Exploring the Nutritive Value of Live Food in Aquaculture: A Key to Larval Growth and Survival

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Abstract

Live food is an essential part of the diet for aquatic animals, such as fish and aquatic pets, as it provides critical nutrients that enhance their growth, health, and reproduction. This chapter examines the role of live food in aquatic animal husbandry, exploring the various types of live food and the unique nutritional advantages they offer, such as proteins, essential fatty acids, vitamins, and bioactive compounds. These nutrients are instrumental in promoting better growth, boosting immunity, and supporting overall well-being. The text also compares live food with processed alternatives, highlighting its benefit in encouraging natural feeding behaviors and fostering proper development. It addresses the challenges associated with sourcing and storing live food, including the risks of disease transmission. Selecting the appropriate live food for different species is key to ensuring the best outcomes in both aquaculture and pet care. When incorporated into a well-rounded diet, live food plays a significant role in maintaining the health and vitality of aquatic species.

Keywords: Live food, Phytoplankton, Zooplankton, Live feed organisms, Sustainable aquaculture

Introduction

Live food organisms, including phytoplankton and zooplankton, are essential for the survival and growth of economically significant fish and shellfish species in aquaculture. Phytoplankton form the base of the aquatic food chain, serving as food for zooplankton, which in turn nourish fish and shellfish larvae. The inherent mobility of live food organisms stimulates the feeding response in larvae, aiding efficient consumption and growth (Bengtson, 2003). These organisms are crucial as a first feed for larval fish, especially for those hatching from small eggs with limited yolk reserves and underdeveloped digestive systems. Live feeds provide a natural "microencapsulation" of essential nutrients such as free fatty acids, amino acids, digestive enzymes, and beneficial bacterial microflora. The swimming action of live prey is vital for small larvae with low fat reserves to begin active feeding promptly. In the wild, fish and shellfish larvae rely on phytoplankton and zooplankton, with greenish pond water indicating the presence of natural food organisms like phytoplankton. Copepods are particularly valued for meeting the nutritional needs of marine fish larvae. Often referred to as "living capsules of nutrition," live feeds provide a complete nutritional profile, including proteins, lipids, carbohydrates, vitamins, and fatty acids (New, 1998). To maximize growth and survival rates in aquaculture, ensuring the timely availability of appropriate live food is essential. Analyzing the nutritional content of natural food resources and employing enrichment or bio-encapsulation techniques can enhance the value of live feeds. Regardless of aquaculture's scale, cultivating live food organisms remains a foundational step for success.

Importance of live food organisms in aquaculture

In aquaculture, maintaining healthy stock is critical for success, and live food plays a vital role alongside artificial feed in ensuring the good health and development of cultured species. Artificial diets often lack essential nutrients required by fish, making live food indispensable, especially for shellfish and fish larvae that depend on small-sized, easily digestible, high-protein diets. While live food can be costly and limited in availability, cultivating it is a cost-effective alternative.

Live food includes both phytoplankton and zooplankton. Phytoplankton consists of chlorophyll-containing organisms like *Microcystis*, *Volvox*, and *Oscillatoria*, as well as non-photosynthetic saproplankton like bacteria and fungi. Zooplankton, however, is the primary nutritional source for aquaculture species, especially in tropical regions. Common zooplankton include protozoans (*Arcella sp.*, *Difflugia sp.*), rotifers (*Brachionus spp.*, *Keratella sp.*), planktonic crustaceans like Artemia, cladocerans (*Moina spp.*, *Daphnia spp.*), ostracods (*Cypris*, *Stenocypris*), and copepods (*Mesocyclops* and *Heliodiaptomus* species).

Microalgae enhance zooplankton nutrition, improving their value as live feed for fish and aquatic larvae. Live food organisms provide protein, amino acids, vitamins, essential PUFAs, pigments, and sterols, which are crucial for growth and survival. In natural ecosystems, zooplankton, particularly rotifers and copepods, are key food sources for fish larvae, making them highly effective and widely used in aquaculture.

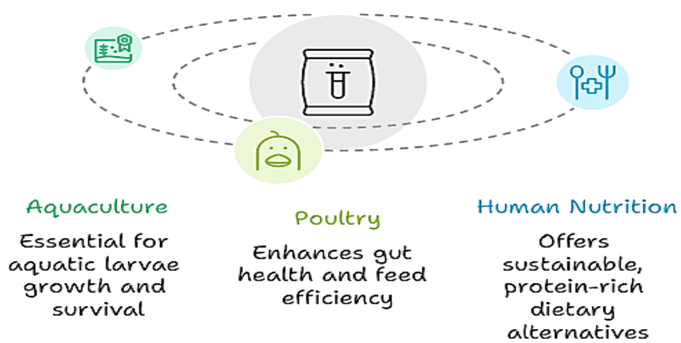

Fig. 1. The Role of Live Food Across the Sector

Types of live feeds

Phytoplankton

Phytoplankton includes organisms containing chlorophyll, such as *Microcystis*, *Volvox*, *Eudorina*, and *Oscillatoria*. It also encompasses non-photosynthetic plants, referred to as saproplankton, which include fungi and bacteria.

Zooplankton

Zooplankton comprises animal-origin plankton, including:

- **Protozoans**: Examples include *Arcella sp.*, *Difflugia sp.*, *Actinophrys sp.*, and *Vorticella sp.*
- **Rotifers**: Such as *Brachionus spp.*, *Keratella sp.*, *Polyarthra vulgaris*, and *Filinia opoliensis*.
- **Planktonic forms of crustaceans**: Also referred to as microcrustaceans.
  - *Artemia spp.*
  - **Cladocerans**: Includes species like *Moina spp.*, *Daphnia spp.*, and *Ceriodaphnia sp.*
  - **Ostracods**: Examples are *Cypris*, *Stenocypris*, and *Eucypris*.
  - **Copepods**: Such as *Mesocyclops*, *Leuckarti*, and *Microcyclops varicans*.

Other feed organisms

- Infusoria (*Paramaecium*), Sludge worm (*Tubifex*), Blood worm *(Chironomids*), Earth worm (*Eisenia foetida*)

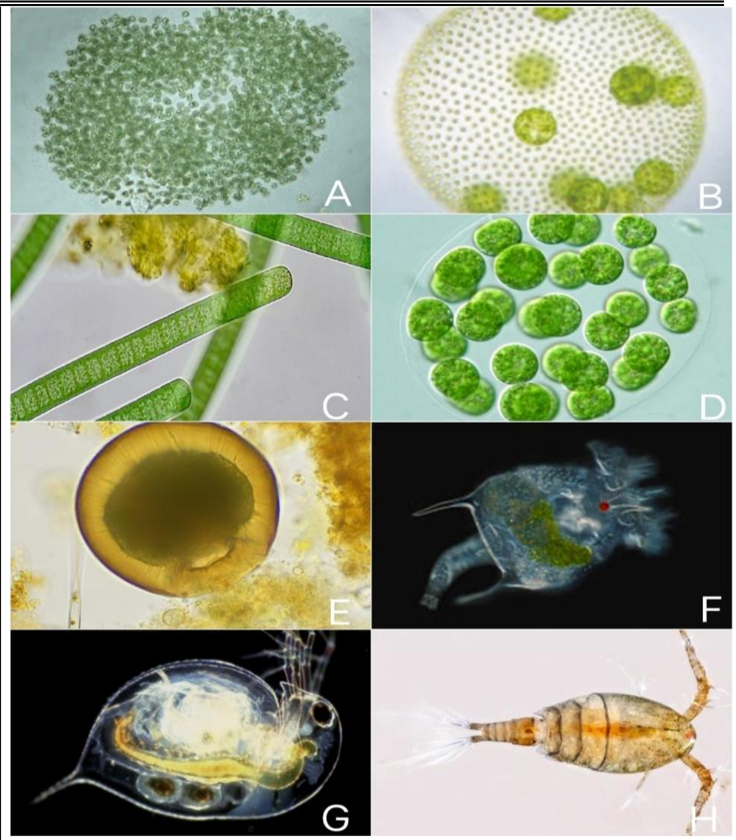

Fig. 2. A. *Microcystis spp.*, B. *Volvox spp.*, C. *Oscillatoria*, D. *Eudorina*, E. *Arcella spp.*, F. *Brachionus spp*, G. *Daphnia spp.*, H. *Microcyclops varicans*

Important live feeds and its nutritive value

There are various types of live feed used in aquaculture, and some of the key ones are highlighted below:

Microbes

Yeast is a widely used primary food source for many types of larvae, particularly as feed for zooplankton, which are then utilized in larviculture. It is also a key ingredient in artificial larval diets and has been explored as a substitute or supplement for algae in feeding post-larval Penaeid shrimp. Similarly, bacterial cells are nutritionally valuable, offering essential amino acids, proteins, and polysaccharides. They also supply exogenous enzymes that enhance digestion by breaking down complex particles into simpler forms, improving nutrient absorption for larvae and other organisms. In larviculture, bacteria can be introduced into larvae's diets either by enriching live food or directly into the gut, contributing to better digestive efficiency. The use of probiotics in this context has demonstrated significant benefits, including improved growth rates, enhanced survival, and increased disease resistance in larvae.

Micro algae

Algae, essential to aquatic ecosystems and aquaculture, are classified into green (Chlorophyta), brown (Phaeophyta), and red (Rhodophyta) groups based on their pigments and habitat. Green algae are primary producers in freshwater ecosystems, while brown and red algae thrive in marine environments, with uses such as iodine, algin, and agar production. Microalgae, due to their nutritional value and small size (5-25 microns), are crucial in hatcheries for feeding young aquatic species like fish larvae, shrimp, and mollusks. They also serve as feed for live food organisms like rotifers and brine shrimp, enhancing growth and survival rates. Nutritionally, microalgae are rich in protein, essential fatty acids (DHA, EPA, AA), and vitamins, contributing to improved enzymatic activity and water quality by removing nitrogenous waste. Their versatile applications and ecological significance make them indispensable in aquaculture.

Table 1. Biochemical components of Live feed; Plant origin -Micro Algae

Component (%)	***Spirulina***	***Chlorella***	***Scenedesmus***
Protein	62-68	40-50	50-55
Lipids	2-3	10-15	12-19
Carbohydrates	15-20	12-16	10-15
Fibre	5-8	6-8	10-12
Ash	10-12	8-10	6-8
Nucleic acid	6	6	4-6
Moisture	5-6	5-8	5-7

Becker, W. (2007), Spolaore, P., et al. (2006), Richmond, A. (2004)

Table 2. Nutritive value of microalgae (% of dry wt.)

Algal class	**Chl-a**	**Protein**	**Carbohydrate**	**Lipid**
Chlorophyceae	0.5-2	20-30	12-23	15-21
Prasinophyceae	1-1.5	30-35	12-13	10-17
Haptophyceae	0.5-1	25-30	6-13	12-25
Bacillariophyceae	1-3	12-34	5-6	7-16

Brown, M. R., & Jeffrey, S. W. (1992), Guiry, M. D., & Guiry, G. M. (2023)

Infusoria

Infusoria are tiny, single-celled organisms that belong to the class Ciliata within the phylum Protozoa. They are not only small but also soft-bodied and highly nutritious, making them an ideal starter diet for the early stages of fish larvae. In the initial developmental phases of fish larvae, infusoria and other small live organisms are essential. Common freshwater infusoria include *Paramecium* and *Stylonychia*, while *Fabrea* and *Euplotes* are examples found in marine environments.

Rotifers

Rotifers, particularly the genus Brachionus, are vital live food organisms in aquaculture hatcheries, serving as an ideal starter diet for early larval stages of fish and prawns in marine and freshwater environments. Globally, there are approximately 2,500 rotifer species, with Brachionus plicatilis being the most commonly used in fish hatcheries. Their size ranges from small (50–110 microns) to large (100–200 microns), selected based on the mouth size of the larvae being cultured. The nutritional value of rotifers depends on their diet, with highly unsaturated fatty acids (HUFA) like DHA and EPA being critical for fish larvae growth and survival. Rotifers typically contain 52–59% protein, up to 13% fat, and 3.1% n-3 HUFA, making them highly nutritious. Various cultivation methods, including feeding rotifers with algae, baker's yeast, and artificial diets, are used to enhance their nutritional content, ensuring the health and development of fish larvae in aquaculture systems

Copepods

Copepods are a common type of zooplankton found in freshwater and brackish water and serve as a natural food source for the larvae and juveniles of many fish and crustaceans. In the wild, marine fish larvae typically feed on copepod eggs and nauplii during their first few weeks of life. Some copepod species have very small larvae that are rich in highly unsaturated fatty acids (HUFAs) and other essential nutrients. In fact, certain marine fish larvae cannot be successfully reared using rotifers as their first food and are instead raised on copepod nauplii, either collected from the wild or cultured in laboratories. Copepods have a high lipid content in their early stages and are particularly rich in phospholipids and n-3 polyunsaturated fatty acids like EPA and DHA.

Cladocerans: Cladocerans, commonly known as "water fleas," are small crustaceans belonging to the order Branchiopoda within the phylum Arthropoda.

Among the most notable cladocerans are *Daphnia* and *Moina*, which serve as essential live food sources in aquaculture. *Daphnia*, found in freshwater environments worldwide, moves with quick, jerky motions using its antennules and produces digestive enzymes like proteases, lipase, and cellulase. Its larger size makes it suitable for feeding more developed fish stages. In contrast, *Moina* inhabits temporary ponds and ditches and is smaller (0.5–2 mm), yet offers significant nutritional advantages, with protein comprising about 50% of its dry weight. Adult *Moina* also has a higher fat content (20–27%) compared to juveniles (4–6%). Its high protein and fat content make it a valuable alternative to *Artemia* in aqua hatcheries. Historically, *Moina* has been widely used in hatcheries and ornamental fish farming as live food for young fish larvae, supporting their growth and development effectively.

Tubifex

Moina has been widely used as live food in many hatcheries. The nutritional value of *Moina* can vary significantly based on their age and diet. On average, the protein content of *Moina* makes up about 50% of its dry weight. Adult *Moina* typically have a higher fat content compared to juveniles. For adult females, the fat content ranges from 20-27% of dry weight, while juveniles have a lower fat content of 4-6%. In the past, *Moina* was a popular live food choice for feeding young fish larvae in ornamental fish farming.

Chironomid larvae

Chironomids, also known as non-biting midges, are one of the most widespread, varied, and ecologically significant groups of aquatic macroinvertebrates. They are insects classified under the order Diptera, class Insecta, and phylum Arthropoda. Commonly referred to as blood worms because of the haemoglobin present in their bodies, chironomid larvae initially reside in soft tubes made of organic material. When fully developed, these larvae are dark red in color. Chironomid larvae are considered a valuable food source for many fish and cultured invertebrates. They are particularly popular in the aquarium fish industry as live food. Chironomid larvae are a rich source of protein, lipids, vitamins, and minerals. They are well-recognized as an important food source for various fish species and cultured invertebrates. With a relatively high protein content of 56% and a digestibility rate of 73.6%, chironomid larvae are not only nutritious but also serve as an effective growth promoter for fish and crustaceans when included in their diets. This makes them an ideal food source for many aquatic organisms.

Artemia

Artemia, or brine shrimp, are a type of zooplankton extensively used as live food in aquaculture and the aquarium industry for rearing marine finfish and crustacean larvae. With over 50 geographical strains identified, Artemia is commercially available in various qualities, with the Great Salt Lake in Utah supplying about 90% of the global harvest of brine shrimp cysts. High-quality cysts can yield 200,000 to 300,000 nauplii per gram when hatched.

Artemia is prized for its nutritional value and efficient conversion rate, with all life stages—cysts (decapsulated), nauplii, juveniles, and sub-adults—used as feed. Nauplii are the primary diet in aquaculture hatcheries, while frozen adults are popular among aquarists and fish breeders. Beyond aquaculture, Artemia biomass serves as a food supplement for livestock, a source for pharmaceutical extraction, and a component of protein-rich food products. In some regions, Artemia is even consumed by humans. This versatility has fueled the growth of the Artemia trade, making it a vital and expanding global industry.

Biochemical components of live feed- animal origin

	Protein (%)	Lipid (%)	CHO (%)
Artemia	58-60	18-20	11-16
Rotifer	28-63	9-28	10.5-27
Copepods	57-69	9-15	11
Daphnia	50	20-27 (adult Female) 4-6 (Junvenile)	
Tubifex	11-13	2-3	
Chironomids	56		
Microworms	40	20	
Earthworm	54	4	11

Leger, P., et al. (1986), Lavens, P., & Sorgeloos, P. (1996), Rønnestad, I., et al. (2013), Tacon, A. G. J. (1987)

Major constraints in live feed culture

Live feed remains the most effective option for rearing larvae in aquaculture, taking into account various factors. However, maintaining a consistent supply of sufficient live feed at the right times in intensive culture systems is a challenge. For example, microalgae production can be difficult due to issues like obtaining pure strains and the lack of proper infrastructure, such as controlled environmental labs for culture maintenance. Additionally, live feed can serve as a carrier of diseases, posing a risk to fish and shellfish larvae, which makes hygiene during production crucial. It is also important to assess the nutritional value of live feed organisms for different larval stages. Therefore, more research should focus on evaluating the suitability of available live food organisms for aquaculture.

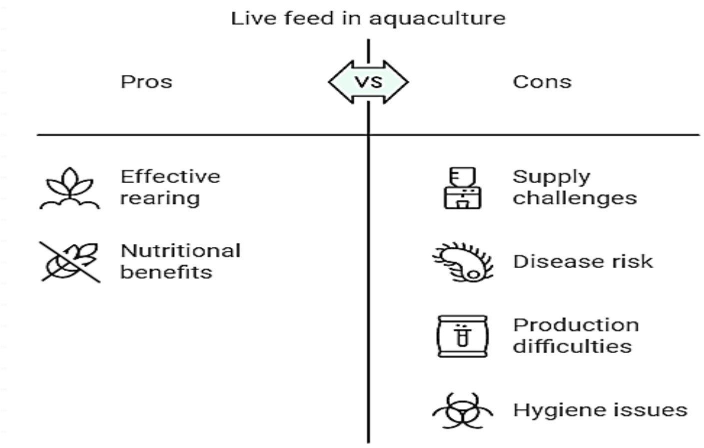

Fig. 3. Promising Candidates for Future Live Food Production

Ciliates, earthworms, and fairy shrimp are promising options for live food production in aquaculture:

Ciliates are nutrient-rich and naturally consumed by larval fish and crustaceans. They reduce organic waste in culture systems by feeding on fine organic particles. However, further research is needed to maximize their potential as a sustainable live food source. Earthworms are high in protein and offer multiple benefits, including enhanced growth, improved feeding behavior, and reduced waste in aquaculture. They can be used alone or combined with other feed sources for optimal results. Fairy shrimp (freshwater relatives of Artemia) are rich in carotenoids, beneficial for enhancing coloration in ornamental fish. Their high protein (45-50%) and lipid (5-6%) content make them a valuable nutritional source. They are also suitable for nutrient enrichment and bio-encapsulation for larvae.

Future Outlook

As the live food production industry continues to evolve, it will be essential to enhance production efficiency, improve nutritional quality, and foster greater consumer acceptance for it to succeed in global markets. Ongoing research into alternative live food species, improving culture techniques, and developing innovative feed formulations will solidify live food's place as a critical element in sustainable and ethical food systems. With continuous improvements and innovation, live food production can play a significant role in meeting the growing demand for alternative protein sources, supporting environmental sustainability in aquaculture, and contributing to global food security.

Conclusion

Live food plays a crucial role in the diets of aquatic species by providing vital nutrients that support their growth, health, and overall well-being. Its significance in promoting growth, enhancing immunity, and supporting reproductive health, particularly during early developmental stages, makes it indispensable. Different types of live food, such as brine shrimp, Daphnia, and bloodworms, each offer distinct advantages. The correct selection of live food, tailored to the species and specific developmental needs of the fish, is essential for optimal results. Live food also has notable advantages over processed feeds, including its ability to encourage natural feeding behaviors and provide nutrients in forms that are more easily absorbed by the animals. Despite these benefits, there are challenges, such as the risk of disease transmission and issues related to sourcing and storage. By carefully addressing these challenges and integrating live food into a balanced diet, aquaculturists and fishkeepers can greatly improve the health, growth, and reproductive success of their aquatic species, supporting more sustainable and ethical aquaculture practices.

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