SPIRULINA: AN EFFECTIVE FUNCTIONAL FEED IN AQUACULTURE

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Introduction

Aquaculture is one of the most significant and fast growing food industry, that provides the nutritional needs to consumers all over the globe (Ansari et al., 2019). Fish protein meets a significant percentage of the human daily requirement of protein to maintain normal physiology. As a result, aquaculture production is expanding to meet the global demand for human nutrition. The productivity rate on the other hand is influenced by many factors such as feed, seed, environment, water quality, etc. However, the major effect on production and profitability is contributed by feed (accounts for >65% of the production costs). Due to this, finding an affordable substitute and a feed component with a balanced nutritional profile is crucial for ensuring the global sustainability of both aquatic feed and production.

Spirulina, a microalga has gained popularity in recent times due to its rich nutritional profile (Zhang et al., 2020).Owing to the well-balanced nutritional profile such as macronutrients, amino acids, proteins, and fatty acids garners, spirulina can be utilised as an as an effective alternative feed in aquaculture and the commercial production of spirulina has thus gained popularity. Thus, this microalgae represents a promising possibility for boosting aquaculture production, particularly in developing nations such as India, where spirulina can be grown on a modest scale in rural regions (Mo et al., 2018).

Spirulina

Spirulina, a multicellular blue-green cyanobacteria of phylum Oscillatoriaceaehas, has been utilized as food for generations by various tribes. Spirulina is easier to digest than other microalgae and grabbed the attention of the food and pharmaceutical industry as a unique supplement containing high protein level, mineral composition, vitamins, carotenoids, and essential fatty acids (Table 1) (Fig.1). The two most common species, Arthrospira plantensisand Spirulina maxima are more important due to their high nutritional content.

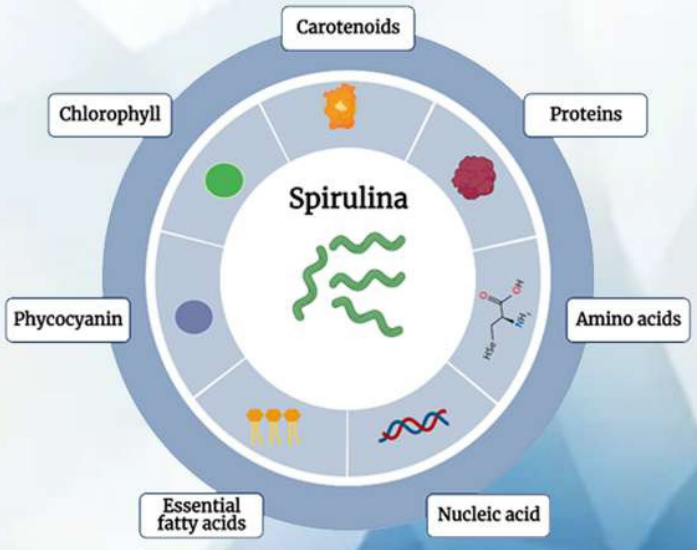

Fig.1. The biochemical composition of spirulina

Table 1: Biochemical composition of Spirulina (Rosas et al., 2019)

Composition	*Spirulina* (%)
Crude protein	57.5
Amino acids	
Isoleucine	0.81
Leucine	1.28
Lysine	3.03
Phenylalanine	0.80
Tyrosine	0.54
Methionine	1.15
Histidine	3.21
Valine	3.51
Arginine	1.09
Tryptophan	0.93
Carbohydrates	15-21
Nucleic acid	2.2-3.5
Essential fatty acids	1.5-2.0
Natural pigment enhancers	
Phycocyanin	14
Chlorophyll	1
Carotenoids	47

Data from National Research Council (2011)

Spirulina as an effective functional feed in aquaculture

Spirulina has been deemed a beneficial aquafeed supplement because of its nutritional content and inclusion of bioactive substances that improve disease resistance and stress tolerance in the organism. Consequently, over the last decades, there have been several researches that involve spirulina as an effective feed supplement in fish and shrimp aquaculture (Altmann and Rosenau, 2022). Spirulina also improves immune response and increases resistance to pathogenic microbial infections(Macias-Sancho et al., 2014). As a result, extensive multi-nutritional and therapeutic potential has made spirulina as an excellent functional feed in aquaculture (Figure 2).

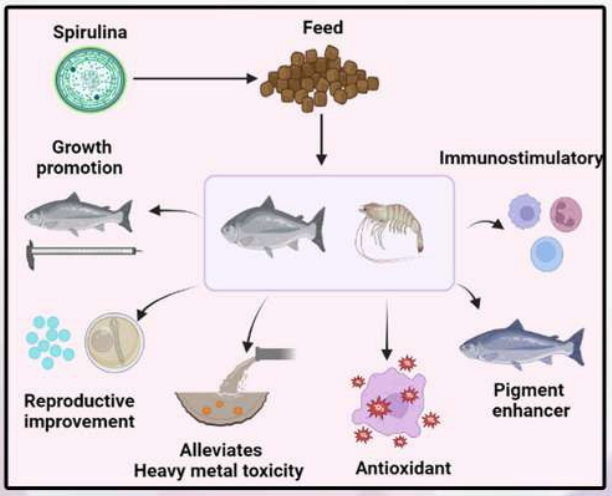

Fig.2. Functions of spirulina as an effective feed in aquaculture

Spirulina as a growth promoter

Various research has demonstrated that spirulina improves the growth and performance of various fishes and shrimp. The improvement in growth and feed utilisation after feeding with live spirulina has been recorded in many aquatic species. In context, A. platensis has a good effect on Nile tilapia fish growth and performance (Velasquez et al., 2016). Additionally, fish feed combined with A. platensisincreased feed efficiency and disease resistance in aquatic animals (Macias-Sancho et al., 2014). Hence,spirulina could be considered a superior replacement for a protein source of feed as a growth booster in the aquaculture industry.

Spirulina as an Immunostimulant and an antimicrobial agent

Immunostimulants could defend infection and stress in aquatic animals by improvement of non-specific immune response (Talpur et al., 2013). Various immuno-stimulants, including lipopolysaccharides, chitin, and glucan, have been proven to increase fish immune defences when administered orally(Sakai, 1999). Spirulina has been recognized to stimulate the immune system in aquatic organisms such as fishes and shrimp by enhancing phagocytic activity, lysozyme activity, bactericidal activity, and white blood cell functions. Additionally, spirulina regulated the expression of gene signalling molecules such as cytokines, etc.Spirulina has also shown significant antibacterial characteristics that can effectively combat dangerous pathogens. Spirulina excretes a variety of metabolic by-products, including organic acid, vitamins, and phytohormones. Spirulina cell extract has also demonstrated antibacterial activity against pathogenic microorganisms such as Saccharomyces sp., Bacillus sp., Streptococcus sp., Escherichia coli and Staphylococcus aureus (Vo et al., 2015). Thus, spirulina could function as an efficient modulator of the immune system.

Spirulina boosts reproductive performance in aquatic organisms

Spirulina supplements boost reproductive performance such as improved spawning, fecundity, fertility and hatching rate in fish and shrimp due to their compositions like essential fatty acids, ascorbic acid, and carotenoids. In this context, carotenoids in the feed have been reported to improve broodstock performance in yellowtail fish (Watanabe and Vassallo-Agius, 2003). Additionally, spirulina is high in linolenic and linoleic acid, both of which are precursors of arachidonic acid. Arachidonic acid is required for the synthesis of prostaglandin, which is required for steroidogenesis, oocyte maturation and ovulation. Hence, spirulina is rich in the nutrients which are required for the reproduction of aquatic animals.

Spirulina as a colour enhancer in ornamental fishes

Ornamental fish farming generates significant revenue for exporting countries (Leal et al., 2016). Pigmentation is an important feature in ornamental fish pricing and carotenoids are pigments that are responsible for their colour (Storebakken et al., 1987). Thus, the healthy growth and pigmentation of ornamental fishes is reliant on diet that contains a appropriate amount of carotenoids. On the other hand, spirulina is rich in carotenoids, beta carotene and zeaxanthin and incorporating it into the fish diet can enhance fish pigmentation. Thus, spirulina can be utilized as a colour enhancer in the ornamental fish farming industry.

Spirulina alleviates heavy metal poisoning and its role in nanotherapeutics

Heavy metal poisoning exhibits severe ill effects in aquatic animals, causing oxidative stress resulting in the production of reactive oxygen and nitrogen species, which are implicated in cellular damage (Lushchak, 2011). Spirulina contains a variety of pigments, including beta carotene and phycocyanin, which are both antioxidants and anti-inflammatory. Spirulina's chlorophyll content also serves as a cleaning agent and a phytonutrient detoxifier (Wu et al., 2016). As a result, spirulina-rich diets reduce the harmful effects of heavy metals in aquatic animals and could be considered as an effective supplement that could alleviate heavy metal poisoning. In recent times spirulina is also employed in nanoscience (photosynthesized nanomaterial system).

Conclusion

Spirulina could serve as an effective dietary supplement with positive effects on growth performance, immuno-stimulation, antioxidant, antimicrobial, anti-inflammatory, reproductive improvements, pigments synthesis and alleviation of heavy metal toxicity. Hence integrating spirulina into traditional feed systems in aquaculture appears to be a great alternative feed.

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