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Increased yields of marine fish and shrimp production through application of innovative techniques with *Artemia* *

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SUMMARY

The larval culture of fish and shrimp can be seriously improved thanks to the results of recent research and developments in the field of *Artemia* production and utilization.

The present article provides a historical overview of *Artemia* cyst demand and provision, summarizes the latest results of *Artemia* production in extensive and intensive culture systems and correlates the increased outputs in fish and shrimp hatcheries with improved applications of various *Artemia* products.

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Modern aquaculture production is achieved through complete domestication of cultured species, e.g. fishes and crustaceans. This involves the elaboration of "egg to egg" culture techniques contrary to earlier farming of wild caught fry. Mother animals are induced to spawn in captivity. Their offspring are transferred to culture tanks where the larvae grow onto a juvenile or postlarval stage. In the following "nursery" phase, juveniles are conditioned for the transfer to natural conditions in the "grow-out" ponds or cages where they are farmed up to a marketable size on natural plankton and/or benthos eventually supplemented with prepared feeds. A small part of the harvest is used to restock the "maturation" unit, closing the cycle.

Intensive larvi-production of most marine fishes and crustaceans is still hampered by the requirement for live food, at least during their early stages. Since the techniques for collecting or culturing their natural diet, characterized by a wide diversity of plankton, are either commercially unfeasible or technically hard to realize, a suitable substitute for natural plankton had to be found. The most used live food in the sucessful larval rearing of fishes and crustaceans is the brine shrimp *Artemia* . Technically speaking the advantage of using *Artemia* is that one can produce live food "on demand" from a dry and storable powder, i.e. dormant *Artemia* cysts (eggs) which upon immersion in seawater regain their metabolic activity and within 24 hours release 0.4 mm freeswimming larvae (nauplii). Actually more than 100 tons of dry *Artemia* cysts are marketed annually for worldlife production of freshly hatched *Artemia* nauplii to be used as food in the hatchery phase of fish and crustacean aquaculture.

The history of *Artemia* cyst production and use reveals an interesting evolution. In the 1960's, commercial provisions originated from a few sources in North America which seemed to be unlimited. However with the expansion of aquaculture production in the 1970's, the demand for *Artemia* cysts soon exceeded the offer and prices increased exponentially. The dramatic impact of the aggravating cyst shortage on the expansion of hatchery-aquaculture of marine fishes and crustaceans was repeatedly underlined at international conferences. Especially the third world countries could hardly afford to import the very expensive cysts.

Fundamental and applied research with brine shrimp *Artemia* was initiated at the Ghent State University in the early 70's. Based on our (theoretical) knowledge, we claimed at the Kyoto 1976 FAO Technical Conference on Aquaculture that the cyst shortage was an artificial and only temporal problem. During the following years several national and international aid organisations provided opportunities to verify our theoretical claims and to proof the possibility of the local production of cheap *Artemia* in various third world countries. As of today, *Artemia* is being produced and exploited on the five continents. In addition, demonstrations of integrated *Artemia* productions have been/are being set up in several third world countries opening interesting opportunities for improved socio-economic situations.

Brine shrimp *Artemia* has unique characteristics which offer a great potential for mass production purposes :

- in optimal conditions, brine shrimp grows from larvae to adult in less than two weeks increasing in length by a factor 20 and in biomass by a factor 500;

- abiotic as well as biotic requirements do not change throughout the animal's development;

- *Artemia* can be cultured in a wide range of water salinities; i.e. from 10 ppt to saturation level. Above 100 ppt no predators nor food competitors survive resulting in a monoculture under natural conditions;

- several hundreds of natural strains of *Artemia* are found in coastal salinas as well as in inland salt lakes (rich in chlorine, sulphate or carbonate salts) found on the five continents;

- this crustacean can reproduce by two ways, either live reproduction (free-swimming nauplii) or cyst production (the embryos develop into gastrulae at which stage they are encapsulated in a cyst shell and their metabolism is reversibly interrupted;

- *Artemia* has a high fecundity rate (more than 100 cysts or nauplii, every four days) and a long lifespan (exceeding six months);

- since this animal is a non-selective particulate filter-feeder, a wide range of very cheap foodstuffs and fertilizers can be considered to culture *Artemia*, e.g. organic manures (chicken, dung), agricultural byproducts (rice bran, whey, brewer's yeast), etc.;

- *Artemia* can be successfully grown in very high densities (i.e. more than 10000 animals per liter) in salt water and is not very demanding as to the qualitative and quantitative composition of this water;

- the adult brine shrimp has a very high nutritional value : i.e. its exoskeleton is very thin (less than 1 m), 60 % of its dry weight consists of proteins rich in essential amino acids; *Artemia* furthermore contains significant concentrations of vitamines, hormones, carotenoids, etc.

Proper knowledge of the biological and ecological (life cycle and habitat, **Figs 1 and 2**) characteristics of brine shrimp reveals the potential to exploit existing natural sources of cysts and biomass in operational saltworks (salinas) or salt lakes. The natural distribution (better "dispersion") of *Artemia* can be enhanced by human intervention, i.e. introduction (better "transplantation") of a selected *Artemia* strain into a suitable environment (e.g. operational salina) can result in the establishment of new *Artemia* populations which eventually can be commercially exploited. In regions with a pronounced rainy season, *Artemia* cannot resist predation during the wet season and should be reinoculated at the onset of the dry season when the salinity conditions can support a monoculture of brine shrimp. Small ponds, manured with chicken dung, can yield up to 20 kg dry weight cysts or 1500 kg live weight adult *Artemia* (so called "biomass") per hectare and per month. Although already at commercial operation in artisanal saltworks in SE-Asia, this type of *Artemia* production can be further optimized and requires more extension services. In view of the beneficial effects of *Artemia* on solar salt production, integrated production of salt and brine shrimp, eventually combined with shrimp farming provide the most attractive cost-benefits. Furthermore, this possibility to valorize abandonned salinas or to revitalize solar salt production systems operated at the limits of profitability (many examples in several third world countries in Asia and the America's) opens interesting opportunities for socio-economic improvements in depressed areas.

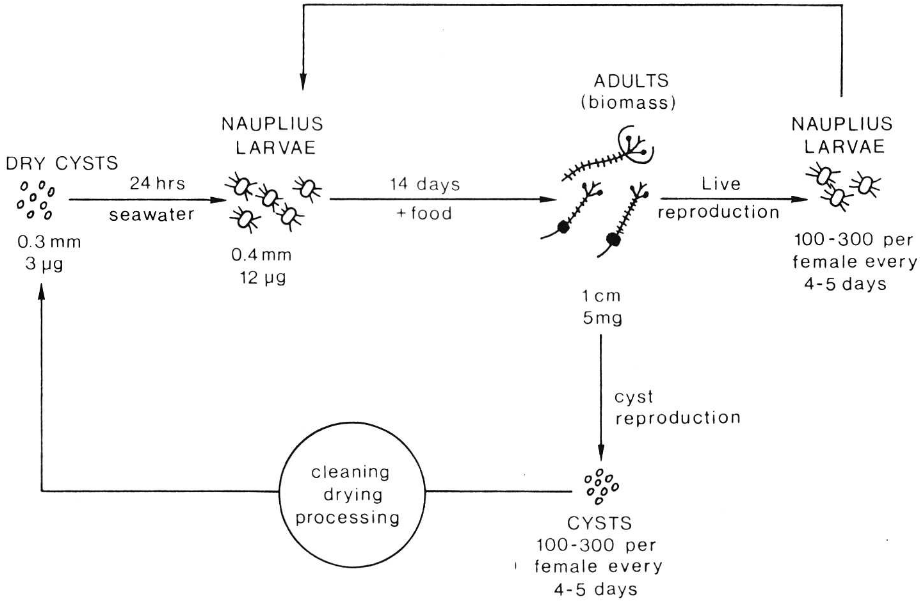

Fig. 1. Schematic diagram of *Artemia* life cycle.

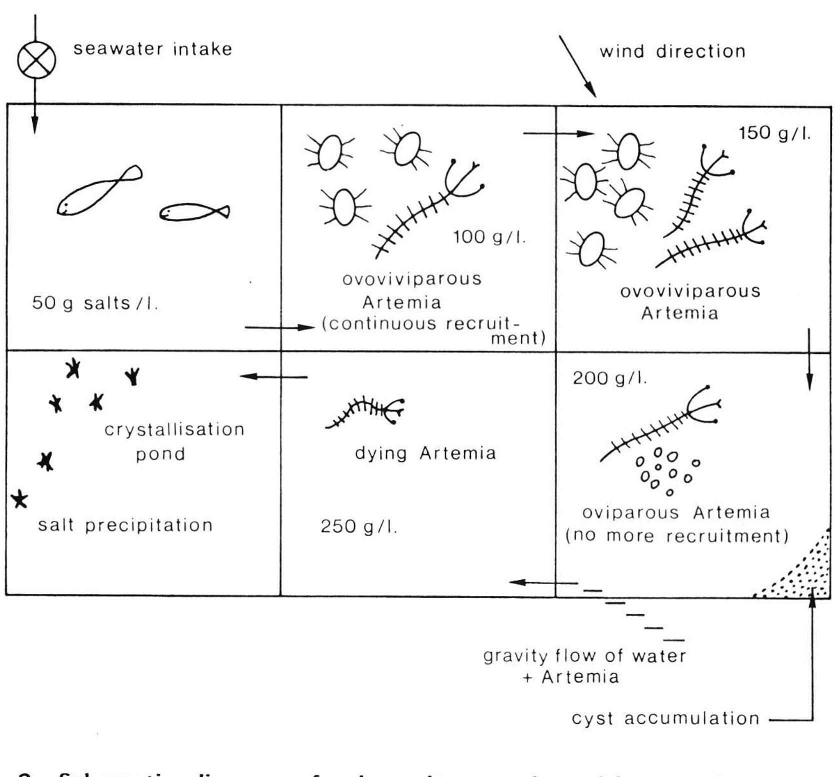

Fig. 2. Schematic diagram of solar salt operation with natural occurrence of *Artemia*.

When conditions for pond production of *Artemia* are inappropriate (e.g. too low salinity levels during the rainy season), intensive culture techniques with natural seawater and micronized agricultural byproducts such as rice bran can be set up within the fish or shrimp farm. Using batch or flow-through culture systems, bi-weekly yields of 5 respectively 25 kg live weight *Artemia* can be obtained per tank of 1 m^3 content. The production cost of *Artemia* biomass grown in intensive culture systems is much higher than from wild harvests or pond produced biomass. Nonetheless, this new type of controlled *Artemia* production can easily be integrated in the hatchery operations (similar technical prerequisited), be operated on a yearround basis and moreover providing better opportunities for quality control/manipulation (size, biochemical composition) of the *Artemia* as a nursery and maturation diet (see further).

Improved technologies of cyst/biomass harvesting and processing technologies (cleaning, freezing / drying and packaging) should be applied as they influence the quality of the endproduct.

In many situations, the utilization of *Artemia* in fish and shrimp farming can be greatly improved. Although the production of nauplii from hatching of cysts appears to be a simple procedure, special precautions have to be taken to ensure maximal hatching outputs when incubating large quantities of cysts (e.g. optimal conditions for temperature, salinity, oxygen, pH, light and disinfection). For several reasons, the use of "decapsulated" *Artemia* cysts are to be preferred in the fish/shrimp hatcheries. Through oxidation with hypochlorite, the outer shell of the cysts can be removed without affecting the viability of the embryo. Upon incubation in seawater, the hatching output of these disinfected and naked embryos has increased and their nauplii have a higher energetic value as compared to the nauplii produced from untreated cysts; the use of decapsulated cysts furthermore eliminates the need of the cumbersome separation of the nauplii from the empty shells.

Since the commercial availability of various *Artemia* strains from widely different geographical sources, significant differences in larval culture success have been reported with several fish and shrimp species. The *Artemia* nauplius size can be too large for handling and ingestion by the larvae. It is therefore advisable to start feeding with frequent additions of freshly hatched nauplii from selected *Artemia* strains producing small nauplii. As to reduce hatching operations and to ensure maximal valorisation of the nauplii, high *Artemia* concentrations can be stored at low temperature for up to 48 hrs.

Detailed biological and biochemical analyses revealed that the nutritional composition of particular *Artemia* strains or even of specific batches from the same strain does not always meet the requirements of the fish or shrimp larvae. Probably the most critical factor determining the dietary value of *Artemia* as a food source for marine fish and shrimp larvae is the presence and concentration of HUFA's (highly unsaturated fatty acids 20 : $5\omega3$ and 22 : $6\omega3$) which, in function of the strain or even the specific batch of cysts from the same geographical origin, might be inconsistent to minimal if present at all. In order to overcome this variation in biological effectiveness of specific *Artemia* cyst products, enrichment diets have been formulated and bioencapsulation techniques developed (**Fig. 3**). Application of these new techniques results in significant improvements of the nutritional effectiveness of the latter low

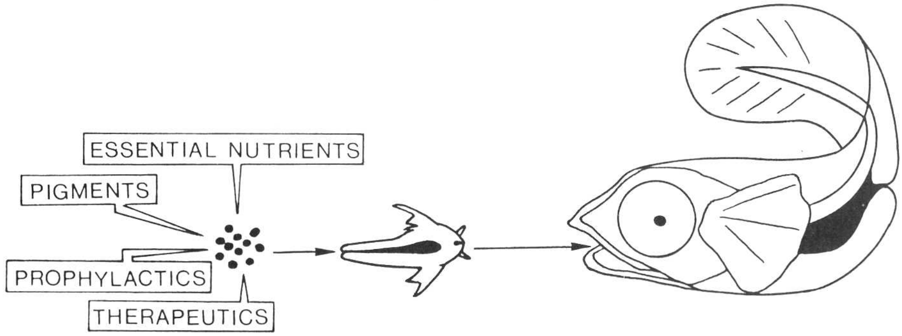

Fig. 3. Schematic outline of the technique using *Artemia* as a carrier for various nutritional, prophylactic and therapeutic components.

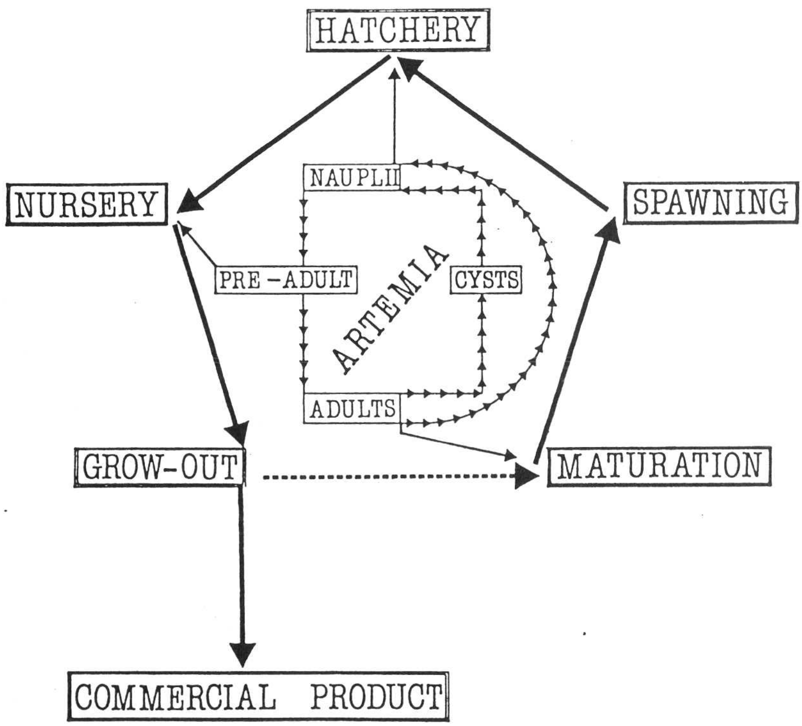

Fig. 4. Schematic outline of the integrated use of various *Artemia* products in fish or shrimp production.

quality cyst products; i.e. diets containing high HUFA-levels are bioencapsulated in the gut of *Artemia* nauplius during its hatching incubation or after separation of the emerged nauplii. Using this *Artemia* bioencapsulation technique, it has been demonstrated that hatchery production yields can be increased considerably (i.e. higher survival, larger/bigger larvae, better disease resistance, fewer deformities, better pigmentation, etc.).

Because of limited availability, the use of ongrown and adult has mostly been restricted to relatively small scale culture trials. During recent years, however, commercial scale use of *Artemia* biomass harvested from local saltworks (especially in SE-Asian countries, but also Brasil, Panama and Ecuador) is gaining more and more interest especially in the nursery stage (in both fish and shrimp farming) and the maturation of penaeid shrimp (**Fig. 4**). Feeding adult *Artemia* for one to two weeks to the juveniles in nursery ponds or intensive raceways results in significant increases in nursery survival and growth. A diet of adult brine shrimp not only is optimal for hatchery reared fry at its transition from a controlled environment to fluctuating conditions in the wild, it has also proven to be very useful for acclimating wild fry (e.g. milkfish) that often has become weak as result of excessive handling and transport.
In addition, it has recently been found that a diet of *Artemia* biomass can improve maturation success in several *Panaeus* shrimp species. Further enhancement of the nutritive properties of the *Artemia* biomass can be achieved by application of the bioencapsulation technique with enrichment products (e.g. emulsified diets for enhancement of maturation, better postlarval pigmentation, vitamin supplementation, prophylactic treatment, etc.).

The earlier cited developments of *Artemia* enrichment diets have been at the origin of the development of algal substitutes which are successfully applied for feeding the first stages of penaeid shrimp (*Zoea* and *Mysis*). Unicellular algae production (e.g. *Skeletonema*, *Tetraselmis*, *Chaetoceros*) not only is very costly (investment, energy, products and labour), it has been proven on several occasions that their nutritional effectiveness may vary considerably throughout the year. In this regard, the availability of a non-living substitute, as an "off the shelf" feed, that guarantees a constant and equal performance in the hatchery outputs may be considered as a major breakthrough in shrimp farming.

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