Global Veterinaria 22 (3): 139-143, 2020
ISSN 1992-6197

DOI: 10.5829/idosi.gv.2020.139.143

Dietary Supplementation of *Spirulina* on Health Status and Meat Quality of Rabbits

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Abstract: In this study, an attempt was made to explore the effects of *Spirulina* as animal feed for rabbit nutrition. This review illustrated the antioxidant effects, the anti-cholesterol effects, the immune responses, meat quality and the reproduction responses of rabbits supplemented with *Spirulina*. The demand for healthy meat product with low saturated fatty acid content and high-quality polyunsaturated fatty has increased in recent times and the anti-cholesterol effect of *Spirulina* in rabbits suggests its incorporation in animal feed. Reduction of reactive oxygen species in rabbits mediated by γ-linolenic acid content in the microalgae suggests the functional benefits of the microalgae. Also, *Spirulina* proves to be the sustainable animal feed in terms of improving growth and meat quality of rabbit.

Key words: Rabbit Meat, · Rabbit Farming · *Spirulina* · Animal Feed · Anti-Cholesterol

INTRODUCTION

The intensification of rabbit farming for meat production led rabbit farming to become a highly specialized, technically-advanced and unique livestock industry. Due to its digestive physiology, the rabbit can therefore exploit cellulose-rich feed converting about 20% of its protein into edible meat [1] and without competing with humans for food, thus being useful in the context of a sustainable livestock industry. The addition of dietary supplements to develop novel food products capable of improving animal health status and welfare has received particular attention [2]. The identification of new feed resources is therefore crucial for sustainable animal production and future viability. Ideally, the new feed resource should have high nutritive value and conversion efficiency, be able to optimize animal product quality and use land and water efficiently. The incorporation of microalgal biomass into feeds may provide vitamins, essential amino acids, polysaccharides, mono- and n-3 and n-6 polyunsaturated fatty acids, minerals and pigments. In particular, many nutritional and toxicological assessments have shown that microalgal biomass may be used as feed supplements [3]. Trials using dietary *Spirulina* in feed rations of many agriculturally significant animal species have already shown improvements in productivity, health and product quality.

The nutritive value of microalgae for livestock production is highly variable. Firstly, it depends on microalgae species and its chemical composition (e.g. protein, lipids, polysaccharides, vitamins, antioxidants and minerals) and secondly, on the adaptation of animal to the ingredient [4]. Sulfated polysaccharides in *Spirulina* extract can repair DNA damage, protect against oxidative and nitrative stress [5] and reduce the serum concentrations of interleukin and tumor necrosis factor-α. Phycocyanin ameliorates lipid peroxidation and inhibits the activities of inducible nitric oxide synthase and cyclooxygenase enzymes, as well as the synthesis of pro-inflammatory cytokines [6]. Sulfolipids inhibit DNA polymerase activity, decrease the phosphorus demand and inhibit the production of superoxide anion [7]. In this study, an attempt was made to explore the effects of *Spirulina* as animal feed for rabbit nutrition. Both positive and negative effects were studied in this review article.

Antioxidant Response in Rabbits Fed with *Spirulina*: Dietary supplementation of antioxidants is one of the most valid strategies for its management because oxidative stress is almost inevitable especially in animals due to increased energy requirement associated with growth and economic activities such as reproduction, milk and meat yield [8]. Microalgae are examples of natural

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sources of antioxidants for potential exploration because they contained modified metabolites of functional benefits suitable for improving quality of animal lives [9].

Spirulina minimized the nephrotoxic effects of amikacin through their antioxidant and anti-inflammatory activities [10]. Kim *et al.* [11] evaluated the effect of *Spirulina* supplementation on antioxidant status and oxidative DNA damage in hypercholesterolemia-induced rabbits. Supplementation with 5% *Spirulina* markedly increased the levels of glutathione, glutathione peroxidase, glutathione reductase and glutathione S-transferase activities in the liver by 213.5%, 145.3%, 166.7% and 132.4%. Daily consumption of *Spirulina* may reduce the susceptibility of lymphocyte DNA to oxidative damage induced by cholesterol-enriched diet in rabbits. Rabbits treated with S. *platensis* in dose 1g and 1.5g/kg diet resulted significant reduction in MDA and protein carbonyl levels and down regulation in GSH as well as in SOD levels [12]. In a study by Meineri *et al*. [13], *S. platensis* was able to reduce the ROS value in rabbits fed the high fat diet probably due to beneficial effect of the γ-linolenic acid content in the microalgae.

Immune response in rabbits fed with *Spirulina*: The immune stimulatory effect of *Spirulina* may be due to stimulation of the macrophage phagocytic activity, promotion of cytokine and antibody production, induction of NK cells accumulation in tissues and stimulation of maturation and mobilization of T and B cells [14]. Aladaileh *et al.* [12] explored the potential ameliorating role of dietary supplementation of different levels of *Spirulina platensis* to Pb-intoxicated rabbits. *Spirulina* decreased the total leukocyte count, particularly with regard to monocytes and lymphocytes in dose dependent manner. This reduction may be attributed to the fact that cellular differentiation and chemotactic processes were modified by the cyanobacteria during the development of Pb-induced inflammation, perhaps due to the suppression of proinflammatory cytokines. Even though there is very strong evidence suggesting the immunomodulatory of *Spirulina* and its extracts in rabbits, the active substances eliciting these responses have not been determined conclusively.

Anti-cholesterol effect in rabbits fed with *Spirulina*: The prevalence of animal protein and low fiber levels in the diet may increase the risk of cardiovascular disease and hypercholesterolemia. Algal extracts can activate the enzyme lecithin cholesterol acyltransferase which inhibits the biosynthesis of cholesterol and also plays an important role in the transverse cholesterol pathway when cells are unable to metabolize cholesterol. The enzyme increases the ability of HDL to stimulate the flow of cholesterol from cells to their receptors in the liver to decompose [15, 16]. The reduction in the triglyceride level of hyper-cholesterolemic rabbits treated with algal extract may be due to the presence of active compounds that activate lipoprotein lipase, which hydrolyzes triglyceride to fatty acid and glycerol in the liver [17]. The algal extract may also activate the cholesterol-lowering protein, cholesterol ester transfer protein, which transfers triglycerides to the VLDL molecule and then is destroyed in the liver, leading to a decrease in the serum triglyceride level [18].

Kata *et al.* [19] investigated the effect of the alkaloid extract of *Spirulina platensis* on the lipid profile of hypercholesterolemic male rabbits. Alkaloid extract of *Spirulina* succeeded in decreasing levels of total cholesterol, triglycerides and low-density lipoprotein and in increasing the level of high-density lipoprotein in the serum of rabbits. The effects of *Spirulina* on blood lipid profiles and the prevention of atherosclerosis in hypercholesterolemia induced rabbits were determined by Cheong *et al.* [20]. The serum total cholesterol and low-density lipoprotein cholesterol was decreased by 29.4% and 41.2% respectively in 5% *Spirulina* treated rabbits. Further, *Spirulina* supplementation remarkably improved the atheromatous lesions induced by hypercholesterolemia. The results suggest that *Spirulina* intake can cause the reduction of hyper-cholesterolemic atherosclerosis, associated with a decrease in levels of serum total cholesterol, triglyceride and low-density lipoprotein cholesterol and an elevation of high-density lipoprotein cholesterol level. In the study of Colla *et al*. [21] with rabbits, hypercholesterolemia was induced by a high cholesterol diet and the effects of feeding 0.5 g *Spirulina* for 30 and 60 days on the induced hypercholesterolemia was evaluated. The diet resulted in decrease of serum total cholesterol by 49% while HDL cholesterol was increased by 25%.

***Spirulina* on Rabbit Meat Quality:** Rabbit meat has a high nutritional value and is highly valued because of its dietary properties, since it is a lean meat with a low-fat content and less saturated fatty acid and cholesterol than other meats [22]. Rabbit meat is appreciated for its vitamin B_{12} content; considered the highest among all the most common animal meat species, for its low sodium, low cholesterol, with proteins providing 80% of its total energy value [23]. In addition, it is a good source of

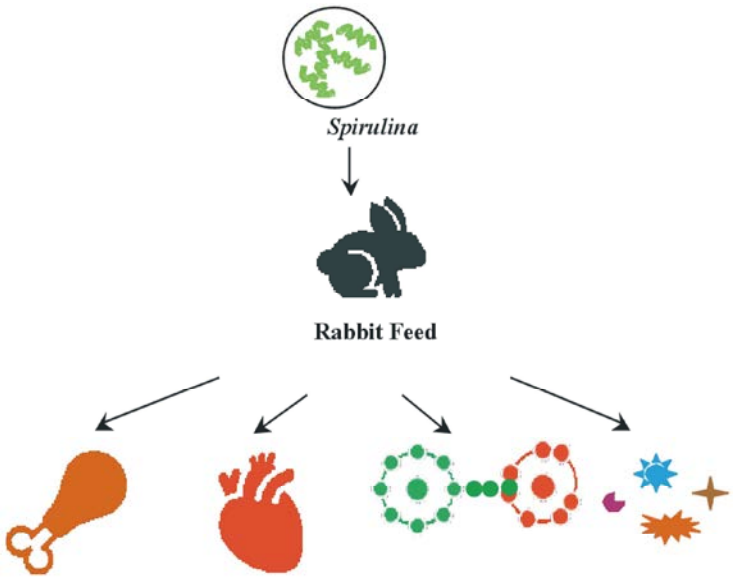

Fig. 1: Effect of S*pirulina* feed on rabbits

potassium, phosphorus and selenium. *Spirulina* due to its high crude protein content accounts for its use as protein supplement to rabbits grown for meat purposes [24]. To control the oxidative susceptibility of rabbit meat when its content in unsaturated fatty acids has been enhanced, the dietary incorporation of natural antioxidant compounds has been a widely studied strategy to ensure rabbit meat shelf-life [25].

Spirulina supplementation increased the linoleic acid and γ-linolenic acid content of rabbit meat as 48.2 % and 7.0 %, respectively [26]. In another study, *Spirulina* diet had a significant effect on redness and yellowness of *Longissimus dorsi* in rabbits [27]. *Spirulina* at 3% can be included in the diet of growing dwarf rabbits without affecting proper growth performance [28]. The dietary treatment can improve the fatty acid profile FA profile, especially γ-linolenic acid. Peiretti and Meineri [29] evaluated the effects of S. *platensis* based diets on the carcass characteristics and meat quality of rabbits. The poly unsaturated fatty acid content was higher in the fat of the rabbits fed diets supplemented with *Spirulina*. The meat of rabbits fed *Spirulina* supplemented diets presents lower atherogenic and thrombogenic indexes with consequent benefits on the nutritional quality of rabbit meat for consumers, mainly concerning the well known relationship between meat fat composition and human cardiovascular diseases.

Reproduction: Dietary supplementation with *Spirulina platensis* at 300 mg kg^{-1} diet had positive impact on reproductive performance of rabbit does used in breeding program [30]. Fouda and Ismail [31] recommended *S. platensis* at a level of 700 mg/buck as oral administration for 5 weeks period to be used in natural mating or artificial insemination. This also improved semen production of rabbit bucks and fertility of doe rabbits mated with these bucks.

Though the available literatures support the positive effects of *Spirulina* in rabbits (Fig. 1), there seems to be contrary findings in terms of growth performance. For example, *Spirulina* in growing rabbit diets did not exhibit substantial effects on growth performance or health status [32]. Similarly, Seyidoglu and Galip [33] reported that there were no significant differences occurred in growth performances and biochemical parameters in rabbits fed with S. *platensis*. In another study, supplementation of diets with *S. platensis* had no significant effect on the body length, body height, hearth girth, abdominal girth, fore canon length and thigh length of rabbits [34]. Hence, there continues to be more studies which are necessary to determine dietary concentration and the effects of S. *platensis* in rabbit growth.

CONCLUSION

Protein sources based on microalgae can provide production increases necessary for a stimulus in growth rate of the animal and satisfy meat consumers' expectations offering the best nutritional product, not detracting from being environmentally sustainable. Understanding rabbits respond to supplementation with

Spirulina would be vital in assessing the benefits of its inclusion in a rabbit ration. In this regard, *Spirulina* proves to be the sustainable animal feed in terms of improving growth and meat quality. The findings of this study recommend the effective supplementation rate of the algae in the diet of rabbit.

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