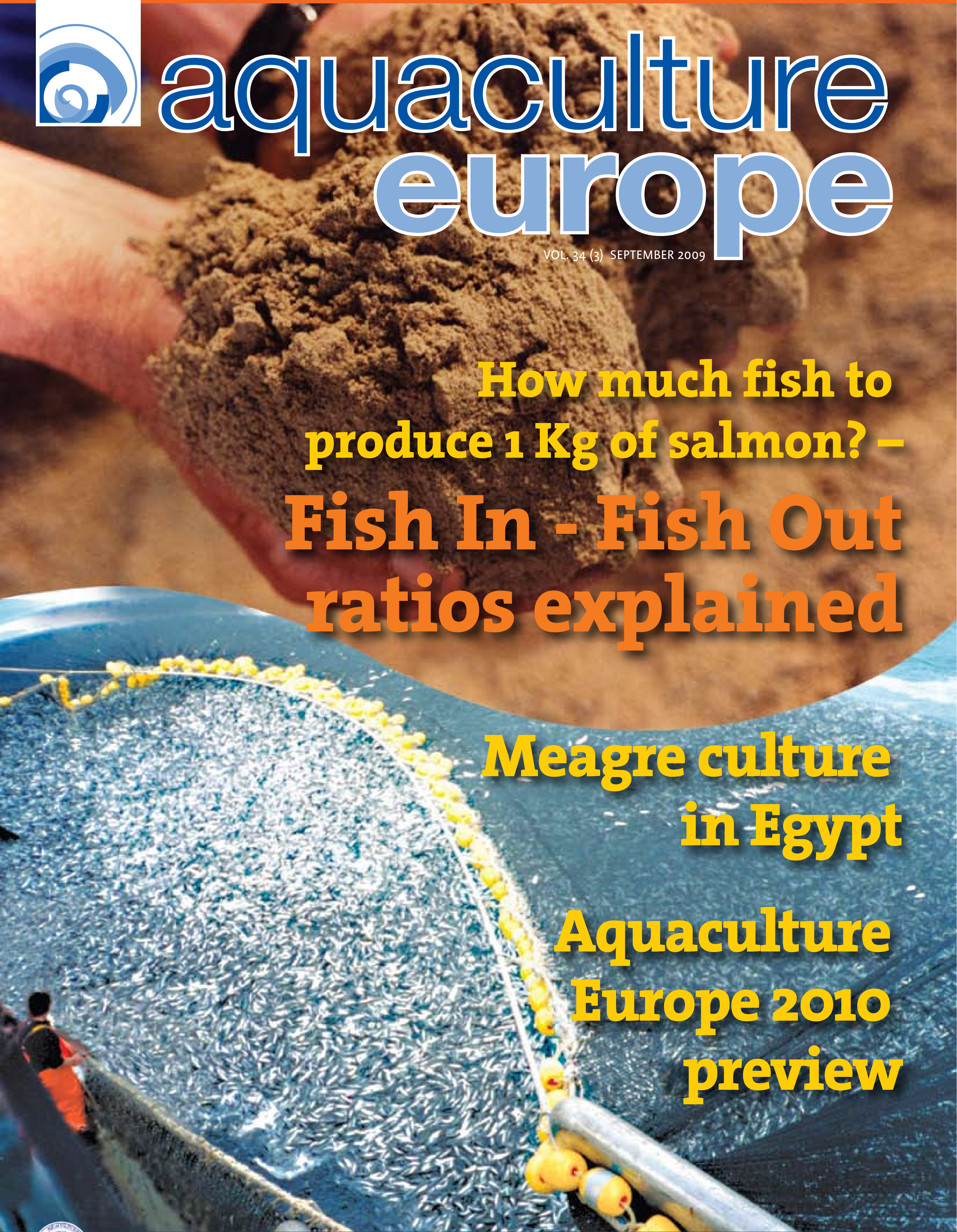
Aquaculture Europe 2010 – Seafarming Tomorrow



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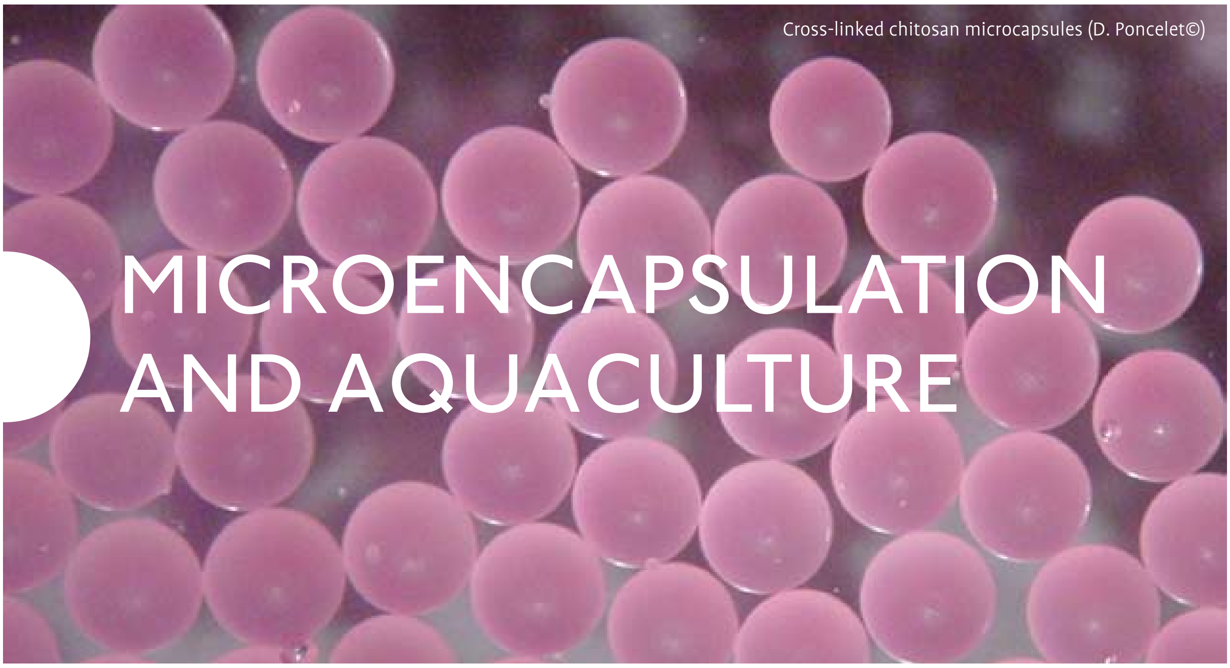
Cross-linked chitosan microcapsules (D. Poncelet©)

MICROENCAPSULATION AND AQUACULTURE

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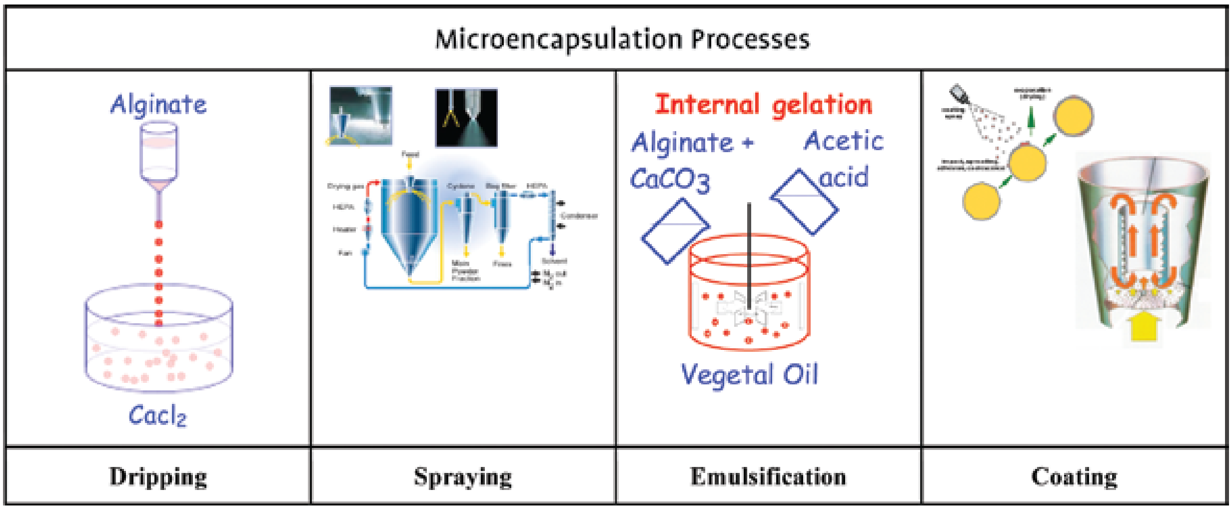
Those, who have read the last Ken Follett's novel "world without end" would have observed that in the middle age the main protein source was fish. It is still the case in many world area such Asian and African countries. Developing aquaculture and water restock is needed not only for avoiding an ecological disaster but also as important sources of food for humans.

The aquaculture industry has to face many challenges in the coming years to achieve the expected and necessary increase of the worldwide production. A priority in this increasing scenario is to meet the criteria for quality, safety and sustainability of products and production systems. Aspects such as how to nourish aquatic species adequately from larvae to breeding stock, how to fight against pathogens in large open system or how to advance in environmental friendly processes are key issues that need to be solved properly. The contribution of different multidisciplinary approaches and technologies appears crucial in progressing in research and development of innovative methodologies. One of these particular interesting technologies is the microencapsulation.

Encapsulation focuses on entrapping a material in small micro-particles. Microencapsulation allows

- immobilization of the material, avoiding for example washout
- protection against water, oxygen or gastric juice,
- control of core material release at the right place and at the right time,
- structuring the material from liquid to solid, reducing sticking, increasing the dispersibility
- Functionalizing the material, increasing its appetence.



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Microcapsules are sometimes called "artificial cells" and their main function can also be to mimic biological cells or more generally the usual food structure for sea food and fish. There is a large range of microencapsulation technologies but generally the microencapsulation process can be described in three steps:

1. The material to be encapsulated (generally called active) must be dispersed in the microcapsule core. Depending of core and active physical properties, this operation may consist in:
    - dispersing the active in a liquid core as solution, suspension or emulsion
    - absorbing the active on solid particles, coating the core with the active or entrapping the active by agglomeration of very fine core particle

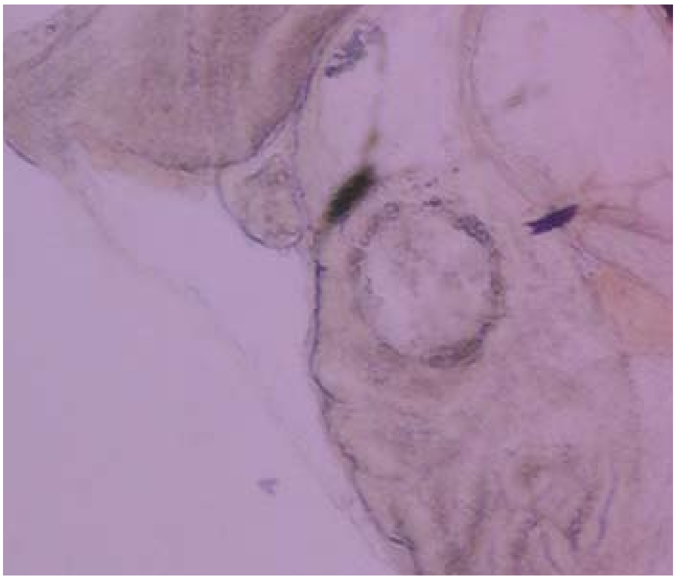
2. The second step comprises the dispersion of the core,
    - for a liquid core as uniform droplets (dripping), a spray or an emulsion, and
    - for a solid core (powder) by mainly fluidization (suspension of particle in a upstream air flow) and spraying of a coating solution onto the particle surface .

3. The last step is to "stabilize" the capsules
    - by gelation or solidification of the droplet,
    - by coacervation (precipitation), polymerisation or reticulation of polymer at the droplet interface,
    - by evaporation of water or solvent from the droplet or the particle coating.

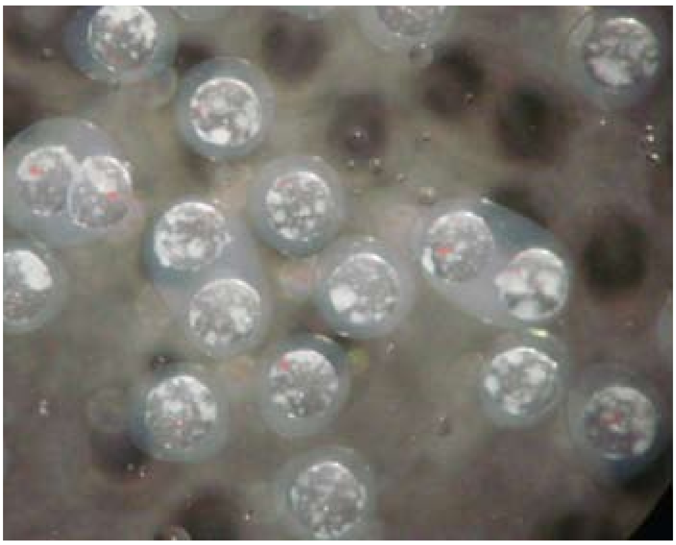
In aquaculture, microencapsulation techniques have been used with different purposes. The feeds design and manufaucture have been an activity, in which the involvement of these techniques is more noticeable. Particularly, microencapsulation has been used in the design of diets for bivalves and microdiets for larvae of fish and crustaceans as well as in the preparation of dietary combinations for nutritional enrichment of planktonic organisms used as larval prey. Another important application is the inclusion of antigens and probiotics in the fish feeds for oral supply. Finally, microencapsulation is one of the techniques used for the immobilisation of microalgae, a procedure with many different applications such as the production specific metabolites and energy, as well as removing undesired or valuable substances from media.

Only a few methods have been tested for all these purposes (coacervation, hydrogel beads, liposomes …). However, encapsulation technologies must meet many constraints according to the different purposes. In the case of microdiets for fish larvae and suspension feeder organisms the microparticles have to match very exigent requirements. The main challenge in designing microdiets for replacing live prey in the feeding of larval fish is to achieve an equilibrium

Fish larva starting feeding with microcapsules (M. Yufera©)



Gut of 13 days-old fish larva showing microcapsules almost-digested and completely disintegrated (M. Yufera©)



Alginate beads entrapping oil phase (D. Poncelet©)

Alginate microencapsulated diet in comparison to rotifers (M. Yufera©)

between a particle stable enough to retain the dietary ingredients after rehydration including small hydrosoluble compounds, but unstable enough to allow the release of small amounts of amino acid before being ingested and to be digestible by the immature digestive tract of larvae. Accordingly some of the main characteristics are:

- First of all, the size of the capsules must be carefully selected with respect to the preferences of the fed organism (bivalve, zooplankter, or fish larvae). For example, *Brachionus* spp and *Artemia* prefer particles between 2 and 10 µm approximately, while larval fish prefer particles between 60 and 400 µm depending on the species and developmental stage.
- Microcapsules have to be stored and moved from production sites to consumer, sometimes overseas. In this case they must be mechanically resistant and frequently stabilised by drying. Unfortunately, instability of microcapsules during drying is often a limitation.
- Capsules have to be stable and sometimes impermeable in suspension in water. Taking into account a membrane of a few micrometers, this constitutes a challenge. It is even more challenging problem, if capsules must be suspended in sea water. Many hydrogels would be unstable in such a condition. The question of the permeability is especially critical in microdiets for larval fish. Microdiets should have a high water content to resemble the live prey. Therefore the shell of the particles must allow the rehydration when immersed in water, but once hydrated it should retain the hydrosoluble nutrients. Impermeability may also concern oxygen, that could react with core material.
- Capsules must represent an attracting food replacement for aquatic species, both in term of textures, smell and tastes.
- The capsule material either must be a feed material itself or represent a small part of the capsules. In all case, it shall not effect the overall food composition.
- Capsules must be degraded during gastro-intestinal transit and release their content at the right place in the intestine. For instance, in the case of larval feeds it should be degraded by the immature stomachless gut of larval marine fish. In the case of fish oral vaccination, the microcapsules should resist the degradation at low pH in the stomach to deliver the antigen within the intestine.
- Capsules have to have adequate physical and mechanical properties. Their density must allow them to remain suspended in the water column time enough to be ingested .

In to the light of all these constraints, especially the size, the dispersion step will generally consist in spraying a liquid core in air or emulsifying it in an immiscible liquid. The liquid core itself could be a solution of the active material (feed, probiotic, drug or vaccine), or suspension for insoluble solid active material or an emulsion for insoluble liquid material. As mentioned before, the microencapsulated larval diet should be stable in water and easily digestible. The encapsulation techniques preventing leakage from the capsule tend to negatively affect digestion of the particle. Several types of microdiets have been developed and tested trying to overcome these constraints, but none seems to solve all problems. Micro-bound and cross-linked protein-walled capsules are effective in delivering lipids and high-molecular weight nutrients to larvae, such as proteins and carbohydrates, while liposomes, lipid-walled capsules and lipid spray-beads are more useful in delivering low-molecular weight, water-soluble nutrients, such as amino acids and water-soluble vitamins. Complex particles have also been proposed to take advantage of both lipid-walled capsules and micro-bound diets. Other constraints to consider refer to large scale production. The use of practical ingredients from food industry and methodologies not requiring aggressive reactants and potentially toxicants compounds for cultured animals and environment are conditions to take into account in the scaling up of these technologies.

Although the examples considered so far primarily deal with edible material, similar and additional problems and challenges can be found in the other microencapsulation uses briefly commented before. All of these appliactionshave a high potential to improve production processes and consequently to raise the benefits for and from aquaculture industry.

Innovations and collaborations are certainly a pre-requisite and the key to overcome the actual limitations. The involvement of microencapsulation in solving some of the aquaculture problems must be a multidisciplinary approach. Nutritionists have to define feed requirement, biologists have to bring understanding ecology, veterinarians will treat diseased and defined adequate controlled release systems, chemists are needed to design microcapsules and engineers to optimize and scale-up processes. An international network would allow to speed up the scientific progress but also to spread more rapidly the results of research and development.

Promoting such a network is the objective of the Bioencapsulation Industrial Symposium to be held in Puerto Varas (Chile) on November 26-27, 2009. We invite you to join us and participate in the establishment of a network for research, collaboration and business development of aquaculture solution involving microencapsulation.

More information : http://bioencapsulation.net/2009_PuertoVaras