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Review Article

## Rotifer for Aquaculture: A Comprehensive Review of its Importance, Constraints and Future Prospects

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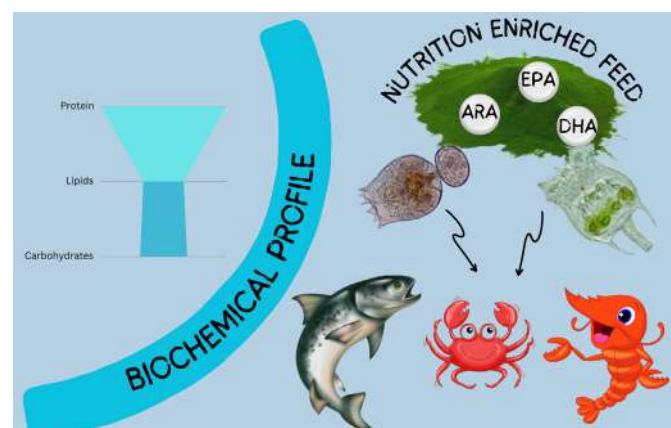
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**Abstract:** Rotifers are the best live food for feeding fish and shrimp larvae in their early stages. For rotifers live feed, certain wild animals were now harvested and fed to the larvae and brooders. Still, unfortunately, the collected wild live feeds are forming a way to the entry of pathogenic organisms, which can cause diseases to the cultivable species. Additionally, gathering live feeds from the wild is a labour-intensive task, and it is never sure that the requisite organisms will be available in the appropriate quantities. In this context, the current review focused on the rotifer and the methods for collecting, morphologically identifying, and mass-producing it. A range of alternate uses for rotifers can also be investigated. For a nation like India and other nearby countries, cultivating live feeds is essential, especially the culture of rotifer species in captivity. Unfortunately, due to a lack of adequate cultural technology and guidance and a lack of brood-stock facilities, there are currently viable technologies for the comprehensive production of the marine rotifer in the aquaculture business, especially in India. This necessitates the development of culture and technology for each conceivable species of marine rotifer, as well as the preservation and distribution of a pure culture of that species to farmers, researchers, and aquaculture practitioners across the country. Possibilities for high-density cultivation, microbial problems, and associated nutrient requirements have all been discussed.

**Keywords:** Rotifer. Live feed. *Brachionus angularis*. *Colurella*. Nutrition. Aquaculture.

**Graphical Abstract:** Rotifers as a Significant Live Feed in Aquaculture.



## Introduction

A record 214 million tonnes of fisheries and aquaculture products were produced in 2020, including 178 million tonnes of aquatic animals and 36 million tonnes of algae. This increase was mostly attributed to the expansion of aquaculture, notably in Asia [1]. Asia is the world leader in fish farming, producing 89 % of the total volume in the last 20 years. Africa and the Americas have seen a gain in share during the same period, whereas Europe and Oceania have seen a modest decline. Over the past 20 years, several significant producing nations outside of countries (China, Bangladesh, Chile, India, Indonesia, Philippines, South Korea, Egypt, Norway, Vietnam and Japan) have cemented their shares in global aquaculture production to varied degrees over the past two decades. On a global scale, there has been a rise in the production of algae, crustaceans, molluscs and other aquatic species. To ensure their health, live feeds are essential for the success of aquaculture. Feeding cultured stock live food together with supplemental artificial feeds will help you maintain a healthy, disease-free live feed. Supplemented artificial diets are unable to provide all the nutrients needed for fish to thrive. Therefore, live foods (rotifers) must be used to feed fish and shellfish [2]. Although larval rearing is one of the riskiest aspects of aquaculture, it also has the potential to be one of the most lucrative endeavours. To reduce the possibility of a high mortality rate at this stage of culture, special planning and techniques are needed. For some cultured fish, zooplankton serves as their first food source, while for others it promotes faster growth and higher survival. Fish and shellfish larvae cannot consume artificially supplied feed. Live feeds are an easily digestible protein-rich diet for fish and shellfish. These live feeds can be purchased from the market, which is costly and may not be available as and when required. It will also increase production.

These live streams can be bought in the market, but they are expensive and might not be offered when needed. Additionally, it will raise the price of production. However, it is simple and affordable to culture these live foods [3]. The term "live feeds" refers to these nutritional planktons that could coexist with farmed larvae in the raising system and be consumed anytime the larvae choose. Zooplankton is recognised as a carefully guarded source of animal protein throughout the world. It acts as a link in the food chain, which benefits the well-being of any aquatic ecosystem. The effective farming of these species depends on the hatchery rearing of commercially significant finfish and shellfish larvae and live feed (phytoplankton and zooplankton) plays a crucial role in this regard. The majority of emerging species in the freshwater and marine aquaculture and aquarium farms/industries have sensitive and small-mouthed larval stages as a result of a lack of appropriate initial feeding practices. To promote the swiftly growing marine larviculture industry, live feed production programs must improve innovation and diversification. Aquaculture live feed production technologies are therefore a prominent area of interest worldwide.

Based on the above-mentioned justification, the current review paper explores the utilisation of a micro-algae diet for rotifer larviculture. The majority of rotifer research has focused on the nutrition profile of these organisms and microalgae-based laboratory and mass-scale growth techniques have been created most commonly. The algal and non-algal groups can be used to broadly classify the live-feed organisms. The phytoplankton (Microalgae: *Spirulina*, *Chlorella*, *Azolla*, and *Diatoms*), yeast, and bacteria are examples of algal feeds (food). Through the conversion of solar energy into trophic resources and bioavailable organic molecules, micro-algae play a crucial part in aquatic food webs. The zooplankton in the non-algal feed including, rotifers, copepods, artemia, amphipods and polychaetes is essential for the hatcheries that produce seeds of aquaculture to fishes/shrimps/prawns of post-larval. Therefore, it is impossible to obtain survival rates, growth rates and nutritional profiles without these live meals (foods). For juvenile finfish and shellfish to grow and survive as much as possible, the quality of their live food (feed) is crucial [4]. The live feed is continually available to finfish and shellfish larvae and may swim in the water column, hence they are likely to drive larval eating behaviours [5,6]. At some phases of their larval development to larval stages of fish and crustaceans require live food. The use of suitable live feed is essential for the success of hatchery operations for fish and shrimp/prawn cultivation [4,7]. Especially in artificial larval feeds are no more a match to live food organisms in terms of acceptance, nutritional profiles and other factors.

Although different species of fish have distinct live feeding preferences in natural bodies of water, all fish need protein-rich live food to thrive, spawn successfully and survive [8,9,10]. The value and potential of live food organisms will be increased through the cultivation of aquatic larval species. The availability of sufficient live food for feeding fish and shrimp larvae, fry and fingerlings is crucial for the success of hatchery production of fish and shrimp for stocking in grow-out production systems. Live feeds are often referred to as "living capsules of nutrition" since live food organisms are excellent suppliers of all nutrient profiles, including proteins, lipids, carbohydrates, vitamins, minerals, amino acids, and fatty acids [4]. The availability of zooplankton of the right size and at the right place and right time during the first feeding period of fish and shellfish larvae constitutes the famous match/mismatch hypothesis [10].

Young fish and shellfish must have access to sufficient live food promptly to grow and survive to their full potential. To maximize the production and profitability of the nutritional components of natural foods, it is required to identify and measure the live food organisms as fully as possible. It is commonly agreed that producing live food creatures-including moving those organisms both horizontally and vertically remains an essential initial step in expanding aquaculture. Global perspective for them. In aqua-hatcheries, a few of the most significant natural species of rotifers, artemia, and micro-algae are now being cultivated and employed. In developing countries with increasing aquaculture activity, there is still a significant demand for less-priced substitutes for expensive *Artemia* nauplii. In light of this, rotifera might be a simple culture and a good substitute live feed for the evaluation of current research pokes. Rotifers' nutritional profile and culture will be built into a worldwide overview for them even if live food organisms have not yet been identified for them.

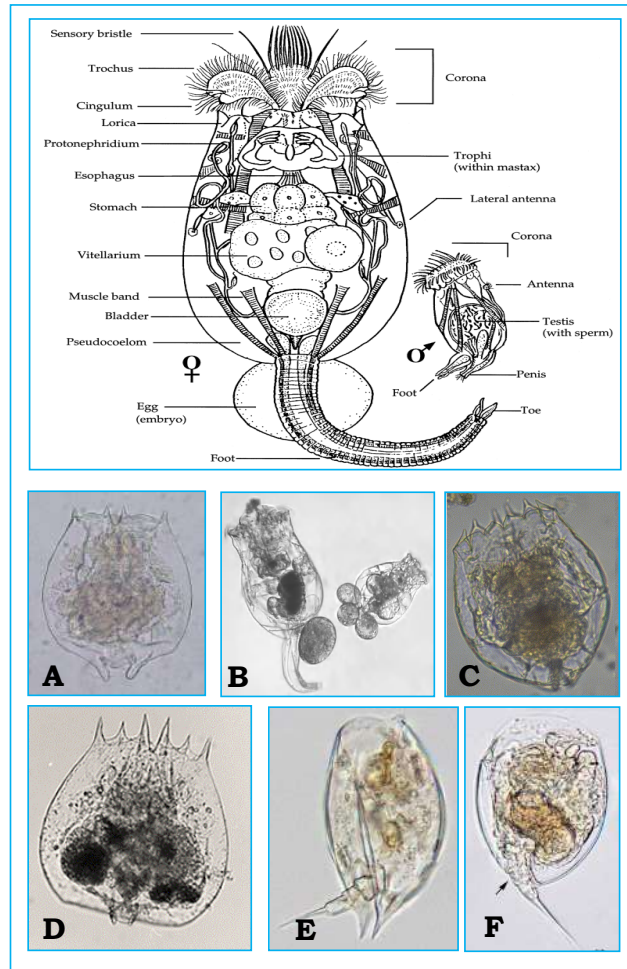
### Origin and General information of Rotifer

The first was described by Rev. John Harris (1696), and other forms were described by Van Leeuwenhoek (1703). The Rotifera (Rotatoria) is a large class of the pseudocoelomate phylum Aschelminthes, clearly originating in freshwater; only two significant genera and a few species are marine. About three-quarters of the rotifers are sessile and associated with littoral substrates. Currently, 2,200 species of rotifers have been described. Their taxonomy is currently in a state of flux. One treatment places them in the phylum Rotifera, with three classes: Seisonidea, Bdelloidea and Monogononta [11]. The largest group is the Monogononta contains about 1,570 species-level taxa, to the vast majority of them (1488) are free-living fresh or inland water taxa [12]. Monogononts occur in all types of water bodies worldwide; they are particularly abundant and diverse in lentic freshwater habitats, although many species also occur in haline habitats [13] and followed by the Bdelloidea, a class of rotifers, comprises about 460 species, with only one known to be strictly marine, while the rest are limnoterrestrial or of unknown ecology. There are only two known genera with three species of Seisonidea [14]. There are only two known genera with three species of Seisonidea. The Acanthocephala, previously considered to be a separate phylum, have been demonstrated to be modified rotifers. The exact relationship with other members of the phylum has not yet been resolved. One possibility is that the Acanthocephala are closer to the Bdelloidea and Monogononta than to the Seisonidea; the corresponding names and relationships.

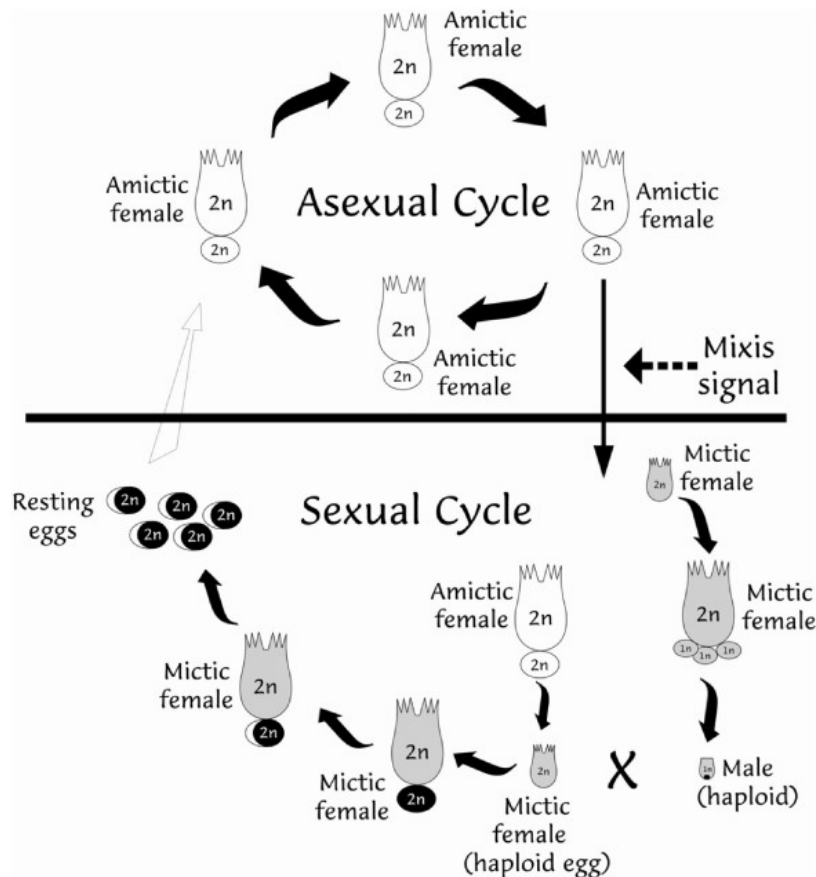
Rotifera, strictly speaking, are confined to the Bdelloidea and the Monogononta. Rotifera, Acanthocephala and Seisonida make up a clade called Syndermata. Rotifers also referred one called "Wheel Animalcules", are a small phylum of tiny to microscopic animals. The name "Rotifer" is derived from the Latin word meaning "wheel-bearer" and has a length of 0.4-2.5 mm; this refers to the crown of cilia around the mouth of the rotifera [15]. It is mostly around 0.1-0.5 mm long (0.004 to 0.02 inches) however, the full-size range is from 50 µm to over 3 mm long. Some are even smaller than some protozoa, most are transparent, a few are brightly coloured, great diversity in shape within the phylum. Their name comes from the rotating wheels of cilia, known as the corona, used for locomotion and sweeping food particles toward the mouth (Fig. 1). The mouth is generally anterior and the digestive tract contains a set of jaws (trophi) to grasp the food particles and crush them. The characteristic ciliated crown - corona; on the head. The corona is resembling the rotating wheels of all invertebrates. They primarily inhabit freshwater and damp terrestrial habitats. A few (<5%) species can live in brackish or salt waters. Species that inhabit terrestrial habitats either live in wet soil or are associated with moist lichens and mosses.

Their distribution includes marine, brackish, and fresh waters, as well as the thin films of moisture that cover terrestrial mosses and hydrate soils (limnoterrestrial). Rotifers fill important ecological roles in many inland waters, both fresh and saline. Because of their high reproductive rates, they can easily reach population densities of over 1000 individuals per liter, occasionally dominating zooplankton communities. Rotifers may be so numerous that in spite of their small size, they represent a significant portion of total zooplankton biomass; and they are an important link between the microbial loop and higher trophic levels. Because of their rapid reproduction and ready consumption by larval fishes, rotifers are grown in mass quantities for aquaculture. Although most rotifers inhabit freshwaters, some genera also have members that occur in saline waters. For example, 21 of the 39 species in the genus *Synchaeta* are known to occur in brackish to full-strength marine waters. However, only about 100 species distributed among 22 genera in the phylum are found exclusively in marine habitats [16]. In general, rotifers are not as diverse or as abundant in marine environments as micro-crustaceans, but they occur in estuarine waters, as well as in interstitial, tide pools, and near-shore marine habitats. Occasionally rotifers comprise an important portion of the biomass of marine zooplankton [17]. Inland saline waters, termed athalassohaline, are also habitats for rotifers. Because of their high population levels and rapid metabolism, rotifers probably play an important role in nutrient cycling in soils. Only about 50 species are exclusively marine.

**Figure 1:** Diagrams of Rotifer species (A. *Brachionus angularis*, B. *Brachionus plicatilis*, C. *Brachionus rotundiformis*, D. *Brachionus urceolaris*, E. *Colurella adriatica*, F. *Colurella ovalis* sp. nov.



**Figure 2:** The life cycle of reproduction in the *Brachionus plicatilis* (Source: Denekamp et al., 2019).



## Bio-geography of marine and brackish water Rotifer

The marine and brackish-water rotifers are commonly overlooked worldwide because it is often hard to collect sufficient material and because of the time-consuming and laborious techniques needed to extract and prepare them for study [18]. Rotifers have always been considered non-interesting biogeographically, due to their capacity to produce resting stages, and their considerable abilities for passive dispersal. On the contrary, recent studies from continental habitats show a different scenario, with areas with high numbers of endemic taxa. The rotifer record is highest in the Northern Hemisphere, but this may be due to the higher number of studies in those regions. Diversity hotspots are northeast North America, tropical South America, Southeast Asia, Australia, and Lake Baikal. Endemicity is low in Africa (including Madagascar), Europe, the Indian subcontinent, and Antarctica. Data for marine rotifers are still too scarce to allow sound conclusions about their biogeography [13].

## Marine, brackish and freshwater Rotifer

Most known rotifer species live in freshwater and limnoterrestrial habitats, while marine habitats, both brackish and seawater, are considered to possess a few species [19]. Although marine rotifer species richness is probably lower indeed, it is unquestionably underestimated due to e.g. the few taxonomists studying them and insufficient sampling efforts. The first to present and discuss an estimate of the number of marine and brackish water species, and more recently [13] reviewed available data on marine rotifers. To date, about 396 rotifer species, belonging to 66 genera, have been reported worldwide from saline waters, either marine, brackish or inland saline.

## Universal characteristics of Rotifers

Rotifers are multicellular organisms with body chambers lined with mesoderm. These organisms have specialized organ systems and complicated digestive systems that include both a mouth and an anus. Despite their small size, rotifers are considered animals because they share characteristics with other animals. Most rotifer species are between 200 and 500 microns in size. However, some species, such as *Rotaria neptunia*, can reach a length of over a millimeter [20]. So, rotifers are multicellular organisms that live on a similar scale to single-celled protists. The main body structure of a rotifer is broken down into four basic parts: the head, neck, trunk (body), and foot. Most species of rotifers have a corona (crown) of cilia on their heads that draws a vortex of water into their mouths, where they strain through it in search of food. The trophies (jaws) located in the pharynx just behind the mouth grind the flour themselves (pharynx). The rotifer's body is segmented on the outside but not on the inside. The body is telescopic and has a semi-flexible and stretchable transparent cuticle. According to their cuticle, rotifers are regarded to be close relatives of roundworms and arthropods. Within the body are the stomach and reproductive organs. The foot is the last part of the rotifer body, and it finishes in a "toe" that has a cement gland that allows the rotifer to adhere to submerged objects and sift food at will. Since rotifers are microscopic organisms, their diet must consist of foods that will fit in their extremely small mouths when they are filter-feeding. Even though the majority of rotifers are omnivorous, cannibalism has been observed in some of them. In aquatic settings, rotifers primarily devour phytoplankton, such as unicellular algae and other primary producers, as well as dead or rotting organic debris. These eating habits result in some rotifers becoming their primary consumers. Secondary carnivores such as shrimps and crabs eat rotifers for food. Rotifers have unusual reproductive habits in addition to their distinctive structure and dietary preferences.

Rotifers can reproduce in a variety of ways. Some creatures have only females and they reproduce parthenogenetically, producing daughters from unfertilized eggs. These parthenogenic organisms can therefore develop asexually from an unfertilized egg. Some species produce two types of parthenogenetic eggs: one type develops into females and the other into males without the ability to reproduce sexually (sexual dimorphism). When these organisms mate, a fertilized egg is formed inside the rotifer. The males can produce sperm that fertilize eggs, leading to the development of resistant zygotes that can survive when the area's water supply runs low. The eggs hatch after being released into the water. As the egg develops in the summer, it can cling to the rotifers until hatching. A specific group of rotifers, known as bdelloids are found in almost all freshwater environments, as well as sporadically in brackish and marine waters. Bdelloids have a remarkable cryptobiosis strategy that they employ to survive desiccation. A rotifer's ability to endure desiccation over a long period depends on the humidity and temperature conditions in which it is kept. Higher humidity and mild to warm temperatures that avoid extreme dryness create the optimal setting for rotifers.

Although the rotifer phylum contains a wide range of behaviors, the majority of its species are found in the wild. So while some free-living species are parasitic or epizoic, others are true plankton species. The majority of wildlife prefer to move across a substrate. There are about 25 different species of rotifers, some of which are parasitic, sessile or not, and colonial. Rotifers are widespread in freshwater ecosystems and are essential to both freshwater zooplankton and a several marine species. They thus provide a significant food source for small predators such as active carnivores and filter-feeders. The rotifers' fragile bodies have prevented them from leaving many fossils, despite being a group of ancient organisms.

However, some endemic species have more restricted geographic ranges. Several *Brachionus* genera have been cultivated in the past and are currently being cultivated using live forage aquaculture. Thus, aqua farmers and aquaculture researchers have been recognized primarily among the many live food rotifers in the species of the genus *Brachionus*. Three species of *Brachionus plicatilis*, *Brachionus rotundiformis* and *Brachionus angularis* were specifically selected as the first live food for various marine fish and shellfish larvae. In 1995 the genus *Brachionus* was expanded to include the species *B. plicatilis* and *B. rotundiformis*. There are differences in feed efficiency, growth rate, and associated microbial communities between these lineages that may be important for aquaculture, although *B. plicatilis* complex rotifers are still classified as SS, S, SM, or L-type [21]. Rotifers are in high demand in the current larviculture industry because of their size range (100-250  $\mu$ m) and slow swimming style for the first feeding of commercially important fish species such as sea bream and sea bass; parthenogenetic reproduction allows for high duplication rates [22]. Ability to tolerate high population densities and environmental variations.

### How many rotifer species are consumed by finfish and shellfish larvae?

Dietary profiles of rotifers can vary based on dry weight, caloric value and chemical composition [23]. As a result, fish larvae do not digest rotifer loricae and amictic rotifer eggs during the early stages of development. The chemistry of rotifers is also influenced by the biodynamic processes of saturation, starvation and reproduction [24]. The amount of food that enters the larvae's intestines depends on how many rotifers they consume. According to the size or age of the larva, the daily consumption of rotifers rises from 55-72 for every 3.9 mm long larva to 4700 for each 11.4 mm long caterpillar. There are considerable differences between the nutritional content and intake of *B. plicatilis* and *B. rotundiformis* rotifers among each species' various populations [25]. Rotifers grow in size from the time they hatch from their amictic eggs until they reach sexual maturity and each population or species suffers size differences throughout its life cycle [26]. Size is also affected by cultural factors including salinity, temperature and food. When these factors are considered combined, it is challenging to compare the outcomes of multiple reviews of the same publication.

### The dry weight and calorific value of rotifers

The size and nutritional status of rotifers determine their dry weight. In the rotifers species of *B. plicatilis* are three to four times heavier (about 200 ng) than *B. rotundiformis* and their weight fluctuates according to their reproductive rate [27]. It was discovered that the caloric value of the diet varied, ranging from  $1.34 \times 10^{-3}$  kcal per rotifer fed on baker's yeast to  $2.00 \times 10^{-3}$  kcal per rotifer after 6 hours of enrichment using a specially designed enrichment meal [28]. The dry weight of rotifers is determined by their size and nutritional health. The weight of *B. plicatilis* rotifers varies according to their reproductive rate and is three to four times heavier (approximately 200 ng) than *B. rotundiformis* rotifers. The caloric value of the diet was found to vary, ranging from  $1.34 \times 10^{-3}$  kcal per rotifer fed on baker's yeast to  $2.00 \times 10^{-3}$  kcal per rotifer following 6 hours of enrichment with a tailored enrichment meal.

### Biochemical composition of Rotifers

For animal body nutrition, the biochemical profiles of protein, carbohydrates, and lipids were essential. Between 28 and 63% of the dry weight of rotifers are proteins, whereas between 9 and 28% are lipids [29]. On the growth and survival of marine fish larvae, it has been conclusively determined that the general lipid plays the largest role. A tiny quantity of monoacylglycerols, diacylglycerols, sterols, sterol esters, free fatty acids, and phospholipids (which make up about 34 to 435 of the lipids in rotifers) can also be found. The carbohydrate content varies from 10.5 to 27% of the dry weight [28]. Rotifers' reproductive rate, as well as their protein, carbohydrate, and lipid contents, are influenced by their food intake. Individual rotifer protein content rises by 60 to 80% when food ration increases, however neither food ration nor kind of food affects rotifer amino acid composition [30]. Triacylglycerols and rotifer phospholipids have comparable fatty acid compositions, although these are significantly influenced by the lipids consumed by the animals. For instance, it has long been known that the fatty acids eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids (20:5n-3 and 22:6n-3, respectively), are crucial for the survival of marine fish larvae [29]. Since marine fish cannot synthesize EPA and DHA from linolenic acid (18:3n-3), these acids are crucial dietary components. In general, marine fish possess substantial levels of EPA and DHA in the phospholipids of their cellular membranes. More particularly, DHA is found in high concentrations in the membranes of the nervous and visual systems, and its deficiency in the diet of larvae may have detrimental effects on a variety of physiological and behavioural functions. These include poor pigmentation, decreased vision in low light conditions, which reduces the larvae's capacity for hunting, and poor neuroendocrine system development [31].

Likewise, fish have a restricted ability to convert linoleic acid (18:2n-6) to n-6 HUFA, including arachidonic acid (ARA, 20:4n-6), which has recently received more attention and is now also regarded as an essential fatty acid. It has been demonstrated to increase the stress tolerance of fish larvae [32]. ARA is a crucial eicosanoid precursor fatty acid that is transformed into biologically active substances including prostaglandins, thromboxanes and leukotrienes or can react to hormonal stimuli. A growing body of investigation supports the idea that marine fish larvae should consume an ideal ratio of EPA, DHA, and ARA.

Furthermore, the ideal delivery method for these polyunsaturated fatty acids is phospholipids rather than triacylglycerols (PUFA). The inability of fish larvae to synthesize phospholipids on their own is likely the cause of this. The ideal balance of DHA, EPA, and ARA for turbot is 1.8:1:0.12 and too much ARA may be harmful [10]. Although it is generally known that rotifers may be cultivated on yeast with ease, rotifers raised in this manner are nutritionally unsuitable for marine fish larvae because they lack sufficient quantities of DHA, EPA, and ARA. These fatty acids must be added to rotifers, and enrichment techniques include feeding rotifers algae, lipid emulsions, lipid-containing micro-particulates or microcapsules, or lipids with protein and carbohydrates. Short enrichment periods on varied diets including lipid emulsion can be used to change the quantitative and qualitative lipid content of rotifers. Triacylglycerol fraction was more affected by these diets than rotifer phospholipids [33]. The primary sources of DHA or EPA are commercial fish oils, which are primarily composed of triacylglycerols. Except for tuna orbital oil, which may contain as much as 2% ARA, their ARA level varies according to the kind of fish. Most artificial diets for rotifers frequently include these oils. Rotifers can also be fed algae that are rich in EPA and DHA, such as *Nannochloropsis* and *Isochrysis*, which also contain ARA, to get the lipids they need. It was discovered that a mutant strain of *Nannochloropsis* lacked EPA [23]. It can be utilised as an alternate source of ARA because it contains a lot of it (23.3 mol% in whole cell extracts of the mutant strain against 4.2 mol % in the wild type). Algae can be obtained straight from cultures, either living or after being freeze-dried and concentrated [34]. The freshwater chlorella is a different source of lipid enrichment. Since rotifers often have lower levels of lipids than the organisms that serve as their meal, lipids must be used by rotifers. In highly reproducing cultures, rotifers use more DHA, and lipid utilisation is temperature-dependent. These findings indicate that depending on how the rotifers stain, they acquire three to five times as many total lipids when housed at 10°C than at 25°C.

### **Vitamin bio-enrichments of Rotifer**

Vitamin enrichment of rotifers has not received much research. In addition to vitamin B12, which was previously noted, fat-soluble vitamins (A, D, and E) were discovered to stimulate rotifer reproduction [29]. When rotifers converted from a diet of baker's yeast and lipid emulsion to *isochrysis*, their concentration of water-soluble vitamins increased. Ascorbic acid and thiamine content had the biggest increases. Rotifers, which feed on algae, are a good source of vitamins, particularly vitamins C and E, for fish larvae [35], and while they generally contain adequate levels of these, some nutrients like vitamin A, iodine, and selenium might need more attention in rotifer diets. However, enhanced levels of lipid-soluble vitamins in rotifers, caused by feeding them fish oil emulsions, were quickly depleted when the rotifers were switched to a diet of *Isochrysi*. Nevertheless, their final content in rotifers exceeded the recommended levels needed for the proper growth of fish larvae. Vitamin C (ascorbic acid) not only promotes rotifers' growth but also has a key role in fish larvae's ability to survive [23,29]. Due to its great abundance of different types of algae, it was discovered that the content in rotifers varied depending on the diet. Rotifers that had been supplemented with ascorbyl palmitate attained the highest levels [36].

### **Marine Rotifer Live Feeding in Aquaculture Hatcheries: Present and Future**

Increasing the likelihood that fish raised in hatcheries will survive in the wild as part of stock enhancement programmes, developing culture methods for new species and enhancing the consistency of production for existing species are the three main areas of focus for marine hatchery aquaculture research today. Several tactics boost production dependability. Future selective breeding programmes for fast growth and disease resistance should boost hatchery production, while those for improved flesh quality should ultimately lead to a better product being sold. Improved management of the microbial ecology in hatchery tanks by better husbandry, the use of probiotics, etc., should also assist reliable production. *Artemia's* global supply is still unknown and marine hatcheries still have a labour-intensive need to cultivate algae and rotifers. As a result, the search for live feed replacements is progressing quickly. The discovery of culture techniques for new species frequently illustrates how similar the requirements are for rearing them, demonstrating similarities between different marine fish species rather than stressing differences. Research in this field usually concentrates on improving generally known principles and techniques for application to the novel species in issue. If a species' culture needs more than fine-tuning, its economic development may be impeded or impaired. To give an example, if live feed other than rotifers and *Artemia* is required, the emergence of a new species is instantly delayed. The majority of studies [2,10] concentrated on increasing hatchery fish's chances of surviving in the wild, although more recently, additional studies have followed their methods [37].

The cornerstones of this field of study are the production of extremely high-quality juveniles from hatcheries (using only first-generation brood stock to preserve genetic integrity with the natural population), the identification of optimal release strategies (fish size, season, release site), and the use of conditioning techniques, both in the hatchery and in the wild. A fish can go from the hatchery to its natural habitat using these techniques with the highest chance of survival. The fish are usually released when they are still young, which makes them highly adapted to prepared meals.

However, it is clear that to produce the high-quality juveniles required for release, high-quality live feed must be used early in the hatchery. The industry is currently facing a crisis in the supply of *Artemia* cysts at the hatchery level. This is partly due to recent poor harvests from Utah's usually bountiful Great Salt Lake and more stringent rules on fishing in those areas. The identification of new sources of *Artemia* cysts for harvest, such as Asian countries that were formerly part of the Soviet Union, gives rise to some optimism that this crisis will pass quickly. Recalling that the last *Artemia* crisis in the mid-1970s led to the discovery of new geographical strains and focused research on *Artemia* cyst quality, one wonders what the current crisis will yield. A renaissance in research on formulated diets to replace *Artemia* is already underway [38] and one hopes that the results will be more commercially viable than those from the flurry of research on micro-diets that arose from the last *Artemia* crisis. Similar to the *Artemia* crisis, recurrent fish meal shortages around the world (often brought on by climatic circumstances off western South America) lead to intense research into substitutes for fish meals. However, in recent years, the aquaculture sector as well as environmental organizations have questioned whether the industry's expected growth over the following 30 years is feasible given the availability of fish meal even in the best of circumstances [10].

It appears that if the sector wants to expand to the required level, partial or entire replacement of fish meals in the composition of diets for some species will be required or desirable. Even though grow-out producers are the ones who will be most affected by the answer, the implications will undoubtedly extend back to the industry's hatchery phase as well would we no longer grow species that require a fish meal? Should we choose people who only require a small amount of fish meal? The future of biotechnology in aquaculture is the subject of one more important topic. Goods for the avoidance, detection, and treatment of disease are already influenced by the biotechnology sector. For several of the key aquaculture species, genome mapping is starting (M. Gomez-Chiarri, personal communication), but authorities are still debating whether to allow genetically modified organisms (GMOs) in the marketplace. Whether consumers will embrace such things is an even bigger unknown. Before aquaculture will significantly address those concerns, the solutions will likely be found in GM products from terrestrial agriculture. Both a general overview of the value of micro-algae culture and the significance of rotifer as live feed for the larval growth of different species of fish and shrimp with potential for mariculture were frequently used. Additional key factors for choosing a live feed include its size, simplicity of rotifer culture, nutritional content and other factors. Nearly all of these requirements should be mentioned in the literature review to validate the nutritional profile of rotifers as a live feed.

## Conclusion

The significance of rotifer as live feed for the larval growth of several species of fish and shrimp with potential for mariculture, as well as a general overview of the value of micro-algae culture, were commonly employed. A live feed's size, ease of rotifer culture, nutritional composition and other aspects are all important considerations. To confirm the nutritional profile of rotifers as a live feed, nearly all of these needs must be covered in the literature review. A member of the rotifer genus *Brachionus* such as *B. plicatilis*, *B. rotundiformis*, *B. angularis*, and *Colurella* sp. were frequently found in aquaculture live feed. The species of *Colurella* sp. and *B. angularis* are no longer active or detectable in aqua hatcheries. Mass production of this *Brachionus* rotifer species would be beneficial for the hatchery seed production of various finfish and shellfish species because groupers, damsels, breams, and other fish with very small larval mouth sizes are now being fed on rotifer during their early larval stages.

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