University of Thi-Qar Journal of agricultural research
Thi-Qar Journal of agricultural research
ISSN Onlin:2708 -9347, ISSN Print: 2708 -9339 Volume 15, Issue 1 (2026)
https://iasj.rdd.edu.iq/journals/journal/issue/20226 *https://doi.org/10.54174/utjagr.9898*

Benefits of Lactic Acid Bacteria as Alternatives to Antibiotic Growth Factors in Animal Feeding

Zainab A. Ali[1], Tamadher. M. K. Al-Tememe [2], Abdulbasit F.Hasan [1], Keefah AL-Garallaa[3], Raghad Saad Al Musa[1], Ahmed Sami Shaker[4]

1 Department of Food Science, College of Agriculture, University of Basrah, Basrah, Iraq.

2 College of Veterinary Medicine, University of Basrah, Basrah, Iraq

3 Al-Qasim Green University, College of Biotechnology, Department of Medical Biotechnology

4 Medical Laboratory Technical Department, Health and Medical Technical College, Al-Qalam University, Kirkuk, Iraq

Corresponding author: Zainab.abdali@uobasrah.edu.iq

Abstract:

Recently, there has been a growing interest in safe, natural growth promoters as a safer alternative to antibiotics, which were previously used to stimulate growth, mostly as feed additives. Since antibiotics used for growth promotion are synthetic compounds with numerous side effects. Medical reports also confirm that the use of antibiotics and chemical growth promoters in animal and poultry feed is one of the causes of cancer and many other serious diseases in humans. Therefore, the Food and Agriculture Organization of the United Nations (FAO) has called on countries worldwide to withdraw antibiotics and take serious steps to prevent their use in food products. Since 2006, the European Union has banned and criminalized the use of antibiotics in poultry feed and has focused on adopting safer and more effective alternatives, such as natural growth promoters. The aim of this study is to focus on Lactic acid bacteria (LABs), which possess probiotic properties, natural, safe growth promoters that can be used in animal feeding and poultry farming. Provide essential health benefits for animals and help maintain the balance of gut flora, and improve feed efficiency.

Keywords: Lactic acid bacteria, Antibiotic residues, food animal, antimicrobial resistance, probiotic.

Introduction:

- Antibiotics:

Antibiotics are chemicals produced wholly or partially by germs, usually fungi or bacteria, and have a special ability, when in low concentrations, to stop the growth or kill many germs. Their presence in food is considered a chemical poison that must be avoided. Antibiotics reach human food in the following cases: when used to prevent some diseases or to help treat some diseases that affect poultry, or when used as a growth stimulant for poultry flocks. Intensive poultry farming systems require the use of many antibiotics to control diseases and improve growth rates. Statistically, the rate of antibiotic use in poultry production far exceeds the rate of antibiotic use in other animal production for several reasons, including: the need to treat all birds, not just the infected ones; the prevalence of diseases and the desire to control them quickly; the difficulty of having diagnostic laboratories on every farm; and the mistaken belief

University of Thi-Qar Journal of agricultural research
Thi-Qar Journal of agricultural research
ISSN Onlin:2708 -9347, ISSN Print: 2708 -9339 Volume 15, Issue 1 (2026)
https://iasj.rdd.edu.iq/journals/journal/issue/20226 https://doi.org/10.54174/utjagr.9898

among breeders that adding antibiotics will solve all health problems and eliminate disease Hutchings et al., 2019; Sana et al.,2025]. The direct impact of antibiotics on the consumer comes when breeders resort to using many antibiotics on the farm, believing that it will eliminate the disease, or for prevention, or as growth stimulants. In all cases, the failure to stop using antibiotics before slaughter with sufficient time leads to them reaching the consumer through the consumption of these poultry products of meat and eggs, and the occurrence of cases of poisoning in humans (Zhou et al.,2025). Poultry farms use antibiotics to promote poultry growth and prevent disease. Therapeutic doses of antibiotics commonly used also improve feed efficiency. However, the effects of these antibiotics on eggs and meat consumed by humans are significant (Samad et al.,2026).

- The Dangers of Antibiotics:

The danger of using these products to humans lies in the possibility of allergic reactions in some individuals. Antibiotics can transform within an animal's body into more dangerous and toxic substances due to the simultaneous use of multiple types. This leads to interactions and the production of toxins that can affect human health when meat or eggs are consumed. Furthermore, the similarity in the active ingredients between antibiotics used in poultry and those used in humans can result in bacteria developing resistance to these antibiotics, thus reducing or eliminating their effectiveness in treating certain diseases and serious conditions. The presence of antibiotics in food over extended periods can contribute to the development of tumors and cancers in the human body, as well as mutations and birth defects. Antibiotics also disrupt the microbial balance of the human gut flora, leading to various digestive system disorders. The emergence of new strains of bacteria hinders disease diagnosis, both in terms of symptoms and treatment. The high use of antibiotics in poultry production raises serious concerns among producers and consumers due to the accumulation of drug residues in edible tissue areas and the associated risks to food safety, animal health, and public health (Arsène et al.,2022). In recent decades, the European Union has imposed laws and restrictions on the use of antibiotics as growth promoters, limiting the emergence of antibiotic-resistant bacteria that pose a risk to human health, increase the spread of animal diseases, disrupt the balance between beneficial and pathogenic bacteria, and contribute to the development of antibiotic-resistant bacterial strains (Dimuccio et al., 2026).

In addition, the presence of antibiotic residues in animal tissues exceeding the permissible limit is a serious problem for food safety. These can be replaced by functional feed additives that have properties that improve meat quality characteristics, such as color, texture, and nutritional value. These additives maintain the nutritional value of poultry products and consumer confidence, which contributes to raising the prices of antibiotic-free products (Yusha'u et al.,2026; Monika et al.,2024; Mandey and Sompie, 2021).

- Antibiotic resistance:

Antibiotic resistance occurs when pathogenic microbes, constantly exposed to antibiotics, develop mechanisms that render these treatments ineffective. This resistance arises through horizontal gene transfer or gene mutations that alter the metabolic pathways and gene expression of the microbes. Furthermore, these changes often lead to the production of modified proteins and other adaptations, making it more difficult to combat pathogens (Uddin et al., 2021). The use of antimicrobial growth promoters (AGPs) has recently increased significantly following the emergence of several livestock diseases. While global efforts continue to restrict their use, projections indicate an 8% increase between 2020 and 2030. Although AGPs have proven effective in improving livestock production and profitability, their overuse raises serious concerns about antibiotic resistance (AMR) (Mulchandani et al., 2023).

University of Thi-Qar Journal of agricultural research
Thi-Qar Journal of agricultural research
ISSN Onlin:2708 -9347, ISSN Print: 2708 -9339 Volume 15, Issue 1 (2026)
https://iasj.rdd.edu.iq/journals/journal/issue/20226 https://doi.org/10.54174/utjagr.9898

- Probiotic

Probiotics are a vital food supplement consisting of beneficial microbes that benefit the host by improving the balance of intestinal bacteria and maintaining an optimal level of intestinal acidity, thereby improving the healthy immune status of animals. Figure 1 illustrates the applications of probiotics (Mârza et al., 2025).; Banerjee et al., 2018).

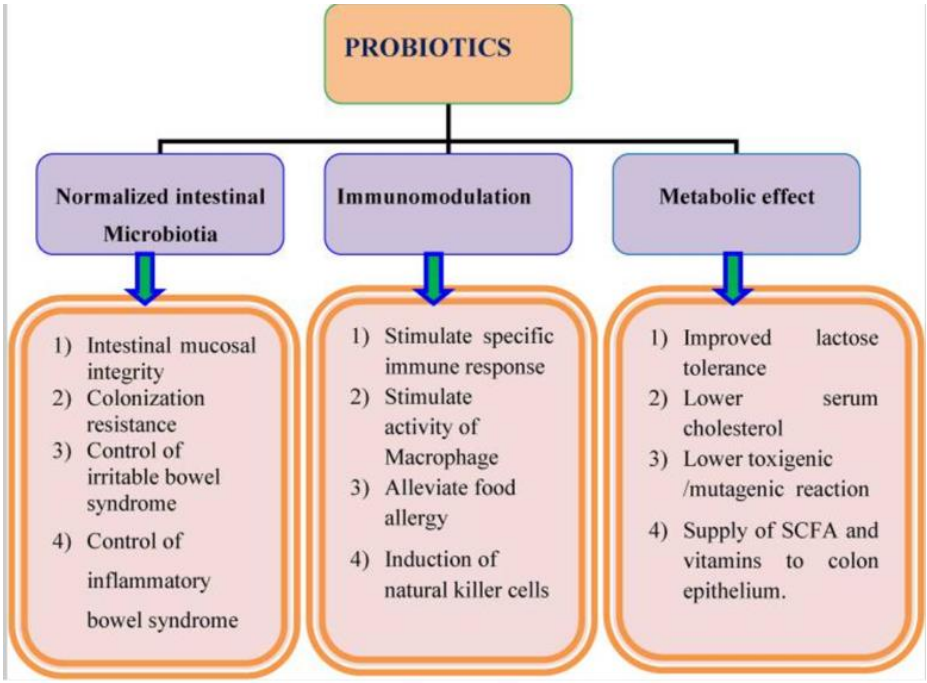

Figure 1: The applications of probiotics (Banerjee et al., 2018).

Probiotics are a promising treatment and preventative option due to their immune-modulating effects on the body and their ability to treat a variety of diseases, such as inflammatory conditions. Consuming probiotics in the form of drinks, powders, or capsules helps restore beneficial bacteria in the gut, thus benefiting the body by boosting the immune system. Probiotics have many advantages over meat products. It improves meat color, pH, oxidation state, fatty acid levels, body composition, and water-holding capacity. It also increases the percentage of protein and fat, thus improving the quality of meat (Dong et al.,2024). Probiotics have emerged as a promising alternative to antibiotics in poultry processing, offering enhanced growth rates and reducing the incidence of animal diseases (Ayana and Kamutambuko 2024).

-Lactic acid bacteria

Lactic acid bacteria (LABs) are a large and widespread group of prokaryotes in nature, sharing distinctive physiological, morphological, and metabolic characteristics. Probiotics are live, beneficial bacteria found in some beverages, foods, and dietary supplements. They are similar to the beneficial bacteria naturally present in the human

University of Thi-Qar Journal of agricultural research
Thi-Qar Journal of agricultural research
ISSN Onlin:2708 -9347, ISSN Print: 2708 -9339 Volume 15, Issue 1 (2026)
https://iasj.rdd.edu.iq/journals/journal/issue/20226 https://doi.org/10.54174/utjagr.9898

body. Among the benefits of probiotics are their contribution to strengthening the beneficial bacteria in the body and enhancing their important functions, such as aiding digestion, maintaining normal bowel movements, absorbing nutrients, and boosting the body's resistance to infections (Sarita et al.,2025). Ecologically, genetically diverse, yet functionally related, the genera belonging to the order Lactobacillales of the phylum Firmicutes include the families Aerococcaceae, Enterococaceae, Lactobacillaceae (including those formerly part of Leuconostocaceae), Carnobacteriaceae, and Streptococcaceae. Forty bacterial genera were included in this group in 2015 (Zhuo et al., 2025). The updated classification of the Lactobacillus family and the reclassification of the genus Lactobacillus, resulting in 23 new genera, significantly increased this number in 2020 (Arsène et al., 2022). Although belonging to the phylum Actinobacteria, some researchers have included Bifidobacteria within the lactic acid bacteria group, given that both possess probiotic potential and occupy similar ecological niches. They are non-aerobic, tolerant of air, and grow as catalase-negative cocci or bacilli. Most are non-motile, non-spore-forming, and can grow in high salt concentrations and low pH. It is essential for both food fermentation and host health, characterized by its antimicrobial properties and its role in sensory changes, antioxidant activity, and the release of peptides and polysaccharides, decarboxylation of amino acids, and production and degradation of biogenic amines. Probiotics are a vital food supplement consisting of beneficial microbes that benefit the host by improving the balance of intestinal bacteria and maintaining an optimal level of intestinal acidity, thereby improving the healthy immune status of animals (Chowdhury et al., 2025). In addition to digesting nutrients, lactic acid bacteria are used in humans and animals due to their antimicrobial and beneficial properties, acting as probiotics or treating a variety of diseases. Antibiotics are renowned for their high efficacy in improving animal nutrition and reducing mortality rates due to a decrease in clinical and subclinical disease incidence. In animal production, lactic acid bacteria contribute to animal health and productivity. Animal products, such as fermented products and dairy, are major natural sources of lactic acid bacteria. In the food industry, these bacteria are used as preservatives and bioprotective agents, leading to improved food safety and quality (Miranda et al., 2021; Kolech et al.,2026). In humans, LABs, such as Lactobacillus species and related genera, improve intestinal barrier integrity and digestive function, modulate the immune system, inhibit bacterial pathogen growth, increase the production of valuable secondary metabolites, including short-chain fatty acids, and contribute to vitamin synthesis and mineral metabolism (Soundharrajan et al., 2026). LAB supplementation as a probiotic significantly improves human health and reduces metabolic disorders and diseases such as diabetes, obesity, muscle wasting, cardiovascular problems, and liver cirrhosis (Nousheen et al.,2025; Dong et al.,2024).

University of Thi-Qar Journal of agricultural research
Thi-Qar Journal of agricultural research
ISSN Onlin:2708 -9347, ISSN Print: 2708 -9339 Volume 15, Issue 1 (2026)
https://iasj.rdd.edu.iq/journals/journal/issue/20226 *https://doi.org/10.54174/utjagr.9898*

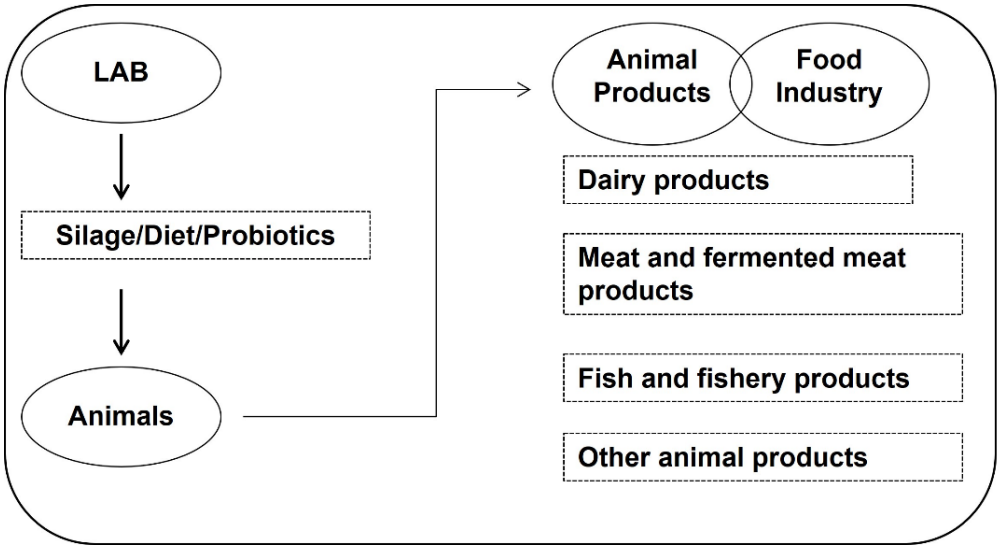

Figure 2. The importance of lactic acid bacteria in human and animal nutrition

-The role of lactic acid bacteria in animals:

The global demand for consumption of meat products is increasing due to the high nutritional value of red meat of all types and sources, and white meat. Diagram 3 illustrates the importance of LAB in nutrition. (Dong et al.,2024)

University of Thi-Qar Journal of agricultural research
Thi-Qar Journal of agricultural research
ISSN Onlin:2708 -9347, ISSN Print: 2708 -9339 Volume 15, Issue 1 (2026)
https://iasj.rdd.edu.iq/journals/journal/issue/20226 *https://doi.org/10.54174/utjagr.9898*

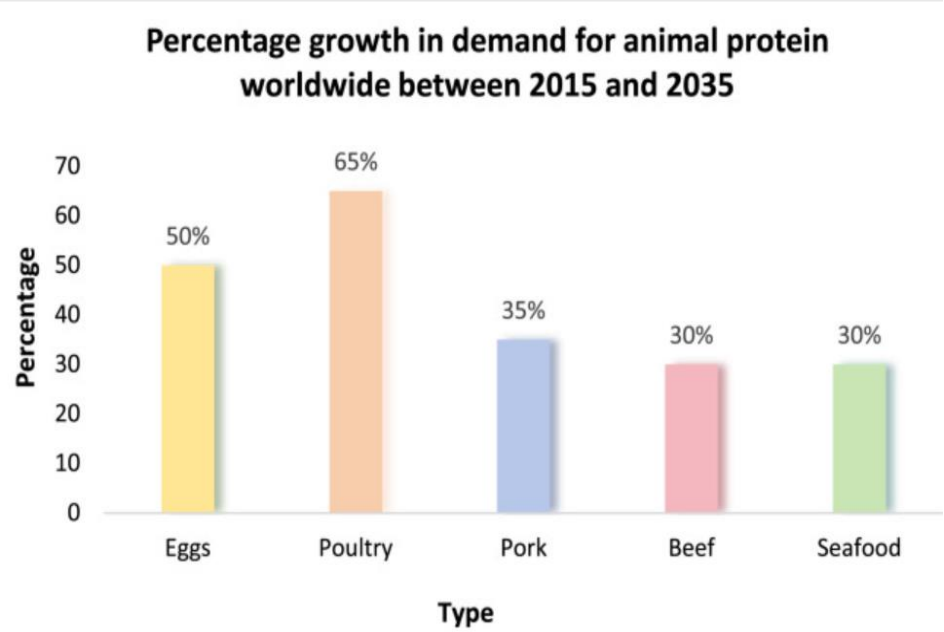

Fig 3. Percentage of animal protein worldwide growth demand between 2015 and 2035 (Dong et al.,2024)

In animals, the bacteria are widely used as a tonic in livestock farming due to their ability to enhance nutrient absorption and digestion, balance the gut microbiota, help prevent or control infections caused by pathogenic microbes, and strengthen mucosal integrity by producing antimicrobial substances. Probiotics contribute to enhanced animal immunity and productivity by producing compounds that compete with pathogens for nutrients and have antimicrobial properties. They also help to balance the gut microbiome and strengthen the intestinal barrier, inhibiting the growth of pathogenic species and promoting the growth of beneficial bacteria. It has been noted that pathogens such as *Clostridium perfringens* and *Salmonella* in cattle are inhibited by the activity of *Lactobacillus* and *Bifidobacterium* (Sachdeva et al.,2025).

Probiotics include many species, for example, beneficial gut microbes and yeast or fungi, and the mainly recommended probiotic strains are Bacillus subtilis, Bifidobacterium, Lactobacillus, and Streptococcus, which inhibit the development of many pathogenic bacteria such as *Clostridium perfringens, Staphylococcus aureus, Salmonella typhimurium, and Escherichia coli* (Zamojska et al.,2021). Adding Bacillus licheniformis to animal diets enhanced the color, flavor, and juiciness of the meat produced and increased the percentage of protein and aromatic and essential amino acids (Yi et al.,2024). Figure 4. Cleared the Improving quality of poultry and its meat products with probiotics (Yi et al.,2024).

University of Thi-Qar Journal of agricultural research
Thi-Qar Journal of agricultural research
ISSN Onlin:2708 -9347, ISSN Print: 2708 -9339 Volume 15, Issue 1 (2026)
https://iasj.rdd.edu.iq/journals/journal/issue/20226 https://doi.org/10.54174/utjagr.9898

Figure 4. Improving quality of poultry and its meat products with probiotics (Yi et al.,2024).

Probiotics boost immunity and improve resistance to pathogenic bacterial colonization. For example, supplementing chicken feed with *Enterococcus faecium* has shown an antimicrobial effect on the small intestine microflora (Naeem and Bourassa 2025). Probiotics include many genera and species, such as beneficial gut microbes, yeast, or fungi. The main recommended probiotic strains are Bacillus subtilis, Bifidobacterium, Lactobacillus, and Streptococcus, which inhibit the development of many pathogenic bacteria such as Clostridium perfringens, Staphylococcus aureus, Salmonella typhi, and Escherichia coli (Sarita et al.,2025). Among the many commercially available and commonly used probiotic strains for poultry are Lactobacillus species (*L. acidophilus, L. plantarum*), as well as species of the genus *Bifidobacterium*, and other important species such as *Bacillus* (*B. subtilis, B. licheniformis*). Halder et al.,2025 indicated that adding various types of probiotics to poultry feed improved growth, physiological functions, and immunity. This can contribute to reducing the use of growth inhibitors, and probiotics can be considered an effective alternative that benefits animals in general, and poultry in particular, and consequently humans.

- Probiotics Action Mechanism

The mechanisms of action of probiotics are divided into two main ways: first, they promote growth efficiency, and second, they improve immune function. The function or mechanism of action of different bacterial strains within a probiotic community can vary. For example, isolated bacteria may be unique within the same species, and their adhesion sites, immune responses, and other physiological behaviors may differ. Probiotics improve the body's microbial balance, as well as the balance of the surrounding environment. When taken orally, they protect epithelial membranes from harmful microorganisms as they pass through the mucous membranes of the stomach and other mucous membranes. Probiotics, such as Bifidobacterium and Lactobacillus, produce acids like acetic, lactic, and

ISSN Onlin:2708 -9347, ISSN Print: 2708 -9339 Volume 15, Issue 1 (2026)
https://iasj.rdd.edu.iq/journals/journal/issue/20226 https://doi.org/10.54174/utjagr.9898

propionic acids, which lower the pH and inhibit the growth of harmful bacteria. They also play a role in modulating the immune system (Ahmad and Khalid 2018.

-Conclusion:

The review found that lactic acid bacteria, classified as a probiotic, offer numerous advantages for use in animal husbandry and production. The excessive use of chemically manufactured antibiotics in animals to enhance their performance has negative consequences, including weakened immunity, increased antibiotic resistance, disease outbreaks, and consequently, reduced production. To help mitigate this global problem, the use of probiotics derived from lactic acid bacteria is considered a promising and effective alternative. Various benefits were observed in animals fed different types of probiotics derived from these bacteria. Furthermore, probiotics derived from lactic acid bacteria were found to control the development of bacterial diseases, increase the weight of healthy animals, and improve product quality. Selection of appropriate probiotic strains can reduce the harmful effects of antibiotic resistance use and has many beneficial outcomes due to its ability to prevent the development of pathogens.

References:

1- Ahmad A., Khalid S. Elsevier; 2018. Therapeutic aspects of probiotics and prebiotics; pp. 53–91. (Diet, Microbiome and Health).
2- Arsène, M. M. J., Davares, A. K. L., Viktorovna, P. I., Andreevna, S. L., Sarra, S., Khelifi, I., & Sergueïevna, D. M. (2022). The public health issue of antibiotic residues in food and feed: Causes, consequences, and potential solutions. Veterinary world, 15(3), 662. doi: 10.14202/vetworld.2022.662-671.
3- Ayana, G. U., & Kamutambuko, R. (2024). Probiotics in disease management for sustainable poultry production. Advanced Gut & Microbiome Research, 2024(1), 4326438. doi.org/10.1155/2024/4326438.
4- Banerjee D., Jain T., Bose S., Bhosale V. Springer; 2018. Importance of probiotics in human health; pp. 539–554. (Functional Food and Human Health).
5- Chowdhury MR, Hassan M, Shimosato T. Gut health management in livestock: roles of probiotics, prebiotics, and synbiotics in growth, immunity, and microbiota modulation. Vet Res Commun. 2025 Oct 20;49(6):361. doi: 10.1007/s11259-025-10927-1.
6- Dimuccio, M. M., Conforti, V., Celentano, F. E., Circella, E., Salvaggiulo, A., Bozzo, G., & Corrente, M. (2026). Regulation of Antibiotic Use in Livestock: European and International Strategies to Prevent and Control Antimicrobial Resistance and Ensure Animal Welfare. Antibiotics, 15(1), 67. doi: 10.3390/antibiotics15010067.
7- Dong S, Li L, Hao F, Fang Z, Zhong R, Wu J, Fang X. Improving quality of poultry and its meat products with probiotics, prebiotics, and phytoextracts. Poult Sci. 2024 Feb;103(2):103287. doi: 10.1016/j.psj.2023.103287.
8- Halder, N., Joardar, S. N., Sunder, J., De, A. K., Bhattacharya, D., Abd El Wahed, A., ... & Mondal, S. (2025). Impact of multi-strain probiotics supplementation on growth, immune responses and physiological traits in backyard poultry of Andaman and Nicobar Islands, India. Frontiers in Microbiology, 16, 1625167. doi.org/10.3389/fmicb.2025.1625167.
9- Izah, S. C., Nurmahanova, A., Ogwu, M. C., Toktarbay, Z., Umirbayeva, Z., Ussen, K., ... & Guo, Z. (2025). Public health risks associated with antibiotic residues in poultry food products. Journal of Agriculture and Food Research, 21, 101815. doi.org/10.1016/j.jafr.2025.101815.

10- Kolech A, Alemu S, Milkessa T. Evaluation of the antimicrobial properties of potential probiotic lactic acid bacteria from raw and fermented cow milk. Sci Rep. 2026 Feb 11;16(1):8355. doi: 10.1038/s41598-026-39586-1.
11- Mandey, J. S., & Sompie, F. N. (2021). Phytogenic feed additives as an alternative to antibiotic growth promoters in poultry nutrition. In Advanced studies in the 21st century animal nutrition. IntechOpen. doi: 10.5772/intechopen.99401.
12- Mârza, S. M., Munteanu, C., Papuc, I., Radu, L., & Purdoiu, R. C. (2025). The role of probiotics in enhancing animal health: Mechanisms, Benefits, and applications in livestock and companion animals. Animals, 15(20), 2986. doi: 10.3390/ani15202986.
13- Miranda C, Contente D, Igrejas G, Câmara SPA, Dapkevicius MLE, Poeta P. Role of Exposure to Lactic Acid Bacteria from Foods of Animal Origin in Human Health. Foods. 2021 Sep 4;10(9):2092. doi: 10.3390/foods10092092.
14- Monika, M., Tyagi, J. S., Sonale, N., Biswas, A., Murali, D., Sky, ... & Rokade, J. J. (2024). Evaluating the efficacy of Lactobacillus acidophilus derived postbiotics on growth metrics, health, and gut integrity in broiler chickens. Scientific reports, 14(1), 24768. doi: 10.1038/s41598-024-74078-0.
15- Mulchandani, R., Wang, Y., Gilbert, M., & Van Boeckel, T. P. (2023). Global trends in antimicrobial use in food-producing animals: 2020 to 2030. PLOS Global Public Health, 3(2), e0001305. doi.org/10.1371/journal.pgph.0001305.
16- Naeem M, Bourassa D. Probiotics in Poultry: Unlocking Productivity Through Microbiome Modulation and Gut Health. Microorganisms. 2025 Jan 24;13(2):257. doi: 10.3390/microorganisms13020257.
17- Nousheen, S., Amir, I., Ismat, N., Fatima, H., Bukhat, H., Bibi, I., & Yasin, M. (2025). Role of Probiotics in Modulating and Managing Metabolic Diseases. doi: 10.5772/intechopen.1013150.
18- Sachdeva, A., Tomar, T., Malik, T., Bains, A., & Karnwal, A. (2025). Exploring probiotics as a sustainable alternative to antimicrobial growth promoters: mechanisms and benefits in animal health. Frontiers in Sustainable Food Systems, 8, 1523678. doi.org/10.3389/fsufs.2024.1523678.
19- Samad, A., Muazzam, A., Alam, A. N., Kim, S., Kim, C., An, S., ... & Joo, S. T. (2026). Impact of Functional Feed Additives and Lower Antibiotic Use on Poultry Meat Quality and Consumer Perception. Foods, 15(11), 1868. org/10.3390/foods15111868.
20- Sana, S. S., Atuahene, D., Nagy, V., Shaikh, A. M., & Knop, R. (2025). The Rising Threat of Antibiotic Resistance in Poultry: Veterinary and One Health Perspectives. Veterinary Sciences, 12(11), 1059. doi: 10.3390/vetsci12111059.
21- Sarita B, Samadhan D, Hassan MZ, Kovaleva EG. A comprehensive review of probiotics and human health-current prospective and applications. Front Microbiol. 2025 Jan 6; 15:1487641. doi: 10.3389/fmicb.2024.1487641.
22- Soundharrajan, I., Ravindran, B., & Choi, K. C. (2026). Special Issue "Studies on Lactic Acid Bacteria and Their Products in Health and Diseases". International Journal of Molecular Sciences, 27(3), 1514. doi.org/10.3390/ijms27031514.
23- Uddin, T. M., Chakraborty, A. J., Khusro, A., Zidan, B. R. M., Mitra, S., Emran, T. B., ... & Koirala, N. (2021). Antibiotic resistance in microbes: History, mechanisms, therapeutic strategies and future prospects. Journal of infection and public health, 14(12), 1750-1766. doi.org/10.1016/j.jiph.2021.10.020.

24- Yi W, Liu Y, Fu S, Zhuo J, Wang J, Shan T. Dietary novel alkaline protease from Bacillus licheniformis improves broiler meat nutritional value and modulates intestinal microbiota and metabolites. Anim Microbiome. 2024 Jan 6;6(1):1. doi: 10.1186/s42523-023-00287-z.

25- Yi W, Liu Y, Fu S, Zhuo J, Wang J, Shan T. Dietary novel alkaline protease from Bacillus licheniformis improves broiler meat nutritional value and modulates intestinal microbiota and metabolites. Anim Microbiome. 2024 Jan 6;6(1):1. doi: 10.1186/s42523-023-00287-z.

26- Yusha'u, I., Muhammed-Sadiq, H., Jibril, M. A., Ibrahim, A., Kun, H. U., Yahaya, A., ... & Agi, A. M. (2026). Antibiotic Residue Accumulation in Poultry Meat and its Implications for Food Safety and Public Health in Keffi Metropolis, Nigeria. African Journal of Agricultural Science and Food Research, 22(1), 01-27.

27- Zamojska D, Nowak A, Nowak I, Macierzyńska-Piotrowska E. Probiotics and Postbiotics as Substitutes of Antibiotics in Farm Animals: A Review. Animals (Basel). 2021 Dec 1;11(12):3431. doi: 10.3390/ani11123431.

28- Zhou, Y., Zhang, A., van Klinken, R. D., Jones, D., & Wang, J. (2025). Consumers' perspectives on antibiotic use and antibiotic resistance in food animals: A systematic review. NPJ science of food, 9(1), 29. doi: 10.1038/s41538-025-00381.