ROLES AND POTENTIALS OF ARTEMIA IN COASTAL SALTWORKS

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ABSTRACT

The recent developments in aquaculture production of fish and shrimp have resulted in increased demands for Artemia cysts and biomass as valuable sources of live food. Solar salt works are suitable biotopes for the integrated exploitation of salt, Artemia and eventually fish or shrimp. Artemia may be present as a natural resource in local saltworks; however, in some situations characteristics of the endemic strain might justify the introduction of another Artemia species to increase productivity.

THE NATURAL OCCURRENCE OF ARTEMIA

Natural populations of Artemia are found in salt lakes (coastal or inland waters rich in chloride, sulphate or carbonate) and especially in coastal salinas (man-made and/or managed solar saltworks). Detailed reviews can be found in Persoone and Sorgeloos (1980) and Sorgeloos et al (1986).

In saltworks Artemia is found in the evaporation ponds only at intermediate salinity levels from about 100 ppt, the upper tolerance level of predators, to about 200–250 ppt. (when food becomes limiting, because they need more energy for osmoregulation or when the water becomes more toxic in ionic composition as a result of selective crystallisation of salts (see schematic outline in Figure 1). In most populations animal densities are limited by low nutrient contents of the intake waters. Natural habitats with dense Artemia populations are mostly found near human population centers, estuaries or mangrove areas where nutrient inputs are high. At high salinities, depending on the local strain as well as the hydrobiological conditions in the ponds (e.g. water retention time, water depth, pond productivity) cysts of Artemia (see Figure 2) are produced seasonally or year-round. They float, tend to be driven by the wind, and often accumulate on the shores of evaporation ponds. The quality of the Artemia produced differs from strain to strain and from location to location as a result of genotypical and phenotypical variations (for reviews see Leger et al, 1986; 1987a). It largely reflects the food conditions of the local habitat; adults as well as cysts may be contaminated with high levels of heavy metals, and/or may be deficient in fatty acids essential for marine predators. Particular strains in specific habitats may produce cysts with unusually low caloric content, e.g. the “sulphate strain” in Chaplin Lake, Canada (Vanhaecke et al, 1983).

EXPLOITATION OF NATURAL ARTEMIA HABITATS

Prior to considering commercial exploitation of Artemia for specific use in aquaculture nutrition, it is imperative to determine the nutritional quality of the adults (which we refer to as “biomass”) and the cysts.

Techniques for cyst/biomass harvesting and treatment are outlined by Sorgeloos et al (1986). Maximum sustainable yields of cysts and biomass are influenced by the population dynamics of the local Artemia population. The recruitment rate of the population may be high in ponds where the dominant reproduction mode is ovoviviparity, and low in cyst–production ponds. In the low salinity ponds it may be influenced by the role of cysts as inoculum, either after the winter or throughout the year. Furthermore, predation by waterbirds needs also to be taken into consideration. The determination of maximal harvesting rates is complicated by the heterogenous distribution of the Artemia, which makes accurate sampling and consequently precise population estimates very difficult. (For more details, see Wear and Haslett, 1987 a, b). Natural recruitment can eventually be increased by introduction of a more productive strain. Fertilization of the Artemia ponds can also result in increased production potentials (see below).

BENEFICIAL ROLE OF ARTEMIA IN SOLAR SALTWORKS

Since early times, man has developed systems to concentrate seawater and to harvest sodium chloride as a basic need for his nutrition and health. Over the centuries hundreds and thousands of hectares of salt pans have been constructed all over the world, in tropical and subtropical belts, for so-called solar salt making. The annual production presently amounts to about 200 million tons per year. Less than 10% is used for human consumption, the bulk being consumed by chemical industries (e.g. the chlorine–alkali industries).

Seawater contains salts of almost every chemical element including gold in at least trace amounts. Salt is normally produced by pumping seawater from one evaporation pond into another, allowing carbonates and gypsum to precipitate, and finally draining NaCl–saturated brine or “pickle” (just before the so-called “salting point” is reached) into crystallizer ponds where sodium chloride precipitates. Before all the NaCl has crystallized out, the mother liquor, now called bittern, has to be drained off to reduce contamination of the sodium chloride with bromides and other salts that begin to precipitate at these elevated salinities. The technique of solar salt production thus involves fractional crystallization of the salts in different ponds to obtain sodium chloride in the purest form possible, e.g. up to 99.7% on a dry-weight basis.
The hydrobiological activity in a solar—salt operation largely determines the quality and quantity of salt produced (Davis, 1978, 1980; Sorgeloos, 1983). In many sites the natural conditions ensure a maximal salt production (e.g. in France, Brazil and South Africa); in other locations, however, proper biological management is needed (e.g. in India, Italy, Australia, Bahamas and Venezuela). Algal blooms, induced by natural availability of organic and inorganic nutrients, are generally beneficial since they ensure increased solar heat absorption, resulting in faster evaporation and increased yields of salt. However, if they are not metabolized in time, algal excretion and decomposition products, such as dissolved carbohydrates, act as chemical traps and consequently prevent early precipitation of gypsum which will contaminate the sodium chloride in the crystallizers and reduces salt quality. Furthermore, such organic impurities as algal agglomerations, which turn black on oxidation, may contaminate the salt and reduce the size of the crystals and hence the salt quality. In the worst situations, high water viscosities may completely inhibit salt crystal formation and precipitation. The presence of the brine shrimp Artemia in sufficient numbers is essential not only for controlling algal blooms (Davis, 1980), but also for providing essential nutrients from Artemia metabolites and/or decaying animals as suitable substrates for the development of Halobacterium in the crystallisation ponds (Jones et al. 1981). High concentrations of red halophilic bacteria promote heat absorption, thereby accelerating evaporation, and reduce concentrations of dissolved organics. Lower viscosity levels promote the formation of larger salt crystals, and thereby improve salt quality (Sorgeloos, 1983; Haxby and Tackaert, 1987). In many salt operations natural recruitment of Artemia from cysts dispersed by wind and water birds assures the presence and development of sufficient numbers of brine shrimp for optimal salt operation. In some situations, however, the salt producer should not rely on this opportunistic dispersion of Artemia. In saltworks with short water—retention times in their evaporation ponds, a rapid dilution may wash away the Artemia population; a hurricane or season of exceptionally heavy rainfall may eliminate or so reduce the local population that it cannot effectively cope with the algae blooms. Some saltworks may be completely isolated from natural sources of Artemia dispersion. In such cases salt producers should optimize the hydrobiological activity in the evaporation ponds through a controlled introduction of brine shrimp. Situations have also been observed where the local Artemia population has a poor productivity and remains too small to control the algae and optimal hydrobiological activity for the salt production. The introduction of a foreign strain, better adapted to the prevailing conditions or with better production characteristics, may improve conditions for production of high quality salt. It is not possible to formulate a general strategy with regard to Artemia introductions in solar—salt operations. Each situation needs to be analyzed for specific requirements, with regard to selection of a suitable Artemia strain. The quality and quantity of Artemia to be introduced must be determined in consideration of the water retention times in evaporation reservoirs, food concentrations, water temperatures, etc. (Sorgeloos, et al., 1986).

Proper Artemia management should lead not only to improved salt production outputs but also provide opportunities for the exploitation of the valuable by—product Artemia, as cysts and biomass.

INTRODUCTION OF ARTEMIA

Although Artemia is clearly cosmopolitan, a closer look at the regional level reveals that its distribution is discontinuous. Artemia does not occur in every existing body of seawater. Brine shrimps cannot migrate from one saline biotope to another via the sea, because they lack anatomical defenses against predation by such carnivorous aquatic organisms as larger crustaceans and fish.

The Artemia found in several salt works have probably been accidentally introduced by man. Following an old custom, some salt farmers seeded new salt pans with salt, often containing Artemia cysts, from an operational saltworks. All Artemia populations in Australia were probably originally introduced by man and now compete, at least in low salinity ponds, with the endemic brine shrimp Parartemia spp. (Geddies and Williams, 1987). The absence of a migration route of water birds probably explains why along the northeast coast of Brazil the very large salinas (several 10,000 hectares in total area) contained no brine shrimp until Artemia franciscana was introduced in 1977 by man in just one saltern in Macau. A few years later it had already been dispersed by local water fowl from Macau to most of the saltworks of NE Brazil, over a distance of more than 1,000 km (Camara and De Castro, 1983; Camara and De Medeiros Rocha, 1987).

Introduction of Artemia by man into suitable biotopes certainly provides interesting opportunities for aquaculture production. However, much caution is needed if one is to preserve the genetic diversity of indigenous brine shrimp populations, especially on the Australian continent, where several endemic species might be endangered by the presence of Artemia (see Geddies, 1980, 1981; Geddies and Williams, 1987). On other continents, detailed ecological analyses as well as collection and storage of viable cysts should precede any such new introductions.

Commercial considerations might eventually justify new Artemia introductions in solar salt operations where the salt production, quality and quantity, may be impaired by the absence or poor performance of local strains of Artemia (e.g. in India, Italy, Venezuela, Bahamas). The habitat to which an Artemia population is adapted may have been modified by man in order to improve salt production, resulting in new (suboptimal) ecological conditions e.g. in the deep Lago Salpi near Margherita di Savoia in Italy, which was converted into shallow evaporation ponds in which water temperatures in the summer rise above 30°C, lethal temperatures for the local A. parthenogenetica strain (Bargozzi and Trotta, personal communication; Vanhaecke et al., 1984). An accidental introduction of A. parthenogenetica from China into the solar salt operation on Great Inagua, Bahamas, resulted in significant reductions in salt
quality and output. However, production returned to normal after the introduction of A. franciscana, which had previously been shown to control algal blooms under the local climatic conditions (Haxby, personal communication).

A new Artemia should be introduced only when one can be reasonably sure of its success, and certainly not before enough viable cyst material of the locally occurring strain has been collected to safeguard the conservation of this Artemia gene-pool. In accordance with a resolution adopted at the 2nd International Artemia Symposium, "...all possible measures (should) be taken to ensure that the genetic resources of natural Artemia populations are conserved". Such measures include the establishment of genebanks (cysts), close monitoring of inoculation policies and, where possible, the use of indigenous Artemia for inoculating Artemia — free ponds (Beardmore, 1987). Selection of the inoculated strain should be based on the available data on temperature and salinity tolerances (Vanhaecke et al., 1984; Vanhaecke and Sorgeloos, 1988), growth and production, reproductive characteristics, etc. Whenever possible, culture tests with various Artemia strains should be performed in simulated conditions, using the untreated waters of the habitat as culture medium. Competition between parthenogenetic and bisexual strains might favour the first when dealing with European bisexuals (A. tunsisiana), although coexistence has been reported (Amat, 1983) with dominance of the parthenogenetic strain in the summer months. On the other hand we can confirm that A. franciscana strains always out-compete any other Artemia strain (Browne, 1980). Strain selection might also be restricted by the intended application of the produced Artemia in local aquaculture, e.g. an Artemia strain producing small cysts might be selected for use in sea-bass farming. Such introductions generally result in the permanent establishment of an Artemia population; introduction of an unsuitable strain cannot be readily rectified. Furthermore, adaptation of a newly inoculated strain may result in phenotypical and genotypical variations in the pre-existing stocks, eventually yielding a new Artemia genotype (Vanhaecke and Sorgeloos, 1988).

UTILISATION OF ARTEMIA IN FISH AND SHRIMP FARMING

The increased interest in Artemia in relation to salt production may in due course promote an increase in commercial availability of cysts, both qualitative and quantitative, for the rapidly expanding aquaculture industries in the Mediterranean, Central and South America, and SE–Asia. They are still considered the most critical item, although aquaculture people should be more aware of the potential of adult Artemia biomass as food for cultured shrimp, prawn, crab and fish. In nutritional value, adult Artemia is superior to freshly hatched nauplii (see review in Leger et al., 1986). On a dry-weight basis the protein content increases from an average of 47% in nauplii to 60% in adults. Furthermore, protein quality improves as adults are richer in essential amino acids. In contrast to that of other food organisms, the exoskeleton of adult Artemia is extremely thin, which facilitates digestion of the whole animals by the predator. As the predators grow they can handle a bigger prey, and consequently better results are obtained in terms of relative rates of energy intake. Improved growth, developmental rate and survival have been reported for numerous fish and crustacean species when adult Artemia are supplied as a transition food between nauplii and dry feed. In lobster and sturgeon farming, adult Artemia is used as a starter feed in larval rearing. For direct feeding of live adult Artemia to marine or freshwater animals, one should first thoroughly wash them to remove salts that accumulate between the thoracopods (Artemia is a hypo-osmoregulator, and its body fluids always contain about 9 ppt salts even when collected from, e.g., a 180 ppt evaporation pond).

A diet of adult brine shrimp is very suitable for hatchery-reared fry in transition from a controlled environment to fluctuating conditions in the wild. It has also proven useful for acclimating wild fry, which often become weak as a result of excessive handling and transport (De Los Santos et al., 1980). In Thailand large quantities of live biomass (up to 3 ton/day) are harvested from local salt cum –Artemia farms and used as a starter feed in shrimp nursery ponds. As demonstrated in China, Artemia biomass can also be used as a main source of feed throughout the entire life cycle of penaeid shrimps. Obviously, this practice is limited to situations, such as those in China, where abundant quantities of cheap biomass are locally available and when artificial feeds may be of low quality or unavailable. The recent finding that a diet of adult Artemia may induce maturation in various Penaeus spp. (several personal communications) may further be of major importance in future shrimp farming. The biochemical composition of adult Artemia can vary greatly, especially with regard to its fatty acid profile (see review by Leger et al., 1986). Deficiencies in essential fatty acids can be remedied by application of enrichment techniques, using diets similar to those routinely used in many fish and shrimp farms (Leger et al., 1987b). In fact this technique of encapsulation provides opportunities for using Artemia biomass not only as food but also as a carrier of essential nutrients, pigments, prophylactics, therapeutics, hormones, etc. to the predator larvae (Leger et al., 1986). In addition to its direct application as a food source, Artemia biomass can also be used as a valuable dietary ingredient or gustatory attractant in artificial diets, such as micro-particulated diets and flakes, for fish and crustacean larvae (Leger et al., 1986). It can even substitute for freshly hatched nauplii when supplied in the form of a freeze-dried and micronised meal (Guimaraes and Lira do Rego, 1987).

CONCLUSIONS

Now that it has been shown that salt making and Artemia production go hand in hand, one can envisage attractive joint ventures for shrimp and fish aquaculture operations to integrate with solar saltworks in some of the many thousands of hectares of salinas in the tropical–subtropical areas, often in climates that favour crustacean or fish–farming. Furthermore, it can lead to an extra source of income for families in many developing countries (Sahavatcharin, 1981).
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REFERENCES


Figure 1—Schematic diagram of solar salt operation with natural occurrence of Artemia
(from Sorgeloos et al., 1986)

Figure 2—Schematic diagram of Artemia life cycle (from Sorgeloos et al., 1986)