Global Veterinaria 22 (3): 160-165, 2020
ISSN 1992-6197

DOI: 10.5829/idosi.gv.2020.160.165

Enhancing Milk Quality, Animal Welfare and Meat Characteristics in Ruminants through *Spirulina* as a Feed Supplement

R.S. Pavan Kumar and G. Sibi

Department of Biotechnology,
Indian Academy Degree College-Autonomous, Bangalore, India

Abstract: A wide range of alternative feed sources have proved efficient in improving cattle and sheep (ruminants) performances with reducing feeding cost. Microalgae can be used as an economical unconventional animal feed source as they have the dual potential of biofuel feedstock and animal feed. Feeding natural antioxidant such as *Spirulina* could be advantageous to animal welfare and consumer safety. This review summarizes the research on *Spirulina* that can contribute to ruminant health and productivity. Dietary benefits resulted from consumption of milk produced by microalga fed cows improved human health due to increased concentrations of health promoting fatty acids. Enrichment of meat and milk products of ruminants has been more difficult to achieve due to the activity of ruminal microbes that alter unsaturated fat to form saturated fat whereas using *Spirulina* may lead to a more efficient and sustainable animal feed for dairy and sheep farming. However, the microflora in the rumen of ruminant play a role in the digestion of ration supplemented with microalga has proved an effective utilization of *Spirulina* as ruminant feed.

Key words: *Spirulina* · Ruminants · Cattle ration · Sheep · Milk quality · Antioxidant

INTRODUCTION

A sustainable animal diet should be balanced in all nutrients and free from harmful components to meet the production objectives and to generate safe animal products for human consumption for integrating the planet, people, profit and ethical dimensions of sustainability [1]. The increasing demand for animal protein will become dramatic in the coming decades, because dedicated soybean food crops the conventional feedstuff for animal feeding, will occupy an increasing fraction of arable land. Enrichment of meat and milk products of ruminants has been more difficult to achieve due to the activity of ruminal microbes that alter unsaturated fats to form saturated fats via the processes of lipolysis and biohydrogenation [2]. Despite this difficulty, some studies have successfully enriched ruminant milk and/or meat through dietary supplementation [3-6]. Microalgae may be regarded as a promising food or feed ingredient, owing to their nutritional features. A wide spectrum of biologically active compounds has been found in microalgal biomass in the form of protein, polyunsaturated fatty acids (PUFAs), pigments, vitamins and minerals, or as extracellular compounds [7]. Further microalgae can be used as an economical unconventional animal feed source, since they are very efficient in converting solar energy, are not dependent on external environmental conditions and characterized by higher productions per unit area than traditional crops. In addition, microalgae have the dual potential of biofuel feedstock and animal feed [8].

In this review, we summarize published research on *Spirulina* that can contribute to ruminant health and productivity. First, we present a description of research on cows fed with *Spirulina* supplementation and their applications. Second, we provide more details on *Spirulina* applications in sheep farming. This review provides new insights into the understanding of ruminant production and products and how the results of using *Spirulina* may lead to a more efficient and sustainable animal feed for dairy and sheep farming.

Dairy Farming

Milk Quality: Milk yield and milk quality (such as protein and fat content) are the most important economic traits in

Corresponding Author: G. Sibi, Head of the Department, Department of Biotechnology,
Indian Academy Degree College- Autonomous, Bangalore, India.

dairy production and are affected by multiple factors such as breed, genetic potential, lactation stage, nutrition, environment, management and disease. In recent years there has been increased interest in ways to manipulate the fatty acid composition of foods such as milk and milk products, because it contains a lot of health promoting components, such as n-3 fatty acids and conjugated linoleic acid. The high intake of n-3 PUFAs are able to reduce the risk factor of coronary heart disease, like the formation of blood clots leading to a heart attack. Great advances have been made in our knowledge of the roles that genetics, nutrition and management have played in milk production from dairy cows over the past century. This has increased milk yield for human consumption produced ever more efficiently. Modifications in ruminant diet can multiply concentrations of bioactive compounds (e.g., cis-9 trans-11 18:2 or omega-3 fatty acids) in dairy products. Methionine-rich feeds such as *Spirulina* had potential to improve milk production [9]. *Spirulina* had increased milk fat yield resulted in higher secretion of palmitic acid (16:0) in milk [10]. Microalgae is suitable protein feed for dairy cows, though the protein value is likely lower than that of rapeseed meal [11]. *Spirulina* increased glucose and unsaturated fatty acids profile (C18:1, C18:2 and C20:1), while it decreased saturated fatty acid content of milk from Holstein cow [12]. Similarly, dietary *Spirulina* decreased saturated fatty acids, whereas it increased monounsaturated and polyunsaturated fatty acids [13]. Poti *et al.* [14] investigated the effect of these microalga as fat supplement on fatty acid profile of cow milk. *Spirulina* supplements considerably increased rumenic acid concentration in milk (0.75% *vs*. 0.85%). The n-3 fatty acids were higher in milk (0.47 *vs*. 0.56) and in addition the n-6/n-3 ratio was also more favorable in the microalga supplemented groups (4.18 *vs*. 3.36). It was found that cows receiving 200 g of *Spirulina* daily in the diet had 21% increase in their milk yield [15]. As a result, consumers have dietary benefits from consumption of nutraceutical milk by microalga fed cows due to increased concentrations of health promoting fatty acids, which improve the human health (Fig-1). Simkus *et al*. [16] investigated the potential influence of *Spirulina platensis* on the milk production and serological parameters in Lithuanian Black-and-White cows. In cows fed *Spirulina*, the average amount of milk fat increased by 17.6-25.0%, the average milk protein increased by 9.7% and amount of lactose increased by 11.7% compared to controls. In addition, diet supplementation with 29.1% of *Spirulina platensis* reduced the amount of somatic cells in milk. Further, in *Spirulina*-fed cows, the mean amount of hemoglobin increased by 8.9% and the erythrocyte count increased by 13.1%.

Animal Welfare: A major goal for the dairy industry now and in the future is to achieve more balanced breeding goals that not only emphasize production traits but also take into account health, welfare and environmental sustainability traits. Garces *et al.* [17] evaluated the effects of *Spirulina* supplementation on oxidative stress, immunity and productive performance during the transition period by grazing dairy cattle. Body weight and body condition score and total antioxidant capacity were not affected by *Spirulina* supplementation. At the same time, cows supplemented with *Spirulina* during the transition period had a tendency to increase the concentration of IgG in the colostrum and the percentage of lactose in milk. Similarly, Ponce *et al*. [18] reported that *Spirulina* supplementation had increased IgG concentration in colostrum of grazing dairy cattle.

Phycocyanin from *Spirulina fusiformis* is a potent profibrinolytic protein in the calf vascular endothelial system [19]. Sodium spirulan is a sulfated polysaccharide was isolated from the blue-green alga *Spirulina platensis* could inhibited bovine aortic vascular endothelial cell proliferation accompanied with suppression of whole protein synthesis but without non-specific cell damage [20].

Protein supplementation typically increases the silage intake and milk production of dairy cows [21, 22]. However, supplementation of *Spirulina* showed no effect on ruminal internal environment of dairy cow, whereas it could significantly increase the ruminal degradation of fiber in diet and decreased the ruminal degradation of the diet crude protein [23].

Sheep Farming: Livestock, mainly sheep and goats, rearing is the mainstay of the land and most of the rural population depends on their by-products. Due to the increasing rate of rangeland degradation and economic instability at the international level, livestock feeding has faced serious difficulties in relation to the quantitative and qualitative provision of nutrients and this is exacerbated by the continuous increase of feedstuffs' prices. A wide range of alternative feed sources and some natural compounds proved efficient in improving sheep and goat performances and or reducing feeding cost. Numerous studies have investigated the effects of supplementing *Spirulina* in sheep (Fig-1) [diets 24-28].

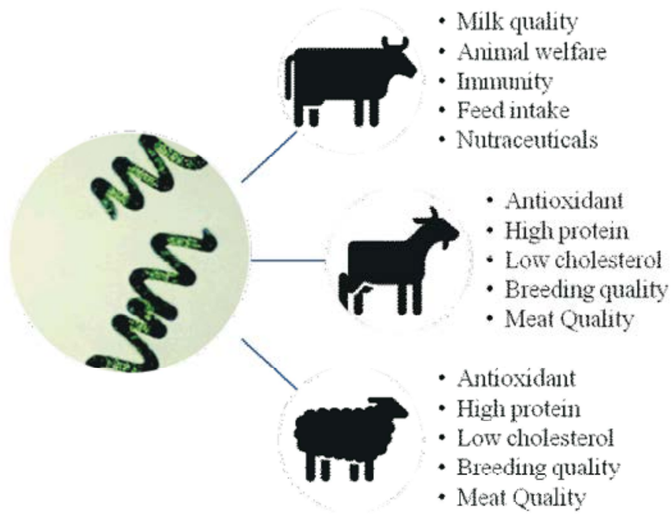

Fig. 1: Effects of *Spirulina* feed in ruminants

Antioxidant Activity: The high metabolic rate during intensive feeding is accompanied by an increased production of free radicals and any imbalance between production of these molecules and their safe disposal may culminate in oxidative stress, which can damage cells and tissues [29]. Interestingly, feeding natural, rather than synthetic, antioxidant could be advantageous to animal welfare and consumer safety [30, 31]. *Spirulina* supplementation can be incorporated into the diets of fattening lambs as an antioxidant, immuno-stimulant and growth promoter [32]. In lambs, it increased the levels of vitamin A and GSH but decreased the oxidant production specially the lipid peroxide malondialdehyde (MDA). The antioxidant function of *Spirulina* is related to phycocyanin, polysaccharides, α-tocopherol and β-carotene, because these active ingredients can act as potent antioxidants and inhibit the lipid peroxidation mediated by reactive oxygen species [33]. The antioxidant enzymes including glutathione peroxidase (GPx) and superoxide dismutase (SOD) and catalase (CAT) activities, the total antioxidant capacity (T-AOC) content in the serum and liver increased significantly when lambs fed diets supplemented with *Spirulina* [34].

Biochemical Properties: Malau-Aduli and Holman [28] found that high concentrations of *Spirulina* (10%) increased the ratio of albumin to globulin in lambs. It was also demonstrated that *Spirulina* supplementation does not negatively impact lamb health and productivity. *Spirulina* supplementation influenced serum biochemical characteristics in Hu sheep [34]. The serum concentrations of cholesterol, triacylglycerol and high-density lipoprotein cholesterol significantly decreased. Results from El-Sabagh *et al.* [32] indicated that *Spirulina* could be incorporated in the diets of fattening lambs as an antioxidant, immune-stimulant and growth promoter. *Spirulina* improved final live body weight, daily live weight gain, feed intake and feed conversion ratio. Also, hemoglobin, total white blood cell count, serum globulin, vitamin A and reduced glutathione were higher while the aspartate amino transferase, alanine amino transferase, cholesterol, glucose and serum malondialdehyde levels were lower.

Breeding Quality: *Spirulina* supplementation improved the Australian dual-purpose lamb live weights [25]. Body conformation measurements and growth increased with an increase in the level of *Spirulina* supplementation, particularly under simulated drought conditions than during typical pasture grazing with significant interactions with sire breed and sex of lambs. Similarly, Holman *et al.* [24] evaluated the effects of varying levels of *Spirulina* supplementation, sire breed and gender on live weight and body conformation traits. Lambs fed 10% *Spirulina* levels obtained the highest mean live weight. Highly significant sire breed interactions with *Spirulina* level resulted in the heaviest and lightest average live weights in Black Suffolk-sired crossbreds and purebred Merino lambs respectively, supplemented with 20% *Spirulina* level. The findings identified the usefulness of *Spirulina* as a supplement and the optimal sire breed choice for the best performance response that is cost-effective when using dietary protein-rich supplements for their dual-purpose prime lamb operations.

Meat Quality: Meat with superior eating qualities and healthier nutritional composition commands a higher price that consumers are generally prepared to pay. Traditionally, the fat content of meat has been considered as an important source of essential fatty acids and as a calorie-dense nutrient. There are two types of factors that influence both type and composition of lipids in animal products: extrinsic and intrinsic factors. Modification of animal diets using bioactive feed supplements such as *Spirulina* is one strategy for producing such foods [35]. Kashani *et al*. [26] investigated the effect of level of *Spirulina* supplementation on the fatty acid compositions of subcutaneous adipose, longissimus dorsi muscle, kidney, heart and liver tissues in purebred and crossbred Australian Merino sheep. Their results demonstrated significant variations in the growth and the body conformation traits and tissue and organ FA composition in response to the *Spirulina* supplementation. *Spirulina* treatment at 100 ml/head/day significantly increased the omega (ω)-3 and ω-6 polyunsaturated fatty acid (PUFA) composition in all tissues and organs. Further, the compositions of longissimus and heart muscles were favourably improved in lambs as *Spirulina* supplement produced the lowest levels of palmitic acid and highest levels of linoleic acid and ω-6 PUFA. The authors also assessed the effect of dietary *Spirulina* supplementation levels on the mRNA expression patterns of genes controlling lipid metabolism in the subcutaneous adipose tissue (SAT) and Longissimus dorsi muscle of Australian crossbred sheep [27]. The *Spirulina* supplementation level was 200ml/head/day in the ratio of 2g of *Spirulina* powder:10mL of water or 20% wt/vol) resulted in a decrease in intramuscular fat content in due to the enhanced production of melatonin in sheep muscle tissues and strong up-regulation of mRNA expression of B-*cell translocation gene 2* (BTG2) in SAT which negatively affected fat deposition. In contrast, low *Spirulina* supplementation level strongly up-regulated the Adrenergic beta-3 receptor (ADRB3) and Fatty acid synthase (FASN) genes responsible for fat production with higher long-chain PUFA content.

CONCLUSION

Alternative feed resources such as microalgae could improve cow and sheep health, performances and the quality of their products. Investigations on microalgae feed warrants the effective utilization of microalgae in ruminant nutrition. However, it may be noted that the lower acceptability of microalgae by animals might be caused by the taste and odour properties, nutritive characteristics or physical structure of dry powdery microalgae. Further, role of ruminant microflorain digestion of microalga feed to be considered for the effective utilization of *Spirulina* as ruminant feed.

REFERENCES

1. Makkar, H.P.S. and P. Ankers. 2014. Towards sustainable animal diets: A survey-based study. Anim. Feed Sci. Technol., 198: 309-322.
2. Lourenço, M., E. Ramos-Morales and R.J. Wallace. 2010. The role of microbes in rumen lipolysis and biohydrogenation and their manipulation. Animal, 4: 1008-1023.
3. Bichi, E., G. Hervas, P.G. Toral, J.J. Loor and P. Frutos, 2013. Milk fat depression induced by dietary marine algae in dairy ewes: Persistency of milk fatty acid composition and animal performance responses. Journal of Dairy Science, 96: 524-532.
4. Boeckaert, C., B. Vlaeminck, J. Dijkstra, A. Issa-Zacharia, T. Van Nespen, W. Van Straalen and V. Fievez, 2008. Effect of dietary starch or micro algae supplementation on rumen fermentation and milk fatty acid composition of dairy cows. Journal of Dairy Science, 91: 4714-4727.
5. Moate, P.J., S. Williams, M. Hannah, R. Eckard, M. Auldist, B. Ribaux, J.L. Jacobsans and W.J. Wales, 2013. Effects of feeding algal meal high in docosahexaenoic acid on feed intake, milk production and methane emissions in dairy cows. Journal of Dairy Science, 96: 3177-3188.
6. Stamey, J.A., D.M. Shepherd, M.J. de Veth and B.A. Corl, 2012. Use of algae or algal oil rich in n-3 fatty acids as a feed supplement for dairy cattle. Journal of Dairy Science, 95: 5269-5275.
7. Vidanarachchi, J.K., M.S. Kurukulasuriya, A.M. Samaraweera and K.F. Silva, 2012. Applications of marine nutraceuticals in dairy products. Advances in Food and Nutrition Research, 65: 457-478.
8. Lum, K.K., J. Kim and X.G. Lei, 2013. Dual potential of microalgae as a sustainable biofuel feedstock and animal feed. J. Anim. Sci. Biotechnol., 4: 53.
9. Lamminen, M., A. Halmemies-Beauchet-Filleau, T. Kokkonen, A. Vanhatalo and S. Jaakkola, 2019. The effect of partial substitution of rapeseed meal and faba beans by *Spirulina platensis* microalgae on milk production, nitrogen utilization and amino acid metabolism of lactating dairy cows. Journal of Dairy Science, 102: 7102-7177.

10. Lamminen, M., A. Halmemies-Beauchet-Filleau, T. Kokkonen, S. Jaakkola and A. Vanhatalo, 2019. Different microalgae species as a substitutive protein feed for soya bean meal in grass silage based dairy cow diets. Animal Feed Science and Technology, 247: 112-126.
11. Lamminen, M., A. Halmemies-Beauchet-Filleau, T. Kokkonen, I. Simpura, S. Jaakkola and A. Vanhatalo, 2017. Comparison of microalgae and rapeseed meal as supplementary protein in the grass silage-based nutrition of dairy cows. Animal Feed Science and Technology, 234: 295-311.
12. Christaki, E., M. Karatzia, E. Bonos, P.F. Paneri and C. Karatzias, 2011. Dietary *Spirulina* in dairy cows. Current Opinion in Biotechnology, 22: s40.
13. Christaki, E., M. Karatzia, E. Bonos, P. Florou Paneri and C. Karatzias, 2012. Effect of dietary *Spirulina platensis* on milk fatty acid profile of dairy cows. Asian Journal of Animal and Veterinary Advances, 7: 597-604.
14. Poti, P., F. Pajor, A. Bodnar, K. Penksza and P. Koles, 2015. Effect of micro-alga supplementation on goat and cow milk fatty acid composition. Chilean J. Agric. Res., 75: 259-263.
15. Kulpys, J., E. Paulauskas, V. Pilipavicius and R. Stankevicius, 2009. Influence of cyanobacteria *Arthrospira* (*Spirulina*) *platensis* biomass additive towards the body condition of lactation cows and biochemical milk indexes. Agronomy Research, 7: 823-835.
16. Simkus, A., V. Oberauskas, R.J. Laugalis, R. Zelvyte, I. Monkeviciene, A. Sedervicius, A. Simkiene and K. Pauliukas, 2007: The effect of weed *Spirulina platensis* on the milk production in cows. Veterinarijair Zootechnika, 38: 60.
17. Garces, C.N., D. Vela, A. Mullo, V. Cabezas, A. Alvear and C.H. Ponce, 2018. *Spirulina* supplementation during the transition period by grazing dairy cattle at tropical highland conditions. Tropical Animal Health and Production, 51: 477-480.
18. Ponce, C.H., D. Vela, A. Mullo, V. Cabezas and A. Alvear, 2017. Effect of level of *Spirulina* supplementation on oxidative stress, immunity, productive performance and reproductive parameters during the transition period by grazing dairy cattle. Journal of Animal Science, 95: 271-272.
19. Madhyastha, H.K., K.S. Radha, M. Sugiki, S. Omura and M. Maruyama, 2006. Purification of c-phycocyanin from *Spirulina fusiformis* and its effect on the induction of urokinase-type plasminogen activator from calf pulmonary endothelial cells. Phytomedicine, 13: 564-569.
20. Kaji, T., Y. Fujiwara, C. Hamada, C. Yamamoto, S. Shimada, J.B. Lee and T. Hayashi, 2002. Inhibition of cultured bovine aortic endothelial cell proliferation by sodium spirulan, a new sulfated polysaccharide isolated from *Spirulina platensis*. Planta Medica, 68: 505-509.
21. Allen, M.S., 2000. Effects of diet on short-term regulation of feed intake by lactating dairy cattle. J. Dairy Sci., 83: 1598-1624.
22. Huhtanen, P., M. Hetta and C. Swensson. 2011. Evaluation of canola meal as a protein supplement for dairy cows: a review and a meta-analysis. Can. J. Anim Sci., 91: 529-543.
23. Zhang, J., S. Miao, S. Huang, S. Li, J.Z. Zhang, S.J. Miao, S. Huang and S.L. Li, 2010. Effect different levels of *Spirulina* on ruminal internal environment and degradation of fibre in dairy cows. China Cattle Science, 36: 32-36.
24. Holman, B.W.B., A. Kashani and A.E.O. Malau-Aduli, 2012. Growth and body conformation responses of genetically divergent Australian Sheep to *Spirulina* (*Arthrospira platensis*) supplementation. American Journal of Experimental Agriculture, 2: 160-173.
25. Holman, B.W.B., A. Kashani and A.E.O. Malau-Aduli, 2014. Effects of *Spirulina* (*Arthrospira platensis*) supplementation level and basal diet on liveweight, body conformation and growth traits in genetically divergent Australian dual-purpose lambs during simulated drought and typical pasture grazing. Small Ruminant Research, 120: 6-14.
26. Kashani, A., B.W. Holman, P.D. Nichols and A.E.O. Malau-Aduli, 2015. Effect of dietary supplementation with *Spirulina* on the expressions of AANAT, ADRB3, BTG2 and FASN genes in the subcutaneous adipose and Longissimus dorsi muscle tissues of purebred and crossbred Australian sheep. Animal Feed Science and Technology, 57: 1-8.
27. Kashani, A., B.W.B. Holman, P.D. Nichols and A.E.O. Malau-Aduli, 2015. Effect of level of *spirulina* supplementation on the fatty acid compositions of adipose, muscle, heart, kidney and liver tissues in Australian dual-purpose lambs. Annals of Animal Science, 15: 945-960.
28. Malau-Aduli, A.E.O. and B.W.B. Holman, 2015. Effect of *Spirulina* supplementation on plasma metabolites in crossbred and purebred Australian Merino lambs. International Journal of Veterinary Science and Medicine, 3: 13-20.
29. Lykkesfeldt, J. and O. Svendsen, 2007. Oxidants and antioxidants in disease: Oxidative stress in farm animals. Vet. J., 173: 502-511.

30. Call, D.R., M.A. Davis and A.A. Sawant, 2008. Antimicrobial resistance in beef and dairy cattle production. Anim. Health Res. Rev., 9: 159-167.
31. Makkar, H.P.S., G. Francis and K. Becker, 2007. Bioactivity of phytochemicals in some lesser-known plants and their effects and potential applications in livestock and aquaculture production systems. Animal, 1: 1371-1391.
32. El-Sabagh, M.R., M.A. AbdEldaim, D.H. Mahboub and M. Abdel-Daim, 2014. Effects of *Spirulina platensis* algae on growth performance, antioxidative status and blood metabolites in fattening lambs. Journal of Agricultural Science, 6: 92-98.
33. Riss, J., K. Decorde, T. Sutra, M. Delage, J.C. Baccou, N. Jouy, J.P. Brune, H. Oreal, J.P. Cristol and J.M. Rouanet, 2007. Phycobiliprotein C-phycocyanin from *Spirulina platensis* is powerfully responsible for reducing oxidative stress and NADPH oxidase expression induced by an atherogenic diet in hamsters. Journal of Agricultural and Food Chemistry, 55: 7962-7967.
34. Liang, Y., Y. Bao, X. Gao, K. Deng, S. An, Z. Wang, X. Huang, D. Liu, Z. Liu, F. Wang and Y. Fan, 2020. Effects of *Spirulina* supplementation on lipid metabolism disorder, oxidative stress caused by high-energy dietary in Hu sheep. Meat Science, pp: 108094.
35. Doreau, M., D. Bauchart and Y. Chilliard, 2010. Enhancing fatty acid composition of milk and meat through animal feeding. Anim. Prod. Sci., 51: 19-29.