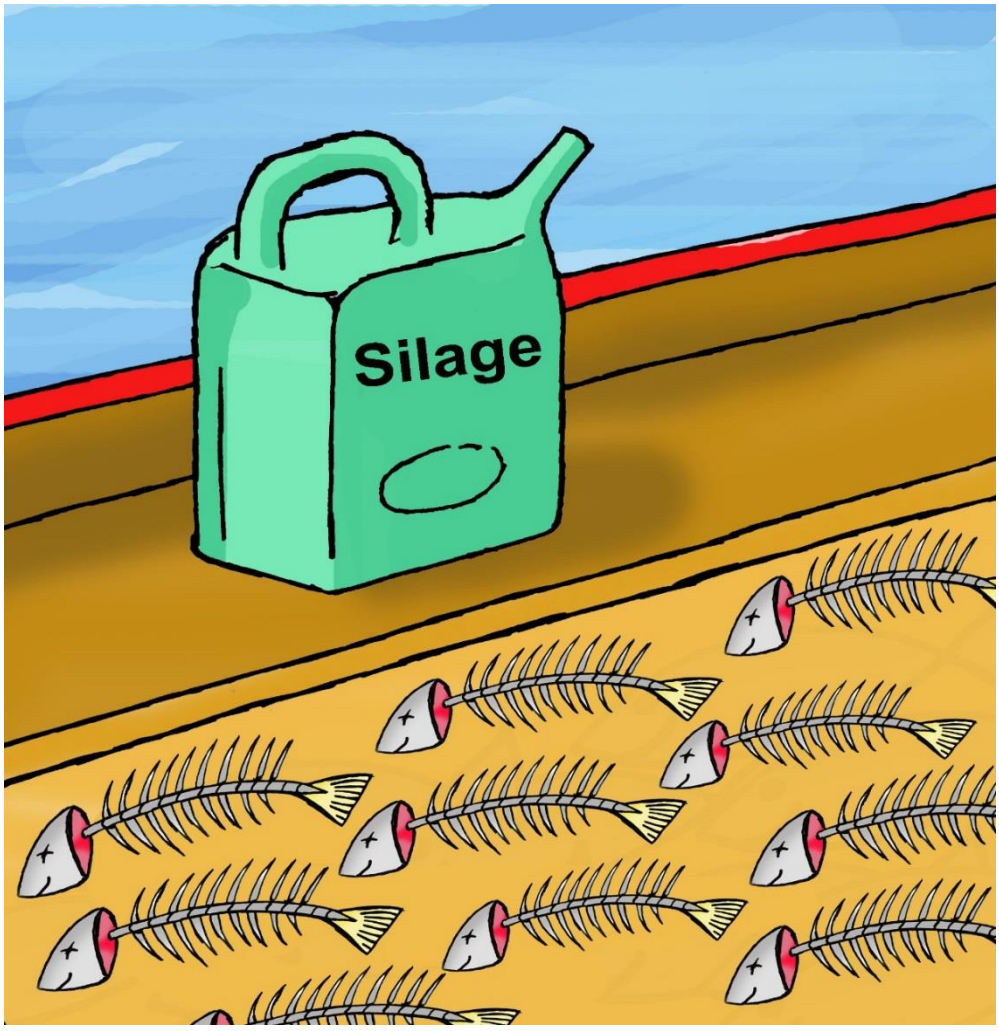
Food and Agriculture Organization of the United Nations

Production and utilization of fish silage

A manual on how to turn fish waste into profit and a valuable feed ingredient or fertilizer



Illustrations: Nelson Avdalov

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A manual on how to turn fish waste into profit and a valuable feed ingredient or fertilizer

by

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Fish and other foods from the aquatic environment are highly perishable. If not preserved or processed within a short time following harvest, post-harvest losses could be significant and a highly valuable fish, or parts of fish, would be lost. Processing of fish will in many cases lead to high amount of waste. By using the technology of fish silage, fish waste can be preserved and transformed into valuable feed input for livestock or fertilizer for crop production. Thus, the technology can turn waste into a product with a high value both from an economic and nutritional point of view.

This publication aims to provide technical guidance on the production and utilization of fish silage. This is intended for individuals and communities involved in fish processing, feed manufacturers and farmers. Setting up a small unit for fish silage production does not require sophisticated and expensive equipment nor highly advanced training. This Manual will focus on a simple technology to convert fish waste into a valuable product, addressing environmental impacts, animal health and economic gains.

Abstract

The processing of fish leads to a significant removal of parts of the fish, such as heads, bones, guts, etc., these parts can represent between 30-70% of the fish. The fish silage process transforms fish waste into a liquid mix of hydrolysed proteins, lipids, minerals and other nutrients, easily digestible by both terrestrial and aquatic animals. It can also serve as an excellent fertilizer. Fish silage could make a difference in terms of; i) environmental impact - by reducing levels of waste, ii) animal health - by providing nutrients and bioactive components, iii) economic gains - as waste is converted into a valuable product that can replace expensive feed ingredients, or be used as a fertilizer. This manual will provide technical guidance and explain each step and main principles of production and utilization of fish silage.

Contents

Preface

Fish and other foods from the aquatic environment are highly perishable. If not preserved or processed within a short time following harvest, post-harvest losses could be significant and a highly nutritious fish intended for human consumption would be lost. In addition, some species of fish and parts of fish are often not considered for food purposes and therefore wasted; adding to post-harvest losses. In many cases processing of fish leads to a significant removal of parts of the fish, such as heads, bones, guts, etc., these parts can represent between 30-70% of the fish. However, simple technology could ensure that more of these resources are utilized and contribute to improved nutrition and food security, directly as a component in local diets or indirectly as a feed ingredient.

In a world where 850 million people are identified by the UN as hungry and where the global population is expected to increase to 9 billion by 2050 it is essential that food is not lost from the food chain. In addition to the strong moral and ethical arguments it also makes economic sense and can contribute to the incomes of lower socio-economic groups. The full utilization of all food resources, including from the aquatic environment, will become increasingly necessary as time goes on. A wide range of technologies is available to convert fish that is currently allowed to spoil or results as waste during processing operations, to products for human consumption, pharmaceuticals, ingredients for the food industry or for fish and animal feed. At issue is the level of sophistication, and cost of the technology selected. Capital intensive technologies such as fish meal and oil production or protein hydrolysates generally require consistent, high volume, raw material throughputs. On the other hand there are simple technologies that can be employed.

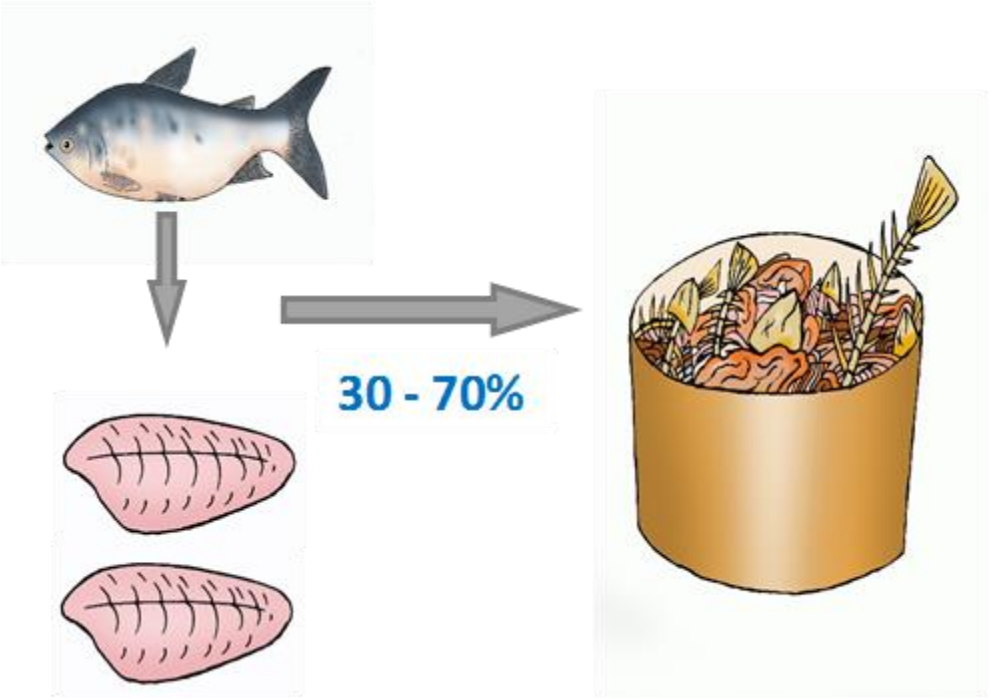
By using a technology such as fish silage, fish and parts of the fish not ending up as human food, could easily be preserved and transformed into a valuable feed input for aquaculture, or for chicken, pork or other livestock production. It could also be used as a natural fertilizer for crop production. This Manual will focus on preserving fish waste by converting it into fish silage using simple technologies, which can be implemented by village communities. The fish silage process transforms fish waste into a liquid mix of hydrolysed proteins, lipids, minerals and other nutrients, easily digestible and absorbed by terrestrial and aquatic animals. Silage produced by adding an organic acid or by adding a fermentable substrate and a bacterial culture, which produces an organic acid, can be stored for years and used when needed. This additional source of animal feed provided by fish silage could make a difference in terms of; i) environmental impact - by reducing levels of waste, ii) animal health - by providing nutrients and bioactive components, iii) economic gains - as waste is converted into a valuable product that can replace expensive feed ingredients. Fish

silage is a valuable feed ingredient with unique qualities that have been shown to improve feed qualities for pork and chicken, as well as farmed fish. Recent research has shown that inclusion of fish silage in feed increased appetite and growth rates of terrestrial animals. It also contributes to a stronger pellet, thus reducing feed losses due to pellets dissolving or breaking before consumption. The organic acids in fish silage have been found to have antibacterial properties, enabling livestock to better resist diseases and stress and thus leading to reduced mortality. This could contribute to elimination of the use of nontherapeutic antibiotics in feed. The free amino acids and peptides in the silage are pre-digested proteins and the presence of limited amounts in feed may result in improved growth. Due to the unique properties of fish silage, major fish feed producers for the aquaculture sector now replace 5-15% of fishmeal with fish silage or silage protein hydrolysate and silage oil, in their feed. The advantages of using fish silage in pork and poultry feed are also well documented. Setting up a small scale unit for fish silage production does not require sophisticated and expensive equipment nor highly advanced training. This manual will guide you through the main principles, and explain each step of the process in order to successfully become a fish silage producer! You will also be shown how the final product can be stored and used as an ingredient for feed or eventually as a fertilizer.

1. Production of silage

1.1 Fish silage in short

Fish processing results in a significant amount of raw material that is unutilized and may be wasted if not converted into by-products. In most cases this can represent from 30 to 70 percent of the original fish. Although ideally, a bigger share of the fish should end up as food, huge amounts of fish raw material never end up on our tables.



At bigger industrial fish processing units the by-products are often processed into fishmeal and fish oil. However, at small scale processing units, investing in a fishmeal plant is not economically viable unless several tonnes of raw material is available on daily basis. When this is not the case, preservation of the raw material by acid silage could be a simple and inexpensive alternative. The silage process preserves the fresh fish by-products, resulting in a product that can be stored for long periods and serve as an excellent feed ingredient.

1.1.1 What is fish silage?

The fish silage consists of minced fish by-products or minced whole fish not suitable for human consumption, with a preservative added to stabilize the mixture. Usually the preservative is an organic acid such as formic acid. Alternatively, a fermentable carbohydrate and a lactic acid producing bacterial starter culture are mixed with the minced fish. Enzymes, mainly from the fish guts, which are active in acid pH range, will then break down proteins by autolysis, into peptides and amino acids, leaving a liquid solution rich in low molecular nutrients and, depending on the fat content, an oil phase.

1.1.2 Why make fish silage

Fish silage is a liquid where proteins are pre-digested, but with a nutrient composition similar to fishmeal. The process is simple and does not require huge investments. The product can be preserved for long periods, even years. Since the silage is liquid, it can easily be pumped into storage tanks or tanks for transport by road or sea. By making silage a waste problem can be converted into profit.

1.1.3 How to make fish silage

The raw material for silage production should be as fresh as possible. You will never make a good silage based on a bad raw material! The raw material, usually fish by-products, will be preserved by adding an organic acid such as formic acid. In order to ensure an efficient preservation of the product, the raw material must be minced and mixed with the acid. The amount of acid needed to prevent growth of bacteria depends on the raw material, but typically, 2-3% formic acid (w/w) is added. However, the final mixture should have a pH of less than 4.0, ideally closer to 3.5 to prevent growth of fungi as well. At this pH, the enzymes from the fish gut will do the rest of the work through hydrolysis, leaving a highly nutritious liquid product.

1.2 Raw material for silage production

Silage can be used as a technology for preservation of many types of raw material. The process is also used for preserving a number of crops like maize, sorghum, and other species of fodder. Producing fish silage follows the same principles, but in addition includes a complete hydrolysis of the product due to the proteolytic enzymes from the fish.

1.2.1 What can be used for fish silage production

Any whole fish, or parts of fish can be used for fish silage. In most cases, fish by-products following fish processing will be the most relevant raw material for silage production. It is important to include fish viscera to ensure sufficient enzymes for hydrolysis are present.

1.2.2 Condition of raw material

The raw material to be used as the basis for fish silage production should be fresh and raw, preferably only a few hours after the fish has been processed to the by-products being ensiled. High quality silage can only be made from high quality raw materials. If the raw material is of low quality, the silage will likely not be usable for feed purposes, but can eventually be used as fertilizer.

1.3 Main principles for fish silage production

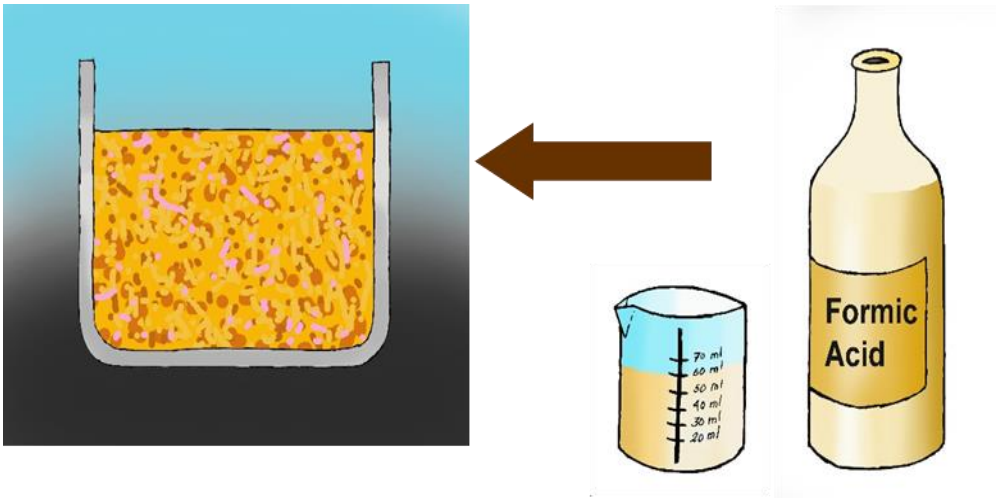
Converting fish waste or by-products into silage, preserves the raw material and increases the bioavailability of the nutrients. This makes fish silage an excellent way of reducing waste and at the same time converting the waste into a valuable product both in terms of nutrition and in terms of economy. The first step in silage production is preservation of the raw material. This is done by first grinding the fish and parts of fish into small sized particles. Then an acid is added to reduce the pH to ensure the product is preserved. Enzymes from the fish active in the acid pH-range, will immediately start a process of hydrolysis, breaking down the protein into peptides and amino acids. When hydrolysis is complete, a liquid product is ready for use or storage.

1.3.1 Use of acid

The simplest way of making and preserving fish silage is by adding organic or inorganic acids to the mixture. Using a lactic acid producing bacteria initiates a fermentation process that can also reduce pH and preserve the product. However, this method is more complicated and requires closer control during the whole process.

The most successful fish silage producers use an organic acid for preservation. If using an organic acid like formic acid, a pH of 3.5 is recommended to ensure a stable and storable product in a tropical climate. This pH will normally be achieved by adding 2-3% industrial grade formic acid (w/w) to the minced fish. Inorganic acids might be of lower cost, but will require a lower pH to ensure the product is preserved

well; a pH of around 2.0 is needed when using sulphuric acid. This implies that the product must be neutralized before feeding.



1.3.2 Enzymatic degradation

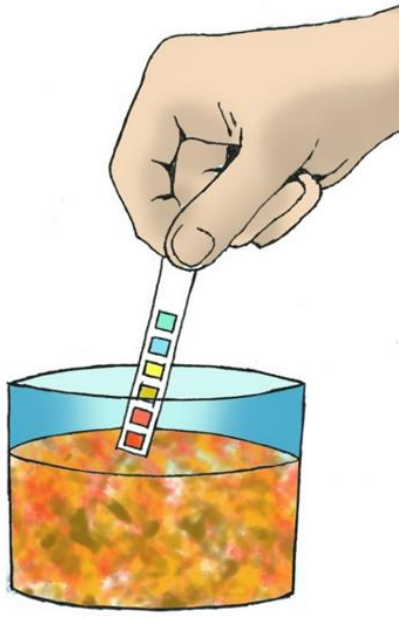
Producing fish silage is not only a preservation method. Fish silage is a mix of hydrolysed fish protein and micronutrients. Enzymes mainly from the digestive system of the fish, but also some enzymes from the skin and the muscle, breaks down the proteins to peptides and amino acids. This makes the nutrients in silage highly bioavailable and easily digestible for animals provided silage in their feed. The acidic environment with a pH of 3.5 to 4.0 is ideal for enzymatic degradation. The temperature in the silage will impact the time it takes to hydrolyse the proteins. Temperatures should optimally be between 5 and 40 degrees Celsius. Lower temperatures slow down the process, and too high temperatures will inactivate the enzymes. In tropical climates the whole process of hydrolysing the proteins will only take a few days, but weeks in colder climates.

1.3.3 Particle size

In order to ensure the mixture is properly preserved, the fish must be ground into particles that are small enough (max 1mm) to ensure the acid can penetrate all cells. If particle size is too large, the inner part of the particle might start rotting and subsequently affect the quality of the whole batch of silage.

1.3.4 Quality control

The first step in ensuring a good quality silage is to check the quality of the raw material; it should be as fresh as possible. The raw material must be minced and mixed with an organic acid, usually formic acid, immediately. Control that pH is below 4.0 throughout the process. The pH might rise before the mix becomes stable, for example if there are a lot of fish bones. Additional acid, approximately one-third of initial volume, must then be added to bring the pH down. Mixing of the silage and control of pH should be done on a daily basis until the mixture has stabilized with a pH below 3.5.



Then it can be pumped into storage tanks and stored for at least 6 months, or even more. Excessive use of acid should be avoided, primarily to keep production cost as low as possible. In the storage tanks pH should also be checked regularly (e.g. every week), and eventually corrected by adding more acid if needed.

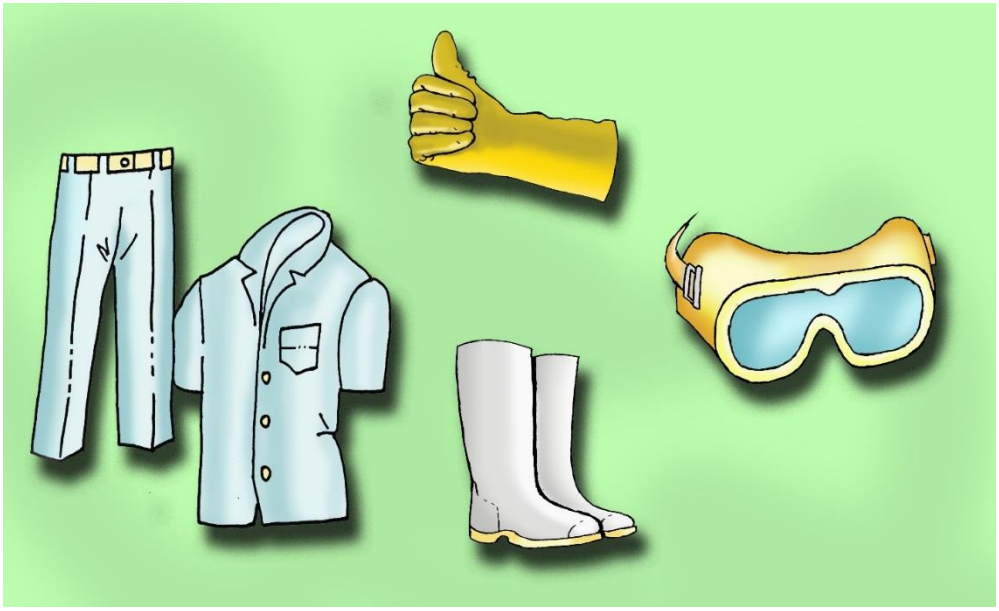
1.3.5 Potential problems

Silage production is a relative simple process if procedures and quality control are strictly followed. However, variations in the raw material might lead to some challenges. If the raw material is of bad quality, it can impact the quality of the whole batch of silage if added.

High levels of bones can neutralize the acid to some extent, raising the pH to levels that could lead to a rotting process of the product. Bones not dissolved will sink to the bottom of the silage tank. Bones settling in the tank should be removed regularly to ensure the quality of the silage in the tank.

1.3.6 Safety

Handling of any acid requires great attention. Protective glasses/safety face shields should always be worn during handling at any steps of the process. During the addition of acid and mixing of acid and silage, acid resistant gloves, rubber boots and protective clothing should be worn in addition. The final product with a pH of between 3.5 and 4.0 (if formic acid is used) is a safe product; in comparison, Coca Cola has a pH of around 2.5!

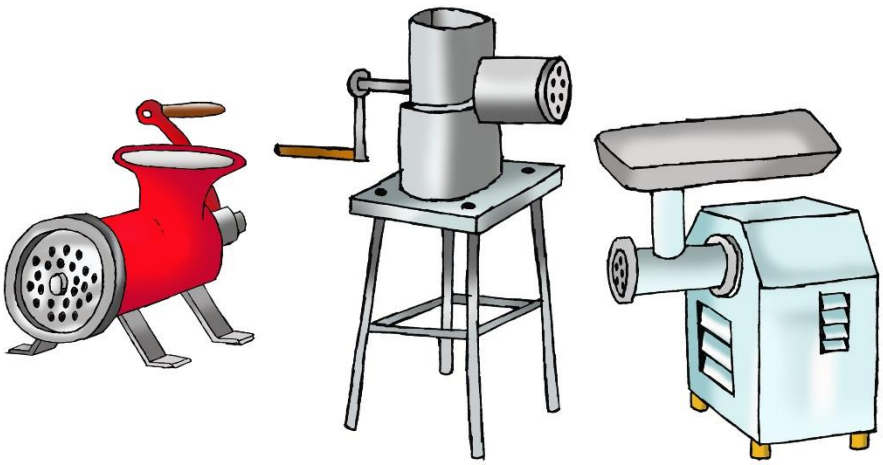


1.4 Equipment

The equipment used for silage production is not highly sophisticated, but regular checks, cleaning and maintenance is needed to ensure good quality silage, and a cost efficient process. The equipment needed can be from small and low cost manual units to bigger automated plants.

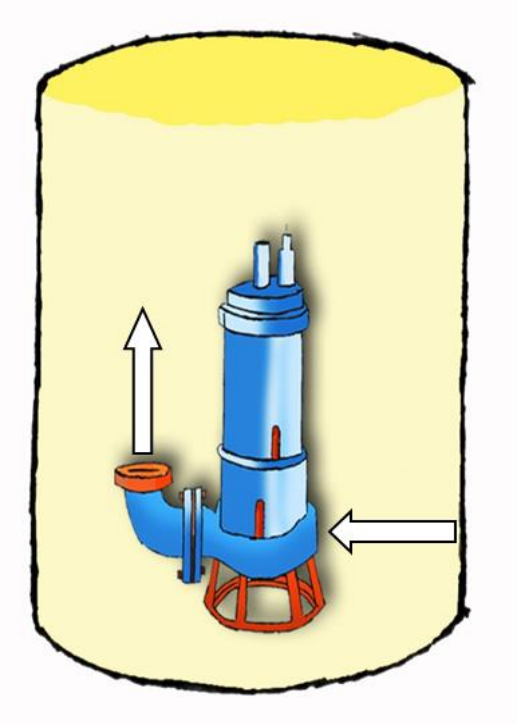
1.4.1 Grinder

The first step in the production process is to grind the product. If volumes are small, this can be done with a manual meat grinder. For bigger volumes an electric grinder will be needed. It is important the grinder produces particles that are small enough to enable the preservative (the acid) enter into the heart of the particle. Maximum particle size should be less than 1mm.



1.4.2 Pump

Pumps are used to move silage from one place to another, for example from production tank to storage tank. They are also used for circulating the product to ensure all fish particles are exposed to acid and enzymes that transforms the fish into silage. In many units a grinder pump is used, doing the job of both grinding and pumping in one operation. Grinder pumps are typically used to treat sewage, but can be used for silage purposes. However, to ensure the pump can resist long time exposure to pH levels of 4.0 or lower, more expensive grinder pumps are available.



1.4.3 Mixing tank

In batch production, which is the most relevant for small scale producers, the grinding of the fish and mixing with the acid, and eventually an antioxidant, is done in the mixing tank. When the enzymes have done their job in breaking down the fish into a liquid, then it is a stable soup of hydrolysed proteins, if pH is still 4.0 or below. In tropical climates, the maturation process will take only a 2-4 days depending on the amount of viscera used, and pH should be below 3.5 to prevent fungal growth. In colder climates the process is longer, maybe a few weeks. The mixing tank should be made of an acid resistant material such as plastic, fiberglass or stainless steel. Some producers of fish silage include sulphites (e.g. potassium metabisulfite) in the silage to control oxidation and fungal growth. In a similar way as producers of wine have been doing for centuries.

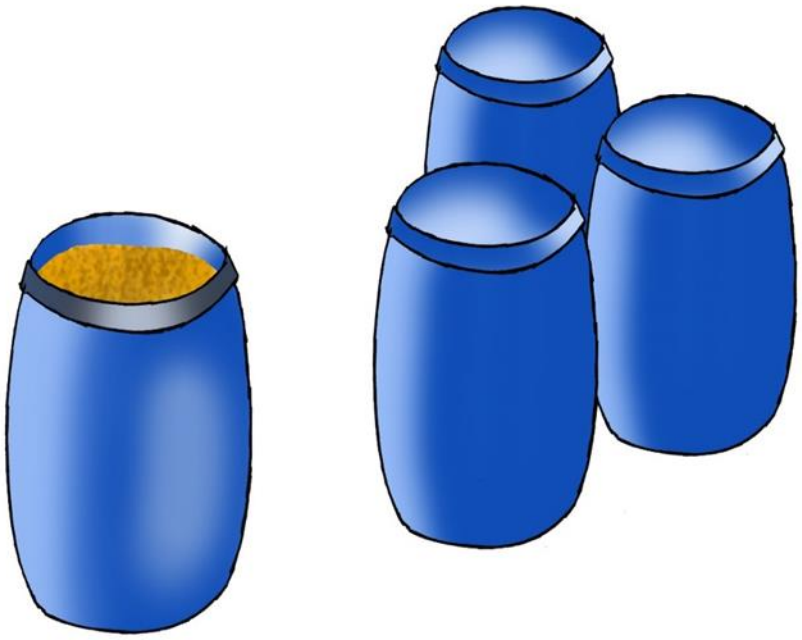
During the process daily mixing is required. This can be done with a pump, or even by stirring the tank with for example a wooden paddle. The pH must be controlled and eventually corrected on a daily basis until stable. Control of pH can be done with a pH-meter. However, in most cases using litmus paper to check pH will cost less and be a good option.

1.4.4 Storage tank

Although the product in the storage tank is supposed to be stable, the pH of the product should be checked regularly. For example every week. The content of the storage tank should also be circulated regularly to avoid any eventual rotting taking place in pockets of the tank. The material used for the storage thank should be resistant to corrosion, and could be of plastic, fiberglass, or even steel. The fat in the silage seems to protect metal when a weak acid such as formic acid is used. However, *galvanized materials should not be used*, this could lead to the development of some toxic components.

1.4.5 Batch production

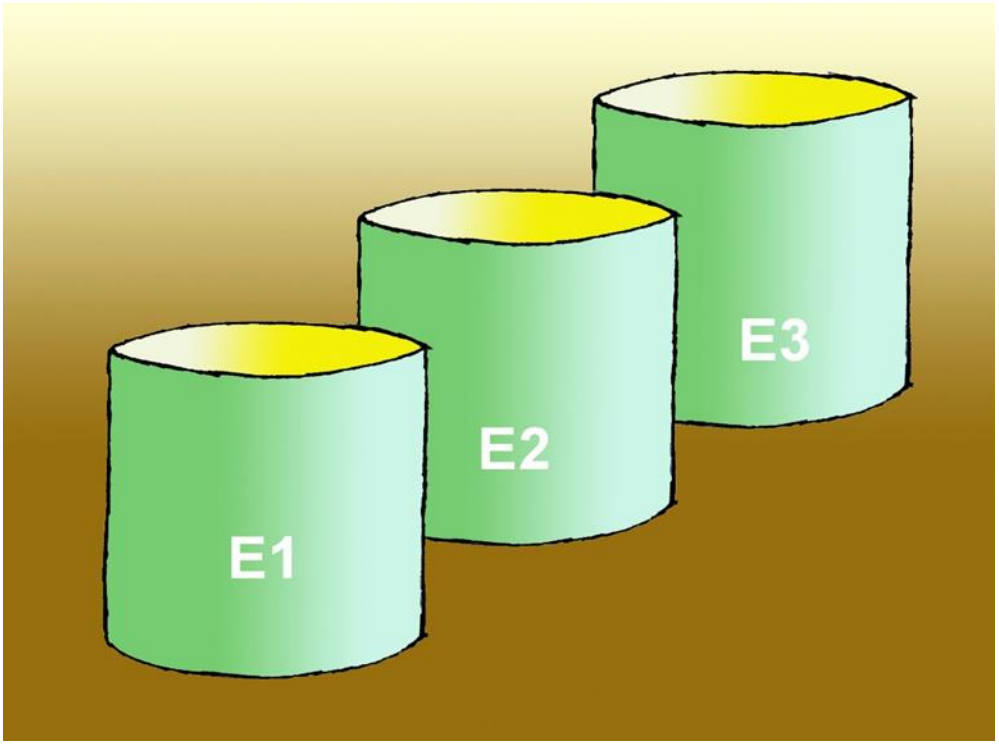
For a small scale fish silage unit, batch production is most relevant. The raw material, acid and eventual antioxidant is added to a tank where all ingredients are minced/mixed in one process. Fresh raw material and acid can be added to the tank until it is 3/4 full. Following one hour of mixing/grinding, the mixture can be pumped to a storage tank if needed.



2. Storage of silage

2.1 Shelf life

If procedures are followed, mature fish silage can be stored for years without any significant reduction in its nutritional quality and safety. Regular stirring of the silage, and pH control and eventual correction is essential. However, studies have shown that levels of the amino acid tryptophan might be reduced in the silage during storage.



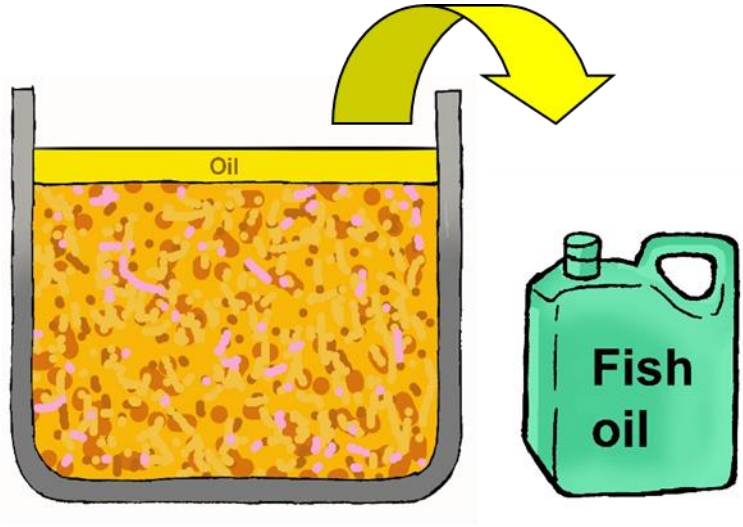
2.2 Quality assurance

Regular control, maintenance and cleaning of the equipment is important to ensure safety for the workers and good quality of the product. To insure the quality, in terms of safety and nutrition is retained in the silage, regular stirring and pH control/correction of the product is essential.

2.3 Separation of oil

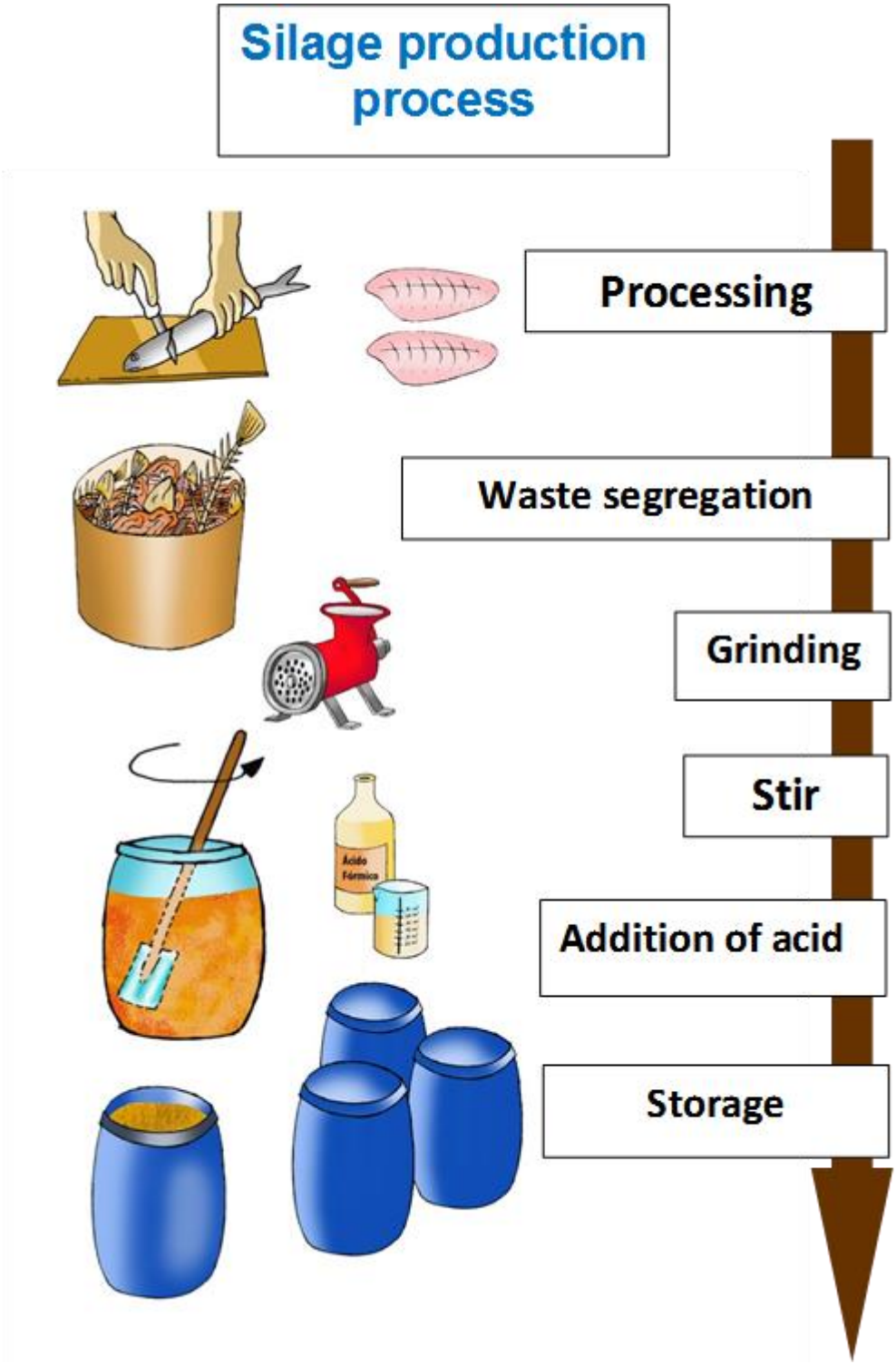
In warmer climates, the fat/oil will float on top of the silage. If no antioxidant is added, this oil will easily go through an oxidation process, impacting on the quality of the silage. In any case, this oil should be separated from the rest of the silage.

This is easiest to do by decantation, however, leaving the silage without mixing for a while will allow the oil to separate from the aqueous phase. This oil can then easily be collected and removed into another tank. If an antioxidant is used, it should be added when acid is added to the mix, to ensure a good quality oil. This oil is a good feed ingredient, particularly for aquaculture feed.



2.4 Separation of bones

High levels of bones or crustacean shells in the raw material will usually lead to a higher consumption of acid in order to reach the recommended pH level. Bones are therefore in some cases separated and not included in the silage, to reduce the cost of acid and to avoid any problems due to pockets with higher pH in the silage, where bacteria can grow and impact negatively on the entire batch of silage. In other cases, where bones are not removed, the bones might settle in the bottom of the storage tank if circulation of the product is limited. These bones should be removed from the tank on a regular basis. Caution should be taken by workers entering storage tanks for cleaning. Gases, particularly CO_2 and H_2S, produced in the residues in the tank could lead to reduced levels of oxygen and cause dangerous situations for workers if ventilation in the tank is not good.

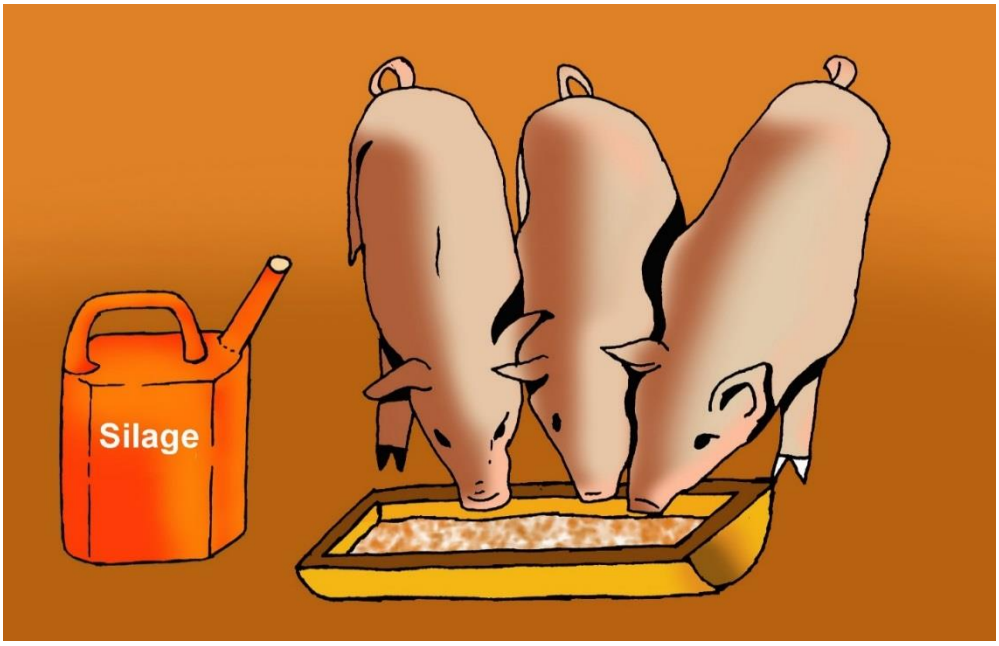

Silage production process
Processing
Waste segregation
Grinding
Stir
Addition of acid
Storage
Ácido Fórmico

3. Utilization of silage

Fish silage is a nutrient dense product ideal for feed purposes, or for eventual use as a fertilizer. The nutrient composition is in practice the same as the raw material used for silage production, and comparable to the nutrient composition of fishmeal on a dry matter basis. The only disadvantage is the high water content, which adds to transport costs. Fat free fish silage will typically have a moisture level of close to 80%, protein level of around 15%, and ash level of less than 4%. If required, the silage may be evaporated, if a higher dry weight is required. Fish silage has similar nutritional properties to fishmeal, but with a higher digestibility due to the hydrolysed proteins. In addition, the organic acid in the silage has antibacterial properties in the intestine of the animal, in addition to serving as a preservative in the silage itself.

3.1 Directly as feed

Due to a relatively low acidity, fish silage can be fed directly without any prior mixing and treatment. This has been done successfully by including fish silage as part of the daily feed for pigs, resulting in higher growth rates, improved health and reduced mortality. In the case of farmed fish, one should not feed fish with processed animal protein from same farmed species.



3.2 Mixed with other feed ingredients

The fish silage can also be mixed with other feed ingredients such as grains or other dry feeds. Following the inclusion of silage, the mix can be fed directly to livestock as wet feeds. This will not require any further processing, but at the same time retain all the nutritional and health benefits of including fish in the feed.

3.3 Use in pellet production and extruded feeds

It is recommended that fish silage partially replaces fish meal in feeds. Due to the highly hydrolysed proteins, silage has a high level of free amino acids and peptides, which have been shown to improve growth performance when included. Use of fish silage for extruded feeds is well documented with good results. The silage can replace part of the fish meal (typically 5-15%), and will partially replace the water added to the mixture before extrusion. The inclusion of silage has also shown that pellets produced by extrusion are stronger and more resistant than without silage. A stronger pellet reduces waste e.g. dust during transport and feeding.

3.4 Fertilizer

The silage may be used as a fertilizer if it does not meet the quality requirements for feed purposes. Fish silage is a good source of Nitrogen (from the protein), Phosphorus, Potassium, Calcium, and Magnesium (particularly from the bone structure) and most trace elements needed for plants.

The application of fish silage as a fertilizer can be done as part of the irrigation process by directly adding around 2-5 % liquid silage to the irrigation water. The nutrient composition of the silage may vary depending on the raw material used, so if the proportion of bones is high, levels of, for example, phosphorous and magnesium will be higher.

Fish processing leads to by-products like heads, bones, guts, etc., that represent between 30-70% of the fish when processed, and are often not utilized. The technology for producing fish silage is simple and could ensure that these resources are utilized and not wasted. The fish silage is a fish hydrolysate that can be used as a feed ingredient or eventually as a fertilizer. Fish silage is a valuable feed ingredient with unique qualities that have shown to improve feed qualities for livestock and farmed fish, enabling better resistance to diseases and stress and reduced mortality. The use of an organic acid, as proposed in this manual, will also lead to fish silage with antibacterial properties.

This manual provides guidance on adding value to fish waste thru fish silage technology and includes the main principles and steps to follow in order to become a producer of fish silage. Proper storage and useful applications such as feed ingredient or fertilizer are also discussed. The production of fish silage does not need sophisticated and expensive equipment, and can be done even by small scale fish processors and farmers.

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