FROM SEA TO SOIL: ADDING VALUE TO FISH WASTE

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Every year across the Pacific, thousands of tonnes of fish waste are either discarded at sea by fishing vessels, or buried in landfills where the stench from the rotting waste attracts flies, rats and other pests. Turning this waste into useful silage adds value to an otherwise untapped and unused resource, and can provide island communities with an inexpensive source of organic fertiliser.

With this in mind, the Nearshore Fisheries Development and Training Section of the Secretariat of the Pacific Community (SPC) facilitated a pilot project to turn fish waste into fish silage for use as a fertiliser and/or as a livestock food additive. The project took place at Wé on Lifou Island in New Caledonia's Loyalty Islands group, where the local seafood retail shop processes several tonnes of fish every month.

The practice of dumping waste from processed fish in the municipal landfill has raised concerns in Lifou communities. Subsequently, in 2007, the Loyalty Islands provincial fisheries department sought SPC's assistance to turn local fish waste into a commercially valuable byproduct. Fish silage was quickly identified as the most suitable option, due to the presence in Lifou of a number of organic farms. Farmers there import large amounts of fertilisers, including fish silage (4400 litres sold at XPF 1000 per litre in 2007).[4]

The primary goals of the project were to source and supply the equipment and materials needed to carry out the trial production of silage, produce silage that was liquid enough to be mechanically sprayed onto food crops, and advise the Poisson-nerie de Lifou and the Loyalty Islands provincial fisheries department on the specifications of a fish silage facility, including processing equipment, and the procedures required for medium-scale commercial production of fish silage.

Initial funding for the project came from the French Pacific Fund, the Loyalty Islands Province and SPC. Local stakeholders included the Loyalty Islands provincial fisheries department, staff of Poissonerie de Lifou, and local farmers

What is fish silage?

Fish silage is a liquid organic product made entirely from ground up fish waste (e.g. heads, guts, skin and cartilage). The waste, which contains minerals, trace elements, complex nutrients and amino acids, can be used as a fertiliser for soil or as a supplement to animal food.

Making and storing silage

Silage production begins with chopping or mincing fish waste into small particles. In the pilot project, two types of "cutters" were used: one for processing the heads and skeletons of large pelagic fish such as tuna, mahi mahi and marlin, and a smaller cutter for use on reef fish.

The large cutter used during the trial was a machine regularly used on New Zealand toothfish longline vessels as a preparatory step for making fishmeal, or as a way to minimise the volume of waste on board when vessels are fishing in seas where waste and offal cannot be discharged directly overboard (e.g. the Southern Ocean).

The smaller, hand-operated cutter can be used by a single person and can be fitted with a small motor to increase its power and efficiency. The cutter was designed to process split heads but there was no equipment on hand during the trial to break down the heads prior to loading into the cutter. The cutter has since been returned to New Zealand for modification. In addition to increasing the gearing ratio and making it more robust, the small cutter will be fitted with a fish head breaking device.

After the fish waste was cut up, it was placed in several plastic tubs, of either a standardised volume or a standardised weight. Formic acid was then added to each tub to aid in the liquefaction process; the entire mixture was then thoroughly mixed so that all of the material came into contact with the acid, otherwise, any untreated fish particles would putrefy. The proportion of acid used was 3.5% by volume (i.e. 350 ml acid to 10 kg of fish waste). The acidity of the mixture was kept at pH 4 or lower to prevent bacterial action. The natural silage process then began.

The rate of liquefaction depends on the type of fish, the parts used, freshness of the raw mate-

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[4] USD 1 = XPF 95

Top. The large fish cutter; typically used in New Zealand's longline fishery in the Southern Pacific Ocean. This model was purchased second-hand and was reconditioned prior to its shipment to Lifou. The inside view of the cutter shows the steel shaft that is made of a series of hammers, which pre-breaks fish waste on a corresponding series of anvils.

Bottom. The manual fish cutter is aimed for use by small-scale reef fishing operators.

rial, and the temperature of the mixture. In fact, the warmer the mixture, the faster the silage process. According to an FAO report,[5] silage made from fresh white fish viscera takes two days to liquefy at 200°C, but takes 5–10 days at 100°C, and even longer at colder temperatures.

During the Lifou trial, the time allocated for on-site silage production was only 10 days, but within this period, the conversion of fish waste (from tuna, marlin and mahi mahi) into stable silage was successfully accomplished.

Most kinds of fish can be made into silage, but the parts used for processing should be fresh; thawed, previously frozen fish can also be used. Sharks and rays are difficult to liquefy and so should be mixed with other fish species.

The inclusion of fish guts in the mixture is very important for speeding up the process, as the viscera contain enzymes that aid in liquefying the fish. During the trial operation, very little viscera were available as the raw material originated from longline-caught fish, which are typically gilled-and-gutted at sea. However, the effect of the low ratio of enzymic material on the overall quantity of raw product was dealt with by working with small control batches. In the future though, it will be necessary to encourage fishermen not to dump viscera at sea, but to bring it back to port for processing.

Due to a lack of adequate testing equipment during the Lifou trials, it was not possible to finely control the pH of the mixture. However, if the proper pH level is maintained, then the silage should keep at room temperature for about two years.

[5] http://www.fao.org/wairdocs/tan/x5937e/x5937e00.htm

FISH SILAGE PROCESSING

Preparation

- **Decant the acid into a small easy-to-use container. Wear gloves and eye protection.**
- **Minced product should be placed in containers with a standardised volume or a method of weighing batches.**
- **A non-ferrous stirring pole should be available.**
- **A pH meter should be ready for use.**
- **The cutter equipment should be ready and clear of residue from previous processes or any other material. (See below for routine maintenance.)**
- **The fish parts used for processing should not be stale. Thawed, previously frozen fish is acceptable. The inclusion of guts is important to speed the liquefaction process. Batches should not be made up of only sharks or rays.**
- **Ensure there are no hard foreign materials among the fish parts, such as hooks or stones.**

Process

- **Lift the fish parts into the cutter ensuring hands, loose clothing and personal effects are kept well away from the moving parts. Do not place any uncut parts in with the cut product. The action of cutting/mincing allows the natural enzymes and acid to make contact with the greatest amount of product as quickly as possible. Where possible, batches should consist of different fish parts (i.e. be a homogenous mixture).**
- **The chopped fish is collected in small batches of either a standardised volume or weight. The required amount of formic acid is added and the batch is well mixed. There will be a change in the product's texture when the acid has made good contact. There will also be a colour change throughout the batch. The amount of acid to be added is 3.7% by weight (370 g to 10 kg of fish waste) or 3.5% by volume (350 ml to 10 L or kg of fish waste).**
- **Batches should be stirred and tested daily for acidity (pH). The pH of the mixture should be between 3.5 and 4. If the pH is above 4, then thoroughly stir the mixture before adding more acid.**
- **When the batches become more liquid, brown and easy to stir, they can then be transferred to a non-ferrous storage vessel.**
- **Until experience is gained, the pH of the product in the storage containers should be tested daily for the first three days, or until it is used or full.**
- **Clear the machine of material after processing. Two full buckets of water are better than a hose. Remove top and bottom orifice plates to aid.**

Notes

Fish silage will reduce in quality and become unpalatable if it is stored in hot conditions, has a high oil content, or is exposed to sunlight.

1. **Fish silage is high in nutritional value. After processing, the higher the temperature of the product, the greater the reduction in high value amino acids.**
2. **The silage should be in a liquid form after four days in warm weather.**
3. **Silage made from fish with a low oil content should be stirred before decanting from the storage container.**
4. **In its liquid form silage can be stored for several months.**
5. **In fisheries where the gills and gut are removed at sea these should be kept chilled or frozen and brought ashore to assist in the process (autolysis).**
6. **Cutter maintenance should be performed every five days of operation or when there is likely to be a period of idleness. Check for loose nuts and bolts. Grease the front and rear bearing nipples. Overhauls, including the replacement of knives and anvils, will be required after a year of frequent use or as inspection dictates.**

Silage processing facility needed

The pilot fish silage trial was carried out in a workshop adjacent to the Poissonnerie de Lifou at Wé. The Poissonnerie de Lifou operates under HACCP protocols, which do not permit a product that is unfit for human consumption (i.e. fish waste) to be processed in the same environment as fish being processed for markets. Because the processing could not be accommodated in a controlled environment, it was carried out in a nearby workshop.

However, this makeshift facility proved to be less than ideal because of the lack of working surfaces, and a floor that sloped away from the nearest drain, which made the cleaning of equipment and the facility difficult. The makeshift premises highlighted the need for a purpose-built fish silage plant. Rough specifications for such a processing plant on Lifou have been developed, although the shape and design of any supplementary equipment will need to be incorporated into the overall building design (see box below).

Basic requirements for a silage plant on Lifou

Easy to clean interior surfaces with a good fall in the floor to drains (both sides), with solid drain traps and vermin-proofing all leads to the sewer.

- **Easy access from the waste storage area of the fish processing building to two holding rooms: one for freezing and the other for chilled storage of fresh, ready-to-use product.**
- **The door opening to the main processing area should allow fork lift access, although the regular lifting of heavy drums could be done with an overhead gantry.**
- **3 Phase and single phase power should be available from an overhead supply to avoid cables lying on the floor.**
- **A separate mechanically ventilated room to accommodate the storage and handling of formic acid. This could also act as a laboratory/records office.**
- **The upper part of the building (loft) could serve as a storage area for empty containers.**
- **There should a place for staff to hang their outside clothes and to be able to shower in case of acid contamination.**
- **The general working space must accommodate the large cutter, a mechanical mixer, storage of batch buckets, holding drums or storage tanks, a blender/mill/filter as dictated by final product form and client requirement.**

Left. The remains of a large opah (*Lampris guttatus*) are fed into the fish cutter.

Right. Ground up waste is collected after the passage through the orifice plate.

Benefits and use of fish silage

The benefits of fish silage production include:

- Value is added to an otherwise untapped and unused waste product. Adding value and using often discarded fish waste would contribute towards a more sustainable use of scarce fisheries resources.

- The amount of imported fertiliser and animal feed is reduced. Currently, local farmers on Lifou and elsewhere in New Caledonia and the Pacific rely on expensive imported fertilisers to improve soil condition, particularly on atolls, which have impoverished soils.

- Fish waste disposal costs are reduced. In New Caledonia, fish market vendors are responsible for and bear the cost of the proper removal and disposal of fish waste.

- Fish waste dumped in landfills is greatly reduced. The current practice of disposing of fish waste in landfills results in the attraction of flies, rats and other pests, which can affect human health through diseases and water contamination.

- Relatively low technology equipment and facilities are needed to carry out the production of fish silage. This means that operating costs are relatively low and any necessary repairs are simple to carry out.

- Skilled or specialised labour is not required, so silage production can be done in most Pacific Island communities. It may also be an area of income generation for women.

- Additional income generation opportunity is possible for processors.

Top. Formic acid is carefully added to the grinded fish waste, its role is to stabilise the resulting silage by avoiding bacterial spoilage.

Bottom. After the addition of acid, the grinded fish waste is transferred into plastic buckets with lids.

After 24–48 hours, the product is transferred into large holding containers where the silage will mature for another 3–4 days, depending on temperature and the amount of natural enzymes in the fish waste.

In addition, the making of fish silage has virtually no negative environmental impact because the only input other than fish waste and manpower is a small quantity of organic acid.

Future silage production needs

In order to determine the composition of the silage produced during the Lifou trials, laboratory analyses were carried out (see figure below). The proportion of nitrogen, water, protein, minerals and other substances will determine how suitable the silage is as a fertiliser or as animal food. It may be necessary to adjust the ratios, depending on the end use. At the time this article went to press, advice was being sought from staff of SPC's Land Resources Division on the suitability of the Lifou silage as fertiliser and animal feed.

Another aspect of the process that needs refining is producing a liquid fertiliser that is fine enough to be broadcast from a sprayer onto plant foliage. The silage produced during the trials contained many particles that were large enough to clog the nozzle of a sprayer, although it was suitable for pouring underneath plants directly onto the soil. Future trials will need to investigate and source equipment that will break down and emulsify the solid particles even further.

The mixing of the acid with the cut fish needs to be mechanised to ensure a thorough coating of all fish parts in what should be a homogenous batch and to reduce the manual effort used during the trials. Experiments are also underway to find a suitable enzyme that could be used to supplement the natural fish enzymes in achieving a better liquefaction, should the fish continue to be landed without the gut enzymes.

Conclusion

A fish silage plant can be readily built on other islands as well, meaning the success of this project will be of value to both the Lifou community and other Pacific Island countries. Such plants add value to fish waste that would otherwise be discarded, and reduce adverse environmental impacts. Fish silage can also be produced at a smaller scale through the use of a manually operated fish cutter, a prototype of which was successfully trialled in Lifou. This scale of production appears suitable to individual fishers or small fishing cooperatives on islands (especially atolls) where the lack of fertile soil constrains the development of agriculture.

Pacific Island countries are looking for ways in which they can balance the growing nutritional and livelihood requirements of their rapidly increasing populations with the production capacity of their terrestrial and coastal fisheries ecosystems, while at the same time maintaining the integrity of their island environments. Fish silage production may be one small step towards achieving this.

Sample	Nitrogen (g/m^3)	Phosphorus (g/m^3)	Potassium (g/m^3)	Calcium (g/m^3)	Protein (g/100 ml)	Fat (g/100 g)	Carbohydrate (g/100g)	pH
"Combo" (commercial fertiliser imported and used in Lifou)	4719	280	73					3.84
Reef fish silage	6062	140	120			1.7		3.29
Pelagic fish silage (filtered)	5201	130	95	210	16.3	3.3	0.4	3.81
Pelagic fish silage (unfiltered)	7227	200	85	320	69.6	3.5	1.2	3.8

Laboratory analysis of the Lifou fish silage