Deliverable

Project no. FOOD-CT-2007-036298

Project acronym: AquAgriS

Project title: Environmental management reform for sustainable farming, fisheries and aquaculture.

Instrument Co-ordination Action

D19: Report on Exciting advances in fisheries management and the design of aquaculture systems, and the realisation of ETAP objectives

Period covered: n.a.

Due date of deliverable: month 18

Actual submission date: month 24

Start date of project: 01/01/2007

Duration: 36 months

Lead contractor for this deliverable: Università del Salento (UNILE)

Project co-funded by the European Commission within the Sixth Framework (2002-2006)		
Dissemination Level		
PU	Public	*
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

INDEX

1. INTRODUCTION

Aquagris Consortium celebrated the workshop "Exciting advances in waste management in aquaculture and fisheries and the realisation of the objectives of ETAP" on the 9th of March 2008 in Bremen (Germany). This event was arranged at the same time as the Fishinternational Exhibition (www.fishinternational.com). The target of this workshop, which was opened to external participants, was to put the most sustainable waste management technologies and/or practices in aquaculture and fishery industries up for discussion.

AQUAGRIS is the acronym of the "Environmental management reform for sustainable farming, fisheries and aquaculture" project, started on the 1st of January 2007, aiming to increase the understanding and awareness of the problems areas faced by today's farming, fisheries and aquaculture (FFA) industries and develop solutions that have a minimal impact on biodiversity and the environment.

In the framework of the Environmental Technologies Action Plan (ETAP), AQUAGRIS Consortium organized this session focusing on 3 different areas of discussion:

- Technology for treating aquaculture effluents
- Management of fish farm effluent
- Waste management of fish and fish products

The workshop was chaired by Mr. Vincenzo Zonno from the University of Salento (Italy), member of AQUATREAT project Consortium and Co-ordinator of AQUAGRIS project, and hosted by Centiv GmbH (Germany).

The workshop was attended by the members of the project, but also by external participants, interested in the topics. All participants were invited to contribute to the discussions.

2. AQUAGRIS AND THE ENVIRONMENTAL TECHNOLOGIES ACTION PLAN (ETAP)

Since 2004, ETAP covers a spectrum of actions to promote eco-innovation and the take-up of environmental technologies. ETAP complements the DG's regulatory approaches and directly addresses the three dimensions of the Lisbon strategy: growth, jobs and the environment

It includes priority actions along several lines:

- promoting research and development,
- mobilising funds,
- helping to drive demand and improving market conditions.

In fact, it seeks to exploit their potential to improve both the environment and competitiveness, thus contributing to growth and possibly creating jobs. It sets out a number of actions that the Commission will take and some that other stakeholders, such as industry and national and regional governments, should undertake for the plan to be successful (http://ec.europa.eu/environment/etap/index_en.htm).

Since 2004, key- environmental technogies have been identified in agriculture, construction, industrial processes, resources management and transport. Nevertheless, fisheries and aquaculture sectors are still at the beginning of the process and good management practices guidelines are strongly required. In order to face this problem, AQUAGRIS Consortium is developping a state of art report (to be published in 2009), to identify and analyse the current situation of FFA industries, from the technological, environmental and economical point of view.

3. CONTENT SUMMARY

After the introduction of the ETAP objectives by Ms. Patricia Cadaval (CENTIV GmbH), two members from the University of Caen Basse-Normandie (France), one participant from the National Institute of Oceanography (India), and one representative of the Cochin University of Scence and Technology (India) carried out the first part of the session, related to **technologies for treating aquaculture effluents.** Mr. Sébastien Lefebvre stressed the importance of the implementation of modelling in aquaculture waste management. During his presentation he showed how modelling helps to understand the dynamic properties of aquaculture systems and to predict system responses in order to optimize their diverse components like biology, physics, geochemistry and economics. A continuation of this section was made by Clémentine Harma, also from the University of Caen Basse-Normandie, who rationalized why Integrated Aquaculture Systems are a sustainable solution for aquaculture wastes.

The next presentation, by Mr. Professor Kurup, from Cochin, highlighted the importance of feed characteristics in order to minimize waste production. As explained in Chapter 4, an optimization on the Carbon/Nitrogen ratio can influence the Total Ammonia Nitrogen (TAN), Feed Conversion Rate (FCR) or the Protein Efficiency Rate (PER). To conclude this part of the workshops, Mr. Sreepada remarked the importance of Dissolved Oxygen rates in order to ensure an optimal development of natural flora and fauna in ponds. Moreover, he explained how the application of technologies like aeration and monitoring devices may have a positive influence on aquaculture systems.

After this first approach to sustainable aquaculture technologies and already under the topic of **fish farm effluent management**, Mr. Vincenzo Zonno from the University of Salento, and Coordinator of AQUAGRIS, presented the AQUATREAT case studies. AQUATREAT, “Improvement and innovation of aquaculture effluent treatment technology”, funded under the Sixth Framework Programme, is looking at the need for fish farms to improve the management of wastewater and solids, to minimise pollution and optimise the recovery, disposal and re-use of solid waste. It has started in May 2004 and since then developed effluent treatment systems, applicable to all types of land-based fish farms, open and closed systems, fresh water and marine operations, regardless of species. Mr. Vincenzo Zonno, explained how the application of integrated systems in fish-farms can mitigate impact and improve environmental quality.

Before discussions a last presentation in **waste management of fish and fish products** was carried out by Ms. Aintzane Esturo, from Azti Tecnalia (Spain). AZTI showed that waste quantification, waste minimization measures, analytical qualification and waste valorisation options are strongly required.

Along the points 4, 5 and 6 of this report the presentations of the speakers will be further developed.

4. TECHNOLOGIES FOR TREATING AQUACULTURE EFFLUENTS

"Insights from modelling in aquaculture wastes management" Sébastien Lefebvre (2008), Université de Caen Basse-Normandie (France).

"Integrated aquaculture systems: a sustainable bio-solution to aquaculture wastes" Clémentine Harma and Sébastien Lefebvre (2008) Université de Caen Basse-Normandie (France).

"Improved sustainability and production of penaeus monodon in extenstive farming in india trough carbon/nitrogen ratio optimization", Dr.B.Madhusoodana Kurup,Professor (2008) Cochin University of Science &Technology (India).

"Environmental management strategies for coastal aquaculture: experiences from indo-norwegian project", R.A. Sreepada Scientist, Aquaculture Laboratory, National Institute of Oceanography, Dona Paula, Goa (India)

INSIGHTS FROM MODELLING IN AQUACULTURE WASTES MANAGEMENT

Sébastien Lefebvre (UCBN)

UMR 100 Ifremer-UCBN PE²M "Physiologie et écophysiologie des mollusques marins"

Université de Caen Basse-Normandie (France)

Due to their complexity and human driving processes, the use of modelling is of great interest to understand and to manage aquaculture systems in general and particularly in the case of the management of wastes. Two main kinds of waste are produced by aquaculture facilities i.e. particulate and dissolved material whatever the environment of production (land-based or open water systems, marine or freshwater systems). The physical or biological processes that can limit and/or reduce the production of these wastes are rather different so as the associated modelling approach.

As a matter of definition, modelling is a simplification of the reality. From all known laws and mechanisms that drive a process, only the relevant ones will be chosen to simulate the behaviour of a particular system. This simplification and the undergoing choices are made under assumptions related to the objective/question of interest for the scientist and/or the manager. This means that a model is usually structured depending on specific aims/questions and a generic purpose of application is often missing. This statement may rely on the two main approaches available in modelling, i.e. empirical or mechanistical ones. Empirical refers to black box modelling and it is done from the measurements of state variables of a given system. The understanding is limited to the system investigated, the predictions are exact on the short term but the management could be done only for a narrow range of conditions. On the opposite, mechanistical modelling is based on theory and experiments on relevant processes, and the understanding is more general and for the given class of system. While this white box modelling is less exact on the quality of prediction, it can be used for the long term and in a broader range of situations. Actually, experimental studies alone do not capture entirely the dynamic properties of aquaculture systems. In addition, there is no possibility to predict the responses of the system in other contexts than the ones experienced. And finally, there is no possibility to optimize the diverse components of such systems as biology, physics, geochemistry and economics. For these reasons, modelling in general and particularly mechanistical modelling is therefore of interest for the complexity of aquaculture waste management.

However, modelling has been historically underused in aquaculture research and management, but this tendency has been hopefully inversed over the past 15 years. Applicability of modelling in aquaculture waste managements can be drawn from diverse examples in biology, geochemistry, hydrodynamics, and physics. Special modelling aims for particulate material wastes will be for instance the simulation of the deposition of faeces around sea cages and/or the regeneration rate of organic matter into nutrients by bacteria and their consecutively oxygen consumption and degradation of the benthic environment. Special modelling aims for dissolved nutrients will be for instance to simulate their use by autotrophs (plant, algae and bacteria) and indirect incorporation into valuable predators (bivalves, abalone, sea urchins…). Some models can be found for special case studies as recirculating systems or integrated aquaculture systems. In all cases, modelling is interesting to optimize the size and biomass of the different compartment of aquaculture systems and by the way to limit and reduce their wastes. Finally, in order to account for economy, management and biology simultaneously, decision support system tools (DSS) have been recently developed for aquaculture and should be generalised to aquaculture waste managements. However, to be efficient and used in broad range of situations, these tools must be based on mechanistical modelling approaches as much as possible.

INTEGRATED AQUACULTURE SYSTEMS: A SUSTAINABLE BIO-SOLUTION TO AQUACULTURE WASTES

Clémentine Harma and Sébastien Lefebvre (UCBN)

UMR 100 Ifremer-UCBN PE²M "Physiologie et écophysiologie des mollusques marins"

Université de Caen Basse-Normandie (France)

Aquatic living resources are considered as a principal source of animal protein in human diet and their increasing importance is due to increasing human population and rising demand for cheap protein sources. European aquaculture is a recent, intensive industry developed in either inland or open-water systems (for example, fish cages) but it can also be semi-intensive, and even extensive when cultures rely only on the natural production of the ecosystem to grow. Despite increasing the world fish supplies, these practices lead to (more or less concentrated) waste production that weakens the environment and diminishes the actual ecological life support services it provides to other living aquatic resources and men. This constitutes a part of the 'ecological footprint' of human activities, where impacts on environment can be demonstrated. Now, the question is 'how do we reduce negative environmental impacts of aquaculture?' While many improvements and recommendations can be made to minimize waste production; once produced, wastes have to be reduced or converted.

In aquaculture, two kinds of wastes are produced: Particulate (or suspended) organic matter (POM) and dissolved nutrients. Their production depends largely on the type of culture system and its management, the type and quality of feeds used, the type and size of cultured species. From an ecologist point of view, it is interesting to note that solutions can be found in the nature. According to the scheme of a simplified food-web:

- ❖ The POM is converted into nutrients via the <u>saprophagous pathway</u> thanks to decomposers and the microbial loop
- ❖ Nutrients are converted into energy through photosynthesis and this energy is then transferred along the trophic chain via the <u>herbivory pathway</u>.

These two pathways are explained thanks to appropriate case studies, as figures to a better understanding of the processes involved and limitations of recirculating aquaculture systems (referring to the saprophagous pathway) and integrated aquaculture systems (referring to the herbivory pathway).

Treatment based on solids removal and nitrification (coupled with denitrification processes) is probably the most widely used among today's recirculating systems. Recirculating Aquaculture Systems (RAS) are generally highly engineered systems (Lenger *et al.* 2001; Losordo *et al.* 1998) which operate in a large variety of configurations. These systems may be used to rear both freshwater and marine organisms, and they vary widely in the efficiency with which the water and wastes are treated and recirculated. As an example, Twarowska *et al.* (1997) have experimented RAS with tilapias. They observed that physical filtration removed 18% of feed volatile solids input, and bacterial filters approximately 65% of an average total ammonia nitrogen concentration (of 0,62mg/l) in the culture tank. However, 7% of the system volume had to be flushed with freshwater daily to maintain a good water quality. Hence, RAS are often expensive systems and sometimes, ammonia level is difficult to control because the organic load could inhibit the nitrification! In this way, models are useful to estimate the results of system modifications before time and money is spent (Losordo and Hobbs, 2000).

As to the herbivory pathway, research on microalgae treatment systems, although not a new approach, has been neglected (Wang 2003) and only a few studies on marine integrated systems exist (Lefebvre *et al.* 1996; Hussenot *et al.* 1998). On the contrary, various studies have shown that several species of seaweed have high nutrient filtering capacities and thus can be viewed as biological nutrient scrubbers (Chopin *et al.* 1999, 2001) with economic-value as human food (e.g. Nori, Wakame, Kombu; health-food or nutritional supplements Troell *et al.* 1997), or food sources for other valuable aquaculture organisms (e.g. sea urchin, abalone, …) (Wikfors & Ohno 2001). Troell *et al.* (2003) reviewed 28 studies that reported dissolved nitrogen uptake efficiency of seaweeds in integrated systems. Reported values ranged from 2 to 100% for 23 land-based studies. None of the 5 reviewed open-water studies reported any nutrient recovery values as the dispersion of wastes in such system is more difficult to control. The GENESIS (European project -2001 / 2004-) project studied several types of integrated systems in warm water (Israel), temperate water (Southern France) and cold water (Scotland), with a variety of valuable marine products including fish, crustacea, molluscs and aquatic plants. The different systems were evaluated based on their performances in respect to water, nutrients and waste management. Intensification and the use of nutrients, water and energy were optimized. It has been demonstrated that silica enrichment of the effluent from a fish production system can be used to produce diatoms (microalgae) for oyster fattening. The addition of microalgae production resulted in an improved nutrients utilization introduced into the fish production system; microalgae assimilation by oysters allowed the retention of 70 % of the nitrogen introduced with the feed, compared to the 20 to 30% obtained for seabass or seabream reared alone. From the reviewed integrated intensive systems, a fish-microalgae-bivalves-macroalgae system shows the highest overall N retention, 63%, nearly three times more than in modern fish net pen farms (Shpigel *et al.* 1993; Neori *et al.* 2000-2004). All of the modules that comprise integrated systems have specific limitations that are related to kinetic uptakes, nutrient preference, unwanted conversion processes and abiotic factors. Moreover, integrated systems are time-dynamic and need a better management that could be achieved via modelling (Lefebvre *et al.* 2004).

These latter studies lead to a new definition of integrated systems which are seen as coastal food production systems based on existing ecological principles (Brzeski and Newkrik, 1997) or as managed imitation of a natural ecosystem (Neori *et al.* 2004). Integration is then, when beyond monoculture, several organisms are produced in order to reduce environmental impacts of aquaculture activity by converting the wastes (instead of diluting; Folke and Kautsky 1992; Shpigel and Neori 1996; Neori *et al.* 2000), while their production is optimized (so as to increase the commercial value of the system). When each module is properly managed, integrated systems can lead to recirculation of the water, i.e. the use of wastes from one species, as food source for other organisms of different trophic levels (i.e. autotroph and heterotroph) ensures good water quality in a close environment with parameters easily under control.

However, even though integrated aquaculture appears as one of the most sustainable solution for this industry in Europe, some problems remain to be solved for a definitive acceptance of this technique.

IMPROVED SUSTAINABILITY AND PRODUCTION OF PENAEUS MONODON IN EXTENSTIVE FARMING IN INDIA TROUGH CARBON/NITROGEN RATIO OPTIMIZATION

Dr.B.Madhusoodana Kurup,Professor(Fisheries)

Cochin University of Science &Technology,Cochin-682 016,India

& Advisor to Minister(Fisheries)

Govt.of Kerala

The effectiveness of shrimp feed waste containment in extensive shrimp farms of Kerala (India) through the optimization of C:N ratio was investigated. One indoor and one on-farm trial were conducted to evaluate the effect of control of carbon/nitrogen ratio (C/N ratio) by addition of carbohydrate to the water column in extensive types of shrimp culture systems. In the indoor experiment, 25% and 40% dietary protein ('P25 and 'P40) with or with out carbohydrate source addition ('P25+CH' and 'P40+CH') were compared in fiber reinforced plastic tanks of 1200-1 capacity stocked with 6 Penaeus monodon juveniles (0.357+0.01gm^{-2}). In the on-farm trial, 25% dietary protein with carbohydrate ('P25+CH') and 40% dietary protein('P40') were compared in 250-m^2 earthen ponds stocked with 6 post-larvae of P.monodon m^{-2}.

Tapioca flour was used as carbohydrate source and applied to the water column followed by the first feeding during the day in both experiments. The addition of carbohydrate significantly ($p<0.001$) reduced the total ammonia nitrogen(TAN) in the water and sediment in both experiments. It is significantly ($p<0.05$) increased the total heterotrophic bacterial (THB) population both in water column and sediment. In the indoor experiments, lower specific growth rate (SGR) and higher feed conversation ratio (FCR) values were recorded in 'P25' treatment compared to shrimps in other treatments ($p<0.05$). Higher shrimp yield was recorded in'P25+CH' (64.43 gm^{-2}) when compared to'P40' (44.79gm^{-2}) ($p<0.001$) in the on-farm trial. The FCR value was lower ($p<0.05$) in the 'P25+CH' treatment than in the 'P40' treatment. The nitrogen retention (%) and protein efficiency ratio (PER) were higher ($p<0.001$) in the 'P25+CH' treatment when compared to other treatments in both experiments. Survival of the shrimps was not affected by treatment ($p>0.05$). In the on-farm trial the benefit cost ratio was higher in'P25+CH' treatment than'P40' (1.3 against 0.2) and the profit increased 400% in 'P25+CH' treatment. A 35% reduction of feed cost and 54% increase in the revenue from shrimp was recorded in the'P25+CH' treatment when compared to the 'P40'.
Control of C/N ratio by the addition of a carbohydrate source to the pond water column benefited the extensive shrimp culture practices in six ways:

1. increased heteromorphic bacterial growth supplying bacterial protein to augment the shrimp production,
2. reduced demand for supplemental feed protein and subsequent reduction in feed cost and
3. reduced toxic inorganic nitrogen levels in the pond as well as effluents
4. increased the nitrogen retention in harvested shrimp biomass
5. reduced the concentration of TAN and NO_2-N in the pond, and
6. reduced nitrogen discharge making extensive shrimp farming more ecologically sustainable and economically viable.

ENVIRONMENTAL MANAGEMENT STRATEGIES FOR COASTAL AQUACULTURE: EXPERIENCES FROM INDO-NORWEGIAN PROJECT

R.A. Sreepada

Scientist, Aquaculture Laboratory,

National Institute of Oceanography (NIO)

Dona Paula, Goa-403 004 India

Traditional aquaculture has been carried out along the coastal states of India for several centuries. About 50,000 ha of low-lying impoundment (1-10 ha) along bays and tidal rivers is under traditional cultivation and contributes about 25% of the total coastal aquaculture production. Yields from these systems are very low (300-500 kg $ha^{-1}yr^{-1}$) due to low input levels, limited management and tidally dependent stocking and water exchange. In the last few decades, the aquaculture has emerged as one of the fastest growing food production systems in the world, with the bulk of its output currently being produced within developing countries, and with expectations for aquaculture to continue its contributions to food security and poverty alleviation. Pond-based coastal aquaculture, particularly of marine prawns, has gained considerable momentum in India, due to its high demand in both national and international markets and rapid financial returns. India occupies the fourth position amongst the major shrimp farming countries in the world. During the last decade, there has been a remarkable increase in annual shrimp production from 35,500 (1990-91) to about 113,000 tonnes in 2002-2003 with an export value of US $ 800 million. There has also been tremendous increase in farm area from 65,100 ha in 1990-1991 to 154,600 ha in 2002-2003. However, despite the advances in farming practices, careful analysis of production per unit area reveals that the yields are not increasing concomitant with the expansion of the industry. The decrease in yields is due to unsustainable culture practices such as poor pond management, excessive feeding, organic matter loading, nutrient enrichment, lack of adoption of eco-friendly technologies, inefficient waste disposal, etc.

Shrimp culture practices require a careful management and monitoring of water and soil quality in culture ponds not only to avoid economic losses due to impairment in the water and soil quality but also to reduce the environmental deterioration caused otherwise due to its effluents in receiving water bodies. Dissolved Oxygen (DO) is one of the most critical water quality parameter in aquaculture systems for candidate species. Culture species depend on benthic macro, meio and micro invertebrates in the water and sediment for food. It is well known that the development of natural flora and fauna depends on the availability of DO. Sustained reduction of dissolved oxygen is often noticed in tropical earthen ponds and this can lead to hypoxic followed by anoxic conditions. In anoxic environments, denitrifying bacteria lead to formation of ammonia and sulphide formation takes place through bacterial degradation of accumulated organic matter. These are known toxicants and cause mortality of aquatic organisms and make them susceptible to diseases in addition to reduction in growth.

The current shrimp culture practices in India have been inadequate to solve the environmental and disease problems and have raised doubts over the long-term sustainability of shrimp aquaculture. Therefore, for long-term sustainability of the shrimp culture industry, the development of more eco-friendly farm management practices are urgently required. Recent studies and field evidence at some places suggest that traditional approaches in enhancing production capabilities from tropical shrimp culture need a paradigm shift. Although a wide variety of approaches of environmental management have been considered, one method is re-circulation of water and storage of water in large reservoirs. This has been tried by farmers in Thailand, but it is costly and needs large areas. Others have suggested an integrated coastal aquaculture system with halophyte crops which is particularly suitable for abandoned/unused shrimp ponds, salt pans. Another system is a 'third generation' flow through system, which needs high investments and skilled workers. All these systems are expensive and rather complicated to build, operate and maintain.

In order to minimize the formation of anoxic conditions and to obtain optimum yields, different types of aeration devices have been used in shrimp culture ponds. Apart from improving the DO levels and smoothening of DO curve, aeration also plays a role in nutrient recycling. Another strategy is to use eco-friendly aeration technology which has been used in developed countries. We discuss here the results obtained with the adaptation of HOBAS aeration technology from Norway to shrimp aquaculture as one of the eco-friendly strategies for sustainable shrimp culture in India. A comparative assessment of HOBAS aeration technology with control and existing aeration technology (i.e. Paddlewheels) was made in terms of production and water quality parameters. Changes occurring in the experimental and control ponds were monitored closely using Remote Water Quality Logging System. The results indicate that the new aeration technology and remote water quality logging system are adaptable to Indian conditions with subsequent field trials. Water quality variables were found to show high co-linearity and showed no significant differences between aerated and control pond despite higher stocking densities in aerated pond. Water quality was found to be in the optimal limits, thus, indicating better performance of aeration system. It was found that there were no significant differences in the average macro, meiofaunal and microbenthic densities from aerated and non-aerated ponds over two study periods. The gut content analysis of shrimp showed clear demarcation in day and night time feeding preferences. Further, it was found that natural gut fauna and flora decreased and intake of the artificial feed increased as the culture progressed.

5. MANAGEMENT OF FISH FARM EFFLUENT

"Management of fish farm effluent: the aquaetreat case studies in the field and presentation of the manual " effluent treatment in aquaculture: science and practice", Vincenzo Zonno (2008) Università del Salento (Italy).

MANAGEMENT OF FISH FARM EFFLUENT: THE AQUAETREAT CASE STUDIES IN THE FIELD AND PRESENTATION OF THE MANUAL "EFFLUENT TREATMENT IN AQUACULTURE: SCIENCE AND PRACTICE"

Vincenzo Zonno

AQUAETREAT Consortium, DiSTeBA – Università del Salento

Via Provinciale Lecce-Monteroni, 73100 Lecce (Italy)

Land-based fish farms produce effluents that may have, if not properly handled, a negative impact on the quality of water courses and rivers.

AQUAETREAT, "Improvement and innovation of aquaculture effluent treatment technology", is a 3-year SME collective research project, funded under the Sixth Framework Programme, looking at the need for fish farms to improve the management of wastewater and solids, to minimise pollution and optimise the recovery, disposal and re-use of solid waste. It has started in May 2004 and since then developed effluent treatment systems, applicable to all types of land-based fish farms, open and closed systems, fresh water and marine operations, regardless of species, which have been tested at three sites in Italy, France and Denmark. Research institutes in Italy, France and the United Kingdom act as the project's RTD performers and are supported by an Italian engineering SME that is expert in treating effluents. The systems designed have proven to be cost-effective and allow efficient solid removal and sludge thickening. The first step is a mechanical filtration, in which all large settable or suspended particles, both organic and inorganic, are removed; this step produces a high flow of filtered water, where the reduction of solid concentration varies between 30 and 70 %, and a very low flow of concentrated waste water containing 1 to 3 g of solids per litre. The latter flow, also called wet sludge, needs further treatment with additional concentration systems (settling and flocculation-coagulation) to obtain on one hand a concentrated sludge (10-30 % of dry matter content) and on the other hand an effluent containing high concentrations of mineral and organic soluble substances (in particular nitrogen and phosphorus). The final sludge dewatering and thickening process occurs through the employment of different devices, as settling tanks, geotubes and belt filters, while further soluble substances removal from the filtered and the nutrient enriched waste water, occurs through packed biofilters, wetlands, both natural or constructed, and algal ponds.

The composition of all flows has been characterised and protocols and methods have been set up for the re-use and/or disposal of waste and by-products. The quality of the recycled water has been tested by rearing sea bream juveniles in it; preliminary results have shown higher growth rates and less mortality, confirmed by the measurements of some welfare indicators, as well as a comparable quality of the flesh, which has been certified by a panel of experts.

An agriculture test, whereby tomatoes were grown using marine stabilised sludge, has also shown promising results. It has to be noted here that it is advisable to find a way to reuse sludge inside or in the area of the fish farm to avoid high transport costs. As to the sludge composition, nitrogen and phosphate might be limiting factors, but the presence of potential pollutants such as heavy metals, poly-aromatic hydrocarbons and PCBs, has been also excluded.
The effluent treatment systems developed in this project will enable fish farmers not only to reduce the amount of waste they produce, thereby lowering disposal costs, but also to create commercial products as the waste might be used as soil amender or compost for agriculture,

or find uses in other sectors, with benefits to the aquaculture industry and the environment. Within the project, the Federation of European Aquaculture Producers (FEAP) has coordinated an extensive dissemination and training plan, including four regional workshops and four training courses, that allowed the formation of updated and skilled managers and technical staff of aquaculture SMEs. A manual on effluent treatment in aquaculture has been also delivered (downloadable at www.aquaetreat.org).

Project supported by EU, under the Horizontal Research Activities involving SMEs (Collective Research); Contract n° COLL-CT-2003-500305; EC Project Officer: Marta Iglesias.

6. WASTE MANAGEMENT OF FISH AND FISH PRODUCTS

"Waste management of fish and fish wastes", A. Esturo, M. Revuelta, L. Arana, J. Zufía (2008) AZTI-TECNALIA - Food and Marine Research (Spain).

WASTE MANAGEMENT OF FISH AND FISH WASTES

A. Esturo, M. Revuelta, L. Arana, J. Zufía

AZTI-TECNALIA - Food and Marine Research

Txatxarramendi ugartea z/g - 48395

Sukarrieta (Bizkaia) Spain

Introduction

The decrease in extractive fisheries and the increase of the fish consumption demand are factors that favour the increment of the aquaculture fish production. This activity, as many other human activities, also contributes increasing the waste generation with the subsequent issues from the legislative, environmental, economical and social. Spain produced in 2006 about 273.000 tonnes of aquaculture products, from which 28% was aquaculture organic waste such as shells, heads, guts and spines.

According to the EC Regulation 1774/2002, all the products from animal origin are classified according to the possible risks to human health. The fish wastes are classified as category 2 and 3 depending on when and where the fish wastes are generated.

The objective of the presented work was to fulfil the applicable legislation and to define the adequate waste management practices and to valorise the fish by-products, all of which at the end contribute increasing the competitiveness of the sector and the sustainability of the aquaculture activities.

To reach this target, more than 60 companies producing sea bass, sea bream and trout were visited to obtain production and by-products data and "on-site" information, which were processed in an Access DB. Fish wastes were analysed for characterization and to find possible further uses.

In order to minimize the waste generation, clean production techniques were identified and applied (reduce, reuse, recycle) (McDonald et al, 1999) (Henningson, S., 2004). The generated wastes were classified according to legislation, characterized and quantified, in order to know further uses that could be given to increment their value.

Among other compounds, the oils extracted from the wastes were analysed, to determine their profile, which happens to be rich in omega 3 and omega 6 long chains poly-unsaturated fatty acids. The recommended rate consumption of O6/O3 has to be below 4, (Ayo, et al, 2007) and the analyzed fish wastes have a ratio of 1,5, being therefore very interesting from the nutritional point of view.

According to the classification of wastes from animal origin, and the possible valorisations, two groups can be done: category 2 (fouling, dead fish, foams, slurry) and category 3 (heads and guts, shells). With those of category 2, the valorisation options are production of biodiesel, biogas, ensilage and composting, being this last one the best known. For those of category 3 the valorisation options are production of surimi, recovery of oils for food industry and pharmaceutical industry, and production of animal feed.

In summary, this work proves that the wastes volume can be reduced with simple minimisation techniques and the generated wastes or by-products can be valorised with adequate management practices, to produce compost or energy (biogas), or other food compounds (surimi, high nutritional value oils) and animal feed.

7. CONCLUSIONS

The workshop "Exciting advances in waste management in aquaculture and fisheries and the realisation of the objectives of ETAP" represents the beginning of a process to sustainable practices in these sectors. Furthermore, this session may be the first step to reach a consensus in fisheries and aquaculture management guidelines.

Hot topics were discussed during this session and important conclusions were obtained. First of all, and because aquaculture systems are very complex experimental studies do not capture entirely the dinamyc properties of these systems (Jamu and Piedrahita, 2002). Therefore, alternative tools are required in order to be able to identify barriers and optimize the systems. In fact, technologies as modelling, historically underused in aquaculture research and management (Léfebvre, 2008), can help us to understand the sytems behaviour better and to predict the responses of the system in other contexts than the one experienced. Getting in deeper analysis, mechanical modelling is more suitable for our systems because, despite of being less exact, they are valid for for similar systems in a broader range of conditions.

Other important issues considered during this workshop was the composition of the feed. Mr. Kurup did demonstrate how a control in the C/N ratio in the feed of extensive shrimp cultures may have a positive influence on the feed conversation rate, shrimp production, feed related costs and nitrogen retention. The addition of carbohydatre to the water column augments shrimp production, reduces feed related costs and inorganic nitrogen production, enhances the retention of nitrogen and favours the Total Ammonia Nitrogen discharges.

Nevertheless, not only the optimization of feed composition is important to ensure high yield production. In the studied case, presented by Mr. Sreepada, controlled OD rates are also required for the development of natural flora and fauna in the ponds. Anoxic environments favour the formation of ammonia and sulphide by bacterial activity, which are toxics for aquatic organisms. Therefore, monitoring, technologies implementation and eco-friendly management strategies are strongly needed to reduce environmental deterioration. Moreover, recirculation systems and/or integrated systems are suggested as suitable culture practices. However, their high related costs and their requirement of skilled workers make their implementation in farms difficult.

In fact, one of the most important conclusions from speakers and attendants was that "Integrated systems" represent the best solution for environmental problems. Nevertheless, and turning to Ms. Harma argumentation, few research has been done in Integrated Systems. Current state of art shows that seaweeds have high nutrient filtering capacities (Chopin et. al 1999, 2001) and their implementation in integrated systems may mean a solution the problems of nitrogen release into the environment. However, optimization of this technique is required. As it was mentioned in Chapter 4, all the modules that comprise integrated systems have specific limitations that are related to kinetic uptakes, nutrient preference, unwanted conversion processes and abiotic factors. Moreover, integrated systems are time-dynamic and need a better management that could be achieved by modelling (Lefebvre et al. 2004).

Besides, the AQUATREAT project has been demonstrated that not only integrated aquatic cultures are compatible. Also the combination of aquaculture systems with agricultural activities involves important environmental benefits. Sludge from fish cultures becomes a by-product very suitable for tomato growth. But this is only one example. This kind of management may not only reduce the quantity of waste, but may also decrease the waste disposal related costs and creates new markets for by-products commercialization. Nevertheless special considerations about economic benefits (transport cost, competitive markets, production rates, etc.) need to be further studied. Furthermore, integrated systems have a huge potential and interactions of new systems have to be developed.

Figure 1 shows the basic measures for a significant reduction and valuation of waste from any system.

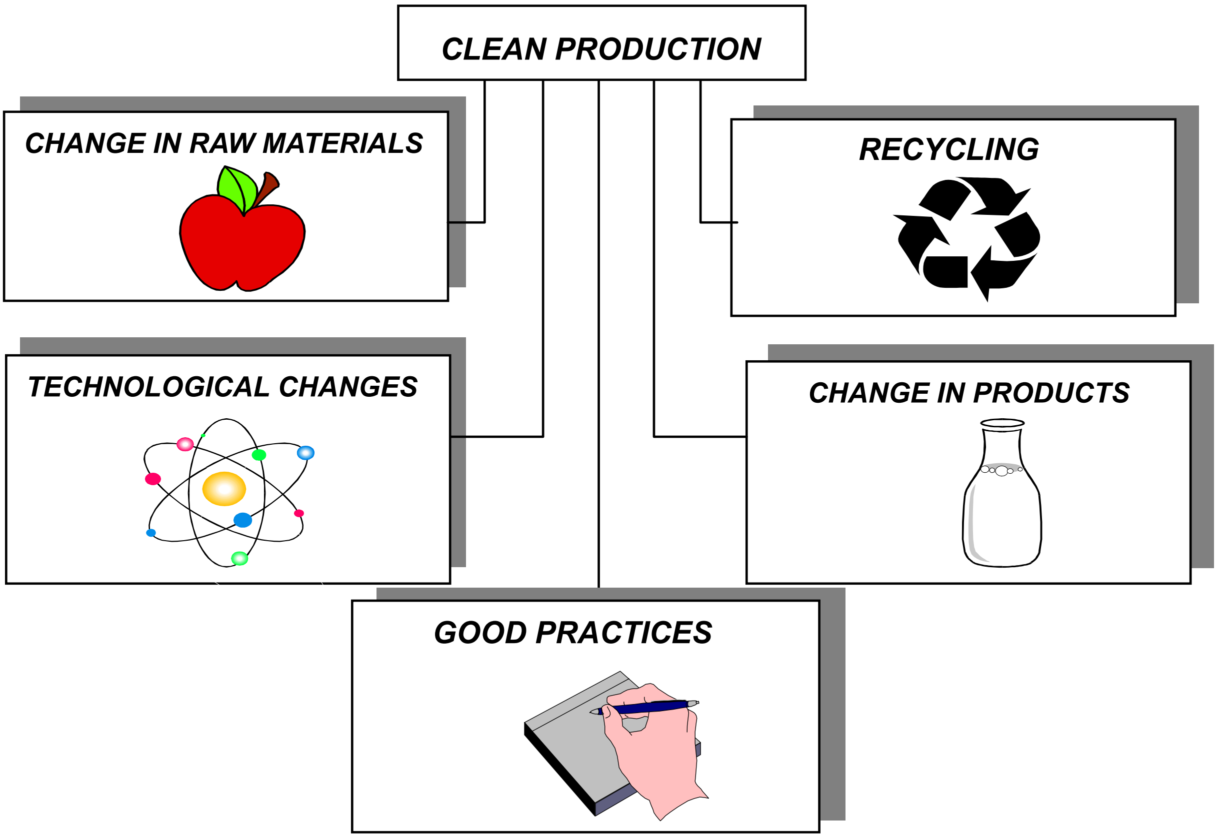

Figure 1: Waste Minimization Measures (source: AZTI-TECNALIA presentation in "waste management on fish and fish wastes")

Considering the approach given by Ms. Asturo about fish waste valuation it is possible to affirm that the volume of wastes can be reduced with simple minimisation techniques. The generated wastes or by-products can be valorised with adequate management practices to produce compost or energy (biogas) or other food compounds (surimi, high nutritional value oils) and animal feed (A. Esturo, M. Revuelta, L. Arana, J. Zufía).

In summary, despite the fact that good results in integrated systems have already been demonstrated, more research has to be done. It is critical to find solutions for fish farming waste reduction and disposal, not only in the scientific point of view, but also considering socio-economical aspects. Indeed, economic- feasibility analyses are required in order to promote a real implementation of these technologies in fish farms.

8. FINAL RECCOMENDATIONS

AQUACULTURE

1. Environmental sustainability of aquaculture is facing challenges from technological, economic and social aspects and therefore innovative targeted research are needed.
2. In the context of new thrust given to sustainable aquaculture development, effective regulation is critical for continued growth and sustainability.
3. There should be a balance in the use of land, water, seed, feed, chemicals, growth enhancers, probiotics, health management products, antibiotics and chemicals.
4. Technology for lowering the protein used for fish feed by improving feed conversion ratio shall be promoted
5. Conversion of aqua farm waste into value added products such as microbial protein by adopting innovative methods, such as biofloc technology, need to be applied. The commercialisation of microbial protein from bioflocs shall be attempted and the product so developed can be utilised as the protein source for fish, shrimps, etc.
6. There is an imperative need to manage solid wastes and dissolved substances to contain the negative impacts of aquaculture on environment. In order to effectively manage suspended solids from the aquaculture systems locally suitable and economically viable technology has to be developed and standardised.
7. Farm sludge contains very valuable macro-nutrients and has proven to be a very good fertiliser for land based crop. Integrated sludge application with fertiliser use can minimise the cost of production both in aquaculture and land based crops. However, such type of application shall be done only after accounting the pollution level in the sludge. Studies must be initiated for the potential use of farm sludge as a fertiliser.
8. Attempts should be made to develop appropriate technologies for using nutrient laden effluent from aquaculture systems through integrated farming.
9. In the context of increasing interest in cage farming, attention need to be paid to assess the quantum waste generated in cage farming operations, with techniques such as macro-algal assays using nitrogen stable isotope ratios, and procedures evolved to assess the impact of waste generated on environment.
10. The sustainability of aquaculture production is very important and for which we have to refine the technologies to ensure continuous use of application of biotechnology by adopting suitable bioremediation measures.
11. It is high time to ensure ecologically sustainable development in aquaculture which is possible only through system specific strategy and multidisciplinary approach with respect to host and pathogen.
12. Bacterial bioremediation has a role in developing novel approaches to treat aquaculture waste which can be employed in management of waste in aquaculture.
13. Quarantine and bio-security of aquatic animals need to be made mandatory in health management in aquaculture particularly for transplanted species.
14. Aqua-farms should consider the implementation of efficient treatment systems and waste management protocols in their production process. The technology is already

available and efforts must be made to adapt this technology to different climate and Regions.

15. Treatment systems will have a cost which can not be sustained by farming alone. Governmental bodies should consider the possibility of establishing treatment systems on cluster basis.
16. In R&D on ecosystem management strategies with special reference to waste generation and pollution, a component on novel and emerging viral pathogens also need to be included for drawing proactive management strategies.
17. There are now standards and certifications imposed on all aquaculture activities at International, National and Regional levels. However, standards and certifications can be a technical barrier to small-scale farmers. About 90% are small-scale farmers and in order to introduce standards and certification programme aqua-societies may be introduced to have better economic acceptability.
18. In EU, aquaculture focuses on environnemental protection. EU follows "Polluter to Pay Policy" as far as pollution and aquaculture wastes are concerned. More R&D input is required for waste management in aquaculture. Adequate monitoring of the aquaculture system is required.

FISHERIES

19. Origin of fish waste in European countries are mainly from by-catches, including small fishes, invertebrates, crustaceans and low valued fishes. The EU has notified EU regulation No. 1774/2002 for valorisation of fish waste. According to this regulation, the fish waste has been divided into three categories; only those included into Category 2 and 3 can be valorised through the following methods: (i) Biogas production, (ii) Composting, (iii) Animal feeds and (iv) Use for products like fish pulp (surimi).
20. Annual discard in fishery in India is estimated at 1,061,821 tonnes comprising of finfish waste (40 %), crustacean (45%), cephalopods (25%). The environmental threat caused by these wastes included health hazards, pollution of air and water and also nutritional loss. By converting fish waste into useful products like fish meal, fish ensilage, PUFA, collagen, gelatine, chitin and chitosan, glucosamine hydrochloride. Technologies for several of these products are available.
21. Reduce and minimise the production of fish waste production through stakeholder education and segregation of the catch to different quality categories such as high value and low value and its utilisation accordingly.
22. Harmonisation of the technology for valorisation of fishery wastes should take place on a global basis by integrating the efforts of and European and Non European researchers, academics and industry.
23. There is a need to reduce bad subsidies to fisheries sector which leads to over exploitation and reduced catch per unit effort.
24. India needs to take more steps to comply with Code of Conduct for Responsible Fisheries to attain sustainability in fisheries.
25. Finding alternative feed sources other than fish meal for chicken and pig farming will significantly reduce the pressure on dwindling fish stocks.
26. The fishermen have to be made aware of the economic viability of trawl operations using regionally optimised coded mesh size.

27. A wide range of proven technologies and procedures are readily available for reduction of bycatch discards in harvesting operations. Adoption of such technologies may only be successful with the active involvement of stakeholders in the process, supported by a system of incentives and disincentives and training, under a participatory management regime.
28. Procedures for minimization of plastic waste originating from abandoned, lost or discarded fishing gear need to be adopted. Fishing vessels must make every effort to retrieve all lost or damaged fishing gear and follow a system of reporting lost fishing gear facilitating its retrieval.
29. Technologies and procedures for minimization of GHG emissions from the fishing fleet need to be promoted through legislation, stakeholder education and training.

Strict compliance of regulations for safe disposal of garbage, oil, oily mixtures and other residues originating fishing vessels operations need to be promoted and implemented.

30. Appropriate waste management and waste utilization procedures should be put in place, in fishing vessels with onboard processing facilities.

GENERAL

31. A balance should be achieved among the social, economic and environmental aspects of sustainability.
32. Communities adjacent to farms may be provided with social and economic opportunities to improve aquaculture with community involvement.
33. Environmental impact assessment may be made integral part of all major aquaculture projects.
34. Awareness about energy conservation and carbon life cycle issues may be addressed
35. There is a need for the recognition of the realities of fisheries sector to work out meaningful standards. Compliance based on the majority should be the basis for regulations.