the breeding season.

It has been reported that young foxes may encounter nutritional problems which have been related to phosphorus deficiency during the early growth period. In some cases, this problem may result in mortality. This can be corrected by replacing sulfuric acid with phosphoric acid in the fish silage to be fed during that period.

High oil fish silage is suitable for fur-bearing animals since the intake of marine oils results in higher quality pelts. However, it must be noted that an antioxidant such as ethoxyquin or BHT at 150-200 parts per million should be added to the silage. The preferred preservative acids are a combination of sulfuric and acetic acids (see Table 2). Other organic acids may reduce the palatability of the fish silage for these species.

PIGS - Fish silage provides a good protein source for pigs. However, unless the silage is low in oil content it must be de-oiled before feeding. It is recommended that the fat content not exceed 1.0% (wet basis) for pigs and that fish silage be removed from the diet at least thirty days before slaughter to ensure that the meat carries no undesirable odor or flavour. In Denmark, current regulations do not permit the feeding of fish silage beyond thirty kg liveweight, but researchers there believe a low-oil silage could be fed up to thirty days before hogs are marketed without reducing pork quality.

Norwegian research has shown that a quantity of ten percent de-oiled viscera silage in the diets of growing pigs resulted in gains equal to those with a soybean meal diet and did not affect pork quality. In addition, no problems should be encountered in feeding fish silage to sows, either regarding their reproductive performance or the vigour of their baby pigs.

In formulating diets for pigs to include fish silage, the composition of the grain mixture must be adjusted to allow for the protein, calcium and phosphorous levels in the fish silage used. This permits the most efficient use of fish silage, and by providing a proper nutrient balance, good animal performance will be assured.

In Norway the use of de-oiled fish silage concentrate is recommended in pig diets. It can be added to meal mixes much the same as molasses is added to a concentrate mix for cattle. Also in Norway, a de-oiled or low-oiled fish silage is made into a produce known as Kleiva fodder. The formula for this product is: fish silage, 55%; ground fresh fish waste, 20%; ground barley, 15%; and grassmeal, 10%. Kleiva fodder contains 30% dry matter and 32% crude protein on a dry matter basis. It is a wet mixture and is delivered by bulk trucks to individual farms where about 1 kg/head may be fed daily to pigs.

Without facilities for mixing and handling wet feeds, fish silage could be hand fed. It could be top-dressed on top of the grain mixture in the proper quantities to give the required nutrient balance. If facilities are available for the mixing and handling of wet feeds this would provide a suitable way of handling fish silage in pig feeding, especially in large operations.

CATTLE (DAIRY AND BEEF) - Since fish protein is largely degraded into amino acids and peptides, it will be of less value to ruminants than to pigs and other monogastric species. Because of the fermentation which occurs in the rumen, the amino acids in fish silage will be quickly degraded and the nitrogen lost unless the animals are on a high energy diet. However, when fish silage protein is available at a lower cost than other protein sources, its usage may be recommended.

Fish silage preserved with organic acids is preferable to silage preserved with inorganic sulfuric acid. This is especially important when the silage is to be combined with other feeds like straw and grain.

Organic acids, especially propionic, will prevent spoilage in such mixtures for a short period.

In Norway cattle are fed the Kleiva fodder which was described under pigs. Feeding rates are up to 3-4 kg/head daily. In Canada where facilities are not likely available for handling wet feeds fish silage may be top dressed on other feeds in the feed bunk or manger, in the appropriate amount.

For cattle feeding as with pigs, the silage must be de-oiled or have a very low oil content to avoid any undesirable flavor or odor in the milk or meat. Studies at Charlottetown showed that fish silage was acceptable to both very young calves and older animals. When a low oil silage prepared from cod offals was fed no undesirable flavor or odor was found in either meat or milk.

FISH - Fish silage is used in preparing pellets for fish feed. In Norway, up to 60% fish silage along with 40% binder is used in pelleted fish feeds. The binder for moist pellets must contain a product such as alginate or guar gum to prevent disintegration of the pellets in water. High oil fish silage containing up to 25% oil can be fed to fish. However, a protective antioxidant must be added.

FISH SILAGE PRODUCTION COST FACTORS

Making fish silage may cost very little in some situations - and considerably more in others. That figure can vary radically from place to place and season to season.

The individual who hopes to use the silage for feed must compare the cost of this material per unit of protein with other high protein feeds like soybean meal or fish meal. These prices, too, can vary considerably.

All potential fish silage operations must be assessed individually. Many factors must be considered and these vary from one location to another. Instead of providing estimated production costs which would not likely apply to most operations (or given economic conditions) we are providing below a detailed listing of the major factors to be considered. A potential producer of fish silage should consider these cost of production factors as they apply to him.

Raw Materials - Is there at present a market for fish processing wastes as fish meal or for fur animal feeding, or is the disposal of these wastes an expense for the processor? Are present disposal methods creating environmental problems which must be corrected? The preservative acids vary in cost and the end use of the fish silage will determine which acid or combination of acids be used.

Equipment - There will be great variation here depending on the scale of the operation. An on-farm operation or a small fish processor may require only a grinder, a suitable pump and storage containers. A processor may actually have several or all of these items available. As volume of production increases so does the sophistication and cost of the equipment up to the fully automated plant which requires large quantities of fish waste to be economical. The end use of the fish silage must be considered. Will de-oiling, desludging and concentrating equipment be necesary? (Schematic illustrations of processing equipment are shown in Figures 1 and 2).

In a fully automated fish silage plant in which the acid(s) is metered in according to the amount of raw material being processed, mixing occurs in the grinding process and the acidified mixture is then pumped into a storage tank where it may be heated to hasten the breakdown of tissue proteins. After becoming liquid, the fish silage is de-oiled by centrifugation, if its oil content is sufficiently high to warrant it, and the silage is not intended for furbearers or fish.

Storage Facilities - Storage needs will vary depending on the seasonal availability of fish wastes and whether the users require a year round supply. Can it be marketed as produced? Will storage be at the site of production or by the user? These factors will greatly influence the storage facilities required and the costs involved.

Transportation - Will the fish silage be produced at the raw material source or by the user? How far must the final product be transported to the end user? Fish silage is high in water content, usually 75 to 80%, so that transportation can be a significant factor in an economic feasibility study. In Norway it was found to be cheaper to concentrate the fish silage to 45-50% dry matter before transporting it. Another factor is whether fish silage itself is to be transported or will it be a component in a mixed feed such as a fur animal diet.

Labour - Labour costs will vary depending on the scale of operation and degree of mechanization. Will fish silage production permit more efficient labor use? That is, will the labour used to dispose of a liability now be used to convert the same material into an asset? In some cases, labour requirement may be decreased.

Energy Costs - These can vary depending on location and must be considered. Energy is required for grinding, mixing, pumping and light. In addition, there may be some heating requirement to speed up the liquefaction process or in some extremely cold situations, to prevent freezing.

Markets - Fish silage will be more valuable to a fur animal or pig producer, or to a fish farmer than to a cattle producer. As outlined earlier, production costs may vary depending on the final use. This can affect the type of preservatives used and whether de-oiling is necessary. Also to be considered is whether fish silage itself is marketed or if it will be marketed as a component of a complete diet.

HOW FISH SILAGE IS PRODUCED

The most important factor in successful fish silage production is to start with fresh raw materials. Whole fish or processing waste (offal) in which some spoilage or bacterial breakdown has occurred is not suitable for silage-making, because the resulting product would be poor in quality, with a high bacterial content and an unpleasant odour. In countries like Denmark where there is a sizable fish silage industry, fish and fish waste products are chilled before being transported from the processing plants or vessels to the fish silage production plant(s). Some trawlers are even equipped to grind and acidify the fish wastes at sea, which has some obvious advantages. This allows the waste which would previously have been dumped to be used and, more obviously, it prevents this material from deteriorating before reaching shcre. The necessity for high quality fresh fish waste products means that the fishing industry must look upon its waste by-products not as trash but as valuable resources, and treat them accordingly.

Contrary to popular opinion, fish silage can be relatively odourless. The lack of odour in Scandanavian plants producing fish silage and formulating wet mink and fox diets mainly from fish waste products attests to that. This is in sharp contrast to the odour problem often encountered in the production of fish meal, which may be caused by the use of partially spoiled raw materials.

One of the main features of fish silage production is the variation possible in the size of operation. This can range from a small, manual operation to a large, fully automated plant which may include facilities for de-oiling the silage. The three major functions - grinding, mixing and storing - are relatively simple procedures that require less expensive equipment than is needed for the production of fish meal. In addition, they use just a fraction of the energy.

PRESERVATIVES

In successful fish silage-making, it is imperative that the right amount of the proper preservative acid (see Table 2) is added to reduce the pH of the ground fish mixture. This is done to inhibit bacterial growth, prevent spoilage and hasten the breakdown of tissue proteins.

Table 2. Some acid preservatives for fish silage and characteristics of the silage.

Preservatives	pH of Silage	Characteristics of the silage
Sulfuric acid, 4-5%	2.5-3.5	Very low pH. Requires neutralization with limestone before use in animal diets.
Sulfuric acid, 2.6%, plus acetic acid, 1.1%, 200 ppm ethoxyquin	3.5-4.0	This is used in Denmark, largely for mink diets. Low pH restricts amount used. Could be fed to other species as well.
Sulfuric acid, 2.5% plus 0.5%, acetic or formic acid	3.5-4.0	This is used in Norway. Uses and restrictions as per Danish formula (above).
Formic acid. 3.5%	4.0-4.5	Less acidic than sulfuric or sulfuric-organic combinations. May be fed to pigs and cattle but may not be palatable to fur-bearers.
Formic acid, 2.0% plus propionic 0.3-0.5%.	4.5-5.0	Used for viscera silage with a low mineral content. Organic acid not acceptable to fur animals and fish.

Several factors affect the choice of preservative acid used in silage-making. These include its availablity, cost and the purpose for which the fish silage is intended. The commonly used materials include inorganic acids, organic acids and various combinations of these acids.

SULFURIC ACID, an inorganic type (see Table 2) is one of the cheapest and most readily available acids for fish silage making. It was one of the first preservatives to be used, but it has several disadvantages. When using this acid a very low pH, 2.5 to 3.0, is required in order to prevent bacterial growth. Therefore, fish silage produced with sulfuric acid must be neutralized before use. Limestone may be used for this purpose. If this is not possible, the quantity of fish silage fed must be limited to avoid a low pH level in the complete diet.

FORMIC ACID, which is readily available, is the most widely used organic acid. It is more costly than sulfuric acid but produces a silage which stores at a higher pH. Formic acid silage should have a pH of 4.0 to 4.5 and should not require neutralization before being fed to animals.

When making fish silage, PROPIONIC ACID is used only in a combination, generally with formic acid. In Norway, viscera silage is preserved with a combination of 0.75% of each acid. Propionic acid kills or inhibits bacteria at a higher pH, preserving fish silage at a pH of 4.5-5.0. However, this acid tends to make the silage less palatable to fur animals, so it is not used in silage intended for these species. However, a SULFURIC-ACETIC ACID combination is commonly used as a preservative in fish silage being fed to mink and foxes. Commonly used amounts are 2.6% sulfuric and 1.1% acetic. This silage will store safely at a pH of about 3.5. It is used in fur animal diets, but only in limited amounts because of its low pH.

THE PRESERVATION PROCESS

As we said, the method most commonly used to make fish silage is to grind or mince the fresh raw material and add the appropriate acid(s), mixing thoroughly to ensure it is completely acidified. In smaller operations, it is recommended that mixing be repeated on several successive days to ensure silage free from spoilage. However, the combined mincing-mixing operation used in larger plants should ensure thorough mixing of the acid with the fish waste.

The amount of preservative acid to add depends on the acid or acid combination and the ash or bone content of the fish material used (see Table 1). Although organic acids like formic, acetic and propionic are more expensive than sulfuric, this factor must be balanced against the greater efficacy of the organic acids and the less acidic silage which requires no neutralization before use. The most economical preservatives, however, may be a mixture of organic and inorganic acids. Using this formula, the less costly inorganic acid is used to lower pH to the the point at which the organic acid exerts its antimicrobial effect. It has been shown that while 4% sulfuric acid alone is required for good preservation, equally good silage is obtained with 3% of a 3:1 mixture of sulfuric and formic acids.

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Liquefaction of the silage is a result of the action of enzymes naturally present in the raw fish waste. The rate of self-digestion (autolysis) depends on the activity of the enzymes present, the pH, temperature and the types of preservative acids used. The most important enzymes, the proteases, have an optimum pH range of 2-5 depending on the enzyme and tissue being digested. A pH in the range of 4-4.5 appears to favor rapid autolysis. It is common, especially in larger, mechanized operations, to heat the acidified mixture to about 30°C to hasten the breakdown of tissue proteins. It has been reported that fish silage protein is about 80% liquefied after one week at temperatures ranging from 23-30°C.

Following liquefaction the silage may be further heated to 80-90°C to allow for proper oil separation. This is done to provide a low oil product for feeding meat or milk-producing animals where the oil may impart an undesirable flavour or odor to the meat or milk.

The oil content of fish silage can be as high as 20% when made from cod viscera which includes the liver. Herring and mackeral are oily fish and could produce a silage containing up to 40% oil. However, fish silage made from the heads and frames of low-oil species like haddock and halibut contain less than 5% oil.

A further step now being done in Norway is to concentrate the de-oiled silage under partial vacuum to reduce the water content from 80% down to 45-50%. Because the resulting silage concentrate contains less water and more nutrients, it is a more economical product to transport. As well, the energy costs for producing this concentrate are about 25% of the energy costs for producing fish meal.

ALTERNATIVE METHODS

An alternative method for preserving fish silage is the lactic acid fermentation technique.

To each 100 kg of fresh fish waste add about 20 kg of a mixture of 1 part malt meal and 5 parts ground oats or barley. This mixture acts as a carbohydrate source for the fermentation.

Another source of fermentable carbohydrates is molasses, added to a level of ten percent of the fish by weight. The fish-carbohydrate mixture should be inoculated with a culture of lactic acid bacteria to ensure proper fermentation and reduce spoilage.

ANTIOXIDANTS

An antioxidant may be added to fish silage to prevent oxidation and rancidity of the fish oil. High-oil silages are desirable for use in fur

animal and fish diets. However, rancidity should be prevented, since some animals will not consume the rancid silage.

Ethoxyquin or BHT at 150-200 parts per million are commonly used as antioxidants. These chemicals should be added at the time of ensiling. Preservation of fish wastes as silage with an antioxidant is the method used in Scandanavia to preserve high-oil material. Even freezing fish waste doesn't necessarily ensure its freshness. Rancidity can develop in spite of storage at below-freezing temperatures.

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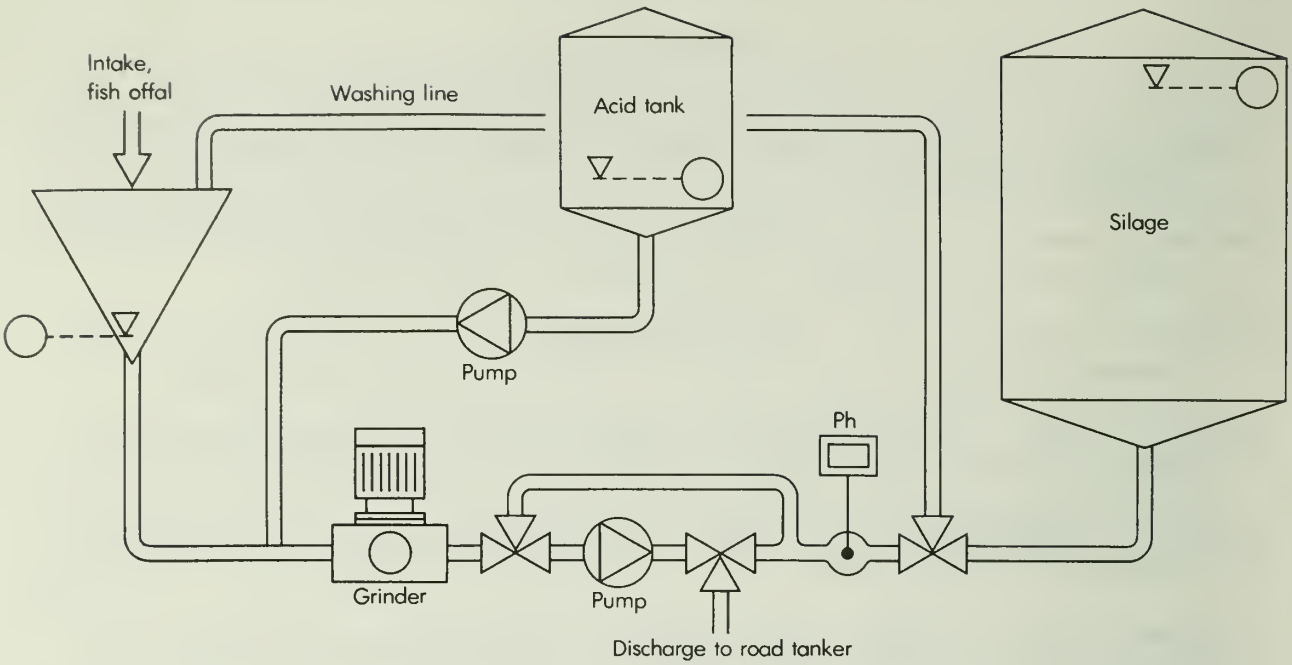

Fig. 1. Schematic diagram of ensiling plant.

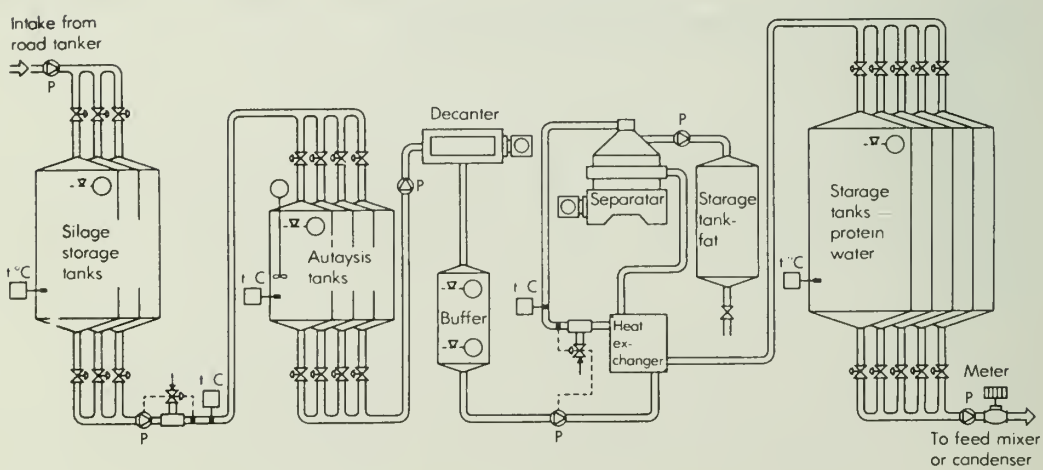

Fig. 2. Schematic diagram of fish silage processing plant.

Winter, K. A.
Fish silage :