Review Article

Journal of Advanced Veterinary Research
(2024) Volume 14, Issue 2, 342-344

Spirulina as an animal feed and its effect on animal health and productivity

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ARTICLE INFO

Recieved: 18 August 2023

Accepted: 23 October 2023

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Keywords:

Spirulina
Animal feed
Animal health

ABSTRACT

The extraordinary increase in demand for animal protein such as meat, eggs, milk, and other animal products, as well as the large quantities of protein feed inputs required for animal production, have principally spurred research into spirulina as an animal feed. Spirulina (*Arthrospira* sp.) is a highly nutritious edible microalga and a prospective feed supply for many agriculturally significant animal species. Animal growth, fertility, beauty, and nutritional product quality have all been linked to spirulina. Spirulina consumption has been related to improved animal health and well-being in studies. Because of its nutritious and protein-rich composition, its impact on animal development was significant, and commercial production was raised to suit consumer demand. As a result, Spirulina is emerging as a cost-effective resource for increasing animal output in order to achieve long-term sustainability and a viable food security future.

Introduction

Meat production requires a lot of input and is therefore considered a premium food in many countries and cultures. However, global demand for animal protein continues to grow owing to rising wages and the growing global population (Wang *et al*., 2021). Spirulina (*Arthrospira platensis*) attracting attention as a sustainable protein source for direct consumption and animal feed (Martins *et al*., 2021). Spirulina (*Arthrospira* sp.) is a filamentous spiral-shaped microalgae that is edible. It is found in alkaline lakes in Mexico and Africa. It is a distinctive blue-green algae due to its lengthy history of safe use. It is utilized as a nutritional supplement for both humans and animals since it is high in protein, lipids, carbs, sterols, and vital minerals like zinc, magnesium, and selenium (Charpy *et al*., 2012). In comparison to other man-made food sources, spirulina's naturally occurring high-quality concentrated nutritional components make it appropriate for ingestion as a whole food supplement. Spirulina is utilized as a nutritional element in a number of food products to boost its nutritional and therapeutic qualities due to its unique and amazing nutrient profile (Mayada *et al*., 2015). By lowering blood sugar levels, decreasing insulin resistance, and managing hypercholesterolemia, spirulina in animal feed can help with a variety of health issues, including diabetes and its complications. In addition to its immunomodulatory qualities, spirulina offers some beneficial therapeutic benefits against inflammation, cancer, and heart disease. Spirulina has recently been discovered to have numerous favorable benefits on the production and reproductive performance of animals and poultry (Nah *et al*., 2012). Spirulina has been shown in recent studies to offer numerous health benefits, including immunological stimulation, antioxidant, anti-inflammatory, antiviral, and antibacterial properties. Spirulina has been found in studies to influence both cellular and humoral immune responses. In terms of cellular immunological responses, various studies have found that spirulina has unique effects on monocytes and natural killer (NK) cells (El-Sabagh *et al*., 2014).

Nutritive value

Spirulina's nutritional benefit is generally recognized for its unusually high protein content, which makes it one of the richest protein sources (60-70% dry weight) and contains all essential amino acids. It has a protein level similar to beans and comparable to meat, eggs, and milk, although it has less cysteine, methionine, and lysine (Mišurcová *et al*., 2014). It contains important fatty acids, gamma-linolenic acid, alpha-linolenic acid, linoleic acid, eicosapentaenoic acid, stearidonic acid, arachidonic acid, docosahexaenoic acid acids, and polyunsaturated fatty acids alpha-3 and alpha-6. It contains vitamins B1 (thiamine), B2 (riboflavin), B3 (niacinamide), B6 (pyridoxine), B9 (folic acid), C (ascorbic acid; AA), as well as calcium, potassium, chromium, and selenium (Gutiérrez-Salmeán *et al*, 2015).

Biological activities

Antioxidant Function: Spirulina can prevent cellular damage by carrying antioxidant defense systems that counteract the effects of reactive oxygen species (ROS) and protect cells from their detrimental effects under normal and stressed situations (Kurd and Samavati, 2015). Because of its high content of carotenoids and tocopherol (TOH), spirulina can be used to produce antioxidant compounds that can directly repair oxidative free radicals via free radical scavenging activity, thereby inhibiting chain growth during lipid peroxidation steps (Ibrahim and Abdul-Daim, 2015).

ISSN: 2090-6277/2090-6269/

Hepatoprotective effect

Spirulina decreases lipid peroxidation, oxidative stress, and apoptosis in the liver; prevents chronic hepatitis from progressing to cirrhosis (Martin *et al*., 2014).

Nephroprotective effect

Spirulina extract protects the kidneys by counteracting the harmful effects of sodium oxalate by normalizing antioxidant and glutathione metabolizing enzyme levels, hence preventing hyperoxaluria (Rodríguez-Sánchez *et al*., 2012).

Neuroprotective effect

Spirulina has a neuroprotective effect, as it lowers cerebral infarction and ischemic brain injury caused by toxic chemicals, as well as reactive oxygen species, nitric oxide, and lipid peroxidation, improves motor function, and reduces spinal cord morphological damage (Aziz *et al*., 2014).

Hypoglycemic and hypolipidemic effects

Spirulina's antioxidant characteristics allow it to lower total blood lipid, cholesterol, and glucose levels while also improving insulin resistance (Vidé *et al*., 2015).

Antitumor effect

It has been proposed that Spirulina's combined antioxidant and immunological modulation properties may have a mechanism of tumor destruction and hence play a role in cancer prevention (Konickova *et al*., 2014).

Immunomodulatory effects

Spirulina boosts macrophage phagocytosis, NK cell and lysozyme activity, and the generation of antibodies, interferon-gamma, and cytokines (interleukins; IL-1, 4, and 17) (Jamil *et al*., 2015).

Anti-inflammatory effect

Spirulina has been shown to have anti-inflammatory qualities by decreasing the release of histamine from mast cells (Pugh *et al*., 2015).

Growth, productivity, and reproductive enhancer of animals and poultry: Spirulina increases the development, productivity, and reproductive performance of animals and poultry by enhancing feed intake, feed conversion rate, nutrient utilization and absorption, and nutrient utilization and absorption, egg mass, egg component, egg quality besides fertility and hatchability rates (Evans *et al*., 2015).

Spirulina in ruminants feed

Cattle

Spirulina supplementation can also considerably reduce the quantity of milk somatic cells, boosting the food safety value of milk. Furthermore, cows given Spirulina had better body condition (8.5-11%) and considerably higher milk fat, protein, and lactose output than cows not given Spirulina (Kulpys *et al*., 2009). Spirulina-fed cows generated 21% more milk. Furthermore, spirulina raised milk fat (17.6% to 25.0%), milk protein (9.7% increase), and lactose (11.7% increase) in cows (Christaki *et al*., 2012). In bulls, spirulina has been proven to boost sperm quality. When bulls were given spirulina bio-extract, their sperm motility, concentration, and post-storage motility improved (Granaci, 2007).

Spirulina platensis supplementation in cows for one month at a rate of 20 gm of powder resulted in a significant drop in somatic cell count, an increase in the mean of Fat, protein, lactose, and casein% in milk, and a significant increase in milk yield. As a result, Spirulina supplementation can improve milk quality and quantity (Ragab *et al*., 2023).

Spirulina supplementation in suckling calves at a rate of 6 gm per day for 45 days resulted in a non-significant increase in body weight and a significant increase in Erythrocytes and leucocytes counts, hemoglobin, total protein, globulin, and total antioxidant capacity with a lower rate of disease incidence in *Spirulina platensis* treated calves. However, there were no significant variations in albumin and immunoglobulin levels. In conclusion, *Spirulina platensis* supplementation in suckling calf starting improved immunomodulator, antioxidant potential, and health status (Ghattas *et al*., 2019).

Sheep

Spirulina-fed lambs had higher live weight and average daily gain (ADG) than non-Spirulina-fed lambs (Bezerra *et al*., 2010). Pregnant ewes given spirulina had heavier lambs (4.07% increase) and greater average daily growth than pregnant ewes not given spirulina (Shimkiene *et al*., 2010). *Spirulina platensis* powder (SPP) supplementation at 1 g/10 kg BW/day resulted in enhanced final live body weight, daily live weight gain, feed intake, and feed conversion rate in fattening lambs compared to lambs who did not receive spirulina. As a result, spirulina can be employed as an antioxidant, immunological stimulant, and growth promoter feed ingredient in fattening lamb diets (EL-Sabagh *et al*., 2014).

Goat

Adding spirulina to the diet of dairy goats improved their average live body weight (LBW) during pregnancy and suckling. Furthermore, feeding spirulina increased milk supply by about 6% during the initial suckling period to 8.6% after 60 days. Furthermore, feeding SP improved the children's performance (average LBW and ADG) and survival rate (El-Deeb *et al*., 2022).

Spirulina in swine feed

Weaned piglets treated with spirulina grew at a 9% faster pace than pigs that were not supplemented with spirulina. As a result, spirulina has been demonstrated to be a viable substitute for nonfat dry milk in pig diets. Spirulina-rich pork diets have been linked to increased boar fertility. Spirulina extract-supplemented boars showed superior overall sperm quality than non-supplemented boars, with an 11% increase in sperm volume and a 5% increase in motility and motility after storage (Granaci 2007).

Spirulina in dog's feed

When compared to controls, dogs fed a spirulina-enriched diet had considerably stronger vaccination responses and higher levels of fecal IgA, resulting in an enhanced immunological state. Spirulina supplementation resulted in dramatically enhanced gut microbiota stability. Finally, Spirulina-enriched meals dramatically improved immune response and gastrointestinal health in dogs (Ebenezer *et al*., 2021).

Spirulina in poultry feed

At low dietary levels of 10 g/kg in the meal, dietary spirulina was associated with higher cost efficiency in chicken production and enhanced chicken health, as birds receiving dietary Spirulina were shown to be in better health than their un-supplemented counterparts. This is attributed to increased macrophage function and phagocytic activity, as well as the

complete mononuclear phagocyte system, and predicts greater disease resistance in hens fed higher Spirulina concentrations (Jamil *et al*., 2015).

Spirulina is thought to be an effective way of modifying chicken product quality to fit consumer preferences. Spirulina, for example, can reduce the overall cholesterol content of eggs by incorporating it in layer hen meals. This is mostly due to the high antioxidant and omega-3 polyunsaturated fatty acid (PUFA) content of Spirulina improves the nutritional value of eggs at the expense of cholesterol content (Rajesha *et al*., 2011). As the amount of spirulina in the diet grew, the color of the egg yolks darkened linearly. The large quantities of zeaxanthin, lutein, and other carotenoid pigments (particularly B-carotene) that accumulate in the egg cause this influence on yolk color (Sujatha and Narahari, 2011). The Spirulina diet has an immune-stimulatory effect on SPF chickens' immune systems. The lowest recommended concentration for inducing an effective immune response, enhancing protection against heterologous virus strains, and reducing viral shedding is 1 g SP per kg ration (Abotaleb *et al*., 2020).

Spirulina in fish feed

Small amounts of algae added to fish diets have been found to improve growth, lipid metabolism, body composition, and disease resistance. Protein synthesis and somatic cell proliferation in red snapper, guppies, African catfish, and Indian carp are stimulated by feeding Streptomyces platensis (Promya and Chitmanat, 2011). The immunomodulatory effect of spirulina was studied in other fish species, where the addition of maximal spirulina to the carp diet improved not only immune performance parameters but also hematological parameters including RBC, WBC, Hb, PCV, MCV, MCH, and MCHC besides parameters of immunological performance including lymphocyte, lysosome activity, monocytes, Alternate Complement Pathway (ACP), IgM, phagocytic Index and Phagocytic Activity (Krishnaveni *et al*., 2013). Supplementation of Spirulina to the diet of Tilapias causes significant increases in nonspecific immune system parameters (phagocytic activity of neutrophils and monocytes) (Şahan *et al*., 2015).

Inclusion of *Spirulina platensis* in the diet of Nile tilapia fingerlings resulted in increased body weight and lower FCR, increased glutathione reductase activity, and increased lysozyme levels, IgG, and catalase activity, indicating that *Spirulina platensis* supplementation increases antioxidant protective capacities (Amer, 2016).

When more than 7.5% of the fish meal in the diet was replaced with *S. platensis* meal, body weight and specific growth rate increased.

The addition of *S. platensis* to the diet improves protein efficiency and feed conversion rate. When *Mystus cavasius* was challenged with Actinomyces hydrophila, total fish mortality decreased as *S. platensis* meal levels increased. Thus, supplementing with *S. platensis* improved the growth and immune system of *M. cavasius* (Al Mamun *et al*., 2023).

Conclusion

Spirulina is an exciting new feed resource that has the potential to meet the needs of future animal production. Trials involving the addition of dietary spirulina to feed rations for a variety of agriculturally significant animal species have shown increases in productivity, health, and product quality.

Conflict of interest

The authors declare that they have no conflict of interest.

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