ARTEMIA SALINA AS LIVE FOOD IN AQUACULTURE

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Since Seale (1933) and Rollefsen (1939) described the high value of freshly hatched nauplii of Artemia salina as food for fish fry, the exploitation of Artemia cysts was started in the Bay of San Francisco (California, USA) and later in Great Salt Lake (Utah, USA) and the salt lakes of Saskatchewan (Canada). It was soon found that the cysts of the brine shrimp which can be harvested periodically from the salt lake's shore, remain viable for years when kept vacuum dry.

Considering its practical handling and the high nutritional value of this food source, the use of Artemia in aquaculture increased exponentially. Nowadays, an overall picture of the aquaculture situation reveals that freshly hatched Artemia nauplii constitute not only the best, but in most cases also the only available source of live food for the youngest stages of most cultured species of larval fishes and decapods (Bardach et al., 1972 ; Goodwin, 1976).

Furthermore although numerous artificial diets have been tested out, older Artemia larvae as well as adult brine shrimps still assure the best results for the culturing of larval fish and crustaceans (Botsford et al., 1974 ; Ministry of Agriculture, Fisheries and Food, 1975).

Whereas a decade ago, the cyst provision seemed unlimited, the actual demand already exceeds the offer and as a consequence puts a considerable burden on the further expansion of aquaculture development. In fact over 30 tons of dry Artemia cysts are consumed yearly in the aquaculture business, the aquarium industry and the research programmes using Artemia as a test-organism.

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Although a more efficient use of Artemia could greatly alleviate the present needs, scientific data on optimizing the use of Artemia are very scarce. In fact most hatcheries and laboratories only consider the brine shrimp either as an intermediate step in the food-production-process or as a test-animal for their research ; as a consequence these institutes do not want to spend neither time nor money to perform that type of research.

The aim of this contribution is to present a short review of the present "state of the art" on the hatching and harvesting of the nauplii, the culturing of the larvae, and the reproduction of the adults.

Although it appears from fundamental studies on the hatching-process (cf. review Sorgeloos and Persoone, 1975) that Artemia nauplii can be hatched from the cysts at a wide range of temperatures, salinities and dissolved oxygen concentrations of the medium, high densities of nauplii can only be obtained in strictly controlled and standardized hatching-conditions.

The principal rules which guarantee a maximal hatching efficiency can be summarized as follows :

1. Since the hatching rate is extremely dependent on temperature and salinity, these abiotic parameters should be kept constant in order to always obtain a maximum yield of nauplii after a well defined immersion period.
2. The cysts must be kept in suspension in oxygen-saturated seawater ; cysts accumulating on the bottom of the hatching apparatus will often be exposed to anaerobic conditions and will not hatch.
3. Shortly after hydration, the cysts must be illuminated because a specific immersion of the cysts in continuous darkness indeed results in a much lower hatching efficiency.

At our laboratory the follwoing standard procedure is applied for hatching up to 5 g cysts in 500 ml seawater : the hatching container consists of a glass cylinder with a funnel shaped bottom (Fig. 1). Continuous aeration from the bottom of the tube keeps all the cysts in suspension ; a few drops of a nontoxic antifoam additive (e.g. Dow Corning Brewing Aid No. 525) prevents foaming. After immersion of the cysts, the cylinder is illuminated by a fluorescent light tube for 1 hour. The water temperature is kept constant at 28°C ; the salinity of the medium may range from 28 - 32 °/₀₀.

In these conditions, the time until maximal hatching approximates 18 hours for San Francisco Bay (California, USA) cysts and 24 hours for Great Salt Lake (Utah, USA) cysts respectively.

Since the empty cyst shells and/or unhatched cysts are harmful when eaten by young fish and decapod larvae or may interfere in experiments with freshly hatched nauplii, various devices have been elaborated in which the hatching debris can be separated from the free-swimming nauplii. Most of these systems are based on the positive phototactic behavior of the nauplii (cf. review in Sorgeloos and Persoone, 1975).

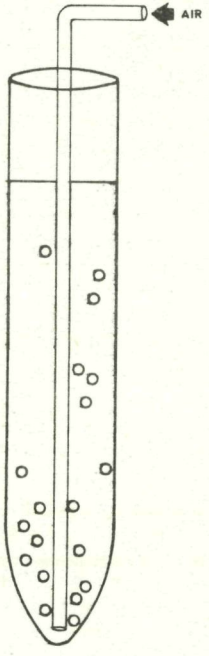


Fig.1. Hatching cylinder.

Since several years we are using in our laboratory a cylindrical separator box (Persoone and Sorgeloos, 1972) (Figs 2 and 3).

Separation is achieved by partly unscrewing or rotating an internal and closed cylinder from its fixed counterpart (glued to the bottom of the box) until two or more slits are freed through which the positively phototactic nauplii can migrate from the darkened interior into the illuminated exterior compartment. Rescrewing the former cylinder into its original position separates the nauplii in the exterior compartment from the suspension of hatching debris in the interior one.

In order to be able to set up experiments with well defined numbers of larvae, optical counters have been developed which enable the distribution of Artemia nauplii in preselected quantities (cf. Van Outryve and Sorgeloos, 1976).

In aquaculture the Artemia are mostly fed to the predator as freshly hatched nauplii. Fundamental research on the molting rate and the energy content of the unfed larvae revealed that the nauplii have to be fed to the predator as soon as possible after hatching. Benijts et al. (1976) indeed demonstrated that after two moltings, which, at 25°C, occur within 24 hours after hatching, the individual dry weight and caloric value had already decreased with respectively 20 % and 27 %.

Although salt lakes with Artemia populations are found all over the world (Mathias, 1937 ; Sorgeloos et al., 1976) only three areas in North America are commercially exploited for Artemia harvesting : San Francisco Bay (California, USA) , Great Salt Lake (Utah, USA) and Chaplin Lake (Saskatchewan, Canada).

From these three sources only the San Francisco Bay Artemia can be used for certain predators ; indeed nauplii from the other available strains are either too large to be swallowed by the predator or do not satisfy nutritionally. High mortality or teratological development of the predator was observed when it was fed with Great Salt Lake (Utah, USA) nauplii (cf. review in Sorgeloos, 1976). Certain authors reported pollutants to be the causal factor of these phenomena, others, however, found out that the same Utah nauplii could be converted into a good food source by feeding them for a number of days on live algae (Wickins, 1972).

During the last 20 years, several papers have been published dealing with the culturing biology of the brine shrimp. As defined by Barker-Jørgensen (1966) Artemia is a "... non-selective, obligate filter-feeder" : for its respiratory activity the thoracopods (bearing the exopodites with gill-function) are always in active movement. In fact all particles which are neither too small nor too large (from very small sand grains up to ciliates of over 50 µm) are ingested by Artemia. Reeve (1963) demonstrated that food is digested most efficiently when the concentration of suspended particles is low. When it is too high, the food is ingested

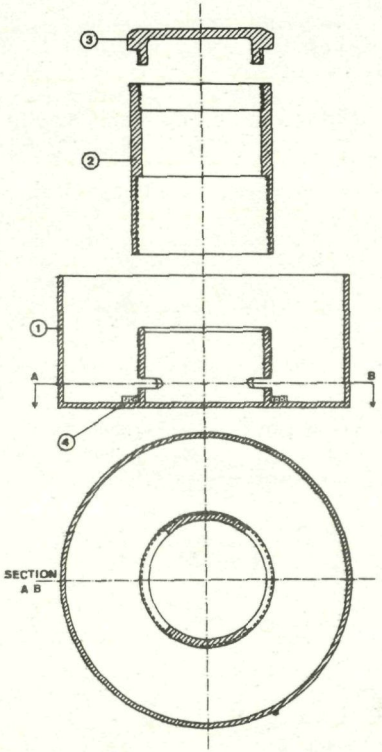


Fig.2. Lateral and section views of the different parts of the separator box.

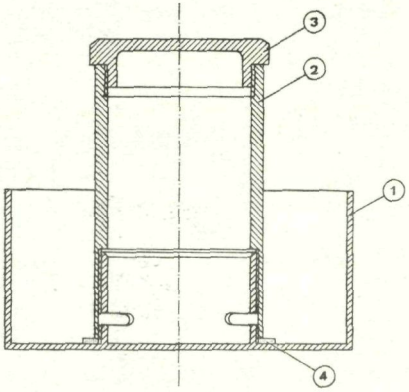


Fig.3. Lateral view of the assembled device.

(1) Cylindrical non-transparent box (PVC) with internal separation cylinder containing slits and screw-thread.

(2) Cylinder with internal screw-thread at top and bottom.

(3) Led with external screw-thread.

(4) Rubber ring glued to bottom of box.

at such a high rate, that it is transformed into a faeces pellet and excreted before it can be digested. As improbable as it may appear, Artemia is starving when kept in a too high concentration of food particles. The best growth results are obtained when the cultures are fed frequently with small quantities of food.

Provasoli and D'Agostino (1969) reported that from the 3rd instar on, Artemia has to be given particulate food since it seems that from that stage on, soluble food cannot be ingested efficiently any more.

The brine shrimp being unselective in its feeding, it was soon found that Artemia can be cultured on a wide range of diets, varying from unicellular algae (live as well as frozen or dried), yeasts , bacteria, fish meal particles, to even artificially prepared microcapsules with different contents (Sorgeloos, 1974 ; Jones et al., 1976).

To date only a few techniques have been described for the mass-culturing of Artemia ; they were developed either for low density culturing or for small volumes and as such cannot be applied to a larger scale nor be automatized.

Since a few years we obtain very good results for growth and survival rate with so-called "air-lift-pump operated raceways" (Sorgeloos et al., 1977 ; Figs. 4 and 5).

The shape of the tank and the positioning of the air-lift pipes assure a continuous circulation and oxygenation of the entire medium. Cultures started at densities of 3,000 nauplii per liter and fed an inert diet containing dried algae, reach the preadult stage within 2 weeks. Contrary to the techniques described in literature, the medium has neither to be diluted nor to be renewed during the entire culturing period.

Considering the minimum of manual labor involved and the possibility of automatization, we are convinced that with the present technique, controlled mass-culturing of Artemia is economically feasible. A 2 m^3 pilot-scale model has been built and studies are in progress to determine the optimal input-output rates, growth rates, food conversion efficiency, etc.

Until now man has not yet succeeded to strictly control the reproduction process in Artemia, i.e. ovoviviparity (production of free-swimming nauplii) versus oviparity (deposition of cysts which can undergo diapause).

From literature and from our own results, it appears that oviparity is induced at high haemoglobin concentrations in the blood (Sorgeloos et al., 1976). In nature the production of cysts is reported to occur with cyclic intervals when the salinity of the salt lake is at its maximum and when high day-night fluctuations occur in the dissolved oxygen concentration. In the laboratory oviparity occurs in media with low dissolved oxygen concentration or in the presence of chelated iron (ferric EDTA).

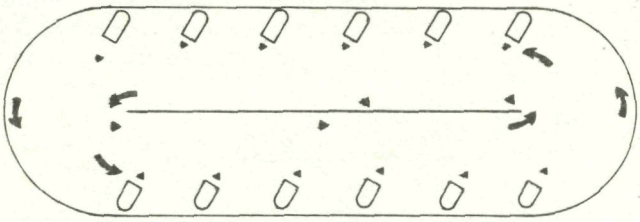


Fig.4. Top view of air-lift-pump operated raceway

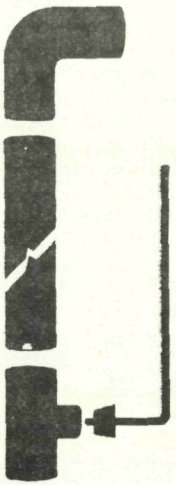


Fig.5. Disassembled air-lift-pump

In conclusion of this short review on the culturing biology of Artemia, it appears that with the information available, the use of this invaluable source of live food in aquaculture can be much improved. It is nevertheless clear that numerous aspects need further study not at least to alleviate the present critical shortage of cysts.

With regard to new applications and/or better utilizations of Artemia in aquaculture, our team at the State University of Ghent (Laboratory for Biological Research in Environmental Pollution, Dir. Prof. Dr. G. Persoone) is studying the following aspects :

1. Automatized high density culturing in pilot-scale raceways (300 to 2,000 liters) (M. Baeza-Mesa, E. Bossuyt, E. Bruggeman) ;
2. Culturing technologies for the artificial controlled production of cysts (D. Versichele) ;
3. Comparative study of different geographical strains (C. Claus, F. Benijts) ;
4. Energetic aspects of the metabolism of hydrated cysts
   - study of the important differences in hatchability from one batch of cysts to another ;
   - elaboration of new or better harvesting techniques which increase or at least guarantee a constant hatchability of the cysts (F. Benijts, G. Van De Putte).

Although our Artemia research is focusing on practical aspects of the optimal use of this food source in aquaculture, we are convinced that results of our study will often be of practical use to other disciplines in fundamental research on Artemia and vice versa. For example we are now studying the antiformin method for the decapsulation of cysts, a method which has been developed by biochemists and which, when applied in aquaculture, might eliminate the separation process after hatching of the nauplii. On the other hand we are confident that for example a method for the artificial production of cysts, will be welcomed by all those who need a reliable and constant material for their fundamental research in their respective disciplines.

In this regard we hope that in the future, Artemia research will be carried out on a much more interdisciplinary basis than is presently the case.

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