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Spirulina as Poultry Feed Supplement to Enhance Nutritional Value of Chicken Meat and Eggs: A Review

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Abstract: Microalgae can be efficiently used in poultry nutrition to enhance the pigmentation and nutritional value of meat and eggs, as well as partial replacement of conventional dietary protein sources. Dietary *Spirulina* is useful for the manipulation of chicken meat colour through accumulation of zeaxanthin within the meat. *Spirulina*-fed samples were less metallic in flavour, had higher values of yellowness, total carotenoids and saturated fatty acids. Increase in egg yolk colour can be achieved due to the β-carotene from *Spirulina*. *Spirulina* diet has also proved increased disease resistance in chickens. The findings showed that the microalgae, *Spirulina* could be a useful protein source for poultry diets and supplementing microalgae in the diet had no negative effect on growth performance.

Key words: *Spirulina* · Poultry Feed · Microalgae · Chicken Meat · Egg Quality

INTRODUCTION

The increasing demand for human protein food sources has resulted in a need for new feed materials which provide a safe source of nutrients for poultry and livestock. The current trend in poultry nutrition is to use natural ingredients as an alternative to antibiotics, growth factors, or other chemicals. The price of conventional feed ingredients, such as maize, has increased substantially over the years. This condition may increase the production cost and reduce efficiency of the broiler industry. The search for alternative protein sources has become urgent and, in this context, algae are worthy of consideration [1]. Microalgae are natural feed with high nutritional value and, therefore, might stand as a promising ingredient in poultry diets [2]. *Spirulina* expects to a new source of high-quality feed resource [3]. *Spirulina* contains high level of various B vitamins and minerals including calcium, iron, magnesium, manganese, potassium and zinc [4, 5]. It is a good source essential fatty acid, gamma-linolenic acid [6]. It is also a good source of essential fatty acids and pigments, such as chlorophyll a, phycocyanin, carotenes and xanthophylls. *Spirulina* contains up to 70% protein of dry weight [7]. *Spirulina platensis* and *Spirulina maxima*, which are generally regarded as rich sources of protein, essential amino and fatty acids.

The use of microalgae in poultry diets has been extensively explored and results have shown that they can act as natural colour enhancers in meat [8] and eggs; enrich meat and eggs with polyunsaturated fatty acids [9, 10] and improve broiler health by selecting and inducing growth of beneficial bacteria in the gut. Dietary vitamin and mineral premixes can be omitted when *Spirulina* algae are included in chicken rations [1]. The metabolisable energy content and digestibility of amino acid for *S. platensis* indicated that the microalgae are potentially an alternative nutrient source for broilers [11]. Ross and Dominy [12] found that dehydrated *Spirulina* at a diet content below 12% may be substituted for other protein sources in chick and broiler diets with good growth and feed efficiency. Venkataraman et al. [1] also showed that substitution of groundnut protein with sun- dried and powdered *Spirulina*, up to 170 g/kg or of fish meal with *Spirulina* up to 140 g/kg, on an equal protein basis resulted in satisfactory performance.

The effects of dietary *Spirulina platensis* on chicken macrophage phagocytic function and nitrite production were examined by Al-Batshan *et al*. [13]. *S. platensis* feeding upregulates macrophage phagocytic as well as metabolic pathways leading to increased nitric oxide synthase activity. *S. platensis* may enhance the functions of mononuclear phagocytic system thereby increasing the disease resistance potential. Similarly,

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Spirulina supplementation at 10,000 ppm level also increased NK-cell activity by two-fold over the controls [14]. The studies shown that *Spirulina* supplementation increases several immunological functions implying that a dietary inclusion of *Spirulina* at a level of 10,000 ppm may enhance disease resistance potential in chickens. Mirzaie *et al.* [15] conducted supplementation of the heat-exposed broilers diet with Spirulina and found enhanced humoral immunity response.

Birds fed with *Spirulina* had a reduction in serum urea, suggesting that microalgae alone promoted a more efficient nitrogen utilization [16], thus contributing to a better balance between body protein synthesis and body protein degradation [17]. Another advantage of *Spirulina* feed is that birds fed *Spirulina* displayed increased antioxidant action because microalgae is a rich source of C-phycocyanin, an antioxidant pigment with hypolipidemic activity [18, 19].

Chicken Meat Colour: Meat colour is one of the most important factors used by customers to evaluate fresh meat products. Meat colour and taste are crucial factors driving consumers' meat choices. Dietary *Spirulina* is useful for the manipulation of chicken meat colour, especially as the range where the fillets produced by feeding *Spirulina* do not fall under the extremes of either dark or light meat. It was observed that *Spirulina*-fed breast filets were darker, redder and more yellow in colour which is s likely a result of the high amounts of carotenoids in the microalgae [20]. Toyomizu *et al.* [8] found that including *Spirulina* in broiler feeds influenced both the yellowness and redness of broiler meat. They reported that the increase of yellowness with dietary *Spirulina* content may be reflected in the common yellow pigment related to the accumulation of zeaxanthin within the meat. Dietary *Spirulina* is useful as a potent source for manipulation of chicken meat colour within the range where the fillets produced by feeding dietary *Spirulina* do not fall under the extremes of either dark or light meat. Dietary *Spirulina* levels at 1% of the total ration in the week prior to slaughter have been found to result in broiler muscle tissue pigmentation at levels best representing consumer preferences [21].

Chicken Meat Quality: Chicken meat is largely consumed around the world, with an increasing demand in recent years. It has been clearly demonstrated that the shelf-life of meat mainly depends on the storage conditions and the quality of meat, which is strictly connected to the life cycle of animals before slaughter. In general, meat is inclined to oxidative deterioration and, in particular, to lipid oxidation, which affects colour, flavour, odour, texture and nutritional value. The lipid oxidation is frequent in poultry due to the high content of polyunsaturated fatty acids (PUFA). Several studies focused on the effects of feed supplementation in improving the oxidative stability of the poultry tissue. Park *et al.* [22] reported that birds fed with *Spirulina* showed significantly lower drip loss as dietary levels of *Spirulina* increased. The effects on meat quality resulting from *Spirulina* protein in poultry diets are studied by Altmann *et al.* [20] *Spirulina*-fed samples were less metallic in flavour and the two alternative feed groups were softer and more tender than the control group. El-Bahr *et al.* [23] recommended supplementation of the *S. platensis* to broilers chickens' diet for improvement of performance parameters, profiles of fatty and amino acids, antioxidant status and meat quality. Similarly, Pestana *et al.* [24] investigated the effect of *Spirulina* as feed ingredient (15% of incorporation) in broiler diets and reported breast and thigh meats from chickens fed with *Spirulina*, with or without the addition of exogenous enzymes, had higher values of yellowness, total carotenoids and saturated fatty acids. Feeding broilers with Spirulina especially at 1% and 2% significantly reduced the serum levels of cholesterol, triglyceride and total lipid as compared with control [15]. Effect of dietary *Spirulina* in broiler chicken had enriched fatty acid profile of the thigh meat especially eicosapentaenoic acid and docosahexaenoic acid after *Spirulina* supplementation [25].

Egg Quality: Laying hen nutrition is essential to achieve the best egg production and to maintain the good health of the flock and special attention is paid to the source, content and quality of protein in feeds. Feeding the hens with *Spirulina* enhances the quality of eggs. Egg quality is an important aspect of poultry production and influences the profitability of production and consumer satisfaction. Mariey *et al*. [26] reported that dietary incorporation of 0.1%, 0.15% and 0.2% *Spirulina* increased the laying rate, egg weight and egg mass. *Spirulina* at a concentration of 0.3% is a functional natural feed additive to improve laying performance, egg quality and hepatoprotective activity of hens [27]. *Spirulina*-based diet increases the polyunsaturated fatty

acids (PUFAs) content and reduces amounts of cholesterol in eggs [28]. *Spirulina* feeding significantly increased the average egg weight, egg yolk colour, eggshell strength and iron content and reduced the cholesterol and triglyceride contents in eggs [29]. A diet containing 2.0%-2.5% of *Spirulina* significantly increased the egg yolk colour [26, 30]. It has been reported that a total of 115 kinds of flavour substances are revealed in eggs [31] and the flavour components of eggs mainly include the aldehydes and pyrazines in egg yolk and acetones and pyrazines in albumen [32]. Chen *et al.* [33] reported that 0.3% *Spirulina* feed diet, promoted the production performance of silkie laying hens and nutritive values and flavour of eggs. Saeid *et al.* [34] evaluated the effect of microalgae enriched with Cu(II) and Fe(II) supplementation on the performance, egg traits and microelements content of eggs of laying hens. The content of Fe, Zn and Mn in the egg albumen was higher in comparison with the control group, respectively by 860%, 113% and 195%. Egg shell strength was improved by 7.5% and the effect of lower number of cracked eggs (by 14%) was noted.

The total cholesterol content of eggs can be lowered by including *Spirulina* into layer hen rations. Total egg cholesterol also decreased from 12.9 to 9.9 mg/g when *Spirulina* was supplemented at a level of 0.3%. This is mainly attributable to *Spirulina*'s high antioxidant and omega-3 polyunsaturated fatty acid (PUFA) content that enriches the nutritional value of eggs at the expense of cholesterol content [35]. Chen *et al*. [36] also reported that the docosahexanoic acid of microalgae may inhibit the activity of 3-hydroxy-3-methylglutaryl-coenzyme A reductase by reducing cholesterol synthesis so that the serum cholesterol concentration decreases.

Egg choice by consumers is no longer only based on yolk cholesterol content or fatty acids profile but also on its color. In White Leghorn layer hens, dietary *Spirulina* levels of 3-9% of the total ration were found to result in egg yolk colours best representative of consumer preferences [37]. Omri *et al*. [38] reported that *Spirulina* had increased egg yolk redness from 1.33 to 12.67 and 16.19 and reduced the yellowness parameter from 62.1 to 58.17 and 55.87. Egg yolks from hens fed *Spirulina* were darker, more red and less yellow in colour than egg yolks from hens fed the control-diet. The effects of dietary *S. platensis* on egg yolk colour was studied by Zahroojian *et al*. [39] and the results indicated that the diet containing 2.5% *Spirulina* increased the egg yolk colour. The reason for coloration intensification is thought to be due to *Spirulina*'s high concentration of β-carotene [40].

CONCLUSION

Use of *Spirulina* as poultry feed have already shown improvements in productivity, meat and egg quality. Investigations into *Spirulina*'s active ingredients and associated biological pathways would aid in broadening our knowledge, scope and applicable ramifications in sustainable poultry production into the foreseeable future.

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