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ROLE OF PROBIOTICS TO CONTROL GUT-RELATED DISEASES IN ANIMALS

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Abstract – The role of probiotics is significant for both human and animal health and is also involved in several functional applications and the creation of animal foods. The various types of research showed that the potential of probiotics is significant in several fields. However, a growing research interest in their application and benefits in ruminant production has been established. For the development of livestock breeding, different procedures are used, and the expectation of breeders is that probiotics show promising effects, including enhancing the growth rate of livestock, showing protective effects against various pathogens, and increasing production. Their application helps to achieve beneficial effects that are comparable to those of antibiotic-based growth stimulators banned on January 1st, 2006. Thus, the livestock expects that the use of probiotics, prebiotics, and symbiotics will enable better maintenance of the equilibrium of the intestinal microbiota of livestock to prevent disease in both their animals and the end consumer.

Keywords: Probiotics, Microorganisms, Ruminant applications.

INTRODUCTION

Probiotics are microorganisms that possess several beneficial effects for humans or other animals when taken in adequate quantity. These beneficial effects are usually secondary to their interaction with the existing microbiome. The diverse and complex communities of microbes in both probiotic cultures and the microbiome include viruses, fungi, bacteria, and protozoa, which produce their effects on the digestive system and other bodily systems through different intrinsic and extrinsic factors. Some of these actions on the digestive materials and the digestive tract, when added to the gut microbiome, include increasing the diversity of species within the gut and increasing the level of different vitamins and co-factors for use by the host. Because of these beneficial effects, probiotics are gaining popularity and are now used in conjunction with other therapies to treat gastrointestinal disorders such as inflammatory bowel diseases in both humans and animals.

METHODS

This paper followed clear methods in the development of a narrative review. The authors utilized the major papers which have come out on the topics of probiotics and prebiotics since 1996. These papers were chosen based on the number of times they were cited and their relevance to the topic of ruminant health and production. Papers were found utilizing key search terms of "Ruminant", "Production", and "Probiotics" or "Prebiotics" on search engines including Google, PubMed, and EBSCO. Papers were excluded based on availability in the English language, status of peer review, public access, and generalizability to the topic.

THE GUT MICROBIOME AND ITS ROLE IN RUMINANT HEALTH

Several research studies have been performed to better understand and characterize the gut microbiota and its role in ruminant health and nutrition. The rumen microbiota varies between individual animals and can be influenced by animal age, health status, and environmental factors. These microbiological populations can further be modified by the introduction of probiotics, which can assist with digestion and protection from harmful pathogens[1]. The dairy cow study found that there are several microbial communities present in the rumen of the cows, with around 100 billion bacteria such as species of *Prevotella*, *methanogens,* and *Methanobrevibacter* and protozoa such as *Fibrobacter*[2]. The main microbial groups that exist in the rumen are *Megasphaera fortune*, *Lactobacillus*, *Streptococcus*, *Selenomonas,* and *Prevotella*[3]. These gut microbes play a significant role in the fermentation and digestion of dietary polysaccharides by the host[4]. Based on this and other research, there is a growing interest in the application of beneficial microbes to ruminant production to aid in balancing the gut microbiota and as a possible alternative to antibiotic use. One study demonstrated a number of benefits with the use of oral administration of probiotics in ruminants, which include the regulation and balance of gut microbes, the promotion of growth and development of the animals, and improved resistance against disease-causing pathogens[5]. Additional studies suggest that the utilization of probiotics as feed supplements improves growth performance and production and enhances the overall health and well-being of the animals.

PROBIOTICS AND PREBIOTICS

In ruminants, subgroups of *Bacillus genera*, *Lactobacillus*, *Enterococcus*, *Streptococcus*, and *Pediococcus* can be used as probiotics. The most common probiotics product used commercially is live yeast (*Saccharomyces cerevisiae*)[6]. Because of the different natures of the mature and developing gut, the use of fungal and yeast probiotics has better efficacy in adult ruminants, whereas, in claves, the efficacy of bacterial species is better[7]. Several routes can be utilized for the administration of probiotics, including transdermal, oral, intraintestinal, and vaginal. Of the aforementioned routes, the most common route of administration is through the oral cavity[8]. In the study by Deng et al[9], periparturient cows underwent an intra-vaginal infusion procedure for probiotics administration containing lactic acid bacteria.

Prebiotics are non-digestible ingredients in food that can affect the growth of one strain or a number of strains of bacteria within the digestive tract. These indigestible compounds can also influence other portions of the GI's upper and lower GI tract. In the case of the upper gastrointestinal tract, these prebiotics can change the rates of digestion, slow gastric activity, reduce the absorption of glucose, and stimulate the release of intestinal peptide hormones. The main prebiotics used in animal diets are carbohydrates and oligosaccharides; non-digestible oligosaccharides used include oligofructose, inulin, lactulose, galactooligosaccharides, and trans-galacto-oligosaccharides[10-12]. When prebiotics and probiotics are ingested in combination, their synergistic effects minimize the number of food-borne pathogens and can, as a result, improve the overall health of the animal[13].

APPLICATION OF PROBIOTICS IN RUMINANTS

Studies have shown that direct-fed or probiotic bacteria introduction of *Lactobacillus* and *Bifidobacteria* improved milk production, growth, and immune response in dairy cows, beef cattle, neonatal calves, and periparturient cows[14-16]. Furthermore, probiotic supplementations decrease ruminal acidosis in feedlot cattle and dairy cows while simultaneously increasing feed intake and improving feed efficiency[17,18]. Probiotics have also demonstrated increased quality and milk yield. However, there are limited studies on the effect of probiotics on beef cattle compared to the research conducted on dairy cows.

PROBIOTICS IN GOAT PRODUCTION

Probiotics have also been used as functional food supplements in goat production. *Lactobacillus reuteri* DDL 19 and *Enterococcus faecium* DDE 39 are commercial probiotics products that consist of a single strain or a mixture of strains. These products function by improving the number of *bifidobacteria* and *lactobacillus acidophilus* in the gut, leading to an increase in goats' body weight and the production of milk[19,20]. The same bacterial strains can also be utilized in the creation of fermented milk products as they alter the physical characteristics of goat milk when cultured with *bifidobacteria*[21]. *Lactobacillus* ME-3 can be used for the fermentation of goat milk and, when tested on animals, this species not only reduced the level of lipoprotein peroxidized but also reduced the level of isoprostanes and increased the antiatherogenic properties in the resultant milk products without changing the quality of the milk product's sensory quality (i.e., smell and taste)[22,23].

PROBIOTICS IN SHEEP

The role of probiotics has also been demonstrated in the care of sheep. The probiotics have shown promise in enhancing the digestion of animal feed and improving the health of the sheep's digestive tracts. *Aspergillus oryzae* and *Saccharomyces cerevisiae*, two important probiotics tested in sheep, do not affect the net microbial flow of protein and the digestibility of nitrogen in the duodenum[24]. These same species were also shown to improve plant cell wall degradation in the whole digestive tract through secondary stimulation of digestion at the rumen level, as indicated by the higher activity of the solid-adherent bacteria in the rumen[24]. *Bacillus subtilis* and *Bacillus licheniformis* are given in ewes at late pregnancy and lactation, which decreases the gastrointestinal tract motility in young lamb and can improve growth speed[25]. The fat content and production of milk per ewe are enhanced with the use of probiotics. When the mixture of probiotics, containing *Enterococcus faecium*, S*treptococcus thermophilus*, *Lactobacillus lactis* and *bulgaricus*, *helveticus*, and *acidophilus, is* given to infected sheep with a non-shiga O-157 toxin-producing *Escherichia coli* (an illness caused by eating contaminated meat) there is a reduction in fecal shedding of the pathogen demonstrating and improvement in the overall health of the sheep and improved strength of their immune response to the pathogens[26]. A summary table of the review discussions is included below in Table 1.

CONCLUSIONS

Scientific reports confirm that probiotics and prebiotics can increase animal health by protecting against pathogens. Combinations of probiotic and prebiotic components have even greater efficiency when used as a symbiotic formula as compared to the individual components alone. Probiotics and prebiotics have additional utility in creating and modifying consumable, market-level grocery products by utilizing the microbiological populations within the supplements to alter the chemical production of necessary acids and nutrients within the milk products. Since the best formula for the creation of this synergetic effect between probiotics and prebiotics is not currently known, future research should focus on the optimal selection of appropriate probiotic and prebiotic components.

Ethics Approval and Consent to Participate

Not applicable due to the type of study.

TABLE 1. SUMMARY OF REVIEW FINDINGS.

Animal Type	Intervention	Benefit
Cattle Subtype: Dairy cows, Beef cattle, Neonatal calves, and Periparturient cows	Introduction of *Lactobacillus* and *Bifidobacteria*	Improved milk production, growth, and immune response[13-16].
Cattle Subtype: Feedlot cattle and Dairy cows	Probiotic supplementation	Decreased ruminal acidosis, increased feed intake, and improved feed efficiency[17-18].
Cattle Subtype: Dairy cows	Probiotic supplementation	Increased quality of milk and increased milk yield[13-18].
Goat Subtype: Dairy Goats	Probiotic supplementation with *Lactobacillus reuteri* DDL 19 and *Enterococcus faecium* DDE 39	Increase body weight and in the milk production[19-20].
Goat Subtype: Dairy Goats	*Lactobacillus* ME-3	Reduced levels lipoprotein peroxidized, reduced levels isoprostanes, and increased antiatherogenic properties in fermented diary products[22].
Sheep Subtype: Ewes in late pregnancy and during lactation	*Bacillus subtilis* and *Bacillus licheniformis*	Decreased motility in young lambs[24].
Sheep Subtype: Individuals infected with a non-shiga O-157 toxin-producing *Escherichia coli*	*Enterococcus faecium*, *Streptococcus thermophilus*, *Lactobacillus lactis* and *bulgaricus*, *helveticus*, and acidophilus	Reduced fecal shedding of the pathogen[25-26].

Consent for Publication

Not applicable.

Availability of Data and Materials

Not applicable.

Conflict of Interest

The authors declare they have no conflict of interest.

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The authors affirm that the production of the submitted work did not use any AI-assisted technology.

Authors' Contributions

UL, TCV, MA, MI, RZ, TK, SA, GS, FAO, MA, CMZ, & ZIM contributed to writing the manuscript; UL, TCV, MA, MI, RZ, TK, SA, GS, FAO, MA, CMZ, & ZIM contributed to the editing and revision process; CMZ & ZIM contributed to overseeing and organizing the project.

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REFERENCES

1. Liong MT. Probiotics: a critical review of their potential role as antihypertensives, immune modulators, hypocholesterolemics, and perimenopausal treatments. Nutr Rev 2007; 65: 316-328.
2. Wallace RJ, Newbold CJ. Microbial feed additives for ruminants. In: Fuller R, Heidt P, Rusch V, van der Waaij D. Probiotics: Prospects of Use in Opportunistic Infections. Herborn-Dill: Institute for Microbiology and Biochemistry; 1995. pp. 101-125.
3. Mackie R, Aminov B, White C, McSweeney C. Molecular ecology and diversity in gut microbial ecosystems. In: Cronjé PB, editor. Ruminant Physiology: Digestion, Metabolism, Growth, and Reproduction. London: CAB International; 2000. pp. 61-77.
4. Zoetendal EG, Collier CT, Koike S, Mackie RI, Gaskins HR. Molecular ecological analysis of the gastrointestinal microbiota: a review. J Nutr 2004; 134: 465-472.
5. Xu H, Huang W, Hou Q, Kwok LY, Sun Z, Ma H, Zhao F, Lee YK, Zhang H. The effects of probiotics administration on the milk production, milk components and fecal bacteria microbiota of dairy cows. Sci Bull (Beijing) 2017; 62: 767-774.
6. Anadón A, Martínez-Larrañaga MR, Aranzazu Martínez M. Probiotics for animal nutrition in the European Union. Regulation and safety assessment. Regul Toxicol Pharmacol 2006; 45: 91-95.
7. Kruis W, Frič P, Pokrotnieks J, Lukáš M, Fixa B, Kaščák M, Wolff C, Schulze, J. Maintaining remission of ulcerative colitis with the probiotic Escherichia coli Nissle 1917 is as effective as with standard mesalazine. Gut 2004; 53: 1617-1623.
8. Schrezenmeir J, de Vrese M. Probiotics, prebiotics, and synbiotics--approaching a definition. Am J Clin Nutr 2001; 73(2 Suppl): 361S-364S.
9. Deng Q, Odhiambo JF, Farooq U, Lam T, Dunn SM, Ametaj BN. Intravaginal probiotics modulated metabolic status and improved milk production and composition of transition dairy cows. J Anim Sci 2016; 94: 760-770.
10. Whitley NC, Cazac D, Rude BJ, Jackson-O'Brien D, Parveen S. Use of a commercial probiotic supplement in meat goats. J Anim Sci 2009; 87: 723-728.
11. Gaggìa F, Mattarelli P, Biavati B. Probiotics and prebiotics in animal feeding for safe food production. Int J Food Microbiol 2010; 141 Suppl 1: S15-28.
12. Patterson JA, Burkholder KM. Application of prebiotics and probiotics in poultry production. Poult Science 2003; 82: 627-631.
13. Bomba A, Nemcová R, Gancarcíková S, Herich R, Guba P, Mudronová D. Improvement of the probiotic effect of micro-organisms by their combination with maltodextrins, fructo-oligosaccharides and polyunsaturated fatty acids. Br J Nutr 2002; 88 Suppl 1: S95-S99.
14. Adjei-Fremah S, Ekwemalor K, Asiamah E, Ismail H, Worku M. Transcriptional profiling of the effect of lipopolysaccharide (LPS) pretreatment in blood from probiotics-treated dairy cows. Genom Data 2016; 10: 15-18.
15. Worku M, Adjei-Fremah S, Ekwemalor K, Asiamah E, Ismail H. 0130 Growth and transcriptional profile analysis following oral probiotic supplementation in dairy cows. Journal of Animal Science 2016; 94(Suppl 5): 61.
16. Adjei-Fremah S, Ekwemalor K, Asiamah EK, Ismail H, Ibrahim S, Worku M. Effect of probiotic supplementation on growth and global gene expression in dairy cows. Journal of Applied Animal Research 2017; 3: 1-7.
17. Stein DR, Allen DT, Perry EB, Bruner JC, Gates KW, Rehberger TG, Spicer LJ. Effects of feeding propionibacteria to dairy cows on milk yield, milk components, and reproduction. J Dairy Sci 2006; 89: 111-125.
18. Kyriakis SC, Tsiloyiannis VK, Vlemmas J, Sarris K, Tsinas AC, Alexopoulos C, Jansegers L. The effect of probiotic LSP 122 on the control of post-weaning diarrhoea syndrome of piglets. Res Vet Sci 1999; 67: 223-228.
19. Poppy GD, Rabiee AR, Lean IJ, Sanchez WK, Dorton KL, Morley PS. A meta-analysis of the effects of feeding yeast culture produced by anaerobic fermentation of Saccharomyces cerevisiae on milk production of lactating dairy cows. J Dairy Sci 2012; 95: 6027-6041.
20. Apás AL, Dupraz J, Ross R, González SN, Arena ME. Probiotic administration effect on fecal mutagenicity and microflora in the goat's gut. J Biosci Bioeng 2010; 110: 537-540.
21. Zhang T, McCarthy J, Wang G, Liu Y, Guo M. Physiochemical properties, microstructure, and probiotic survivability of nonfat goats' milk yogurt using heat-treated whey protein concentrate as fat replacer. J Food Sci 2015; 80: M788-94.

22. Ranadheera CS, Evans CA, Adams M, Baines SK. Co-culturing of probiotics influences the microbial and physico-chemical properties but not the sensory quality of fermented dairy drinks made from goats' milk. Small Ruminant Research 2016; 136: 104-108.
23. Kullisaar T, Songisepp E, Mikelsaar M, Zilmer K, Vihalemm T, Zilmer M. Antioxidative probiotic fermented goats' milk decreases oxidative stress-mediated atherogenicity in human subjects. Br J Nutr 2003; 90: 449-456.
24. Jouany JP, Mathieu F, Senaud J, Bohatier J, Bertin G, Mercier M. Effect of Saccharomyces cerevisiae and Aspergillus oryzae on the digestion of nitrogen in the rumen of defaunated and reunited sheep. Animal Feed Science and Technology 1998; 75: 1-13.
25. Kritas SK, Govaris A, Christodoulopoulos G, Burriel AR. Effect of Bacillus licheniformis and Bacillus subtilis supplementation of ewe's feed on sheep milk production and young lamb mortality. J Vet Med A Physiol Pathol Clin Med 2006; 53: 170-173.
26. Rigobelo EE, Karapetkov N, Maestá SA, Avila FA, McIntosh D. Use of probiotics to reduce faecal shedding of Shiga toxin-producing Escherichia coli in sheep. Benef Microbes 2015; 6: 53-60.