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BRINE SHRIMP *ARTEMIA* IN COASTAL SALTWORKS : INEXPENSIVE SOURCE OF FOOD FOR VERTICALLY INTEGRATED AQUACULTURE

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ABSTRACT

Proper *Artemia* introduction and management should lead not only to optimal salt production outputs but at the same time provide opportunities for the exploitation of valuable by-products, i.e. *Artemia* cysts and adult biomass as cheap sources of high quality food for intensive fish or crustacean farming.

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Since early history, man has developed systems to concentrate seawater and harvest salt as a basic need for his health. Over the centuries hundreds and thousands of hectares of salt pans have been constructed all over the world in the tropical and sub-tropical belt for so called solar salt making. In view of the extreme physico-chemical conditions in these high salinity waters only few plant and animal species can live in salinas, the most popular organism being the brine shrimp Artemia (Persoone and Sorgeloos, 1980).

Brine shrimp populations are found in many hundreds of solar saltworks and salt lakes (Vanhaecke and Sorgeloos, in prep.). Its distribution, however, is not continuous, e.g. Artemia does not naturally occur in SE-Asia, although thousands of hectares of salt ponds are in operation during the dry season (De los Santos et al., 1980); in fact, in the monsoon seasoon all salt ponds are converted into freshwater ponds that in some situations are used for fish farming. Another example is found in NE-Brazil : i.e. until a few years ago no Artemia was present in the more than 20,000 hectares of salinas in Rio Grande do Norte until it was introduced by man (Sorgeloos et al., 1979). Artemia needs indeed active or passive dispersion vectors for its cysts, such as wind, waterbirds or man.
One successful transplantation is mostly enough to assure continuous presence of brine shrimp in a salina. However, adverse weather conditions, like severe rainfall can be sufficient to completely whipe out a population.

As a result of extensive travelling to many salinas around the world, we have had the opportunity to learn about the beneficial role that Artemia plays in the salt production process. At first this might not look very much obvious, especially for the saltwork people who mostly have a chemistry background. Problems in the salt making can arise when algal blooms develop in the evaporation ponds. As a result of the organic metabolites produced by the algae, brine viscosities can get so high that the physical process of salt precipitation in the crystallizers

is hampered ; furthermore salt crystals are small and often contaminated with organic impurities. This can be biologically controlled by the presence of brine shrimp which act as vacuum cleaners, converting any particulate matter into Artemia biomass, cysts or faecal pellets which do not interfere with the salt production. On the contrary, it is now proven that the dark red coloration of the crystallizers, as a result of high densities of halophilic microbes of the genus Halobacterium, is directly correlated with Artemia presence earlier in the system ; i.e. at these high brine concentrations Halobacterium only can develop into large concentrations when it has access to an organic substrate of animal origin, which in a good functioning saltwork is present under the form of Artemia metabolites or decaying Artemia (Jones et al., 1981). Dark red crystallizers assure much better heat absorption and thus faster salt crystallisation than in a situation where the white salt at the bottom of the pond reflects most of the light. In extreme situations where Artemia is either not occurring or present in too small quantities one is sometimes adding chemical dyes to artificially color the water green (Jones et al., 1981).

More and more saltoperators are convinced now of the critical role of the hydrobiological activity in their salt ponds and have initiated Artemia management. Indeed, the same way as they control water flowrates, they decide now about where and when to introduce Artemia, and do not wait until for example a flamingo might fly in with an inoculum of brine shirmp. Now that we better understand the biology and ecology of brine shrimp, more efficient methods could be developed for Artemia inoculation and production (Sorgeloos, 1983); in this regard it might look unbelievable that freshly hatched nauplii, produced in natural seawater, may be directly transferred into saltponds at 100 ppt salinity and grow into adults in less than 2 weeks time (Sorgeloos, 1980 ; Tunsutapanich, 1982).

The increased interest in Artemia by the salt people is of course more than welcome for the aquaculture world. This means, first of all, that an increase in commercial availability of cysts could be expected. This is indeed more than needed, since

the increased demands for high quality cysts by a few countries in Asia, especially Japan and Taiwan, have resulted in recent price rises for cysts up to 50 US dollars per kg FOB Brazil or the USA.

Cysts are still considered as the most critical item. However, aquaculture people are not sufficiently aware of the potential of adult Artemia biomass as a unique food source for their hatcheries, nurseries and maturation facilities for shrimp, prawn, crab and fish.

In a salt work adult Artemia is produced by the metric tons per hectare and per year (Persoone and Sorgeloos, 1980). By the gravity flow in the solar salt operation the animals are drained from one pond to another ; at a certain spot they produce cysts but finally they reach critically high salinity levels where they all die off. A few companies in Europe and North America harvest but small fractions of the locally available Artemia biomass and market it as a live or frozen product for aquarium petshops. At wholesale prices ranging from 10 to 50 US dollars per kg live weight, this adult brine shrimp product is sold at prohibitive prices for commercial aquaculture. However, there are other ways to valorize the vast amounts of cheap Artemia available in saltworks, e.g. as is already demonstrated at commercial scale in Brazil, integrated production of salt + Artemia + shrimp has big potential (Companhia do Rio Grande do Norte, pers. comm.)

Indeed, solar salt operations and aquaculture farms can find joint venture interests via Artemia ; i.e.

- better hatchery outputs can be assured when the Artemia provisions have not to be restricted for economical reasons ;
- no better food is known for postlarval shrimp or juvenile fishes than adult brine shrimp (Sorgeloos, 1980 ; 1982). Nursery systems (in raceways or ponds) in which live or frozen biomass harvested from the saltponds, is fed during 1 to 2 weeks, assure a much more successful transition from hatchery to grow-out than is attained with present techniques. This has been proven

at least for post-larval Penaeus japonicus (Guimaraes, pers. comm.) and for milkfish fry (De los Santos, pers. comm.).

- the most significant effect might be in shrimp maturation, where it was found at least with Penaeus japonicus that a diet of adult brine shrimp is a most effective maturation trigger (Vieira de Castro, pers. comm.). Since Artemia has a very high reproductive activity, it is now being verified if the maturation induction in other crustaceans might be due to brine shrimp hormone activity ;
- last but not least, since continuous harvesting of Artemia easily can be mechanized, one could eventually consider to process the biomass which is not consumed directly, (see above), and valorize it under the form of brine shrimp meal. It is beyond doubt that this high quality product could be an attractive substitute for fish meal in the formulation of pellets, eventually used in the same aquaculture farm in the growout ponds.

Now that it has been proven that salt making and Artemia production go hand in hand, shrimp and fish aquaculture operations should try to integrate with solar saltworks. In view of the many thousands of hectares of salinas in the tropical-subtropical belt, in fact often in climates that favor crustacean or fish farming, this new type of vertically integrated aquaculture has most interesting prospects. Furthermore, in many developing countries it can lead to extra income for family size salt operations often run at limits of profitability (Sahavachasin, 1981).

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