



Potential use of *Spirulina* sp. as fish feed : A mini review

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ARTICEL INFO	ABSTRACT
Keywords: <i>Spirulina</i> sp. Feed Cultivation Protein Carotene Received: 08 May 2024 Accepted: 27 September 2024 DOI: 10.13170/ajas.9.3.38542	<i>Spirulina</i> sp. is one of the microalgae that is used as natural food for fish seeds or larvae. <i>Spirulina</i> sp. contains 60–71% protein, 8% fat, 16% carbohydrates, and vitamins as well as 1.6% Chlorophyll- α, 18% Phycocyanin, 17% β-Carotene, and 20–30% γ-linoleic acid from total fatty acids. Cultivation of <i>Spirulina</i> sp. can be done using organic media and inorganic media. The types of inorganic media that can be used are Urea, TSP, Zarrouk, Conwy and Walne, while the organic media that can be used are vermicompost, quail droppings, guano, liquid waste from banana stems, coconut husks, canna plants, fermented <i>Azolla pinnata</i>, and bioslurry. The cultivated <i>Spirulina</i> can be used as fish feed in either fresh or dried form. Several research results show that giving <i>Spirulina</i> sp. flour had a significant effect ($P < 0.05$) on the growth and brightness of fish color with additional concentrations in the range of 1.2-10 grams/100 grams of feed.

Introduction

Fish is a food commodity that has high protein for human nutritional needs, so demand for fish is increasing. The national fish consumption figure in 2022 will reach 56.48 kg/capita, an increase of 2.39% compared to 2021. This encourages aquaculture business players to continue to increase fisheries production.

The success of a fish farming business is influenced by several important indicators, one of which is feed. Maximum fish production can be achieved if feed availability is met (Simanjuntak *et al.*, 2017). Optimal growth of fry is influenced by factors such as the availability of natural food to support the nutritional and calorie needs of fish, especially the fry phase (Faizi *et al.*, 2023). Mortality in the fry phase is relatively higher, so it is very important to maintain the availability of natural food that supports the nutritional needs of fish fry (Krisnati *et al.*, 2022).

Natural feed is good for fish farming activities because its nutritional content is better than artificial feed (Mufidah *et al.*, 2019). Apart from that, the advantage of using natural food is its small size according to the larva's mouth opening (Rachimi *et al.*, 2016).

Spirulina sp. is one of the microalgae that is used as natural food for fish larvae (Tambunan *et al.*, 2022). *Spirulina* sp. comes from the Oscillatoriaceae family which naturally grows in warm media and alkaline pH so it is relatively easy to cultivate. This algae grows in fresh water and sea water spread across Asia, Europe, Africa, South and North America (Nayyef and Thalij, 2020). *Spirulina* sp. is a type of algae that lives in tropical and subtropical areas, so Indonesia's nature has great potential for the development of *Spirulina*. This is a natural food that is widely used for hatching shrimp and fish larvae. *Spirulina* sp. contains 60–71% protein, 8% fat, 16%

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carbohydrates, and vitamins as well as 1.6% Chlorophyll- α , 18% Phycocyanin, 17% β -Carotene, and 20–30% γ -linoleic acid from total fatty acid (Robi, 2014). *Spirulina* sp. is a natural food source of nutrition that contains the carotenoid type astaxanthin which can be used as an organic material to increase the brightness of fish, especially in terms of color phenotype (Rosid et al., 2019). *Spirulina* sp. it can also break down food components that cannot be digested, there by increasing fish growth (Mamun et al., 2023). This article aims to review the use of *Spirulina* sp. as fish feed.

The research method used is a systematic review. Systematic review is a method of collecting data obtained based on research results related to the subject being reviewed, whether published in the form of journals, proceedings, books, or other forms of research reports (Setiawan dan Kautsar, 2018). Data collection was carried out through internet surfing from various online journal websites. In this article, data comes from research report journals and research articles published in the 2014-2024 period in national and international journals indexed 50 articles. The discussion in this article concentrates on the nutritional content of *Spirulina* sp., the cultivation of *Spirulina* sp., and the use of *Spirulina* sp. on fish feed and its effects. The data was then analyzed comparatively descriptively.

Biology of *Spirulina* sp.

Spirulina is a type of microalgae that has a bluish green color. *Spirulina* sp. included in the Phylum Cyanobacteria, Division Cyanophyta, Class Cyanophyceae, Order Nostocales, Family Oscillatoriaceae, Genus *Spirulina*, with the Species *Spirulina* sp. (Hirata et al., 2000). *Spirulina* sp. has a cylindrical shape resembling a thread and is a series of cells with thin cell walls, 1-12 micrometers in diameter. *Spirulina* has filaments that can live independently (Hariyati, 2008). *Spirulina* sp. has 3 types of pigments for capturing light, namely chlorophyll, phycobiliprotein and carotene pigments. Chlorophyll has specific forms, including chlorophyll-a, which is the main pigment as the center of photosynthesis in the synthesis of active ingredients and functional compounds in *Spirulina* (Widawati et al., 2022). Chlorophyll-a also has a role in culture media as an indicator of nutrient content because this type of phytoplankton requires both macro nutrients such as N and P and micro nutrients

in the form of iron (Fe) as an element that makes up its cells (Nufus et al., 2017). High nitrate concentrations will indicate high concentrations of chlorophyll-a because of the nitrate that will be used by the phytoplankton in the growth process (Zulhaniarta et al., 2015). The appearance of *Spirulina* sp. can be seen in Figure 1 below:



Figure 1. *Spirulina* sp. (Jung et al., 2021)

Nutrient Content of *Spirulina* sp.

Spirulina sp. is a type of microalgae from the Cyanophyta group or blue-green algae that has been widely used as a natural feed in cultivation businesses, especially in hatcheries because it has high nutritional value. *Spirulina* sp. contains 60–71% protein, 8% fat, 16% carbohydrates, and vitamins as well as 1.6% Chlorophyll- α , 18% Phycocyanin, 17% β -Carotene, and 20–30% γ -linoleic acid from total fatty acids (Robi, 2014). According to Leksono et al. (2017), *Spirulina* sp. has a protein content of 40-60%, fat 1.5-12%, vitamins B1, B3, B6, B12, pro vitamins A and E. Apart from that, *Spirulina* sp. contains compounds that can be natural antioxidants such as phycobiliprotein compounds, phenolics, carotenoids and chlorophyll (Ridlo et al., 2016).

Spirulina sp. widely used as natural food in fish farming, especially ornamental fish due to the content of carotenoid pigments that can improve the quality of fish color. Beta carotene is a bioactive compound from the carotenoid group which is a yellow, orange or red-orange organic pigment found naturally in plants, algae, several types of fungi and bacteria (Hanani et al., 2020). The beta carotene compound in *Spirulina* sp. it has the characteristics of being easily damaged due to oxidization at high temperatures, insoluble in water and soluble in oil (Kusbandari and Susanti, 2017). Addition of *Spirulina* sp. flour as much as 3% in commercial feed has a significant effect on increasing the color brightness of goldfish (*Carassius Auratus*) (Ardiansyah, 2019).

Cultivation of *Spirulina* sp.

Cultivation of *Spirulina* sp. is a technique that can be used to grow the microalgae *Spirulina* sp. in a certain controlled environment (Jelizanur *et al.*, 2019). This cultivation aims to increase or double the number of *Spirulina* sp. by multiplying to obtain biomass. Growth of *Spirulina* sp. relatively quickly, this can happen if it is supported by a source of energy and light that is available to carry out photosynthesis. Light is one of the most important factors in the growth of microalgae and the cultivation of cyanobacteria where this energy is captured by pigments to carry out the photosynthesis process (Atta *et al.*, 2014). According to Muliani *et al.* (2018) growth that occurs in *Spirulina* sp. divided into 4 phases, namely the lag phase (adaptation), logarithmic phase, stationary phase and declination phase (death). Growth phase of *Spirulina* sp. can be seen in Figure 2 below.

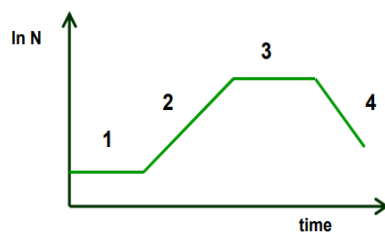


Figure 2. Microalgae Growth Curve (1) Lag Phase (2) Logarithmic Phase (3) Stationary Phase (4) Declination Phase
(References: Dziosa and Makowska, 2016)

Cultivation of *Spirulina* sp. on a laboratory scale is in Figure 3.



Figure 3. Cultivation of *Spirulina* sp.

The cultivation media used when cultivating natural food influences the resulting productivity. Growth of *Spirulina* sp. highly dependent on the availability of nutrients in the culture medium. *Spirulina* can grow on various media containing macronutrients (C, H, N, P, K, S, Mg and Ca) and micronutrients (Fe, Cu, Mn, Zn, Co, Mo, Bo, Vn and Si) (Soni *et al.*, 2017). The nutrients contained in the cultivation media play a very important role in maintaining the quantity, quality and stability of *Spirulina* sp. cell production. Apart from maintaining production stability, selecting fertilizer with a good nutrient composition in the *Spirulina* cultivation media is important for enriching the nutritional content (Piu *et al.*, 2011). Nitrogen and phosphorus are the two macronutrients most needed by microalgae, providing nitrogen and phosphorus at certain concentrations can increase the protein content of microalgae (Suherman *et al.*, 2022). Nitrogen plays a role in the formation of proteins and nucleic acids. Ambarwati *et al.* (2018), explains that nitrogen plays a role in stimulating vegetative growth and increasing cell number. Nitrogen deficiency can cause changes in enzymes in cells which are demonstrated through a decrease in lipid synthesis and chlorophyll synthesis (Juneja *et al.*, 2013). Phosphorus plays a role in various cellular metabolic processes of the cell. Phosphorus is used during energy circulation, energy transfer and stimulates reactions in cell metabolism (Dhyrman, 2016).

Factors in the Cultivation of *Spirulina* sp.

Fertilizer used in cultivation of *Spirulina* sp.

Fertilizer used for cultivating *Spirulina* sp. can be in the form of organic and inorganic fertilizers. Inorganic fertilizer used in the cultivation of *Spirulina* sp. contained in Table 1.

Table 1. Inorganic Fertilizer Used in Cultivation of *Spirulina* sp.

Fertilizer Type	Concentration	Authors
Urea	0.26 g/L	Apri (2015)
Urea	0.105 gr/L	Arrosyd <i>et al.</i> (2024)
Urea and TSP (Triple Super Phosphate)	0.5 g/L urea + 0.0012 g/L TSP	Suherman <i>et al.</i> (2022)
Zarrouk	1ml/L	Mutia <i>et al.</i> (2021)
Conwy	1ml/L	Devita <i>et al.</i> (2018)
Walne	1ml/L	Mahardika <i>et al.</i> (2022)

Based on Table 1 above, the inorganic fertilizer used in the cultivation of *Spirulina* sp. are Urea, TSP (Triple Super Phosphate), Zarrouk, Conwy and Walne. Risamasu and Budi (2011) stated that carbon (C), nitrogen (N) and phosphorus (P) are the most important elements for the growth of *Spirulina* sp. Nitrogen plays a role in stimulating vegetative growth and increasing cell number (Ambarwati *et al.*, 2018). Urea is a single fertilizer that can be used as a source of organic nitrogen to produce macronutrients to meet cell metabolic needs such as catabolism, transportation, assimilation and protein biosynthesis (Apri, 2015). TSP (Triple Super Phosphate) is an inorganic fertilizer containing 44-46% phosphorus (Suherman *et al.*, 2022). Zarrouk fertilizer has a high sodium nitrate (NaNO₃) content so that metabolism runs well which produces protein, fat and carbohydrates (Suminto, 2009). Based on Lananan *et al.* (2023), Conwy media contains micronutrients, metal solutions and vitamins. Walne

is a type of synthetic fertilizer that is commonly used in microalgae culture because it has high protein and fat content and is a media component for macro and micronutrient needs. The use of inorganic fertilizer such as Walne fertilizer for microalgae culture is also considered more practical because of its complete nutrient content compared to organic fertilizer (Budiono *et al.*, 2018).

Spirulina sp. culture activities has obstacles such as the price of inorganic fertilizers such as pro-analyst fertilizer which is relatively expensive. The price of Walne fertilizer for 500 ml has reached IDR 249,000; so this underlies the search for alternative sources of nutrients that come from nature. This alternative solution for using organic fertilizer is expected to reduce production costs, have easy reach and still have nutritional content that can meet the survival and reproductive needs of *Spirulina* sp. Organic fertilizer that can be used in the cultivation of *Spirulina* sp. are in Table 2.

Table 2. Organic Fertilizer Used in Cultivation of *Spirulina* sp.

Fertilizer Type	Concentration	Authors
Vermicompost	0.9 g/L	Muliani <i>et al.</i> (2018)
Coconut shell liquid smoke	2ml/L	Muhardi <i>et al.</i> (2021)
Quail droppings and guano	130 g/L quail droppings + 0.13 g/L guano	Hulu <i>et al.</i> (2023)
Liquid organic fertilizer from forest banana stem waste and coconut fiber	12ml/L	Rubiyah <i>et al.</i> (2023)
Liquid organic fertilizer resulting from fermentation of <i>Azolla pinnata</i>	18ml/L	Leksono, Mutiara, and Yusanti (2017)
POC	20ml/L	Maulana <i>et al.</i> (2023)
Liquid organic fertilizer resulting from fermentation of canna plant crowns	14 ml/L	Wijihastuti <i>et al.</i> (2020)
Bioslurry	31ml/L	Noucana (2014)

Water quality

The quality of the water used during *Spirulina* cultivation will greatly affect the mass production and nutrient content. The water used is filtered to prevent other types of algae from growing (Batista *et al.*,

2019). *Spirulina* sp. is commonly cultivated using open systems due to the ease of development and production processes and has low operating and production costs (AlFadhly *et al.*, 2022). *Spirulina* can be cultivated in open cultivation containers either

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artificial or natural such as ponds, reservoirs, and lakes. The most commonly used types of systems are shallow depth ponds with a large diameter, circular ponds, tanks and raceway ponds (Soni *et al.*, 2017). This open system has several disadvantages, namely poor light utilization by cells, excessive evaporation, diffusion of carbon dioxide to the atmosphere, external contamination, growth of other heterotrophic organisms and large land requirements. In this open system there is poor mass transfer caused by inefficient aeration which can reduce the productivity of *Spirulina* biomass. *Spirulina* growth is also highly dependent on season, location, pH, temperature, carbon dioxide (CO₂), and nutrient content in the media (Cuaresma *et al.*, 2011). One solution that can be done is the use of greenhouses (Soni, Sudhakar, and Rana, 2017).

Temperature

One of the physical factors that affect algae culture in the laboratory is water temperature. Temperature affects metabolism directly, and the environmental conditions of the growth medium are affected indirectly by temperature. Furthermore, an increase in these environmental conditions will affect the metabolism and reproduction of algal cells (Steinman *et al.*, 2015). The optimal temperature for *Spirulina* sp. growth is 25°C - 35°C (Tambunan *et al.*, 2022). *Spirulina* can grow at a temperature of 20°C - 37°C with the best temperature for growth is 29°C - 35°C (Soni, Sudhakar, and Rana, 2017). According to AlFadhly *et al.* (2022), cultivation on a laboratory scale has an ideal temperature ranging from 35°C - 37°C. Cultivation conducted outdoors for several hours can cause an increase in temperature up to 39°C without affecting *Spirulina*'s ability to photosynthesize. *Spirulina* sp. can grow and reproduce with the lowest temperature around 15°C.

Degree of Acidity (pH)

The degree of acidity (pH) plays a role in determining population density, carbon dioxide concentration and the balance between carbonate and bicarbonate in a culture medium. *Spirulina* sp. grows well in slightly alkaline pH conditions and has a high tolerance to alkaline pH than acidic pH (Fay 1983). The optimum degree of acidity (pH) in *Spirulina* sp. culture is 8.5 - 9.5, if the pH is 10 or less than 8 will inhibit growth and significant growth

reduction (Ismaiel *et al.*, 2016). Hariyati (2008), states that the pH for *Spirulina* sp. growth is 7-9. The function of acidity in cultivation media not only determines the solubility of carbon and mineral sources but also directly affects the physiological properties of *Spirulina* and the availability of nutrients (AlFadhly *et al.*, 2022).

Salinity

Spirulina sp. can live in soil, swamps, fresh water, brackish water, sea water, hot springs. The optimal salt ratio for *Spirulina* growth is 20-70 g/L (Saif, 2017). Under good conditions, the cellular osmotic composition of *Spirulina* will be balanced with the environment. If it is not balanced and the cells experience osmotic stress, it will cause physiological changes that increase or decrease biochemical compounds and affect the integrity of *Spirulina* cells. This osmotic stress occurs due to lack or excess salt in the cultivation medium. *Spirulina* has the ability to adapt and grow at salinities of 10-40 psi (Batista *et al.*, 2019).

Light intensity

Light is an important factor for algae culture including *Spirulina* sp. because light intensity is the source of energy that is bound in the photosynthesis process. The light source selected must ensure that the spectral characteristics of the light stream and the wavelength range must be suitable for photosynthetic organisms. Organisms such as *Spirulina* have specific requirements for the amount of light, length of exposure time, and wavelength range that can be used (Rybner, 2016). The light intensity required for good algal photosynthesis is between 3000 lux - 30000 lux (Jorgensen, 1997). The light intensity required in algae culture ranges from 500 lux - 5000 lux (Martosudarmo and Wulani, 1990). With an increase in light intensity up to 5000 lux, photosynthetic activity can increase oxygen production linearly, but above this intensity, the degree of increase in oxygen production decreases. Fluorescent lamps (TL) can help algae photosynthesize in the laboratory. Optimally, the light intensity of *Spirulina* sp. ranges between 2000 and 3000 lux (Cifferi, 1983). The optimal light intensity for *Spirulina* cultivation and biomass is 250-350 W/m² with a maximum light intensity of 400

W/m² which is the death phase of *Spirulina* (Delrue et al., 2017).

Aeration and agitation

Aeration is done to produce maximum *Spirulina*, both in terms of quantity and quality. High biomass can be influenced by the presence of air bubbles that enter the cultivation media. Aeration provides a homogeneous distribution of *Spirulina* filaments to get sufficient light exposure and helps distribute carbon dioxide (Zhang et al., 2015). Agitation in algae cultivation is necessary for homogenization and ensuring good lighting distribution among all *Spirulina* filaments. Agitation using aeration or the help of aeration stones plays an important role in the productivity density of cultivated algae. Continuous agitation of the culture medium is necessary to prevent cell sinking and thermal stratification. It is also necessary to maintain an even distribution of nutrients and to avoid conditions of excess oxygen.

Inoculant concentration

The inoculant used in *Spirulina* sp. cultivation should be highly concentrated with the strain used having a relatively high proportion of coiled

filaments (less than 25% straight filaments (Soni, Sudhakar, and Rana, 2017). The inoculant must be pure, live, and have rapid growth and reproduction to shorten the acclimatization time and minimize less than ideal conditions that occur at the beginning of the acclimatization process. This greatly affects the production process, survival and biomass produced. Inoculant concentrations that are too low can result in the loss of *Spirulina* algae as a result of photoinhibition (Mogale, 2014). Based on research by Bezerra et al. (2020), Zarrouk cultivation media supplemented with 100% (SW100), 50% (SW50), and 25% (SW25) concentrations of nitrogen (NaNO₃), phosphorus (K₂HPO₄), iron (FeCl₃·6H₂O), and disodium EDTA were inoculated into a vertical tubular photobioreactor with a volume of 1.8 L (1.5 L used) and an inoculant concentration of 200 ml/L.

Use of *Spirulina* sp. on Fish Feed and Its Effects

Spirulina sp. it contains nutrients that can be used as fish feed, such as protein, carotenoids and vitamins. Therefore, *Spirulina* sp. widely used as artificial feed in fish farming. The following is the use of *Spirulina* sp. on fish and its effects:

Table 3. Use of *Spirulina* sp. on fish feed and its effects

Concentration	Influence	Authors
<i>Spirulina</i> sp. flour 9 g/100gr feed	Significant influence on the color performance of goldfish (<i>Carassius auratus</i>)	Rahman et al. (2021)
<i>Spirulina</i> sp. flour 1.5 g/100 gr feed	Significant effect on the growth and color intensity of Nemo fish (<i>A. percula</i>) seeds	Palupi (2016)
<i>Spirulina</i> sp. flour 2.1 g/100 gr pellets	Has a real effect on the brightness of the color of the Comet fish (<i>Carassius auratus</i>)	Mbarep Rosid et al. (2019)
<i>Spirulina</i> sp. flour 5 g/100 gr pellets	Has a real effect on the brightness of the color of the Comet fish (<i>Carassius auratus</i>)	Anwar et al. (2021)
<i>Spirulina</i> sp. flour 1.5 g/100 gr feed	Has a real effect on the brightness of the color of the Ambon Betok fish (<i>Chrysiptera cyanea</i>)	Ismail et al. (2020)
<i>Spirulina</i> sp. flour 1.2 g/100 gr feed	Significant influence on the brightness of the color of Sumatran fish (<i>Puntius tetrazona</i>)	Nafsihi et al. (2016)
<i>Spirulina</i> sp. flour 3 g/100 gr feed	Significant effect on the growth and survival of Tilapia fish (<i>Oreochromis niloticus</i>) seeds	Hidayah (2017)
<i>Spirulina</i> sp. flour 3 g/100 gr feed	Really influences the growth of Maru Fish (<i>Channa maruloides</i>)	Razi et al. (2023)
<i>Spirulina</i> sp. flour 4 g/100 gr feed	Has a real effect on the brightness of the color of the platy mickey mouse fish (<i>Xiphophorus maculatus</i>).	Amin et al. (2019)
<i>Spirulina</i> sp. flour 7.5-10 g/100 gr feed	Can improve growth performance, body composition, feed utilization, and immune response of <i>Mystus cavasius</i>	Mamun et al. (2023)

Based on Table 3 above, replacing *Spirulina* sp. flour on feed has been widely used with a concentration range of 1.2-10 grams/100 grams of feed. Use of *Spirulina* sp. flour this mainly affects the increase in fish color. *Spirulina* sp. flour contains carotenoid compounds which have the ability to increase the number of chromatophore cells, which results in improved fish color quality.

According to Subamia *et al.*, (2020), fish food containing carotenoids is absorbed by the small intestine and broken down by the cytoplasm of small intestinal mucosal cells. Next, carotenoids are broken down into retinol and absorbed by the intestinal wall along with the absorption of fatty acids and monoglycerides. Lipids then collect and combine with lipoproteins before being absorbed through the lymphatic channels. Micelle and retinol then enter the bloodstream and go to the liver. The liver combines retinol with palmitic acid to produce retinyl palmitate. If necessary, retinyl palmitate can be bound by retinol-binding protein (PPR) synthesized in the liver. The PPR is then carried to the target cell, namely the chromatophore cell.

Spirulina sp. flour also has an effect on increasing fish growth. *Spirulina* sp. causes an increase in intestinal flora in fish, breaks down indigestible food components to extract more nutrients from food and promotes the synthesis of enzymes that transport lipids for metabolism rather than storage. The high content of vitamins, minerals, essential amino acids, linoleic acid and linolenic acid from *Spirulina* sp. in feed improves growth performance and feed utilization (Mamun *et al.*, 2023).

Conclusion

Spirulina sp. is a type of natural feed that can be used as an additional commercial feed to increase the growth and brightness of fish color. Addition of *Spirulina* sp. flour had a significant effect ($P < 0.05$) on the growth and color brightness of fish with

additional concentrations in the range of 1.2-10 grams/100 grams of feed.

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