Chapter 05

Beneficial Effects of Probiotics on the Animal Production Cycle: An Overview of Clinical Impacts and Performance

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ABSTRACT

Livestock is a significant source of income for small-scale farming and agriculture. The primary element of livestock farming, which has drawn extra attention for enhancing animal performance, is feed. Numerous studies have been conducted to enhance feed utilization by incorporating feed additives. Antibiotics have long been a common addition to livestock diets to promote growth. The search for substitute feed additives has gotten more intense since they are prohibited in many countries. Probiotics are substitutes that are known to be safe for animals. It has been demonstrated that probiotic use of probiotics in livestock has been demonstrated to enhance immunity, productivity, and animal health. Probiotics increased feed conversion rate, nutrient digestibility, and the rumen microbial ecosystem to improve growth performance. The purpose of this review article is to discuss the role of probiotics in livestock production. This paper reviews the beneficial effects of probiotics on the animal production cycle, encompassing aspects of growth promotion, disease prevention, feed efficiency, and environmental sustainability. Probiotics exert their effects through mechanisms such as competitive exclusion of pathogens, modulation of the gut microbiota, enhancement of nutrient absorption, and modulation of immune responses. In poultry production, probiotics have been shown to improve growth performance, reduce the incidence of digestive disorders, and enhance resistance to pathogens such as *Salmonella* and *Campylobacter*. This review attempts to discuss the potential roles of probiotics on productive performance, health, digestive system and immune system of animals.

KEYWORDS
Animal health, Digestibility, Disease prevention, Livestock

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INTRODUCTION

Probiotics, defined as live microorganisms that confer health benefits when administered in adequate amounts, have emerged as valuable tools in optimizing animal production cycles across various agricultural sectors (WHO, 2001). Probiotics, which are classified as non-pathogenic microorganisms, are now frequently added to livestock feed. By maintaining a healthy gastrointestinal environment and enhancing intestinal function, their use aims to improve production performance and disease prevention (Chaucheyras-Durand et al., 2008; Mountzouris et al., 2009).

Antibiotics have been utilized for a very long time in animal husbandry, both as treatments for bacterial infections and as growth promoters (Beyene, 2016). Breeders are under increasing pressure to find alternative, more environmentally friendly techniques due to the ban on using antibiotics as growth promoters and the negative effects of overusing them, such as antibiotic resistance and the presence of antibiotic residues in food and the environment (AMCRA, 2020). From long time nutritionists are interested to manipulate the microbial environment of the rumen to improve feed utilization, thereby improving animal production and health and, in recent years, the safety and quality of ruminant food products. Antimicrobial resistance has emerged as a result of the therapeutic use of these antibiotics in animals as a result, antimicrobial medications are less effective in treating human illnesses and can potentially spread antibiotic resistance to humans (Prestinaci et al., 2015). For this reason, probiotics are thought to be a great alternative to antibiotics or antimicrobial agents in the fields of animal health and livestock production.

Probiotics have been the subject of numerous studies suggesting that they may have a significant impact on breeding as a potential replacement for conventional antibiotics or as a straightforward supplement with positive effects on growth (Nikoskelainen et al., 2003; Biavati et al., 2018). Probiotics are beneficial microorganisms that, when taken in sufficient amounts, can change the microflora in the gut of the host leading to better health (Rook and Brunet, 2005). Several types of bacteria (mainly Lactic acid and Non-Lactic Acid Bacteria), yeasts (milk strains) or fungi can be considered probiotics (Tripathi et al., 2008). The traditional uses of probiotics to improve gut health, such as reducing lactose intolerance, boosting intestinal immunity to infections, reducing traveler's diarrhea, and relieving bloating, have been extensively studied and documented (Tellez et al., 2001). Probiotic studies have been conducted in pets, equine and livestock, with chickens and pigs being the main focus of the research. Clinical studies have shown that probiotics can improve the growth of a variety of domestic animals, including cows, newborn calves, piglets and broilers (Kurtoglu et al., 2004).

Beneficial Effects of Probiotics for Livestock

Probiotics enhance growth rate and feed conversion efficiency (Haddad and Goussous, 2005). They also strengthen defense against infectious diseases (Collado et al., 2007; Vanderpool, 2008; Yan and Polk, 2010), improve nutritional absorption and digestion (Soren et al., 2013), and enhance the quality and yield of milk (Kritas et al., 2006; Reklewska et al., 2000). Additionally, probiotics reduce contamination and improve carcass quality (Abdelrahman and Hunaiti, 2008). Probiotics offer numerous benefits, including enhanced nutrient absorption and digestibility, accelerated growth and productivity (Soren et al., 2013), and the inhibition of disease-causing organisms. They help prevent bacterial infection-related diarrhea, reduce stress following vaccination, antibiotic therapy, and travel, and stimulate the immune system (Collado et al., 2007; Vanderpool, 2008). Regular and sensible intake of probiotics significantly impacts the immune system by increasing the production of natural interferons and immunoglobulins, and stimulating cell-mediated immunity (Koenen et al., 2004). The strain should possess the ability to confer advantageous effects on the host animal, such as heightened growth or resilience against illnesses. It must not be harmful or pathogenic. It must exist as live cells, ideally in big quantities. It must be able to survive and undergo metabolism in the gastrointestinal tract; for instance, it must be resistant to low pH and organic acids. It must be stable and able to endure extended periods of time in both field and storage conditions (Ezema, 2013).

Table 1: Microorganisms used as probiotics and their beneficial effect in animals

Genus	Species	Benefits in livestock	References
	L. acidophilus	Reduced scouring	(Retta, 2016)
	L. casei	Improved feed intake	(Rahimoon et al., 2023)
	L. rhamnosus	Enhanced live weight gain	(Fooks and Gibson, 2002)
Lactobacillus	*L. reuteri Bacillus*		(Lodemann et al., 2006)
	L. plantarum		(Seo et al., 2010)
	L. fermentum		
	L. brevis		
	L. helveticus		
	L. delbruckei		
	L. gallinarum		
	L. salivarius		
	B. subtilis	Incease in live weight gain	(Kritas et al., 2006)
	B. cereus	Enhanced milk production	(Qiao et al., 2009)
Bacillus	*B. toyoi*	increased ruminal digestibility	
	B. natto		
	B. mesentericus		
	B. licheniformis		
	B. bifidum	Increased feed efficiency and Reduced	(Abe et al., 1995)
Bifidobacterium	*B. pseudolongum*	incidence of diarrhea.	
	B. breve		
	B. thermophilum		
	S. cerevisiae	enhanced humoral immunity	(Roos et al., 2010)
Saccharomyces	*S. boulardii*		
Aspergillus	*A.oryzae*	Improved feed intake	(Beharka et al., 1991)
	A. niger	Live weight gain	
Enterococcus	*E. faecium*	Increased production of milk	(Nocek and Kautz, 2006)
Streptococcus	*S. thermophiles*	Improved feed intake	(Retta, 2016)
		Reduced scouring	
Pediococcus	*P. acidilactici*	Deffence against Salmonellosis	(Rahimoon et al., 2023)
Lactococcus	*L. lactis*	Deffence against Salmonellosis	(Rahimoon et al., 2023)

Mode of Action of Probiotics

Probiotics may function through the following mechanisms, according to theories: (1) production of anti-pathogenic compounds; (2) competition for nutrients; (3) immune system stimulation; and (4) competition for colonization sites. Antagonism with the pathogen by immunomodulation of the host and prevention of bacterial toxin production (Isolauri et al., 2001; (Guillot, 2003). While yeasts are specifically linked to the final two mechanisms, lactic bacteria are typically responsible for the first three. Probiotic bacteria differ in how they act depending on the host and strain; therefore, combining probiotics with various modes of action may increase the range of protection offered by biotherapeutic preparations (Lima-Filho et al., 2000).

Other action such as bacterial probiotics produce organic acids that can lower the pH of the stomach in monogastric animals improving the environment for the microbiota living there and decreasing the likelihood of pathogen colonization (lactic or acetic acid). It has been demonstrated that some bacteria are capable of producing enzymes that can hydrolyze bacterial toxins or of emitting antimicrobial peptides like bacteriocins, which can stop the growth of harmful bacteria. The ability of certain probiotics to metabolize inhibitory substances like amines or nitrates and assist in their detoxification is crucial for the anaerobic ecology of the gut (Jouany et al., 2008).

Role and Impact of Probiotics on Animal Production

An early increase in the animal's ability to digest and absorb its food has been associated with a change in the makeup of the bacteria that live in the rumen. A higher forage intake can improve live weight gain, milk output, and fat contents of milk, but in dairy cows, the effects are frequently negligible (Cammack et al., 2018). Probiotics have been linked to a decrease in coliform bacteria in newborn calves, according to numerous studies, indicating that they are crucial for establishing and preserving a balanced microbiota in dairy cattle, probiotics can improve milk production. *Enterococcus faecalis, Bacillus sublitis*, and *Saccharomyces cerevisiae* are examples of probiotic microorganisms that can improve milk secretion (Ma et al., 2020). Probiotics have the ability to increase the body weight of ruminants. One probiotic combination that was taken from a fine goat and fed to other goats for about two months included *Lactobacillus reuteri* DDL 19, *Lactobacillus alimentarius* DDL 48, *Enterococcus faecium* DDE 39, and B*ifidobacterium bifidum* DDBA. As a result, the goat's standard bodyweight increased by 9% (Apás et al., 2010). Numerous studies have demonstrated that probiotics have no effect on a carcass's dressing percentage, marbling score, yield grade, or quality grade. Yet, hot carcass weight was generally greater when probiotics were incorporated into the diet. Nonetheless, compared to heifers not given the probiotic, those given a Propionibacterium probiotic both during the receiving and finishing stages had a higher percentage of carcasses graded (Filho-Lima et al., 2000). Increased production of volatile fatty acids, nutrient digestibility, feed conversion rate, and stimulation of lactic acid-dependent protozoa were used to confirm that probiotics improved growth performance (Abd El-Tawab et al., 2016). Probiotics have been used to boost milk production, decrease diarrhea in both pigs and cattle, and prevent Salmonella from colonizing chickens' digestive tracts. They have also been used to improve the efficiency with which feed is utilized (Bernardeau and Vernoux, 2013). According to a study, probiotics improved performance. Sheep that were allowed to graze in the trials showed increased feed intake and growth. Certain animals were classified as having "high" performance (Seo et al., 2010). A small ruminant study found that in a single trial, the number of "low" emitters per unit of feed intake may increase, and it was confirmed in a follow-up trial that these differences in growth rate, nutrient digestibility, and fermentation persisted when the same type of diet was fed (Oetzel et al., 2010).

Role and Impact of Probiotics on Animal Health

Probiotics have been used as livestock feed supplements. Initially, the idea behind adding them to feed was to boost the animal's resistance to illness, thereby promoting growth and overall health (Kesarcodi-Watson et al., 2008). Probiotics have a proven ability to treat a variety of diseases such as cancer prevention, intestinal health enhancement, orodental disease, or hypercholesterolemia (Kechagia et al., 2013). However, these probiotics must be able to be used against other conditions, including lactose intolerance, acute diarrhea, and antibiotic-associated diarrhea. (Nazir et al., 2023). In the first twenty-four hours following feeding, yeast cultures can accelerate the breakdown of rumen fiber, thereby increasing the amount of fodder consumed by ruminants. Moreover, a correlation has been observed between reduced incidence of diarrhea and higher rates of Lactobacillus loss. On the other hand, when animals experience stress, the Lactobacillus population declines, and infant diarrhea becomes more prevalent. Performance responses are probably not as important as reducing the prevalence of diarrhea, which is particularly common in young pre-ruminants (especially within the first three weeks of life). Beef calves must endure several hardships prior to joining the feedlot, such as weaning, transport, fasting, assembly, immunization, castration, and dehorning (Jouany et al., 2008).

Probiotic supplements have been demonstrated in a few recent studies to improve gut microbiota, lower pathogen shedding and disease symptoms, boost gut immunity, and enhance health and disease resistance in animals (Cao et al., 2019, Chaves et al., 2017, Yang et al., 2015; Vendrell et al., 2008; Sorroza et al., 2013). Probiotics also have an antagonistic effect on foodborne pathogens like Salmonella, *Clostridium perfringens, Escherichia coli, Listeria monocytogenes*, and *Staphylococcus aureus*, as well as the capacity to regulate the gut microflora (Van Immerseel et al., 2006; Giannenas et al., 2012; Jungersen et al., 2014)

Role of Probiotics on Digestive System of Livestock

Probiotics help maintain a healthy balance between beneficial and pathogenic bacteria in the stomach, intestine, and cecum, which speeds up an animal's rate of digestion and makes it easier for absorb nutrients. Additionally, they will help broilers' body weight, digestibility of amino acids, and capacity to be stimulated by calcium be improved (Bai et al., 2013). Probiotics can increase the digestibility of food by increasing the activity of the host's digestive tracts enzymes.

Probiotics provide digestible proteins, vitamins, enzymes, and other cofactors; they also produce lactic acid, which aids in better digestion, nutritional metabolism, and nutrient utilization. The amylase, protease, and lipase content of lactic acid contributes to better feed conversion efficiency by facilitating better feed digestion and absorption of fat, protein, and carbohydrates (Awad et al., 2009). Probiotics improve the host's ability to digest food by boosting the activity of digestive enzymes in the GIT. *Lactobacillus acidophilus*, for instance, is present in probiotic feed that has been shown to increase dry matter intake, daily feed conversion efficiency, and apparent digestibility of nutrients in buffalo calves when compared to the control group (Sharma et al., 2018). In animals, probiotics speed up the digestive process. In broilers, probiotics can improve the composition of cecal microorganisms and the way they digest nutrients (Khalid et al., 2021).

Role of Probiotics in the Immune System

Probiotics have a variety of ways to strengthen the host's immunity. Probiotics have been shown in numerous studies to have immunostimulatory properties (Bilal et al., 2021; Kong et al., 2020; Punetha et al., 2018; Terada et al., 2020). *Lactobacillus fermentum* and *Saccharomyces cerevisiae* probiotics stimulated the gut T-cell immunity, as evidenced by the increased production of CD3+, CD4+, and CD8+ T-lymphocytes in the chicken gastrointestinal tract (Bai et al., 2013). When fed food containing probiotics *Lactobacillus jensenii* TL2937 and *Lactobacillus gasseri* TL2919, the expression of CD3+, IL-2, and IFN-γ genes was higher in the small intestine of neonatal chicks that were three and seven days old (Sato et al., 2009). In chickens, probiotics can also raise serum immunoglobulin levels. IgA and IgM serum levels were increased in chickens by a probiotic feed supplement that included *Lactobacillus acidophilus, Bacillus subtilis*, and *Clostridium butyricum* (Zhang and Kim, 2014).

Lactic acid bacteria, or LABs, have the ability to produce a wide variety of antimicrobial compounds that prevent pathogenic invasions. Defensins, organic acids, bacteriocins, ethanol, carbon dioxide, and diacetyl are a few examples of antimicrobial peptides (AMPs) (Liao and Nyachoti, 2017). It has been demonstrated that organic acids such as lactic acid, formic acid, and short-chain fatty acids can suppress potentially harmful microbes that are significant for farm animals. Lactic acid is the primary byproduct of glucose metabolism that can be produced by Lactobacillus bacteria (Russo et al., 2017).

Table 2: Major beneficial effects for probiotics used in livestock (Ahasan et al., 2015, Newbold, 2006)

Animal	Common benefits
Cattle	Increase in efficiency of feed
	enhancing health and preventing acidosis
	Increase milk yield and quality
	Promote weight gain
Young ruminants	Promote maturation of rumen microflora
	Minimize the colonization of pathogen within the body
	Boosting the safety of digestion during weaning
Equine	improved digestibility of the diet
	Reducing diarrhea in foals
	Prevent digestive disorders such as Colic
	Reduce stress in a racing horse
Poultry	Maintain intestinal microbiota healthy.
	Increased weight gain
	Enhance broiler carcass/meat
	Adjust the immune response
	Risk reduction of salmonellosis in layers
Pig	Enhance milk quality and quantity, as well as colostrum quality.
	Boost the vitality and size of the litter
	Reduce the occurence of diarrhea by increasing piglet weight
	Increase meat quality, digestibility, and feed efficiency
	Minimize constipation

Conclusion

Probiotics enhance the health and performance of livestock, which ultimately benefits their productivity. Probiotics help to enhance digestion by lowering clinical and subclinical acidosis, raise ruminal pH, and enhance the ecology of ruminal microflora. Probiotics improve the quality and quantity of milk and meat produced, as well as the growth of many domestic animals. Additionally, probiotics have the potential to defend animals from infections and strengthen the immune system. In simple words use of probiotics enhance production of livestock by enhancing health, digestion and immune system. Particular probiotic strains need to be carefully chosen for each species of animal in a given environment in order to avoid

any potential harm. Since every probiotic has a unique behavior, it is crucial to determine the ideal circumstances in a given setting for a probiotic to flourish, colonize, multiply, and benefit the host animals. It is important to have a comprehension knowledge of the immunomodulatory impacts of different probiotics and their viability prior to adding probiotics to farm animals' dietary feed. Furthermore, comprehensive studies that are dependent on dosage should be carried out, and molecular testing at a reliable laboratory should be used to confirm the identity of the organisms. Before creating thorough guidelines for the safe and efficient use of probiotics, more research is required.

Ethics Approval

This study did not require an ethics license.

REFERENCES

Abd El-Tawab, M.M., Youssef, I.M., Bakr, H.A., Fthenakis, G.C. and Giadinis, N.D. (2016) Role of probiotics in nutrition and health of small ruminants. *Pol Journal Veterinary Science*, 19, 893–906.

Abdelrahman, M. M., and Hunaiti, D. A. (2008). The effect of dietary yeast and protected methionine on performance and trace minerals status of growing Awassi lambs. *Livestock Science*, 115(2-3), 235-241.

Abe, F., Ishibashi, N., and Shimamura, S. (1995). Effect of administration of bifidobacteria and lactic acid bacteria to newborn calves and piglets. *Journal of Dairy Science*, 78(12), 2838-2846.

Ahasan, A.S.M.L., Agazzi, A., Invernizzi, G., Bontempo, V., and Savoini, G. (2015). The Beneficial Role of Probiotics in Monogastric Animal Nutrition and Health. *Journal Dairy, Veterinary and Animal Research,* 2.

AMCRA. (2020) Centre de Connaissances Concernant L'utilisation des Antibiotiques et L'antibiorésistance Chez les Animaux. Retrieved on 13/09/2020. Available from: https://www.amcra.be/fr/antibiotiques-et-antibioresistance.

Apas, A. L., Dupraz, J., Ross, R., Gonzalez, S. N., and Arena, M. E. (2010). Probiotic administration effect on fecal mutagenicity and microflora in the goat's gut. *Journal of Bioscience and Bioengineering,* 2010. 06. 005.

Awad, W.A., Ghareeb, K., Abdel-Raheem, S., and Böhm, J. (2009). Effects of dietary inclusion of probiotic and symbiotic on growth performance, organ weights, and intestinal histomorphology of broiler chickens. *Poultry Science*, 88, 49–56.

Bai, S. P., Wu, A. M., Ding, X. M., Lei, Y., Bai, J., Zhang, K. Y., and Chio, J. S. (2013). Effects of probiotic-supplemented diets on growth performance and intestinal immune characteristics of broiler chickens. *Poultry Science*, 92(3), 663-670.

Beharka, A. A., Nagaraja, T. G., and Morrill, J. L. (1991). Performance and ruminal function development of young calves fed diets with Aspergillus oryzae fermentation extract. *Journal of Dairy Science*, 74(12), 4326-4336.

Bernardeau, M. and Vernoux, J.P. (2013) Overview of differences between microbial feed additives and probiotics for food regarding regulation, growth promotion e_ects and health properties and consequences for extrapolation of farm animal results to humans. *Clinical Microbiology Infection*, 19, 321–330.

Beyene, T. (2016) Veterinary drug residues in food-animal products:Its risk factors and potential effects on public health. *Journal Veterinary Science Technology*, 7(1):1–7.

Biavati, B., and Mattarelli, P. (2018). The Bifidobacteria and Related Organisms. Cambridge: Academic Press; Related genera within the family Bifidobacteriaceae; pp. 49–66.

Bilal, M., Si, W., Barbe, F., Chevaux, E., Sienkiewicz, O., and Zhao, X. (2021) Effects of novel probiotic strains of Bacillus pumilus and Bacillus subtilis on production, gut health, and immunity of broiler chickens raised under suboptimal conditions. *Poultry Science Journal,* 2020. 11. 048

Camilleri, G.M., Verger, E.O., Huneau, J.F., Carpentier, F., Dubuisson, C., and Mariotti, F. (2013) Plant and animal protein intakes are differently associated with nutrient adequacy of the diet of French adults. *Journal Nutrition*, 143(9):1466–1473.

Cammack, K. M., Austin, K. J., Lamberson, W. R., Conant, G. C., and Cunningham, H. C. (2018). RUMINNAT NUTRITION SYMPOSIUM: Tiny but mighty: the role of the rumen microbes in livestock production. *Journal of Animal Science*, 96(2), 752-770.

Cao, L., Yang, X.J., Li, Z.J., Sun, F.F., Wu, X.H., and Yao, J.H. (2012) Reduced lesions in chickens with Clostridium perfringens-induced necrotic enteritis by Lactobacillus fermentum 1. 20291. *Poultry Science*, 91(12):3065–3071.

Chaucheyras-Durand, F., Walker, N.D., and Bach, A. (2008) Effects of active dry yeasts on the rumen microbial ecosystem: past, present and future. *Animal Feed Science Technology,* 145: 5-26.

Chaves, B.D., and Brashears, M.M., (2017) Nightingale K.K. Applications and safety considerations of Lactobacillus salivarius as a probiotic in animal and human health. *Journal Applied Microbiology*, 123(1):18–28.

Collado, M.C., Meriluoto, J., and Salminen, S. (2007) In vitro analysis of probiotic strain combinations to inhibit pathogen adhesion to human intestinal mucus. *Fd Research Inter*, 40(5):629-636.

Ezema, C. (2013) Probiotics in animal production: A review. Journal of Veterinary Medicine and Animal Health. Vol. 5(11), pp. 308-316.

Food and Agriculture Organization, (2009). Forum D'experts de Haut Niveau L'agriculture Mondiale àl'horizon 2050, 12-13 Octobre. Rome, Italy: Food and Agriculture Organization.

Fooks, L.J., and Gibson, G.R. (2002) Probiotics as modulators of the gut flora. *British Journal Nutrition,* 88: S39-S49.

Fuller, R. (1989) Probiotics in man and animals. *Journal Applied Bacteriology*, 66, 365-378.

Jouany, J.P., (2008). "Effect of live yeast culture supplementation on apparent digestibility and rate of passage in horses fed a high-fiber or high-starch diet.," *Journal of Animal Science*, vol. 1;86, no. (2):339, p. 47.

Giannenas, I., Papadopoulos, E., Tsalie, E., Triantafillou, E., Henikl, S., Teichmann, K., and Tontis, D. (2012) Assessment of dietary supplementation with probiotics on performance, intestinal morphology and microflora of chickens infected with Eimeria tenella. *Veterinary Parasitology*, 188(1-2):31–40.

Guillot, J.F., (2003) Probiotic feed additives. *Journal Veterinary Pharmacology Thereonology*, 26: 52-55.

Haddad, S.G., and Goussous, S.N. (2005) Effect of yeast culture supplementation on nutrient intake, digestibility and growth performance of Awassi lambs. *Animal Feed Science Technology,* 118: 343-348.

Harimurti, S., and Hadisaputro, W. (2015) Beneficial Microorganisms in Agriculture, Aquaculture and Other Areas. Cham: Springer; Probiotics in poultry; pp. 1–19.

Heredia, N. and García, S. (2018) Animals as sources of food-borne pathogens: A review. *Animal Nutrition*, 4, 250 255.

Isolauri, E., Sutas, Y., Kankaanpaa, P., Arvilommi, H. and Salminen, S., (2001) Probiotics: Effects on immunity. *America Journal Clinical Nutrition*, 73: 444-450. PMID: 11157355.

Jungersen, M., Wind, A., Johansen, E., Christensen, J., Stuer-Lauridsen, B., and Eskesen, D. (2014). The science behind the probiotic strain Bifidobacterium animalis subsp. *lactis BB-12® Microorganisms*, 2(2):92–110.

Kesarcodi-Watson, A., (2008) "Probiotics in aquaculture: the need, principles and mechanisms of action and screening processes.," *Aquaculture*. , vol. 31, no. 274(1), pp. 1-4.

Kechagia, M., Basoulis, D., Konstantopoulou, S., Dimitriadi, D., Gyftopoulou, K., Skarmoutsou, N., and Fakiri, E. M. (2013). Health benefits of probiotics: a review. *International Scholarly Research Notices*, (1), 481651.

Khalid, A. H., Ullah, K. S., Naveed, S., Latif, F., Pasha, T. N., Hussain, I., and Qaisrani, S. N. (2021) Effects of spray dried yeast (Saccharomyces cerevisiae) on growth performance and carcass characteristics, gut health, cecal microbiota profile and apparent ileal digestibility of protein, amino acids and energy in broilers. *Tropical Animal Hea and Production*, 11250-021- 02684-5

Koenen, M.E., Kramer, J., van der Hulst, R., Heres, L., Jeurissen, S.H. and Boersma, W.J. (2004) Immunomodulation by probiotic lactobacilli in layer- and meat-type chickens. *Br. Poultry Science*, 45: 355-366.

Kong, Y., Gao, C., Du, X., Zhao, J., Li, M., Shan, X., and Wang, G. (2020) Effects of single or conjoint administration of lactic acid bacteria as potential probiotics on growth, immune response and disease resistance of snakehead fish (Channa argus). *Fish and Shellfish Immunology,* 2020. 05. 003

Kritas, S.K., Govaris, A., Christodoulopoulos, G., and Burriel, A.R. (2006) Effect of Bacillus licheniformis and Bacillus subtilis Supplementation of Ewe's Feed on Sheep Milk Production and Young Lamb Mortality. *Journal Veterinary Medicine A Physiology Pathology Clinicla Medicine,* 53(4): 170-173.

Kurtoglu, V., Kurtoglu, F., Seker, E., Coskun, B., Balevi, T. and Polat, E.S., (2004) Effect of probiotic supplementation on laying hen diets on yield performance and serum and egg yolk cholesterol. *Food Addition Contam*, 21: 817-823.

Liao, S. F., and Nyachoti, M. (2017) Using probiotics to improve swine gut health and nutrient utilization. *Journal Animal Nutrition*, 06. 007.

Filho-Lima, J. V. M., Vieira, E. C., and Nicoli, J. R. (2000). Antagonistic effect of Lactobacillus acidophilus, Saccharomyces boulardii and Escherichia coli combinations against experimental infections with Shigella flexneri and Salmonella enteritidis subsp. typhimurium in gnotobiotic mice. *Journal of Applied Microbiology*, 88(3), 365-370.

Lodemann, U., Hubener, K., Jansen, N., and Martens, H. (2006) Effects of Enterococcus faecium NCIMB 10415 as probiotic supplement on intestinal transport and barrier function of piglets. *Archive Animal Nutrition,* 60: 35-48.

Ma, Z. Z., Cheng, Y. Y., Wang, S. Q., Ge, J. Z., Shi, H. P., and Kou, J. C. (2020) Positive effects of dietary supplementation of three probiotics on milk yield, milk composition and intestinal flora in Sannan dairy goats varied in kind of probiotics. *Journal Animal Physiology and Animal Nutrition,* (berlin).

Mountzouris, K.C., Balaskas, C., Xanthakos, I., Tzivinikou, A., and Fegeros, K. (2009) Effects of a multi-species probiotic on biomarkers of competitive exclusion efficacy in broilers challenged with Salmonella enteritidis. *Br Poultry Science,* 50: 467-478.

Nazir, S., Rasheed, M., Fatima, O., Raazi, E. T., and Fayyaz, M. (2023). Probiotics, An Approach towards Modern Medication. *Journal of Zoo Biology*, 6(1).

Nikoskelainen, S., Ouwehand, A.C., Bylund, G., Salminen, S., and Lilius, E.M. (2003) Immune enhancement in rainbow trout (Oncorhynchus mykiss) by potential probiotic bacteria (Lactobacillus rhamnosus). *Fish Shellfish Immunology*, 15(5):443–452.

Nocek, J. E., and Kautz, W. P. (2006). Direct-fed microbial supplementation on ruminal digestion, health, and performance of pre-and postpartum dairy cattle. *Journal of Dairy Science*, 89(1), 260-266.

Oetzel, G.R., Emery, K.M., Kautz, W.P. and Nocek, J.E., (2007) Direct-fed microbial supplementation and health and performance of pre- and postpartum dairy cattle: A field trial. *Journal Dairy Science*, 90: 2058-2068.

Prestinaci, F., Pezzotti, P. and Pantosti, A. (2015) Antimicrobial resistance: A global multifaceted phenomenon. *Pathology Glob Health*, 109, 309–318.

Punetha, M., Roy, A. K., Ajithakumar, H. M., Para, I. A., Gupta, D., Singh, M., and Bharati, J. (2018) Immunomodulatory effects of probiotics and prilled fat supplementation on immune genes expression and lymphocyte proliferation of transition stage Karan Fries cows. *Veterinary World*, 2018. 209- 214

Qiao, D., Ke, C., Hu, B., Luo, J., Ye, H., Sun, Y. and Zeng, X. (2009). Antioxidant activities of polysaccharides from Hyriopsis cumingii. *Carbohydrate Polymers*, 78(2), 199-204.

Newbold, C.J., (2006) "Dietary additives to control methanogenesis in the rumen.," International congress series. Elsevier.,

vol. 1293, pp. 138-147.

Rahimoon, Mohsen, M., Mirani. A.H., Sahito, J.K., Bhutto, A.L., Khoso, P.A., Leghari, R.A., Kaka, A., et al. (2023). "Ameliorative effect of probiotics used in animals: A comprehensive review." Pure and Applied Biology (PAB) 13, no. 2 (2023): 179-193.

Reklewska, B., Ryniewicz, Z., Krzyzewski, J., Karaszewska, A., Goralczyk, M., Nalecz-Tarwacka, T., and Strzalkowska, N. (2000) Dietary manipulation of milk protein content in goats. Annals Warsaw Agricultural University, *Animal Science*, pp 133-143.

Retta, K. S. (2016). Role of probiotics in rumen fermentation and animal performance: a review. *International Journal of Livestock Production*, 7(5), 24-32.

Rook, G.A., and Brunet, L.R. (2005) Microbes, immunoregulation, and the gut. *Gut,* 54: 317-320.

Roos, T. B., Tabeleão, V. C., Dümmer, L. A., Schwegler, E., Goulart, M. A., Moura, S. V., and Gil-Turnes, C. (2010). Effect of Bacillus cereus var. Toyoi and Saccharomyces boulardii on the immune response of sheep to vaccines. *Food and Agricultural Immunology*, 21(2), 113-118.

Russo, P., Arena, M. P., Fiocco, D., Capozzi, V., Drider, D., and Spano, G. (2017) Lact*obacillus plantarum* with broad antifungal activity: A promising approach to increase safety and shelf-life of cereal-based products. *International Journal of Food Microbiology*, 2016. 04. 027

Safari, R., Adel, M., Lazado, C.C., Caipang, C.M., and Dadar, M. (2016) Host-derived probiotics Enterococcus casseliflavus improves resistance against Streptococcus iniae infection in rainbow trout (Oncorhynchus mykiss) via immunomodulation. *Fish Shellfish Immunology*, 52:198–205.

Sato, K., Takahashi, K., Tohno, M., Miura, Y., Kamada, T., Ikegami, S., and Kitazawa, H. (2009) Immunomodulation in gut-associated lymphoid tissue of neonatal chicks by immunobiotic diets. *Poultry Science*,

Seo, J.K., Kim, S.W., Kim, M.H., Santi, D., Kam, D.K., and Ha, J.K. (2010) Direct-fed microbials for ruminant animals. *Asian-Aust Journal Animal Science,* 23: 1657-1667.

Sharma, A. N., Kumar, S., and Tyagi, A. K. (2018) Effects of mannan-oligosaccharides and Lactobacillus acidophilus supplementation on growth performance, nutrient utilization and faecal characteristics in Murrah buffalo calves. *Journal Animal Physiology and Animal Nutrition,* (berlin), 102, 679–689.

Soren, N.M., Tripathi, M.K., Bhatt R.S., and Karim, S.A. (2013) Effect of yeast supplementation on the growth performance of Malpura lambs. *Tropical Animal Health Production,* 45: 547-554.

Sorroza, L., Real, F., Acosta, F., Acosta, B., Deniz, S., Roman, L., El Aamri, F., and Padilla, D. (2013) A probiotic potential of Enterococcus gallinarum against Vibrio anguillarum infection. *Fish Pathology,* 48(1):9–12.

Vanbelle, M., (1990) "Probiotics in animal nutrition: a review.," *Archives of Animal Nutrition*, vol. 1;40, no. 7, pp. 543-67.

Tellez, G., Petrone, V.M., Escorcia, M., Morishita, T.Y., Cobb, C.W., Villasenor, L. and Promsopone, B., (2001) Evaluation of avian-specific probiotic and R. Salmonella enteritidis, Salmonella typhimurium and Salmonella heidelberg-specific antibodies on cecal colonization and organ invasion of. enteritidis in broilers. *Journal Food Protection*, 64: 287-291.

Terada, T., Nii, T., Isobe, N., and Yoshimura, Y. (2020) Effects of probiotics Lactobacillus reuteri and Clostridium butyricum on the expression of toll-like receptors, pro- and anti-inflammatory cytokines, and antimicrobial peptides in broiler chick intestine. *Journal Poultry Science,*

Tripathi, M.K., Karim, S.A., Chaturvedi, O.H., and Verma, D.L. (2008) Effect of different liquid cultures of live yeast strains on performance, ruminal fermentation and microbial protein synthesis in lambs. *Journal Animal Physiology Animal Nutriton,* (Berl) 92: 631-639.

Van Immerseel, F., Russell, J.B., Flythe, M.D., Gantois, I., Timbermont, L., Pasmans, F., and Haesebrouck, F. (2006) The use of organic acids to combat Salmonella in poultry:A mechanistic explanation of the efficacy. *Avian Pathology*, 35(3):182–188.

Vanderpool, C., Yan, F., and Polk, B.D. (2008) Mechanisms of probiotic action: implications for therapeutic applications in inflammatory bowel diseases. *Inflammatory Bowel Diseases*, 14(11):1585-1596.

Vendrell, D., Balcazar, J.L., Blas, I.D., Ruiz-Zzarzuela, I., Girones, O., and Muzquiz, J.L. (2008) Protection of rainbow trout (Oncorhynchus mykiss) from lactococcosis by probiotic bacteria. *Comp Immunology Microbiology*, 31(4):337–345.

Yan, F., and Polk, D.B. (2010) Probiotics: progress toward novel therapies for intestinal diseases. *Current Opinion in Gastroenterology*, 26(2):95.

Yang, F., Wang, A., Zeng, X., Hou, C., Liu, H.S., and Qiao, S. (2015) *Lactobacillus reuteri* I5007 modulates tight junction protein expression in IPEC-J2 cells with LPS stimulation and in newborn piglets under normal conditions. *BMC Microbiology,* 15(35):32.

Zhang, Z.F., and Kim, I. H. (2014) Effects of multistrain probiotics on growth performance, apparent ileal nutrient digestibility, blood characteristics, cecal microbial shedding, and excreta odor contents in broilers. *Poultry Science,* 2013- 03314.