Chapter 09

Probiotics as Regulator of a Healthy Gut Environment in Dairy Animals

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ABSTRACT

The goals of veterinary medicine are on getting maximum production and maintaining the health of dairy animals. The use of probiotics is one of the methods to achieve this goal. The probiotics are required in adequate amounts to get the maximum benefit. They are also a solution to antimicrobial resistance because they limit the irrational use of antibiotics. A variety of chemicals are released by these probiotics that are harmful to pathogenic microbes. These chemicals include proteases, hydrogen peroxide, and bacteriocins. They also help in the regulation of the immune system by regulating the expression of cytokines. Various gram-positive and gram-negative bacteria are sources of probiotics. Similarly, some species of fungi are also potential probiotics. They improve the health of dairy animals by maintaining the microflora in the gut of these animals and help in the maximum absorption of nutrients from the intestines of these dairy animals. They improve the normal physiological processes of the gut, thus helping a dairy animal to reach its maximum production. However, their exact mechanisms of actions at molecular levels are still unknown to us. So, there is a need for further research studies in this field, so that probiotics can be efficiently utilized.

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INTRODUCTION

Probiotics maintain the microbial population in the gastrointestinal tract (GIT). They are nonpathogenic microorganisms (Williams, 2010). They are living organisms (Gupta and Garg, 2009). They are microorganisms with health benefits. Their dosages depend upon the product (Kligler and Cohrssen, 2008). Their adequate amounts are required for a proper benefit to a host's body (Baumgardner et al., 2021). Probiotics use can be a promising approach to prevent a number of diseases by improving the immune system (Stavropoulou and Bezirtzoglou, 2020). They can also have functions such as immuno-regulatory functions (Wieërs et al., 2020). The probiotics produce lysozymes, proteases, hydrogen peroxides, and bacteriocins which limit the multiplication of other harmful microbes (El-Saadony et al., 2021). The bacteriocins produced by probiotics can help us to combat with the problem of antimicrobial resistance for example, nisin is a bacteriocin produced by the probiotics. It has been used in the treatment of mastitis caused by gram-positive bacteria such as *Staphylococcus* and *Streptococcus* species (Hernández-González et al., 2021). The probiotics in animals regulate the expression of cytokines and interact with immune system of the animal's body (Refeld et al., 2020). These probiotics have the ability to survive in the challenging environment within the host's body such as gastric acidity and pH variations to give benefits to the animal's body (Melara et al., 2022). Various feed additives are being added to the feed of dairy animals, either nutritional or non-nutritional, and they are maintaining the balance of gut microbiota, thus improving the health nutrient utilization capacity, and productivity of dairy animals. Since the emergence of antimicrobial resistance in dairy animals, they have gained great value. Two types of probiotics are being used in the dairy animals. Some of these are monostrain probiotics containing a single strain of probiotics, while some of the administrated probiotics are multistrain probiotics having two or three strains of probiotics (Lambo et al., 2021). The probiotics improve the feed conversion ratio in dairy animals (Maake et al., 2021). As it has been established that probiotics also regulate the production of volatile fatty acids and nitrogen flow, their molecular and metabolic mechanism of action is still unknown to us (Nalla et al., 2022). It is suggested that probiotics improve mucosal immunity by inhibiting the attachment of pathogens to the mucosa of the gastrointestinal tract of animals (Uyeno et al., 2015). Furthermore, the health benefits of probiotics for the animal's body include the control of acidosis, reduction of methanogenesis, enhanced growth of epithelium, and increased nutrient uptake (Abd El-Trwab et al. 2016). This chapter describes the importance of probiotics for the animal's health and also explains how they regulate the gut of dairy animals.

Important Probiotics of Dairy Animals of Bacterial and Fungal Origin

Probiotics that are beneficial for the animal microbiota have been listed in Table 1. Most of these are bacterial in origin and a few of them are fungal in nature.

Table 1: Probiotics of dairy animals

Organism	Species	Reference
Lactobacillus	*L. acidophilus*	Sharma et al., 2018b
	L. alimentarius	Apás et al., 2014
	L. amylorvous	Maldonado et al., 2012
	L. animalis	Ayala et al., 2018
	L. casei	Ayala-Monter et al., 2019
	L. mucosae	Royan et al., 2021
	L. plantarum	Izuddin et al., 2019
	L. amylovorus	Fernández et al., 2018
	L. rhamnosus	Maake et al., 2021
	L. salivarius	Stefańska et al., 2021
	L. sporogenes	Shreedhar et al., 2016
	L. sakei	Sasazaki et al., 2020
Other lactic acid bacteria	*Streptococcus bovis*	Aphale et al., 2019
	Lactococcus lactis	Armas et al., 2017
	Enterococcus faecalis	Maake et al., 2021
	Pediococcus acidilactici	Reddy et al., 2011
	Propriobacterium freudenreichii	Vasconcelos et al., 2008
Bacillus	*B. licheniformis*	Devyatkin et al., 2021
	B. subtilis	Devyatkin et al., 2021
	B. subtilis natto	Chang et al., 2021
	B. toyonensis	Santos et al., 2021
	B. amyloliquefaciens	Schofield et al., 2018
Other	*E. coli*	Tkalcic et al., 2003
	Megasphaera elsdenii	Carey et al., 2021
	Butyrivibrio fibrisolvens	Fukuda et al., 2006
	Prevotella bryantii	Chiquette et al., 2012
Fungi	*Aspergillus oryzae*	Sucu et al., 2018
	Candida rugosa, Candida pararugosa	Fernandes et al., 2019
	Debaryomyces hansenii	Angulo et al., 2019
	Saccharomyces cerevisiae	Shakira et al., 2018
	Candida tropicalis	Suntara et al., 2021a
Bifidobacterium	*B. animalis*	Bunešová et al., 2012
	B. pseudolongum	Maake et al., 2021
	B. ruminantium	Vlková et al., 2009
	B.bifidum	Apás et al. 2014

Probiotics as Gut Regulators in Dairy Animals

Probiotics have different roles like antimicrobial, gut homeostasis, enhancement of digestion, productivity and growth of the dairy animals. It is summarized in Table 2.

Future Perspectives and Challenges

Livestock is a growing economy of the world. Among the livestock sector, the dairy sector has a significant impact on the economy. The developed countries are now towards the peak production of their dairy animals as they are using the latest products such as probiotics as feed additives. There is a lack of proper knowledge about using these probiotics in developing countries. However, some commercial dairy farms are adding probiotics in the feed of animals as feed additives to get maximum milk production from their dairy animals but household farmers lack proper knowledge about these products and are not using them. As a result, milk production of the dairy animals in most of the developing countries is not according to the nutritional requirements of the people living there. So, it is need of the hour that farmers should be given knowledge about the adequate use of probiotics to keep their animals healthy and get proper production from their dairy animals.

Table 2: Probiotics as gut regulators in dairy animals

Probiotic	Function	Reference
Lactobacillus johnsonii, *Lactobacillus reuteri*	Increase the beneficial microflora in the gut of young calves.	Zhang et al., 2016
Lactobacillus casei, Streptococcus faecalism, Bacillus cerevisiae	Population of opportunistic pathogens in the gut declines	Guo et al., 2022
Bifidobacterium adolescentis, Lactobacillus acidophilus, Bifidobacterium longum	Digestion of dry feed increases when used in combination with vanillin	Kondrashova et al., 2020
Bacillus subtilis natto	Improvement in concentrations of ammonia nitrogen, volatile fatty acids, and microbial protein	Chang et al., 2021
Live yeast	Stabilize rumen pH	Maamouri and Ben Salem, 2022
Paenibacillus fortis	Reduce nitrite toxicosis	Latham et al., 2019
Lactobacillus	Assistance in body defence mechanisms	Pyar and Peh, 2014
Saccharomyces cerevisiae, Lactococcus	Reduction in inflammation of mammary glands	Gao et al., 2020
Lactobacillus casei	Reduction in infections caused by *Staphylococcus aureus*	Souza et al., 2018
Lactobacillus gasseri	Reduction in infections caused by *E. coli* and *Staphylococcus aureus*	Blanchet et al., 2021
Lactobacillus casei, Lactobacillus salivarius, Lactobacillus sakei	Improved ruminal fermentation	Stefańska et al., 2021
Bacillus amyloliquefaciens, Bacillus subtilis	Concentration of intestinal fibre degrading bacteria increases	Du et al., 2018
Bacillus amyloliquefaciens	Methane emission decreases	Schofield et al., 2018
Bacillus licheniformis, Lactobacillus plantarum, Bacillus subtilis	Protein fermentation increased	Chen et al., 2021
Saccharomyces cerevisiae	Decreases the protozoa population	Phesatcha et al., 2021
Lactobacillus casei	Improved milk production by the increased absorption of nutteints	So et al., 2021
Pichia kudriavzevii, Candida tropicalis	Increase in milk protein contents	Suntara et al., 2021b
Saccharomyces cerevisiae	High fat contents in milk	Sun et al., 2021
Lactobacillus plantarum	Antibacterial activity	Angelescu et al., 2019; Beck et al., 2019
Lactobacillus paracasei	Antibacterial activity	Mulaw et al., 2019
Weissella confusa	Cholesterol removing properties	Sharma et al., 2018a
Bacillus amyloliquefaciens	Antimicrobial properties	Lee et al., 2017a
Lactobacillus fermentum	Antibacterial activity against *E. coli*	Owusu-Kwarteng et al., 2015
Lactobacillus plantarum	Antibacterial activity against *Salmonella enterica*	Oguntoyinbo and Narbad, 2015
Lactobacillus paraplantarum	Antimicrobial activity against food-borne microbes	Peres et al., 2014
Pediococcus pentosaceus	Prevention of invasion of *Salmonella*	Chiu et al., 2008
Pediococcus acidilactici	Antibacterial activity against *Mycobacterium smegmatis, Bacillus subtilis, Proteus vulgaris, Staphylococcus aureus,* and *Escherichia coli*	Bhagat et al., 2020
Enterococcus lactis	Antimicrobial activity against *Lactobacillus sakei, Enterococcus faecalis, Listeria monocytogenes,* and *Staphylococcus aureus*	Uymaz Tezel, 2019
Lactobacillus rhamnosus	Adherence to epithelial cells	Kumar and Kumar, 2015
Lactobacillus fermentum	Antimicrobial properties	Pan et al., 2011
Enterococcus faecalis	Adhesion to epithelial cells	Kook et al., 2019
Bacillus amyloliquefaciens	Antibacterial activity against *Bacillus cereus, E.coli, Listeria monocytogenes,* and *Salmonella enterica*	Lee et al., 2017b
Bacillus amyloliquefaciens	Antimicrobial activity against *Staphylococcus aureus, E. coli*, and *Bacillus cereus*	Zulkhairi Amin et al., 2020
Lactobacillus kunkeei	Antibacterial activity against *Salmonella typhimurium* and *E. coli*	Sakandar et al., 2019

Conclusion

The probiotics are living microorganisms and are nonpathogenic in nature. They improve the health of animals by regulating the growth of harmful microbes. They help a dairy animal reach its maximum production by allowing the maximum absorption of nutrients from the intestines. They attach to the gut mucosa of animals, thus inhibiting the attachment of pathogens to the mucosa and limiting their pathogenesis. They release various chemicals that are toxic to harmful bacteria such as hydrogen peroxide, bacteriocins etc. Both the fungi and several species of bacteria are potential probiotics for the animals. Some of these fungi are *Aspergillus oryzae, Debaryomyces hansenii,* and *S. cerevisiae*. The bacterial classes include both gram-positive and gram-negative bacteria. The Gram-positive bacteria include *Lactobacillus, Bacillus,* and other lactic acid-producing bacteria. On the other hand, important gram-negative bacteria include nonpathogenic strains of *E. coli* and *Prevotella bryantii*. Some of the very important functions of these probiotics include antibacterial activity against pathogenic strains of *E. coli, Salmonella enterica, Salmonella typhimurium*, and *Staphylococcus aureus*. Similarly, they also regulate the normal physiological processes ongoing in the gut of dairy animals like reducing the chance of nitrite toxicity, improving microbial fermentation, enhancing the metabolism of dry feed, and increasing the milk production of dairy animals. These probiotics are helping dairy animals reach their maximum production capacity. However, there is a lack of proper knowledge about the use of these probiotics in developing countries, as a result of which their dairy animals lack proper health and adequate nutrition. They should be given information about the use of these probiotics.

REFERENCES

Abd El-Trwab, M. M., Youssef, I. I., Bakr, H. A., Fthenakis, G. C., and Giadinis, N. D. (2016). Role of probiotics in nutrition and health of small ruminants. *Polish Journal of Veterinary Sciences*, *19*(4). DOI 10.1515/pjvs-2016-0114

Angelescu, I. R., Zamfir, M., Stancu, M. M., and Grosu-Tudor, S. S. (2019). Identification and probiotic properties of lactobacilli isolated from two different fermented beverages. *Annals of Microbiology*, *69*, 1557-1565. https://doi.org/10.1007/s13213-019-01540-0

Angulo, M., Reyes-Becerril, M., Cepeda-Palacios, R., Tovar-Ramírez, D., Esteban, M. Á., and Angulo, C. (2019). Probiotic effects of marine Debaryomyces hansenii CBS 8339 on innate immune and antioxidant parameters in newborn goats. *Applied Microbiology and Biotechnology*, *103*, 2339-2352. https://doi.org/10.1007/s00253-019-09621-5

Apás, A. L., González, S. N., and Arena, M. E. (2014). Potential of goat probiotic to bind mutagens. *Anaerobe*, *28*, 8-12. https://doi.org/10.1016/j.anaerobe.2014.04.004

Aphale, D., Natu, A., Laldas, S., and Kulkarni, A. (2019). Administration of Streptococcus bovis isolated from sheep rumen digesta on rumen function and physiology as evaluated in a rumen simulation technique system. *Veterinary World*, *12*(9), 1362. https://doi.org/10.14202%2Fvetworld.2019.1362-1371

Armas, F., Camperio, C., and Marianelli, C. (2017). In vitro assessment of the probiotic potential of Lactococcus lactis LMG 7930 against ruminant mastitis-causing pathogens. *PLoS One*, *12*(1), e0169543. https://doi.org/10.1371/journal.pone.0169543

Ayala, D. I., Chen, J. C., Bugarel, M., Loneragan, G. H., den Bakker, H. C., Kottapalli, K. R., and Nightingale, K. K. (2018). Molecular detection and quantification of viable probiotic strains in animal feedstuffs using the commercial direct fed microbial Lactobacillus animalis NP51 as a model. *Journal of Microbiological Methods*, *149*, 36-43. https://doi.org/10.1016/j.mimet.2018.04.012

Ayala-Monter, M. A., Hernández-Sánchez, D., González-Muñoz, S., Pinto-Ruiz, R., Martínez-Aispuro, J. A., Torres-Salado, N., and Gloria-Trujillo, A. (2019). Growth performance and health of nursing lambs supplemented with inulin and Lactobacillus casei. *Asian-Australasian Journal of Animal Sciences*, *32*(8), 1137. https://doi.org/10.5713%2Fajas.18.0630

Baumgardner, R. M., Berreta, A., and Kopper, J. J. (2021). Evaluation of commercial probiotics for antimicrobial resistance genes. *The Canadian Veterinary Journal*, *62*(4), 379. https://pubmed.ncbi.nlm.nih.gov/33867550

Beck, B. R., Park, G. S., Lee, Y. H., Im, S., Jeong, D. Y., and Kang, J. (2019). Whole genome analysis of Lactobacillus plantarum strains isolated from kimchi and determination of probiotic properties to treat mucosal infections by Candida albicans and Gardnerella vaginalis. *Frontiers in Microbiology*, *10*, 433. https://doi.org/10.3389/fmicb.2019.00433

Bhagat, D., Raina, N., Kumar, A., Katoch, M., Khajuria, Y., Slathia, P. S., and Sharma, P. (2020). Probiotic properties of a phytase producing Pediococcus acidilactici strain SMVDUDB2 isolated from traditional fermented cheese product, Kalarei. *Scientific Reports*, *10*(1), 1926. https://doi.org/10.1038/s41598-020-58676-2

Blanchet, F., Rault, L., Peton, V., Le Loir, Y., Blondeau, C., Lenoir, L., and Even, S. (2021). Heat inactivation partially preserved barrier and immunomodulatory effects of Lactobacillus gasseri LA806 in an in vitro model of bovine mastitis. *Beneficial Microbes*, *12*(1), 95-106. https://doi.org/10.3920/BM2020.0146

Bunešová, V., Domig, K. J., Killer, J., Vlková, E., Kopečný, J., Mrázek, J., and Rada, V. (2012). Characterization of bifidobacteria suitable for probiotic use in calves. *Anaerobe*, *18*(1), 166-168. https://doi.org/10.1016/j.anaerobe.2011.09.008

Carey, M. A., Medlock, G. L., Alam, M., Kabir, M., Uddin, M. J., Nayak, U., and Gilchrist, C. A. (2021). Megasphaera in the stool microbiota is negatively associated with diarrheal cryptosporidiosis. *Clinical Infectious Diseases*, *73*(6), e1242-e1251. https://doi.org/10.1093/cid/ciab207

Chang, M., Ma, F., Wei, J., Liu, J., Nan, X., and Sun, P. (2021). Live Bacillus subtilis natto promotes rumen fermentation by modulating rumen microbiota in vitro. *Animals*, *11*(6), 1519. https://doi.org/10.3390/ani11061519

Chen, H., Guo, B., Yang, M., Luo, J., Hu, Y., Qu, M., and Song, X. (2021). Response of growth performance, blood biochemistry indices, and rumen bacterial diversity in lambs to diets containing supplemental probiotics and Chinese medicine polysaccharides. *Frontiers in Veterinary Science*, *8*, 681389. https://doi.org/10.3389/fvets.2021.681389

Chiquette, J., Allison, M. J., and Rasmussen, M. (2012). Use of Prevotella bryantii 25A and a commercial probiotic during subacute acidosis challenge in midlactation dairy cows. *Journal of Dairy Science*, *95*(10), 5985-5995. https://doi.org/10.3168/jds.2012-5511

Chiu, H. H., Tsai, C. C., Hsih, H. Y., and Tsen, H. Y. (2008). Screening from pickled vegetables the potential probiotic strains of lactic acid bacteria able to inhibit the Salmonella invasion in mice. *Journal of Applied Microbiology*, *104*(2), 605-612. https://doi.org/10.1111/j.1365-2672.2007.03573.x

Devyatkin, V., Mishurov, A., and Kolodina, E. (2021). Probiotic effect of Bacillus subtilis B-2998D, B-3057D, and Bacillus licheniformis B-2999D complex on sheep and lambs. *Journal of Advanced Veterinary and Animal Research*, *8*(1), 146. https://doi.org/10.5455%2Fjavar.2021.h497

Du, R., Jiao, S., Dai, Y., An, J., Lv, J., Yan, X., and Han, B. (2018). Probiotic Bacillus amyloliquefaciens C-1 improves growth performance, stimulates GH/IGF-1, and regulates the gut microbiota of growth-retarded beef calves. *Frontiers in Microbiology*, *9*, 2006. https://doi.org/10.3389/fmicb.2018.02006

El-Saadony, M. T., Alagawany, M., Patra, A. K., Kar, I., Tiwari, R., Dawood, M. A., and Abdel-Latif, H. M. (2021). The functionality of probiotics in aquaculture: An overview. *Fish and Shellfish Immunology*, *117*, 36-52. https://doi.org/10.1016/j.fsi.2021.07.007

Fernandes, T., Carvalho, B. F., Mantovani, H. C., Schwan, R. F., and Ávila, C. L. S. (2019). Identification and characterization of yeasts from bovine rumen for potential use as probiotics. *Journal of Applied Microbiology*, *127*(3), 845-855. https://doi.org/10.1111/jam.14350

Fernández, S., Fraga, M., Silveyra, E., Trombert, A. N., Rabaza, A., Pla, M., and Zunino, P. (2018). Probiotic properties of native Lactobacillus spp. strains for dairy calves. *Beneficial Microbes*, *9*(4), 613-624. https://doi.org/10.3920/BM2017.0131

Fukuda, S., Suzuki, Y., Murai, M., Asanuma, N., and Hino, T. (2006). Isolation of a novel strain of Butyrivibrio fibrisolvens that isomerizes linoleic acid to conjugated linoleic acid without hydrogenation, and its utilization as a probiotic for animals. *Journal of Applied Microbiology*, *100*(4), 787-794. https://doi.org/10.1111/j.1365-2672.2006.02864.x

Gao, J., Liu, Y. C., Wang, Y., Li, H., Wang, X. M., Wu, Y., and Qi, Z. L. (2020). Impact of yeast and lactic acid bacteria on mastitis and milk microbiota composition of dairy cows. *AMB Express*, *10*, 1-12. https://doi.org/10.1186/s13568-020-0953-8

Guo, Y., Li, Z., Deng, M., Li, Y., Liu, G., Liu, D., and Sun, B. (2022). Effects of a multi-strain probiotic on growth, health, and fecal bacterial flora of neonatal dairy calves. *Animal Bioscience*, *35*(2), 204. https://doi.org/10.5713%2Fab.21.0084

Gupta, V., and Garg, R. (2009). Probiotics. *Indian Journal of Medical Microbiology*, *27*(3), 202-209. https://doi.org/10.4103/0255-0857.53201

Hernández-González, J. C., Martínez-Tapia, A., Lazcano-Hernández, G., García-Pérez, B. E., and Castrejón-Jiménez, N. S. (2021). Bacteriocins from lactic acid bacteria. A powerful alternative as antimicrobials, probiotics, and immunomodulators in veterinary medicine. *Animals*, *11*(4), 979. https://doi.org/10.3390/ani11040979

Izuddin, W. I., Loh, T. C., Samsudin, A. A., Foo, H. L., Humam, A. M., and Shazali, N. (2019). Effects of postbiotic supplementation on growth performance, ruminal fermentation and microbial profile, blood metabolite and GHR, IGF-1 and MCT-1 gene expression in post-weaning lambs. *BMC Veterinary Research*, *15*, 1-10. https://doi.org/10.1186/s12917-019-2064-9

Kligler, B., and Cohrssen, A. (2008). Probiotics. *American Family Physician*, *78*(9), 1073-1078. https://www.aafp.org/pubs/afp/issues/2008/1101/p1073.html

Kondrashova, K., Duskaev, G., and Kvan, O. (2020). Evaluation of effects of rumen fluid in combination with probiotic preparations and vanillin on the luminescence of a recombinant strain E. coli. In *E3S Web of Conferences* (Vol. 143, p. 02034). EDP Sciences. https://doi.org/10.1051/e3sconf/202014302034

Kook, S. Y., Chung, E. C., Lee, Y., Lee, D. W., and Kim, S. (2019). Isolation and characterization of five novel probiotic strains from Korean infant and children faeces. *PLoS One*, *14*(10), e0223913. https://doi.org/10.1371/journal.pone.0223913

Kumar, A., and Kumar, D. (2015). Characterization of Lactobacillus isolated from dairy samples for probiotic properties. *Anaerobe*, *33*, 117-123. https://doi.org/10.1016/j.anaerobe.2015.03.004

Lambo, M. T., Chang, X., and Liu, D. (2021). The recent trend in the use of multistrain probiotics in livestock production: An overview. *Animals*, *11*(10), 2805. https://doi.org/10.3390/ani11102805

Latham, E. A., Pinchak, W. E., Trachsel, J., Allen, H. K., Callaway, T. R., Nisbet, D. J., and Anderson, R. C. (2018). Isolation, characterization and strain selection of a Paenibacillus species for use as a probiotic to aid in ruminal methane mitigation, nitrate/nitrite detoxification and food safety. *Bioresource Technology*, *263*, 358-364. https://doi.org/10.1016/j.biortech.2018.04.116

Latham, E. A., Pinchak, W. E., Trachsel, J., Allen, H. K., Callaway, T. R., Nisbet, D. J., and Anderson, R. C. (2019). Paenibacillus 79R4, a potential rumen probiotic to enhance nitrite detoxification and methane mitigation in nitrate-treated ruminants. *Science of the Total Environment*, *671*, 324-328. https://doi.org/10.1016/j.scitotenv.2019.03.390

Lee, A., Cheng, K. C., and Liu, J. R. (2017a). Isolation and characterization of a Bacillus amyloliquefaciens strain with zearalenone removal ability and its probiotic potential. *PloS one*, *12*(8), e0182220. https://doi.org/10.1371/journal.pone.0182220

Lee, S., Lee, J., Jin, Y. I., Jeong, J. C., Chang, Y. H., Lee, Y., and Kim, M. (2017b). Probiotic characteristics of Bacillus strains isolated from Korean traditional soy sauce. *LWT-Food Science and Technology*, *79*, 518-524. https://doi.org/10.1016/j.lwt.2016.08.040

Maake, T. W., Adeleke, M., and Aiyegoro, O. A. (2021). Effect of lactic acid bacteria administered as feed supplement on the weight gain and ruminal pH in two South African goat breeds. *Transactions of the Royal Society of South Africa*, *76*(1), 35-40. https://doi.org/10.1080/0035919X.2020.1870018

Maamouri, O., and Ben Salem, M. (2022). The effect of live yeast Saccharomyces cerevisiae as probiotic supply on growth performance, feed intake, ruminal pH and fermentation in fattening calves. *Veterinary Medicine and Science*, *8*(1), 398-404. https://doi.org/10.1002/vms3.631

Maldonado, N. C., de Ruiz, C. S., Otero, M. C., Sesma, F., and Nader-Macías, M. E. (2012). Lactic acid bacteria isolated from young calves–characterization and potential as probiotics. *Research in Veterinary Science*, *92*(2), 342-349. https://doi.org/10.1016/j.rvsc.2011.03.017

Melara, E. G., Avellaneda, M. C., Valdivié, M., García-Hernández, Y., Aroche, R., and Martínez, Y. (2022). Probiotics: Symbiotic relationship with the animal host. *Animals*, *12*(6), 719. https://doi.org/10.3390/ani12060719

Mulaw, G., Sisay Tessema, T., Muleta, D., and Tesfaye, A. (2019). In vitro evaluation of probiotic properties of lactic acid bacteria isolated from some traditionally fermented Ethiopian food products. *International Journal of Microbiology*, *2019*. https://doi.org/10.1155/2019/7179514

Nalla, K., Manda, N. K., Dhillon, H. S., Kanade, S. R., Rokana, N., Hess, M., and Puniya, A. K. (2022). Impact of probiotics on dairy production efficiency. *Frontiers in Microbiology*, *13*, 805963. https://doi.org/10.3389/fmicb.2022.805963

Oguntoyinbo, F. A., and Narbad, A. (2015). Multifunctional properties of Lactobacillus plantarum strains isolated from fermented cereal foods. *Journal of Functional Foods*, *17*, 621-631. https://doi.org/10.1016/j.jff.2015.06.022

Owusu-Kwarteng, J., Tano-Debrah, K., Akabanda, F., and Jespersen, L. (2015). Technological properties and probiotic potential of Lactobacillus fermentum strains isolated from West African fermented millet dough. *BMC Microbiology*, *15*, 1-10. https://doi.org/10.1186/s12866-015-0602-6

Pan, D. D., Zeng, X. Q., and Yan, Y. T. (2011). Characterisation of Lactobacillus fermentum SM-7 isolated from koumiss, a potential probiotic bacterium with cholesterol-lowering effects. *Journal of the Science of Food and Agriculture*, *91*(3), 512-518. https://doi.org/10.1002/jsfa.4214

Peres, C. M., Alves, M., Hernandez-Mendoza, A., Moreira, L., Silva, S., Bronze, M. R., and Malcata, F. X. (2014). Novel isolates of lactobacilli from fermented Portuguese olive as potential probiotics. *LWT-Food Science and Technology*, *59*(1), 234-246. https://doi.org/10.1016/j.lwt.2014.03.003

Phesatcha, K., Phesatcha, B., Wanapat, M., and Cherdthong, A. (2021). The effect of yeast and roughage concentrate ratio on ruminal pH and protozoal population in Thai native beef cattle. *Animals*, *12*(1), 53. https://doi.org/10.3390/ani12010053

Pyar, H., and Peh, K. K. (2014). Characterization and identification of Lactobacillus acidophilus using biolog rapid identification system. *International Journal of Pharmacy and Pharmaceutical Sciences*, *6*(1), 189-193. https://web.archive.org/web/20180413015158id_/http://ijppsjournal.com/Vol6Issue1/7982.pdf

Reddy, P. V. M., Reddy, K. K., Kumar, M. S., Harikrishna, C., and Raghunandan, T. (2011). Effect of feeding Pediococcus acidilactici and Saccharomyces boulardii as probiotics in lambs. *Indian Journal of Small Ruminants (The)*, *17*(1), 53-58. https://www.indianjournals.com/ijor.aspx?target=ijor:ijsrandvolume=17andissue=1andarticle=006

Refeld, A., Bogdanova, A., Prazdnova, E., Beskopylny, A., Olshevskaya, A., Maltseva, T., and Zubtsov, V. (2020). Immunobiotics mechanisms of action and prospects of use in veterinary medicine. In *E3S Web of Conferences* (Vol. 210, p. 06017). EDP Sciences. https://doi.org/10.1051/e3sconf/202021006017

Royan, M., Seighalani, R., Mortezaei, F., and Pourebrahim, M. (2021). In vitro assessment of safety and functional probiotic properties of Lactobacillus mucosae strains isolated from Iranian native ruminants intestine. *Italian Journal of Animal Science*, *20*(1), 1187-1200. https://doi.org/10.1080/1828051X.2021.1947908

Sakandar, H. A., Kubow, S., and Sadiq, F. A. (2019). Isolation and in-vitro probiotic characterization of fructophilic lactic acid bacteria from Chinese fruits and flowers. *Lwt*, *104*, 70-75. https://doi.org/10.1016/j.lwt.2019.01.038

Santos, F. D. S., Maubrigades, L. R., Gonçalves, V. S., Ferreira, M. R. A., Brasil, C. L., Cunha, R. C., and Leite, F. P. L. (2021). Immunomodulatory effect of short-term supplementation with Bacillus toyonensis BCT-7112T and Saccharomyces boulardii CNCM I-745 in sheep vaccinated with Clostridium chauvoei. *Veterinary Immunology and Immunopathology*, *237*, 110272. https://doi.org/10.1016/j.vetimm.2021.110272

Sasazaki, N., Obi, T., Aridome, C., Fujimoto, Y., Furumoto, M., Toda, K., and Takagi, M. (2020). Effects of dietary feed supplementation of heat-treated Lactobacillus sakei HS-1 on the health status, blood parameters, and fecal microbes of Japanese Black calves. *Journal of Veterinary Medical Science*, *82*(10), 1428-1435. https://doi.org/10.1292/jvms.20-0181

Schofield, B. J., Lachner, N., Le, O. T., McNeill, D. M., Dart, P., Ouwerkerk, D., and Klieve, A. V. (2018). Beneficial changes in rumen bacterial community profile in sheep and dairy calves as a result of feeding the probiotic Bacillus amyloliquefaciens H57. *Journal of Applied Microbiology*, *124*(3), 855-866. https://doi.org/10.1111/jam.13688

Shakira, G., Qubtia, M., Ahmed, I., Hasan, F., Anjum, M. I., and Imran, M. (2018). Effect of indigenously isolated Saccharomyces cerevisiae probiotics on milk production, nutrient digestibility, blood chemistry and fecal microbiota in lactating dairy cows. http://www.thejaps.org.pk/docs/v-28-02/06.pdf

Sharma, S., Kandasamy, S., Kavitake, D., and Shetty, P. H. (2018a). Probiotic characterization and antioxidant properties of Weissella confusa KR780676, isolated from an Indian fermented food. *LWT*, *97*, 53-60. https://doi.org/10.1016/j.lwt.2018.06.033

Sharma, A. N., Kumar, S., and Tyagi, A. K. (2018b). Effects of mannan-oligosaccharides and Lactobacillus acidophilus supplementation on growth performance, nutrient utilization and faecal characteristics in Murrah buffalo calves. *Journal of Animal Physiology and Animal Nutrition*, *102*(3), 679-689. https://doi.org/10.1111/jpn.12878

Shreedhar, J. N., Patil, M., and Kumar, P. (2016). Effect of probiotics supplementation on milk yield and its composition in lactating Holstein Fresien and Deoni cross bred cows. *Journal of Medical and Bioengineering Vol*, *5*(1). http://www.jomb.org/uploadfile/2015/0601/20150601031025717.pdf

So, S., Wanapat, M., and Cherdthong, A. (2021). Effect of sugarcane bagasse as industrial by-products treated with Lactobacillus casei TH14, cellulase and molasses on feed utilization, ruminal ecology and milk production of mid-lactating Holstein Friesian cows. *Journal of the Science of Food and Agriculture*, *101*(11), 4481-4489. https://doi.org/10.1002/jsfa.11087

Souza, R. F. S., Rault, L., Seyffert, N., Azevedo, V., Le Loir, Y., and Even, S. (2018). Lactobacillus casei BL23 modulates the innate immune response in Staphylococcus aureus-stimulated bovine mammary epithelial cells. *Beneficial Microbes*, *9*(6), 985-995. https://doi.org/10.3920/BM2018.0010

Stavropoulou, E., and Bezirtzoglou, E. (2020). Probiotics in medicine: a long debate. *Frontiers in Immunology*, *11*, 554558. https://doi.org/10.3389/fimmu.2020.02192

Stefańska, B., Sroka, J., Katzer, F., Goliński, P., and Nowak, W. (2021). The effect of probiotics, phytobiotics and their combination as feed additives in the diet of dairy calves on performance, rumen fermentation and blood metabolites during the preweaning period. *Animal Feed Science and Technology*, *272*, 114738. https://doi.org/10.1016/j.anifeedsci.2020.114738

Sucu, E., Moore, C., VanBaale, M. J., Jensen, H., Sanz-Fernandez, M. V., and Baumgard, L. H. (2018). Effects of feeding Aspergillus oryzae fermentation product to transition Holstein cows on performance and health. *Canadian Journal of Animal Science*, *99*(2), 237-243. https://doi.org/10.1139/cjas-2018-0037

Sun, X., Wang, Y., Wang, E., Zhang, S., Wang, Q., Zhang, Y., and Li, S. (2021). Effects of Saccharomyces cerevisiae culture on ruminal fermentation, blood metabolism, and performance of high-yield dairy cows. *Animals*, *11*(8), 2401. https://doi.org/10.3390/ani11082401

Suntara, C., Cherdthong, A., Wanapat, M., Uriyapongson, S., Leelavatcharamas, V., Sawaengkaew, J., and Foiklang, S. (2021a). Isolation and characterization of yeasts from rumen fluids for potential use as additives in ruminant feeding. *Veterinary Sciences*, *8*(3), 52. https://doi.org/10.3390/vetsci8030052

Suntara, C., Cherdthong, A., Uriyapongson, S., Wanapat, M., and Chanjula, P. (2021b). Novel Crabtree negative yeast from rumen fluids can improve rumen fermentation and milk quality. *Scientific Reports*, *11*(1), 6236. https://doi.org/10.1038/s41598-021-85643-2

Tkalcic, S., Zhao, T., Harmon, B. G., Doyle, M. P., Brown, C. A., and Zhao, P. (2003). Fecal shedding of enterohemorrhagic Escherichia coli in weaned calves following treatment with probiotic Escherichia coli. *Journal of Food Protection*, *66*(7), 1184-1189. https://doi.org/10.4315/0362-028X-66.7.1184

Uyeno, Y., Shigemori, S., and Shimosato, T. (2015). Effect of probiotics/prebiotics on cattle health and productivity. *Microbes and Environments*, *30*(2), 126-132. https://doi.org/10.1264/jsme2.ME14176

Uymaz Tezel, B. (2019). Preliminary in vitro evaluation of the probiotic potential of the bacteriocinogenic strain Enterococcus lactis PMD74 isolated from ezine cheese. *Journal of Food Quality*, *2019*. https://doi.org/10.1155/2019/4693513

Vasconcelos, J. T., Elam, N. A., Brashears, M. M., and Galyean, M. L. (2008). Effects of increasing dose of live cultures of Lactobacillus acidophilus (Strain NP 51) combined with a single dose of Propionibacterium freudenreichii (Strain NP 24) on performance and carcass characteristics of finishing beef steers. *Journal of Animal Science*, *86*(3), 756-762. https://doi.org/10.2527/jas.2007-0526

Vlková, E., Grmanová, M., Rada, V., Homutová, I., and Dubná, S. (2009). Selection of probiotic bifidobacteria for lambs. *Czech Journal of Animal Science*, *54*(12), 552-565. https://cjas.agriculturejournals.cz/pdfs/cjs/2009/12/05.pdf

Wieërs, G., Belkhir, L., Enaud, R., Leclercq, S., Philippart de Foy, J. M., Dequenne, I., and Cani, P. D. (2020). How probiotics affect the microbiota. *Frontiers in cellular and infection microbiology*, *9*, 454. https://doi.org/10.3389/fcimb.2019.00454

Williams, N. T. (2010). Probiotics. *American Journal of Health-System Pharmacy*, *67*(6), 449-458. https://doi.org/10.2146/ajhp090168

Zhang, R., Zhou, M., Tu, Y., Zhang, N. F., Deng, K. D., Ma, T., and Diao, Q. Y. (2016). Effect of oral administration of probiotics on growth performance, apparent nutrient digestibility and stress-related indicators in Holstein calves. *Journal of Animal Physiology and Animal Nutrition*, *100*(1), 33-38. https://doi.org/10.1111/jpn.12338

Zulkhairi Amin, F. A., Sabri, S., Ismail, M., Chan, K. W., Ismail, N., Mohd Esa, N., and Zawawi, N. (2020). Probiotic properties of Bacillus strains isolated from stingless bee (Heterotrigona itama) honey collected across Malaysia. *International Journal of Environmental Research and Public Health*, *17*(1), 278. https://doi.org/10.3390/ijerph17010278