



The role of brine shrimp in sustaining healthy growth in commercial aquaculture

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Abstract

As the global population continues to surge, addressing food security has become a priority across multiple industries, with sustainable aquaculture emerging as a critical solution. To meet the escalating demand for aquatic protein, the aquaculture sector is expanding rapidly. However, this growth faces significant challenges, particularly the high mortality rates observed during the larval stages, often attributed to the lack of appropriate nutritional support. *Artemia* remains the cornerstone of larval feeding due to its convenient shelf-stability, manageable size, and effectiveness as a vector for nutrients. Unfortunately, shifts in global climate patterns have destabilized traditional *Artemia* cyst supplies, prompting a worldwide shift toward localized production to sustain aquaculture operations. Furthermore, because *Artemia* serves as a highly effective delivery vehicle, it can be bio-enriched with essential nutrients, significantly improving the survival rates, development, and overall health of larval fish.

Keywords: Artemia, Live feed, Aquaculture, Hatchery, Biomass, Fish

Introduction

The aquaculture industry serves as a vital tool for alleviating poverty, malnutrition, and hunger, while simultaneously facilitating economic expansion and the responsible management of natural resources (Mugwanya *et al.*, 2021) ^[1]. By aligning with several United Nations Sustainable Development Goals specifically those targeting the eradication of poverty, the achievement of food security and improved nutrition and the promotion of inclusive economic growth, the sector plays a critical role in global development. Given that fish accounts for approximately 17% of global animal protein intake (FAO, 2020) ^[2], production is projected to climb from 40 million tons in 2008 to 82 million tons by 2050 to keep pace with the needs of a rising population. To meet this trajectory sustainably, industry experts emphasize the optimization of feeding strategies and feed quality (Dawood, 2021) ^[3]. Central to this effort is the provision of nutrient-dense, high-quality feed, which is fundamental to successful fish development during the transition to exogenous feeding (Prusinska *et al.*, 2020) ^[4].

Raising fish larvae in aquaculture is frequently constrained by the difficulty of securing consistent supplies of high-quality *Artemia* cysts small crustaceans harvested from hypersaline environments like salt ponds and natural lakes (Al Dhaheri and Saji, 2013) ^[5]. These organisms are a dietary staple in aquaculture, utilized either as decapsulated cysts, freshly hatched nauplii, or nauplii fortified with essential vitamins and highly unsaturated fatty acids (HUFA) (Rasdi and Qin, 2016) ^[6]. Research indicates that incorporating *Artemia* into larval diets significantly enhances growth and development while lowering mortality rates (Łączynska *et al.*, 2016; Prusinska *et al.*, 2020) ^[7]. Furthermore, *Artemia* serves as a vital source of enzymes and nutrients that are critical for larval development but cannot be endogenously synthesized by the fish at such an early stage (Prusińska *et al.*, 2020) ^[4].

Providing zooplankton as a primary food source for fish and shrimp larvae is frequently impractical, often due to high costs or technical limitations (Ayon *et al.*, 2008) ^[8]. As noted by Kideys *et al.*, (2000) ^[9], this scarcity of appropriate

nutritional resources proved to be a significant barrier for early marine aquaculture pioneers. For altricial marine fish larvae which undergo a prolonged developmental phase and possess underdeveloped digestive tracts live feed is indispensable. Because these larvae lack a fully functional intestine at the onset of exogenous feeding, they rely on hindgut epithelial cells for protein absorption, making artificial diets largely ineffective for survival (Sangeetha *et al.*, 2024) ^[10]. In industrial practice, *Artemia* (brine shrimp) nauplii have become the standard solution; their ease of incubation and high nutritional profile consistently correlate with improved growth outcomes and lower mortality rates in larval populations.

In aquaculture larviculture, rotifers serve as the primary live feed when larvae shift from utilizing their internal yolk sacs to consuming external food sources. Once larvae outgrow the rotifer stage, they transition to *Artemia* (brine shrimp) before eventually acclimating to artificial, inert diets. *Artemia* are primitive branchiopod crustaceans, typically measuring 7 to 12 mm in length. Known for their incredible hardiness, these organisms thrive in a vast array of saline environments and are globally dispersed, with over 50 distinct strains identified. They are widely considered the most popular live diet in the industry due to their practicality and accessibility.

A defining characteristic of *Artemia* is their ability to produce dormant embryos known as "cysts." These cysts accumulate naturally along the edges of hypersaline lakes and coastal lagoons, where they are harvested, processed, and packaged for commercial distribution. Because these cysts remain viable for years when stored properly, they provide a reliable, "ready-to-go" food supply. When incubated in seawater for approximately 24 hours, the cysts hatch into free-swimming nauplii highly nutritious prey suitable for various marine larvae. This ease of use makes *Artemia* a low-effort, high-efficiency solution for hatcheries. Each year, global demand exceeds 2,000 metric tonnes of dry cysts, which are hatched on-site to produce 0.4 mm nauplii for feeding juvenile shellfish and finfish. However, much like rotifers, *Artemia* must be nutritionally bolstered before being fed to larvae. Because brine shrimp

are non-selective filter feeders, they easily ingest various supplements, allowing hatchery managers to "enrich" them with vital marine-based highly unsaturated fatty acids (HUFAs) to ensure optimal larval growth.

Artemia is a natural food

Since the 1700s, *Artemia* has played a significant role in various biological studies (Sorgeloos, 1980) ^[11]. A major breakthrough occurred between 1933 and 1939, when researchers Seale, Gross, and Rolfe identified that newly hatched 0.4 mm *Artemia* nauplii served as an ideal nutritional source for larval fish. This discovery revolutionized hatchery practices and significantly increased production capabilities (Sorgeloos, 1980) ^[11]. Biologically, *Artemia*, commonly known as brine shrimp, are small crustaceans classified under the order Anostraca, class Branchiopoda, and kingdom Metazoa.

The *Artemia* genus encompasses both sexual species of which six are currently recognized and those that reproduce through obligatory parthenogenesis. Genetic divergence from their ancestral lineage's dates back over 80 million years, with populations primarily distributed across Mediterranean and Eurasian salt lakes (Naganawa and Mura, 2017) ^[12]. These species are generally categorized into New World and Old World groups.

These crustaceans are renowned for their remarkable resilience in hypersaline habitats across the globe. *Artemia* have evolved to thrive under extreme stressors, including oxygen depletion, high thermal environments, intense ultraviolet radiation, desiccation, and waters with complex chemical compositions, such as those rich in carbonate, chloride, or sulfate (Camara, 2020) ^[13]. Their life cycle is remarkably brief; they typically undergo about 15 molts to reach maturity, a process that can take as little as 8 days (Treece, 2000) ^[14] or up to 20 days (Camara, 2020) ^[13]. Females exhibit high fecundity, producing as many as 250 embryos per brood across a maximum of 20 broods throughout their existence. Furthermore, they utilize dual reproductive strategies: ovoviviparity, which results in the direct birth of live nauplii, and oviparity, which involves the production of dormant, encysted embryos (Camara, 2020) ^[13].

Taxonomy

The taxonomic classification of *Artemia* is as follows

Phylum: Arthropoda

Class: Crustacea

Subclass: Branchiopoda

Order: Anostraca

Family: Artemiidae

Genus: *Artemia*

The *Artemia* genus represents a sophisticated group of species categorized primarily by their inability to interbreed. Historically, researchers labelled various populations as distinct species based solely on physical characteristics, which were often heavily influenced by environmental factors like water temperature and salt concentration. Eventually, this disorganized naming convention was largely replaced by the catch-all term *Artemia salina* (Linnaeus, 1758), a misclassification that persists in some modern literature despite being scientifically inaccurate. Today, the scientific community acknowledges several distinct, sexually reproducing (zygogenetic) species based on evidence of reproductive isolation. The accepted species and their general geographic ranges, as established

by consensus in research (Pilla & Beardmore, 1994; Beardmore, Pilla and Thomas, 1994; Browne and Bowen, 1991) ^[15,16,17] are as follows

A. salina (Linnaeus, 1758): Lymington, England (now extinct), Mediterranean area

A. tunisiana (Bowen and Sterling, 1978) has also been used for this species);

A. urmiana (Gunther, 1990)

A. sinica (Cai, 1989): central and eastern China

A. tibetiana (Abatzopoulos *et al.*, 1998): Lagkor Co Lake, Tibet, China

A. persimilis (Piccinelli and Prosdocimi, 1968): southern South America

A. franciscana: North, Central and South America (the population from Mono Lake, California, the United States of America, is generally recognized as a subspecies of *A. franciscana*: *A. franciscana monica* (Verrill, 1869).

A. sorgeloosi (Asem *et al.*, 2023) ^[18]: Haiyan Lake, Tibet, China; and

Artemia amati (Asem *et al.*, 2023) ^[18]: Kazakhstan.

Additionally, the numerous parthenogenetic *Artemia* populations occurring in Europe, Africa, Asia and Australia are often grouped under the species name *A. parthenogenetica* (Barigozzi, 1974).

Morphology

The genus *Artemia* encompasses between seven and nine distinct species, all of which trace their lineage back to a common ancestor that inhabited the Mediterranean region approximately 5.5 million years ago. These species classifications are primarily defined by the reproductive isolation observed among various regional populations. Currently recognized species include *A. salina*, *A. tunisiana*, *A. parthenogenetica*, *A. urmiana*, *A. sinica*, *A. persimilis*, and *A. franciscana*.

Physically, *Artemia* represents a classic example of a primitive arthropod characterized by a segmented structure. Typically, the body is composed of 19 segments: the initial 11 bear pairs of appendages, the subsequent two often fused house the reproductive system, and the remaining segments terminate in a tail. Adult males generally reach lengths of 8–10 mm, while females are slightly larger at 10–12 mm; both sexes maintain a width of roughly 4 mm when accounting for their lateral appendages.

Anatomically, the organism is organized into a head, thorax, and abdomen, all encased in a lightweight, supple chitinous exoskeleton. This shell serves as an internal anchor for the creature's muscles and must be shed periodically. This moulting process is a vital part of their lifecycle, occurring routinely in females just before each ovulation cycle.

Artemia Decapsulation Procedure

Hydration

To initiate the decapsulation of *Artemia* cysts, the first requirement is hydration, a process that enables the later detachment of the chorion from the nauplii. Begin by soaking the cysts in either freshwater or saltwater at ambient temperature for roughly 60 minutes, maintaining a ratio of 1 gram of cysts to 15 ml of fluid. Throughout this period, it is essential to provide constant aeration to ensure the cysts remain adequately suspended. Once the hour has elapsed, filter the mixture through a 100 µm mesh harvest bag to collect the hydrated cysts, which can then be returned to the decapsulation container for the next stage (Brendan *et al.*, 2019) ^[19].

Decapsulation

To initiate the decapsulation procedure, transfer the hydrated cysts into the designated vessel and add the chilled sodium hydroxide solution, ensuring constant aeration to maintain proper suspension. Next, introduce the chilled bleach to trigger the chemical reaction. Given that this process is exothermic, it is vital to pre-chill all chemical agents to between 2°C and 10°C; this precaution keeps the mixture below the 35°C threshold that would otherwise compromise the integrity of the cysts.

As the chorion is stripped away, the cysts will undergo a distinct color transition, moving from brown to grey, then transitioning through shades of orange until they reach a vibrant, bright orange finish. This vivid coloration is the primary signal that decapsulation is complete. Alternatively, one may observe the buoyancy of the cysts; the process is finished when roughly 90 percent of the material has settled at the bottom of the container. While typically lasting between one and three minutes, the exact duration may vary based on environmental temperature. It is critical to monitor the procedure strictly, as excessive exposure to the chemical solution can degrade the cysts and negatively impact subsequent hatch rates. Calibrating this process to specific local conditions is essential for consistent results (Brendan *et al.*, 2019) ^[19].

Optimum conditions for hatching Artemia cysts

To achieve the best results when hatching *Artemia*, follow these specific environmental guidelines:

- **Temperature:** Maintain the water between 25°C and 28°C (77°F–82°F), with the latter being the ideal target.
- **Salinity:** Aim for a concentration of 25 parts per thousand (ppt), which corresponds to a density of 1.030.
- **Aeration:** Provide robust and uninterrupted airflow to ensure the cysts remain buoyant and properly circulated.
- **Lighting:** The cysts require continuous exposure to light; for a setup of four 1-liter cones, two 40-watt fluorescent lights are sufficient.
- **pH Levels:** The water should be kept at a slightly alkaline pH of approximately 8.
- **Stocking Rates:** Limit your batch to a maximum of 5 grams of cysts for every liter of water.

Equipment Recommendations: Cone-shaped or V-bottomed vessels are the most efficient for keeping cysts suspended. An inexpensive DIY solution is to invert a 2-liter soda bottle with a valve attached to the cap. For professional-grade results, laboratory separation columns are superior, as they allow for the distinct and easy isolation of unhatched eggs, empty shells, and live nauplii. Ultimately, the success rate and total yield will depend on the combination of consistent water quality, strong circulation, and the genetic quality of the specific cyst source (as noted by Granvil and Treece, 2000).

Artemia enrichment

Artemia strains differ in size and nutritional quality, particularly in content of highly unsaturated fatty acids (HUFA). In the 1980s researchers found that fish larvae feed strains containing more than 4 percent eicosapentaenoic acid (EPA) 20:5 n-3 yielded significantly better growth in fish than *Artemia* with less than 3 percent 20:5 n-3. Recent research suggests that docosahexaenoic

acid (DHA) 22:6 n-3 is more important nutritionally than EPA. Premium quality *Artemia* (usually from San Francisco Bay) are higher in 20:5 n-3 (EPA), but are still lacking in 22:6 n-3 (DHA), which is the most important HUFA for marine fin fish larvae. These high EPA *Artemia* are not equal to HUFA enriched *Artemia* in terms of nutritional value, but are helpful in bridging the gap between rotifers and enriched day-old *Artemia*. The premium quality *Artemia* with high hatching rates, small size and greater HUFA levels are relatively expensive and sometimes difficult to find in quantity. As an alternative, a hatchery can purchase a commercial enrichment product to treat lower quality *Artemia*. Here is a simplified formula for *Artemia* enrichment (Granvil and Treece, 2000) ^[20].

Conclusion

Brine shrimp (*Artemia*) serve as an essential live feed, providing the vital nutrients required during the critical early developmental stages of fish larvae. Despite the surging global demand for these organisms within the aquaculture sector, efforts to scale up production over the last few decades have encountered significant challenges. To overcome these international production obstacles, collaborative knowledge sharing is essential. Furthermore, while studies have underscored the benefits of enriching *Artemia* to boost both their own development and that of the larvae they nourish, further investigation is required to establish precise enrichment protocols tailored to specific fish and *Artemia* species.

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