Application of several treatment techniques for solid wastes from freshwater fish farms

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Because of a shortage of some species by extractive fishing and the increasing worldwide demand for fish products, aquaculture seems to be a reasonable alternative to satisfy the demand. Aquaculture is an expanding sector in terms of increasing production tonnage and in the number of new cultivated species.

The consumer demand for fish products has increased because it is known that they are healthy sources of protein and contain beneficial polyunsaturated fatty acids. But the modern life style does not leave much time for food preparation and the consumer demands products that are easy to buy and to cook. In the case of fish products, the demand for degutted and filleted fish is increasing dramatically. This presentation of the product produces increased waste at the production plants, creating environmental and economic problems, not to mention the difficulties in complying with environmental regulations (SFIA 1999).

Aware of this situation, the Spanish Ministry of Agriculture, Fisheries and Food, decided to finance a project to help the development of the Spanish freshwater fish farming sector. The project was carried out by researchers of AZTI-Tecnalia. The proposed work had two parts. The first one was to study the solid waste problem and the second was the application of minimization techniques on 10 rainbow trout farms in Spain. The location of the farms is shown in Figure 1. The project was financed fully by the Ministry.

Goals and Methodology

The main goal of the project was to establish the best alternatives to minimize and manage the solid wastes of the participating freshwater fish farms, with the partial goals of:

- Obtaining a sector diagnosis of the environmental problems,
- Evaluating the alternatives for minimization, recycling and final treatment of wastes for each of the participating farms, and
- Identification of the feasible valorization possibilities for the sub-products and wastes, from the technical and economical point of view.

The methodology used in this project involved:

- Completion of waste characterization of the voluntary participating fish farms and conducting an environmental diagnosis,
- Identification of the main requirements for the wastes, from the legal point of view, taking into account the European, Spanish and local legislation, and from the technical point of view, with a state-of-the-art technology review and identification of potential users (Henningsson 2004), and

- Proposing a personalized action plan, considering the data obtained in the previous steps, such as the:
  1. Suitability of the analyzed wastes for use as by-products,
  2. Economic and technological study of the waste minimization alternatives,
  3. Identification and evaluation of valorization alternatives.
  4. Definition of the process and logistics to make good use of the by-products, and
  5. Disseminating the results.

To carry out the waste characterization, a questionnaire was sent to the participating farms asking for specific data about consumption and generated wastes (SEPA 2005). All the facilities were visited by the expert. In those visits, the technology used and the waste generation points were assessed.

A confidentiality document was signed to ensure that the data given by the plant could not be used for purposes other than the application of the minimization techniques.
to reduce wastes. During each visit any data missing from the completed questionnaires were collected. Finally, the production points where the waste samples had to be taken were identified and samples were taken for further physical-chemical analyses. In those cases where samples could not be taken, a protocol was given with instructions on how to take the samples, conditions of transport of the samples and the transport company contact information.

As result of the data collected from the questionnaire and the visit, an environmental diagnosis report was given to each of the participants, including the improvement points and the analytical results of the samples taken. With this document, a personalized action plan was proposed for each participant.

In this study, it was observed that the main environmental aspects involved in the freshwater fish farm activities were those relating to the use of natural resources and those relating to the filleting and degutting of fish.

The solid wastes generated on the fish farms were materials such as cardboard, paper, plastic, pallets, dead fish as a result of illness or accidents, slaughtered fish that did not meet the commercial requirements, heads, guts and bones, fats, excrement and excess feed and sludge.

**Environmental Management**

Most of the participants had a certified Quality System (40 percent ISO 9001, 30 percent International British Retail Council certificate, 10 percent local Government Quality Certificate), but none of them had an environmental certificate. Nevertheless, the participants engaged in environmental improvement activities, such as the installation of water treatment plants, and participated in projects for correct waste handling and management.

**Observed Waste Management Problems and Alternatives**

The locations of most freshwater fish farms were far from the coast and very close to the mountains, which provide clear and good quality water. These remote locations also presented a problem, because the roads tended to be narrow and the accessibility was not easy.

**Dead fish.** Dead fish are a waste that presents problems for its disposal because it is considered as Category 2 according to the European Union legislation (CE 1774/2002). Therefore, their transport and management present certain difficulties.

From 7-10 percent of the total fish production died from disease, and about 0.07 percent of the total amount of fish died for physical reasons, such as transport and logistics. Another 0.43 percent were recorded as dead fish, because after they were slaughtered they did not meet the quality standards to be marketable. They were too small or had injuries. The occurrence of these deaths is occasional, so it is very difficult to foresee a large amount of dead fish; but it tends to occur with more frequency during the summer months.

The current management alternatives for this type of waste are:

- **Ensilage:** it has high costs if proper installations are acquired, which include purchasing of the facilities, labor to maintain them and the purchase of chemicals (formic acid). The resulting product cannot be used as animal feed and must be transported and managed by licensed personnel, therefore, no profit can be made of it.
- **Burial in landfill:** Calcium oxide is needed to cover the dead fish before their burial. Workers are necessary to fulfill this task. No profit can be made from this practice, which has inherent problems of bad odors and possible subterranean water contamination.
- **Burial in controlled areas:** There must be a controlled area within the surrounding area and it also takes manpower to dispose of the dead fish. No profit can be made from this practice and it also has inherent problems of bad odor and management problems in the immediate area.
- **Compost:** requires having the required facilities available and manpower to dispose of the dead fish. Little profit can be made out of this practice because the compost price is very low.
• Stabilization with calcium dioxide and further sending to a rubbish dump: It requires having adequate facilities nearby plus a licensed manager to manage the wastes. No profit can be made out of this practice and it implies a high management cost.

**Heads, guts and bones.** Heads, guts and bones are considered Category 3 wastes of animal origin and can be used for the production of pet food, biogas, compost, etc. in accordance with Article 33 of CE1774/2002. Twenty percent by weight of the processed degutted fish goes as waste and 50 percent of the processed filleted fish ends up as waste. This type of waste is produced through the whole year, with no specific production peaks.

The current management alternatives for these wastes are the same as for dead fish (ensilage, burial in landfill, burial in controlled areas, compost producing) or other economically interesting alternatives such as:

• Fish meal production. This requires refrigeration or freezing of guts. Proper equipment is needed. Currently, no profit can be obtained from this product. If the fish farm has the ability to send the guts to a fish meal factory and the distance is not too great, the factory could pay something. Cattleman would pick up the guts for free. No further profit can be made out of this option.

• Mink feeding. This requires refrigeration or freezing of the guts.

• Agrarian implementation. There is no cost nor profit, but periodic analysis of wastes and soils must be obtained where the wastes are thrown.

The management of sludge, ensilage and fats originating in the water treatment plant were also studied.

**Proposed Solutions**

When the waste solids were identified and quantified, the expert team from AZTI-Tecnalia proposed on one hand, opportunities to minimize the generation of the wastes, and, when they are produced, the most suitable management for each, according to their characteristics and the quantities.

_Minimization opportunities._ The generation of wastes has been found to occur principally in areas where minimization techniques apply:

• Processing area: The use of appropriate cutting tools is essential, because it helps to improve the production yield. Another important improvement is the use of watertight or waterproof containers, thus avoiding contamination with dirty water. Installation of filters in sinks helps minimize the amount of solids in suspension in the wastewater. The dry recovery of solid wastes minimizes the use of water for floor washing and improves the quality of liquid wastes.

• Degutting area: proper maintenance of the gutting machine and personnel training to get full efficiency in the degutting activity to improve productivity and reduce wastes. If trays are installed below the filleting machine, the wastes can be easily gathered, instead of falling directly on the floor.

• Packaging: dealing with suppliers to negotiate the pick-up of packaging materials and increase the use of large bags.

• Dead-fish: to avoid fish death it is important to optimize the hydraulics of the pools. Another measure is to retain the solid wastes before pumping the water to other pools and to avoid overloading the pools with fish.

• Feed: the optimization of the feeding method is a key factor to reduce feed cost (Cho 2006) and to minimize the generation of sludge in the pools. The best alternative is to fit the farm with facilities to reduce losses by feed handling.

**Exploitation Opportunities**

To make profitable use of the generated wastes, it was necessary to take into account the legal requirements. Some of the wastes were considered Category 2 according to the European Union legislation (CE 1774/2002), the volume of the produced wastes and their organic nature.

The most problematic wastes to manage are fresh guts and the killed fish that are not marketable, the ensiled products, the fats, the sludge from the pools and the dead fish.

The alternatives of waste management applications were studied from the technical and legal points of view. The potential users of the wastes generated on the farms have been identified in the vicinity of the farms in an attempt to minimize the transportation impact and cost.

According to the above-mentioned criteria, the uses of the different wastes are as follows:
1. Fresh guts and nonmarketable slaughtered fish.

Fish meal production. According to a previously study by AZTI-Tecnalia on freshwater fish farm wastes, some aquaculture plants in Spain were sending their wastes to fish meal plants and the tendency was increasing. This was the best alternative for heads, guts, and non-marketable killed fish. A list of fish meal factories in Spain was handed to the fish farmers so they could contact the nearest one. It was important to highlight that dead fish could not be used to produce fishmeal.

Mink feeding. Mink farms were interested in receiving fish guts and fish suitable for, but not marketed for human consumption as long as they were in good condition. A list of fish meal factories in Spain was handed to the fish farmers so they could contact the nearest one. It was important to highlight that dead fish could not be used to produce fishmeal.

Compost. The wastes could be used to produce compost, even if they were considered Category 3 according to articles number 5 and 6 of the CE number 1774/2002. New Spanish law RD 824/2005 about fertilizers includes a list of biodegradable wastes to be used as fertilizers in which aquaculture wastes fit in sections 02.01 and 02.02. The wastes have to be ground and undergo heat treatment at 80°C for five minutes and obtain a local authority certificate assuring that the product has been exposed to adequate treatment and that it was inert.

Acid ensilage. This is another alternative to manage guts and noncommercial fish in a simple way. It consists of accumulating the wastes in a silo together with acids. There was no need of refrigeration or freezing and the product could be collected every 2-4 months. The disadvantages of this option are that not many animal farms were interested in ensiled fish wastes (they prefer fresh or frozen fish), the transport of liquid was not as easy as for solids, the price in the market was quite low and it required personnel to put the wastes into the silo everyday.

2. Ensilaged wastes. Samples taken from different silos were analyzed and it was observed that they had a high content of fats and oils. When the oils were analyzed it was observed that the oil profile corresponded to that of the fish, so it could be used for similar purposes as the fish oil: animal feeding, industrial applications and biodiesel generation. Oils obtained from ensiled dead fish could not be used under any circumstance for animal feeding. Considering that 70 to 80 percent of the ensiled material is water, it might be useful to install fat separators to facilitate the fat and oil extraction from the silos. The profile of the fats and oils are shown in Figure 2.

Biodiesel production. Biodiesel producers use plant and animal oils and fats as raw materials (de Sena in press), but they have some problems with various animal fats but have shown an interest in using fish oils.

Fish meal and fish oils for animal production. Because of the high amount and good quality of fish oil obtained from ensiled wastes it may be possible to use it in animal production. It would be necessary to do further research and to install a centrifuge to eliminate the water. Some fish meal producers have already shown interest in this product as well.

Direct animal feeding. A mink farm has shown interest in using fresh fish wastes to feed mink and also sees a potential role of using ensiled wastes as feed. Further research needs to be done to study the second option.

3. Fish oil. Most of the oil is currently gathered in the water treatment plant but is generated in the trout cleaning area. Therefore, it would be worthwhile to install separating devices to gather the oil and treat it separately. This way, the byproduct could be managed as fish oil, and not as water treatment waste. The most important uses for the oil are industrial applications, such as the biodiesel, lubricants, leather production, or other applications for glue, varnish and paint production. Dobrzanski (2002) found that the fatty acid profile was very similar to the profile of salmonid fish oil, with high oleic, linoleic, linolenic, palmitic and eicosapentaenoic acid. Results of the analysis are as shown in Figure 3.

4. Sludge. The sludge is produced basically in the water treatment plant and the decantation pool. The sludge could be used to produce compost together with other

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fish wastes, as well as dead fish. The European Union established a norm for the agricultural use of water treatment plant sludge by the 86/278/CEE directive. In this norm, the maximum limits for heavy metals in sludge to be used in agriculture were defined. These values are shown in Table 1.

5. Dead fish. According to law CE 1774/2002, dead fish were defined as Category 2 materials. Article 5, chapter 2.e states that dead fish are “animals or parts of animals not mentioned in article 4, that die without being sacrificed for human consumption, including those sacrificed to eradicate an epizootic illness.” In this law it is clearly stated that category 2 materials must be ensiled or composted. But other alternatives are also allowed:

- Incineration in an incineration plant.
- Treatment in an authorized treatment plant to:
  1. Eliminate the waste by incineration.
  2. Use recuperated fats as fertilizers or other uses in oleochemical plants.
- Treatment in authorized treatment plants to:
  1. Use the proteins as fertilizers.
  2. Transform in biogas plants or compost plants.
  3. Eliminate in authorized waste dumps fulfilling the 1999/31/CE directive.

There are some exceptions that allow, category 2 and 3 animal wastes, and always under authorities approval, incineration or “in situ” burying. The alternatives studied for the organic waste are summarized in the Table 2.

Conclusions

Wastes basically originate from two sources:

- Human activities: wastes produced by mishandling and inefficient procedures.
- Equipment and facilities: lack of automation and obsolete equipment reduce the productive ratios and increase the generation of wastes.

In each of the freshwater fish farms, the specific minimization opportunities have to be studied to identify the most suitable opportunities for each farm. As far as the valorization and management of the wastes is concerned, exploitation opportunities for freshwater fish farms are strongly limited by European Union legislation (CE 1774/2002), especially for dead fish, which is still a problem that needs to be solved. The remoteness of the fish farms and the inherent logistical costs for waste collection make it difficult to obtain any profit from the organic wastes.

Apart from that, correct management of those wastes requires a major effort for the farms, basically because of the:

- Need to separate wastes, which means the need to acquire specific storage devices for the different wastes.
- Need to install refrigeration or freezing facilities to maintain fish waste in good condition until it is collected.
- Long distances to be covered by truck to send the wastes to the authorized treatment plants.
- Need to hire the services of a licensed waste management company.

Table 1. Accepted maximum values for heavy metals in sludge

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>LIMIT VALUES</th>
<th>Ground with pH &lt; 7</th>
<th>Ground with pH &gt; 7</th>
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</thead>
<tbody>
<tr>
<td>Cadmium</td>
<td>20</td>
<td>40</td>
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<tr>
<td>Copper</td>
<td>1000</td>
<td>1750</td>
<td></td>
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<tr>
<td>Nickel</td>
<td>300</td>
<td>400</td>
<td></td>
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<tr>
<td>Lead</td>
<td>750</td>
<td>1200</td>
<td></td>
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<tr>
<td>Zinc</td>
<td>2500</td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>16</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>1000</td>
<td>1500</td>
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</table>

Table 2. Management opportunities for each waste type

<table>
<thead>
<tr>
<th>Waste Type</th>
<th>Fish meal feeding</th>
<th>Mink feeding</th>
<th>Compost ensilage</th>
<th>Possible Uses Acid Biodiesel</th>
<th>Animal feeding</th>
<th>Agrarian use</th>
<th>Glue, varnish, paint</th>
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<tbody>
<tr>
<td>Fresh gut/slaughtered fish</td>
<td>*</td>
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<td>*</td>
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<td></td>
</tr>
<tr>
<td>Dead fish</td>
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</tbody>
</table>

* Possible uses of wastes
Nevertheless, there are real opportunities for turning wastes into useful products. Many industrial sectors, such as fishmeal producers, mink farms and biodiesel producers are interested in using those wastes or byproducts as raw materials for their processes. The correct management of wastes will show economic benefits, or at a minimum the management costs will be covered. If we want to assure the future of the aquaculture, it is necessary to help the sector overcome the difficulties they have to face, from the economic and environmental point of view, and correct waste treatment is a first step in that direction.

Notes

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References


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Egyptian Fish Farms