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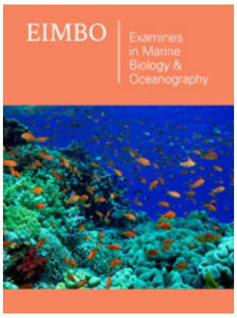
Opinion

Spirulina platensis, A Functional Feed Additive in Finfish Aquaculture – An Update

ISSN: 2578-031X



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Submission: September 19, 2024
Published: September 25, 2024

Volume 7 - Issue 2

How to cite this article: Einar Ringø*. *Spirulina platensis*, A Functional Feed Additive in Finfish Aquaculture – An Update. Examines Mar Biol Oceanogr. 7(2). EIMBO. 000660. 2024.
DOI: 10.31031/EIMBO.2024.07.000660

Opinion

As the price of fish meal is high, cheaper suitable alternatives are evaluated. *Spirulina* could be a functional alternative protein- and vitamins source in finfish aquaculture. The blue-green algae *Spirulina*, microalgae, are multicellular filamentous cyanobacteria [1] and grows well at pH around 8.5 and above, and at temperature around 30 °C. Analysis have shown high amounts of antioxidants, microelements, vitamins, essential amino acids, y-linoleic acid and phenolic compounds [2,3]. In addition, *Spirulina* has revealed cholesterol-lowering properties, beneficial effects in various inflammatory diseases [4], and modulated the gut microbiota composition [5,6]. Due to its high protein content, 60-70% of dry weight [7], *Spirulina* is one of the most used microalgae in aquaculture as feed supplements to replace fish meal to a lower coast and to improve the health and growth performance of aquatic animals [8-10]. In addition, the microalgae are also utilized for treating aquaculture wastewater and reducing environmental impact [11,12]. The present study, address to present and update overview on *Spirulina platensis* administration to finfish, and Table 1 shows beneficial effects in finfish the last five years. The first study on the effect of *Spirulina platensis*, on fish was reported by Stanley and Jones [13]. Aquarium held bigmouth buffalo (*Ictiobus cyprinellus*) were fed the blue-green algae at a daily rate of 29g dry weight kg^{-1} body weight for 28 days, and a growth rate of 14g kg^{-1} and a food conversion rate of 2.0 was recorded. Similar results were revealed by feeding blue tilapia (*Oreochromis aureus*).

Asian sea bass (*Lates calcarifer*)

In a study with Asian sea bass, Siddik et al. [14] fed the fish 5 and 10% inclusion and showed similar growth as control fish, no inclusion of *Spirulina*, in contrast to 20% which revealed significant lower growth. Most parameters investigated were not affected by *Spirulina* administration, but serum antioxidant-enzyme glutathione peroxidase (GPx) and immunological indices, lysozyme activity and immunoglobulin-M, were significantly higher by feeding the 5 and 10% diets vs. fish fed the control diet. In addition, histological evaluations revealed no aberrant hepatocytes in the livers of any of the dietary groups, except for the 20% diet, and in this feeding group higher lipid vacuolization when compared to the other dietary groups. An important finding was improved survival of fish fed 5% following exposure to *Vibrio harveyi*.

Atlantic salmon (*Salmo salar*)

Tibbetts et al. [15] revealed in a seven week study with Atlantic salmon fed a reference diet consisting of FM, poultry by-product meal, wheat gluten meal, soy protein concentrate and corn protein concentrate and a diet added 20% *Spirulina* that Apparent Digestibility Coefficients (ADCs) of ash, crude lipid and fatty acids and energy by *Spirulina* feeding were not affected, in contrast to crude protein ADC and essential amino acids was slightly reduced.

Table 1: Beneficial effects of *Spirulina platensis* in finfish, since 2020.

Source: ↑ - positive effect; → - no. significant effect; ↓ - decrease effect.

	Inclusion and Duration	Fish Species	Effects	References
Spirulina platensis	29g kg^{-1} body weight – 28 days	Bigmouth buffalo (*Ictiobus cyprinellus*) and blue tilapia (*Oreochromis aureus*)	↑ growth of both fish species	[13]
S. platensis	5, 10 & 20% - 8 weeks	Asian sea bass(*Lates calcarifer*)	↑ serum antioxidant-enzyme glutathione peroxidase (GPx), lysozyme activity and immunoglobulin-M, by feeding the 5 and 10% diets and improved survival against *Vibrio harveyi* by feeding the 5% diet → growth by feeding 5 and 10% inclusion ↓ growth by 20% inclusion Histological evaluations revealed dietary effect lipid vacuolization	[14]
S. platenis	20% - 7 weeks	Atlantic salmon (*Salmo salar*)	→ Apparent Digestibility Coefficient (ADC) of ash, crude lipid, fatty acids and energy ↓ ADC of crude protein and essential amino acids	[15]
S. platensis	15% - 93 days	European sea bass (Dicentrarchus labrax)	↓ growth Modulated the gut microbiota	[16]
S. platensis	2.5, 5, 7.5 & 10% - 10 weeks	Gangetic mystus (*Mystus cavasius*)	↑ Growth performance, immune response, hindgut microbiota and disease resistance against *A. hydrophila*	[17]
S. platensis	3, 6% & a diet supplemented 0.3 % *S. platensis* purified polysaccharides - 56 days.	Largemouth bass (*Micropterus salmoides*)	↑ growth performance, protein efficiency, nutrition, antioxidant capacity, and intestinal digestive enzyme activity Modulated the diversity of the gut content microbiota	[12]
S. platensis phycocyanin	5-10g kg^{-1} – 10 weeks	*Nile tilapia*	↑ growth and immunity promoter	[18]
S. platensis	10, 20 & 30g kg-1– 8 weeks	*Nile tilapia*	↑ growth performance, biochemical parameters and growth-related gene expressions by feeding 10g kg^{-1}	[19]
S. platensis	2.5, 5 & 10% - 8 weeks	*Nile tilapia*	↑ growth performance and immune status	[20]
S. platensis	10, 20 & 30% - 42days	*Nile tilapia*	→ growth performance Affected proximate- and fatty acid composition	[21]
S. platensis	5, 15 & 30% - 47days	Sabah giant grouper (produced by artificially fertilising the egg of the tiger grouper (*Epinephelus fuscoguttatus*) with the sperm of giant grouper (*E. lanceolatus*)	↑ growth of fish fed 5% Spirulina Supplementation modulated the hingut microbiota	[5]
S. platensis	2.5, 5, 7.5 & 10% - 70 days	Stinging catfish (*Heteropneustes fossilis*)	↑ growth performance, protein efficiency, whole body protein, ash content, and haemato-logical parameters ↓ lipid and moisture contents Modulated gut microbiota	[22]

European sea bass (*Dicentrarchus labrax*)

Pérez-Pascual et al. [16] revealed that 15% inclusion of S. platensis fed to European sea bass negatively affected growth and modulated the OTUs richness, and Shannon index of the gut content microbiota. As the gut microbiota is an important factor affecting fish health, the autochthonous gut microbiota should be investigated and not only the bacterial composition in gut content.

Gangetic mystus (*Mystus cavasius*)

Mamun et al. [17] showed that when more than 7.5% of FM was replaced by *S. platensis* meal, body weight, specific growth rate, protein efficiency and feed conversion ratio were improved compared to gangetic mystus fed the control diet. The protein efficiency and feed conversion ratio were also positively affected by dietary *S. platensis* meal supplementation. The replacement of 7.5–10% fishmeal with *S. platensis* red- and white blood cells, hemoglobin, hematocrit, and mean corpuscular hemoglobin levels rose. Serum lysozyme value increased with increasing dietary *S. platensis* supplementation. Bacterial analysis showed that the autochthonous hindgut microbiota of hindgut was affected, an increase in the relative abundance of *Pseudomonas, Lentibacillus,* and *Lactobacillus* by increasing supplementation of *S. platensis*. Improved disease resistance against *A. hydrophila* was noticed at 10% inclusion.

Largemouth bass (*Micropterus salmoides*). Zhang et al. [12] fed juvenile largemouth bass, diets containing 0 (no inclusion, control), 3 (SP3), 6% *S. platensis* (SP6) and a diet supplemented with 0.3% *S. platensis* Purified Polysaccharides (PSP) for 56 days. Administration of SP3 and SP6 displayed positive results as the diets significantly improved growth performance, lower hepatosomatic indices, increased whole-body crude protein, protein efficiency and muscle amino acid composition vs. control fed fish. However, crude lipid content decreased by feeding the SP diets. Liver superoxide dismutase activity increased significantly, while malondialdehyde levels declined. Levels of serum triglyceride significantly decreased by feeding 3% *Spirulina* than in the control. Low-density lipoprotein cholesterol decreased significantly in the SP3 and SP6 dietary groups, but no significant effect was noticed in the PSP group. Intestinal enzymes activities were affected by *Spirulina* administration, as trypsin and amylase activities significantly enhanced in the SP3, and SP6 and PSP groups, while lipase activities in SP 3 and PSP groups increased significantly compared to the control group. Analysis of the intestinal content microbiota analysis showed modulation as significantly higher Shannon index scores were noticed when fish were fed diets added *S. platenis* compared to control fed fish.

Nile tilapia (*Oreochromis niloticus*). El-Araby et al. [18] conducted a 10-weeks feeding trial with Nile tilapia to determine the effect of *S. platensis* phycocyanin (SPC) and revealed that supplementation enhanced growth performance, most intestinal morphometric measures, serum catalase and superoxide dismutase activity and immune response indicators (interleukin 10 (IL10), lysozyme activity, complement 3, and IgM serum levels. In contrast, reduced glutathione level and decreased malondialdehyde level was noticed with SPC supplementation. Nile tilapia fed diet supplemented with 10g *S. platensis* meal kg^{-1} enhanced growth, feed utilization, serum protein, globulin levels and growth hormone expression in the brain and muscle compared the other treatments, control and 20 and 30g inclusion [19]. Youssef et al. [20] concluded that supplementation of *S. platensis* to Nile tilapia diets increased body weight and length, weight gain, FCR, phagocytic activity, intestinal parameters as well as gut histology.

In recent study, Nile tilapia was fed diets added 10, 20 and 30% *S. platensis* and displayed no significant effect on growth performance [21]. Analysis of proximate composition showed significantly higher protein content by feeding fish the highest inclusion level, while lipid content was highest by feeding fish 20% *Spirulina*. Whole fatty acid composition showed difference between the treatments, as total saturated fatty acids and oleic acid, increased significantly in the fish fed the *Spirulina* diets. In contrast, linoleic acid was significantly higher in fish fed commercial diet. Of the omega-3 fatty acids, it was noticed that linolenic-, eicosapentaenoic-, and docosahexaenoic acid were significantly higher in fish fed 30% *S. platensis*.

Sabah giant grouper (*Epinephelus fuscoguttatus* and *E. lanceolatus*). Man et al. [5] reported that grouper fed a 5% *Spirulina*-based diet almost tripled its the total weight gain compared to control fed fish. Microbial communities in the hindgut of fish revealed that Simpson's diversity index showed high bacterial diversities in fish fed the *Spirulina* diets. At genus level, *Tolumonas* displayed the highest relative abundance in the hindgut of control fish, in contrast to genus Vibrio showing the highest relative abundance in fish fed the *Spirulina* diets. Stinging catfish (*Heteropneustes fossilis*). In a study conducted by Zahan et al. [22] the authors determined the inclusion effect of *S. platensis* (2.5, 5, 7.5 and 10%) as replacing fish meal in diets to stinging catfish for 70 days. Significantly improved growth performance and serum lysozyme activity was recorded by feeding the fish SP7.5 and SP10 diets vs. control. An important finding of the present study was that challenge with *Aeromonas hydrophila* for 15 days displayed improved survival, 70% in fish fed the SP7.5 diet compared to the control, 30%. Dietary *S. platensis* inclusion modulated the autochthonous gut microbiota by increasing the relative abundance *Pseudomonas*, *Lactobacillus* and *Lentibacillus*. The relative abundance of the gut microbiota by feeding SP5, *Pseudomonas* (28%) and *Lactobacillus* (~19%) were more prevalent, in contrast to *Lentibacillus* (~29%) in SP2.5, while *Corynebacterium* (18%) was the dominant genera by control feeding.

Conclusion

Spirulina could be a functional alternative protein- and vitamins source in finfish aquaculture, as supplementation of *Spirulina* reveal growth enhancement, enhance cellular and humoral immunities, modulate the gut microbiota and disease resistance towards pathogenic infection of various fish species. In addition, *Spirulina* can be used for treating wastewater. Even though beneficial properties are revealed, more research is needed to clarify the beneficial effects of *Spirulina platensis* in challenge studies of aquatic organisms.

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