

Exploring Spirulina as a Sustainable Fishmeal Alternative in RAS Culture of Silver Pompano Juveniles

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Introduction

The global production of aquatic animals reached a record high of 185 million tonnes in 2022 up by 4% compared to 2020 (FAO,2024). Of the 185 million tonnes of fish produced in 2022, 51 percent (94 million tonnes) was from capture fisheries and 49 percent (91 million tonnes) from aquaculture. Aquaculture production gradually increased to 18 percent in the 1990s, 26 percent in the 2000s, and 35 percent in the 2010s as aquaculture practice grew (FAO,2024). The apparent consumption of aquatic animal foods increased at an average annual rate of 3.0 percent between 1961 and 2021, whereas the global population grew at an annual rate of 1.6 percent during the same period. In 2022, 71.1 million tonnes of marine and coastal aquaculture were produced worldwide, comprising 35.3 million tonnes of aquatic animals and 36.4 million tonnes of algae. Globally, compare to fed aquaculture the share of non-fed aquaculture in total farmed animal species production fell from 39.7 percent in 2000 to 27.6 percent in 2020 and to 26.9 percent in 2022 (FAO,2024). According to this data, aquaculture is expanding to support the food production industry. Duo to reduction in fish production and increasing demand for fish meal has made researchers on finding a substitute protein source for fish meal.

Fishmeal is a high-quality, highly digestible feed ingredient that is preferred for addition to the diet of most farm animals, particularly shrimp and fish. Fishmeal has a low carbohydrate content and carries large amounts of energy per unit weight, making it an excellent source of protein, lipids, minerals, and vitamins. The rapid global expansion of the aquaculture industry, fishmeal is becoming increasingly limited. Hence, in the present scenario other sources of feedstuffs being investigated, namely plant origin substitutes for fishmeal and fish oil for aquafeed. Microalgae are considered as a promising substitute that can replace fishmeal and ensure sustainability standards in aquaculture. Commonly used in the field of aquaculture as different fish feed are *Chlorella*, *Dunaliella*, *Haematococcus*, *Ulva*, *Enteromorpha*, *Laminaria*, *Porphyra*, *Sargassum*, *Gracillaria*, *spirulina* and many more reported by Tabarsa, (2012).

Spirulina is a blue-green (Cyanobacteria), filamentous, photosynthetic microalga belonging to the phylum Oscillatoriaceae. It resembles a spiral of long, thin threads. Its cellular structure contains both blue (phycocyanin) and green (chlorophyll) pigments. *Spirulina maxima* and *Spirulina plantensis* are the two significant species used due to their nutritional content (Mosha, 2019). Nutritionally balanced *Spirulina* has a protein content ranging between 41-63% by dry weight. *Spirulina* can cause better growth performance due to their different factors such as its prebiotic effect, increase in enzymatic activity, high vitamin content, antioxidant and immunostimulant activity (Rosas et al. 2019). *Spirulina* can boost resistance to pathogens in two ways, directly through its phenolic chemicals, which have bactericidal properties, and indirectly through stimulating the innate or specific immune systems reported by Rosas et al. (2019). Even though *Spirulina* meal is currently a costly ingredient for use in aquaculture feed, adding small amounts of *Spirulina* to fish diets will have positive effects on health and economic benefits by improving the Feed Conversion Ratio.

RAS is used for fish production in indoor tank-based systems where water exchange is limited and the use of biofiltration is required to reduce ionized and unionized ammonia level by Timmons et al. (2010). More than 90% of the water is recycled back through the culture units after passing through a variety of biological and mechanical filtering systems to make it clean for recycling into fish culture tanks reported by Sugita et al. (2005). Recent developments in RAS, includes ozone treatments, sludge thickening technologies, and denitrification reactors, result in reduced water usage, effective waste removal and less energy consumption. RAS system involves culture of a broad range of species irrespective of temperature requirements and also enable secure production of non-endemic species (Martins et al. 2010). Silver pompano, also known as Snubnose pompano or American pomfret is a pelagic marine fish species of order Perciformes and family Carangidae. It is a euryhaline high value tropical marine finfish with several good criteria such as good meat quality, fast growth rate, easy weaning to pellet feeds and high market demand that reported by Kalidas et al. (2012). Currently, there is no nutritionally balanced feeds are available for commercial production of silver pompano, the creation of an economical feed formulation is underway (Ebenezar et al. 2019). This fish required dietary protein level 42% and dietary lipid level 6%, since the high amount of fish meal used as a protein source in its feed increases the cost.

History of RAS

In the 1950s, the necessity to make better use of the scarce water resources in the area led to the first scientific studies on RAS carried out in Japan, which concentrated on biofilter design for carp production (Murray et al., 2014). Apart from these efforts, scientists in Europe and America tried to modify technologies first created for managing domestic waste water (such as the activated

sludge process in sewage treatment, submerged and down-flow biofilters, trickling, and multiple mechanical filtration systems) (Murray et al., 2014). Between 1970 and 1980, the use of RAS for commercial finfish production expanded (Timmons et al., 2002). However, a number of significant commercial finfish producers over this time have also failed to notably use recirculating systems (Timmons et al., 2002).

Water recirculation

Recirculation aquaculture systems (RASs) are systems in which water is (partially) re-used after undergoing treatment (Rosenthal et al., 1986). Each treatment step reduces the system water exchange to the needs of the next limiting waste component. Based on the system water exchange rate it is suggested the following classification: flow through ($>50\text{m}^3/\text{kg}$ feed), re-use ($1-50\text{m}^3/\text{kg}$ feed), conventional recirculation ($0.1-1\text{m}^3/\text{kg}$ feed) and 'next generation' or 'innovative' RAS ($<0.1\text{m}^3/\text{kg}$ feed) (Martins et al., 2010).

RAS systems are commonly characterised in terms of daily water replacement ratio (% system volume replaced by fresh water over every 24 hours) or recycle ratios (% total effluent water flow treated and returned for reuse per cycle). For a fixed water supply, increasing recycle ratios above 0% (open-flow) corresponds with an exponential increase in production capacity with greatest gains achieved at rates above 90%. By convention 'intensive' or 'fully-recirculating' RAS are typically defined as systems with replacement ratios of less than 10% per day.

Fish Production in RAS

Recirculating aquaculture system is a technology to grow fish or other aquatic organisms in a closed system where the culture medium undergoes mechanical and biological filtration to adequately control the environmental parameters through the removal and transformation of the waste produced by the farmed organisms (Bregnballe, 2022). The use of land-based marine aquaculture systems to improve fish production has grown as a result of environmental disasters and rapid alterations in climate.

Suresh Babu et al., (2022) conducted a study on a low-cost recirculating aquaculture system (RAS) for the production of snubnose pompano *Trachinotus blochii*. For this study pompano fingerlings (5.3 ± 0.02 g size) were stocked at 33 fish/ m^3 in the RAS system and fed on a commercial pellet feed (45% protein). The low cost RAS system consists of a fibre reinforced plastic (FRP) tank having 10,000 litre capacity filled with 6000 litre chlorinated seawater and water was recirculated through a protein skimmer (100 litre with flow rate capacity approximately 40-50 l/min) followed by an indigenous biological filter. The result concluded that after 210 days, a specific growth of 1.68% per day was observed with final average weight of 180.78 ± 4.54 g and a production of 29.28 kg with 81% survival.

Silver Pompano

According to Tutman et al., (2004) selection of new fish species with good potential for aquaculture is crucial for the sustainable development of this growing industry. To make farming economically viable, the potential species needs to have a wide range of qualities, such as ecological acceptability and environmental capacity (Tutman et al., 2004). The silver pompano, *Trachinotus blochii* (Lacépède, 1801), is regarded as a potential species for mariculture due to its ease of adaptation to the culture environment. It is a premium fish that is popular in upscale restaurants because of its appealing look and firm, white, and flavourful meat. Because there is a large demand for premium fin fish both domestically and internationally, there is a huge potential market for this high-value finfish (Mc Master et al., 2003).

Fish meal as a protein source for fish feed

The growth of global aquaculture production increases the demand for aqua feeds. Feed provide nutrient to fish for their faster growth, survival and sustaining their healthy life. It represents one of the major 30-70% of total operational cost in aquaculture production system. Fishmeal is the main protein source and lipid source in aquaculture feeds. Due to its excellent palatability and high nutritional value, fish meal (FM) is the primary source of protein in nutritive diets for cultured fish (Hardy and Tacon 2002). Out of 171 million tonnes of total fish production, about 12% of total catches (20 million tonnes) was reduced to fishmeal and fish oil in 2016 (FAO, 2018). Fishmeal is the crude flour get after drying and grinding fish material. Annually the supply is stable at 6.0-6.5 million ton and approximately 4-5 tons of whole fish are required to produce 1 ton of dry fishmeal (Hodar et al., 2020)

Alternative feed ingredients to Fishmeal

The price of fishmeal and fish oil has increased significantly to over US \$ 1600 and US \$900-1800 per metric ton (FAO, 2012). If the fishmeal and fish oil will remain the primary protein sources in aqua feeds then the growth of aquaculture production will remain costly and unsustainable. Therefore, there is a need to look for an alternative protein and lipid sources which is not cheaper but nutritionally enrich as well. Basic criteria for considering alternative protein sources for fishmeal include nutrient profile, palatability, digestibility, antinutritional factors, availability and price (Hodar et al., 2020). Fish Meal replacement, either whole or in part, has been the norm for the past few years. There exist diverse sources of plant-derived proteins. The typical protein sources are oilseed meals, which are made from the residue left over after oil is extracted from soybeans, cotton seeds, peanuts, canola/rape, and safflower (Hardy, 1989; Friedman, 1996).

Spirulina as a feed ingredient

Spirulina (*Arthrospira platensis*) is the most economically important microalgae in the world (Pulz and Gross, 2004). Spirulina is a filamentous and unbranched cyanobacterium that belongs to the Oscillatoriaceae family. It is an abundant source of several nutrients such as protein (60–70%), essential amino acids (EAAs), vitamins (α tocopherol, vitamin B1, and vitamin B2), minerals (iron, potassium, magnesium, calcium, and phosphorus), pigments (phycocyanin), and essential fatty acids (EFAs) (γ -linolenic acid, linoleic acid, and palmitic acid) (Belay et al., 1996; Khalila et al., 2018). China has become the world's largest producer of *A. platensis* (Holman and Malau-Aduli, 2013). *A. platensis* is rich in nutrients; the crude protein content of the dry powder made from *A. platensis* is 60–72 %; the crude fat content is 5–10 %, and the ash content is 6–8% (Becker, 2007).

Spirulina and fishmeal replacement

Several studies are focusing on fishmeal replacement using alternative sources of high-quality proteins, including microalgae (Christaki et al., 2011). Many characteristics, such as high nutritional value and growth rate, antioxidant properties, and capacity to reinforce the animals against diseases, make microalgae optimal for aquaculture feed (Roy and Ruma, 2015). Their high nutritional value is linked to the protein content that exceeds 70% of total mass, the fatty acid profile showing a high content of linoleic acid, as well as high levels of vitamins, minerals, and bioactive compounds such as biliproteins, chlorophylls, and carotenoids able to protect the organisms from environmental stressors and pathogens in aquaculture systems (Ravi et al., 2010).

Conclusion

Recirculation aquaculture is essential technology for farming fish or other aquatic organisms by reusing the water in the production. The use of RAS is growing rapidly in many areas of the fish farming sector; Recirculation can be carried out at different intensities depending on how much water is recirculated or re-used. Recirculation enables the fish farmer to completely control all the parameters in the production. Aquaculture requires knowledge, good husbandry and persistence. Shifting from traditional fish farming into recirculation does make many things easier (FAO,2022) Selection of new fish species with good potential for aquaculture is crucial for the sustainable development of this growing industry (Tutman et al., 2004). Silver pompano (*T. blochii*) has already been considered a suitable candidate for mariculture due to its easy adaptation to culture systems, acceptance of formulated feeds, and fast growth rates (Chavez et al., 2011). The silver pompano is a pelagic and active species that is easy to domesticate and culture in tropical and subtropical marine waters. However, the specific nutritional requirements of pompano are known and the available diets mainly consist of fishmeal which accounts for up to 70% of the variable cost (Heilman and Spieler, 1999; Webster et al., 1999). This has resulted in other sources of feedstuffs being

investigated, namely plant origin substitutes for fishmeal and fish oil for aquafeed. Spirulina feed could be an option due to its high nutritional value and also it containing high protein, amino acids, vitamin, minerals, essential fatty acid, B-complex and β carotene and also act as best immunostimulant.

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