Meat Research
Vol 4, Issue 2: 1-7, Article 85, April 2024
ISSN: 2790-1971
https://doi.org/10.55002/mr.4.2.85
http://www.bmsa.info/meatresearch

[1]Department of Animal Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[2]Meat Science Laboratory, Division of Applied Life Science (BK21 Four), Gyeongsang National University Jinju 52852, Korea
[3]Department of Poultry Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

***Corresponding Author:**

MA Hashem

E-mail: hashem_as@bau.edu.bd

Keywords:

Probiotic
Immune response
Gut microbiota
Meat quality
Efficiency

Article Info:

Received: 09 March 2024
Accepted: 16 April 2024
Published online: 30 April 2024

Review Article

Probiotics to enhance animal production performance and meat quality: A review

N Mia[1], AMMN Alam[2], MM Rahman[1], MS Ali[3], MA Hashem[1*]

Abstract

The utilization of probiotics in animal husbandry has garnered significant attention as a natural and effective strategy to enhance production performance and meat quality. This review synthesizes current research on the impact of probiotics on various livestock, including poultry, swine, and cattle. Probiotics, which are live microorganisms that confer health benefits to the host, have been shown to improve growth rates, feed conversion ratios, and overall health status of animals. Furthermore, they contribute to enhanced meat quality by influencing factors such as muscle composition, fat content, and oxidative stability. Mechanistically, probiotics exert their effects through modulation of gut microbiota, enhancement of nutrient absorption, and stimulation of the immune system. Studies also indicate a reduction in the incidence of diseases and a decrease in the need for antibiotic growth promoters, addressing concerns over antibiotic resistance. Despite promising results, variability in outcomes suggests that probiotic efficacy is influenced by factors such as strain specificity, dosage, and administration methods. Future research should focus on optimizing probiotic formulations and understanding the underlying mechanisms to maximize their benefits in animal production. This review highlights the potential of probiotics as a sustainable approach to improve animal performance and meat quality, contributing to more efficient and health-conscious animal agriculture.

Introduction

Metchnikoff first used the term “probiotic” in 1908; it is a combination of the Greek terms “pro” and “bios” which means “for life” (Prajapati et al., 2024). According to Nyathi et al. (2024) and Majidi-Mosleh et al. (2017), probiotics are defined as live microbial supplements that positively impact the host by enhancing its gut microbial composition.” Mono or mixed strains of living microorganisms that confer desirable health benefits on the host when used adequately” is the more recent definition that FAO/WHO accepted in 2002. According to Dasriya et al. (2024), a bacterium is considered probiotic if it is nonpathogenic, able to produce a viable cell count, beneficial to the host’s health, and improves digestive tract functioning. Probiotics such as *Lactobacillus acidophilus, L. plantarum, L. lactis, L. bulgaricus, L. helveticus, L. casei, L. salivarius, Bifido bacterium spp., Enterococcus faecalis, E. faecium, Streptococcus thermophilus, Escherichia coli* bacteria, and other probiotic fungi like *Saccharomyces boulardii* and *Saccharomyces cerevisiae* are the most widely used probiotics. Probiotic usage in agricultural animals is advantageous for decades due to its improvements in immunological response, weight increase, and feed efficiency (Elghandour et al., 2024). Probiotic efficacy is contingent upon several aspects, including the host’s age and species, the administration of an appropriate dosage, and the best possible selection of microbial strains. So, before adding probiotics to the diet of farm animals, great thought must be given to the matter. This study aims to address probiotic supplementation and additive use in animal feed and its impact on animal growth and health, productivity & product quality. We’ll also touch on probiotic utilization in fermented and fresh meat products.

Microbiome of the gut

Animals have a highly diversified microbial community in their gastrointestinal tracts (GITs) (Huang et al., 2024). The GIT exhibits variation in microbial density and diversity, with the highest populations seen in regions where the pH range approaches neutral (Rios Galicia, 2024; Yeoman and White, 2014). These regions include the post-gastric cecum of horses, pigs, and poultry as well as the pre-gastric rumen of ruminants. The gastrointestinal tract (GIT) can support up to several thousand distinct microbial species, including bacteria, fungus, protozoa, and archaea, depending on whether the animal is ruminant or monogastric. We plan to concentrate our review on bacteria as these are the microorganisms that are most frequently utilized as probiotics. Most gut bacteria are found in the two major groups Firmicutes and Bacteroidetes, however, there are additional species from Actinobacteria, Proteobacteria, and Verrucomicrobia (Schoonakker et al., 2024). For example, the entire microbiota in the bovine rumen is comprised of around 99% (42% and 57%, respectively) of Firmicutes species, and 96% (49% and 47%, respectively) of Bacteroidetes species (Mi et al., 2018). However, only a tiny fraction (<2%) of Bacteroidetes are found in the cecum of chickens and the hindgut of pigs, where Firmicutes predominate (Kraimi et al., 2019). Animal productivity, general health, growth, and development are significantly influenced by the commensal (indigenous) gut microbiota, which facilitates immune system development and response and enables the extraction of nutrients from the food. The latter is observed in ruminant animals, where the gut bacteria provide more than 70% of the animals' daily energy requirements. Microbial fermentation of carbohydrates produces a significant amount of that percentage, which is then employed as an energy source in the form of absorbed volatile fatty acids. Furthermore, when the microbial populations pass through the rumen and are broken down in the small intestine, they can be used as a source of protein (microbial protein). It is well known that the host immune system interacts with the gut bacteria. However, immunomodulatory cells in the lamina propria and intestinal epithelial cells in the lumen are the conduits for indirect communication between the two "systems." The intestinal epithelium, which has two vital roles, separates immune cells and bacteria. The first step involves physically separating the host immune cells from any foreign materials or microorganisms. The second involves informing immune cells about compounds generated by the gut microbiota, which triggers an immunological reaction (Okumura and Takeda, 2017). Because there is "cross-talk" between the innate immune system, epithelium, and resident commensal microbiota, the link between the gut microbiota and the host's health is therefore complicated. The wellbeing of the animal is enhanced by maintaining a rich and varied microbiota (Conlon and Bird, 2015). An animal's general health, behavior (feeding, social, and stress response), and development are all negatively impacted by a "imbalanced" microbiota (dysbiosis), in which the number of pathogenic bacteria exceeds that of helpful commensal bacteria (Azad et al., 2022; Kraimi et al., 2019). Diet, environment, and host genetics are a few of the elements that are known to affect the microbiota's richness and diversity. There is a complicated link between these three aspects since, depending on the situation, one may have greater influence than the other. For example, A newborn animal's gastrointestinal tract (GIT) is "sterile" at first, but microbial populations from the mother and environment soon populate it. In was found an increasing trend in Firmicutes and Proteobacteria and a decrease in Bacteroidetes with a high-fat diet in mice (Hildebrandt et al., 2009). Providing an example of how a change in food changes gut microbiota. Research has indicated that genetics has a role in regulating the microbiota as well (Bonder et al., 2016), but this role is probably muddled by dietary and environmental influences. Moreover, research has shown that taking probiotic supplements can modify and diversify the gut flora. Probiotics have been demonstrated to be able to replenish and enhance advantageous commensal microorganisms in the event of dysbiosis (Su et al., 2024). Determining the right time to make an alteration in an animal's life cycle is one of the difficulties associated with using probiotics. Some have suggested that since changes in the microbiome during maturity are quite minor, the intervention to modify the microbiome should take place while the animal is young. As a result, when probiotics are used during the growing, weaning, or completing periods of growth, for example, has a significant impact on the gut microbiota (Jørgensen et al., 2016).

Probiotic action mechanism

Since the mid-1970s, probiotic usage for animals has been on the rise. In agricultural animals, probiotic supplements have been utilized as therapeutics to reduce morbidity and mortality, enhance eating behavior, and boost yields of meat, milk, and eggs. Probiotics are also being used in the food sector because of their capacity to suppress a broad range of harmful bacteria that are generated from the environment and diet. Probiotics have been shown to have the ability to suppress undesired microbes through at least two different mechanisms: direct cell-to-cell contacts and/or the creation of inhibitory chemicals (Jonkers, 2016). Probiotics generate antimicrobial substances that can stop the growth of harmful bacteria, including organic acids, bacteriocins, hydrogen peroxide & biosurfactants. The most often generated substances by probiotic bacteria are lactic and acetic acids, which lower pH and inhibit the development of pathogens. Furthermore, via use of nutrients and intestinal adhesion sites that are competitively colonized, probiotics improve resistance to intestinal infections. Probiotics are only viable in tiny quantities because, similar to other organic nutrients in the gut, they are partially broken down and digested.

Probiotics, however, have been demonstrated to be successful in combating microbes that harm the host's health. Probiotics play a crucial function in the immune system's defense against harmful microbes by stimulating it throughout the body. It has been suggested that probiotics have a role in a complex process of stimulating the innate immune system by upregulating the expression of toll-like receptors (TLRs), which in turn causes the production of cytokines such as interferon-γ (IFN-γ), interleukin-4 (IL-4) & tumor necrosis factor-α (TNF-α). Probiotic use has been shown to improve disease resistance and reduce metabolic stress and mortality. A straightforward meal enhanced with a combination of probiotics comprising *Lactobacillus casei, L. acidophilus, Bifidobacterium thermophiles, and Enterococcus faecium* increased the content of immunoglobulins (Ig) M and G in turkeys. This improved the turkeys' resistance to illnesses and growth performance (Khatun et al., 2023). Additionally, piglets and sows treated with Bacillus cereus for 56 days at 2.6×10^5 and 1.4×10^6 cfu/g of feed showed an increase in intestinal IgA. Immune exclusion is the process by which mucosal IgA secretion stops pathogens and poisons from adhering to epithelial cells. A different study (Yi et al., 2018) demonstrated that feeding fish (*Carassius auratus*) Bacillus velezensis JW increased the expression of regulatory cytokine genes (TNF-α, IL-1, 4, and 10, IFN-γ) in the head kidney as well as the activity of several immune response-related enzymes in serum, including glutathione peroxidase, alkaline phosphatase, and acid phosphatase. Furthermore, the same study demonstrated that fish treated with Bacillus velezensis JW had a higher survival rate when confronted with harmful bacteria. Lactobacillus cultures, which have been demonstrated to regulate gastrointestinal pathogenic bacteria populations, are among the most popular probiotics (Chen et al., 2017). In piglets and Salmonella, Escherichia coli, and coliform levels in poultry may all be effectively reduced by a range of Lactobacillus strains (Liu et al., 2014). Steers were shown to have 37% less E. Coli O157:H7 shedding when fed 10^9 CFU of Lactobacillus acidophilus NP51 daily for 126 days. Moreover, it has been demonstrated that Lactobacillus rhamnosus works well in aquaculture against a highly pathogenic strain of *Aeromonas salmonicida*. The capacity of Lactobacillus to drive out other bacteria by fighting with them for adhesion sites and nutrients is typically credited with the lowering of harmful germs in the gut. Requires a thorough analysis of the processes underlying the competition for adhesion sites. All things considered, farm animals' health and immune system performance appear to be enhanced by probiotic treatment.

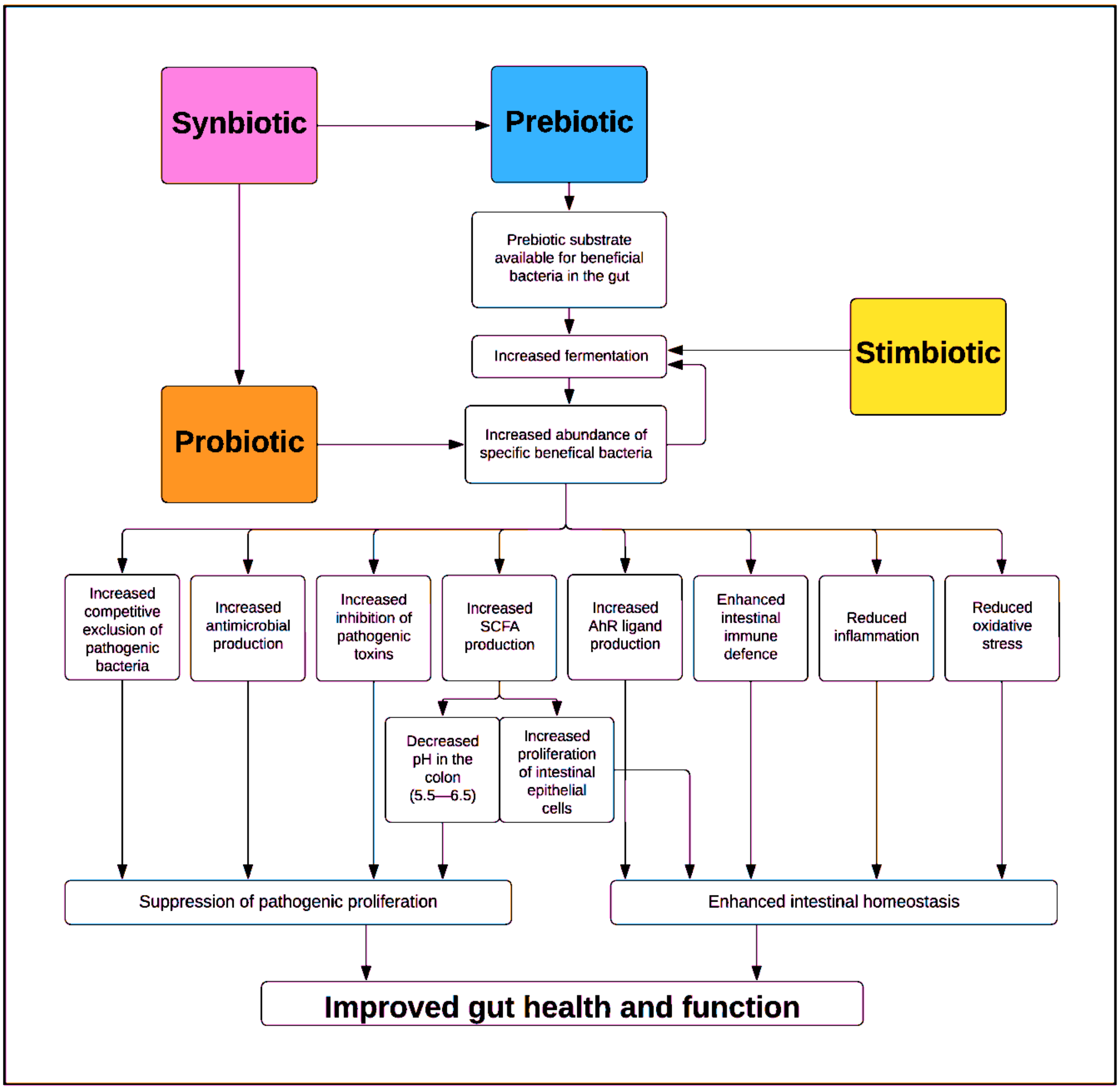

Figure 1. Probiotic action mechanism.

Utilizing probiotics for animal production

The use of probiotics in animal production has emerged as a promising approach to enhance growth performance, improve feed efficiency, bolster health, and elevate meat quality in livestock. Probiotics, defined as live microorganisms that confer health benefits to the host when administered in adequate amounts, have demonstrated multifaceted advantages across various animal species, including poultry, swine, and cattle. This overview examines the key benefits, mechanisms, and considerations for implementing probiotics in animal husbandry. An animal's production can be influenced by a number of factors, including sex, nutrition, age, and genetics. A sufficient nutritional plane is one of those elements that is necessary for an animal's growth and development. An animal needs the right amount of food, but increasing the feed's digestibility is also essential for promoting growth. Meng et al. (2022) found that probiotic supplements including *Bacillus subtilis* and *Clostridium butyricum* improved the growth performance of growing and finishing pigs. Better nutrient digestibility in the probiotic-supplemented pigs as compared to the control group was the reason for the increase in growth performance. Likewise, pigs treated with a Bacillus culture strain showed increased nutritional absorption (Jäger et al., 2018). In this instance, probiotic-receiving pigs demonstrated a 10% improvement in protein consumption after four to five months of supplementation as compared to non-supplied pigs. Probiotic supplementation has also been shown to improve performance and weight gain in broiler chicks and calves. According to Abdel-Azeem (2013), *Bacillus amyloquefaciens* supplemented turkeys fed more often and forlonger periods of time. More recent studies on the gut-brain axis, the relationship between the gut microbiome and the brain have suggested that neurological changes may occur because of which the microbiota may influence farm animals' feeding habits, even though the precise mechanism is still unknown (Kraimi et al., 2019). Probiotics' efficacy and dependability in contrast to antibiotic growth boosters and implants provide one of the largest obstacles to overcome in favoring their usage. Steers given implants alone or in conjunction with antibiotics grew around 10% faster than those given a supplement containing fermented Lactobacillus products, as shown by Ran et al.'s (2019) study. Probiotic efficacy needs to be carefully considered, even though several studies have shown beneficial impacts on development and performance when probiotics are used. This is due to the fact that a variety of factors, including variations in microbial makeup (e.g., single or multi-strains) and viability, dose and delivery methods, environmental stress factors, and the age and health state of the animal, all affect how effective probiotics are. For instance, Zhang et al. (2016) found that Holstein calves treated with Lactobacillus plantarum GF103 and Bacillus subtilis did not exhibit improvements in average daily growth, dry matter intake, or nutritional digestibility. The authors' idea that the probiotics' efficacy was impeded by the healthy state of all the calves included in the research has been supported by other investigations. Table 1 presents the findings from current research on the impact of probiotics on the development and functionality of farm animals. To maximize the benefits of probiotics, the table also includes information on strain, dose, and length of therapy.

Table 1. The impact of probiotics on the development and functionality of farm animals

Host	Host Age	Probiotic Strain	Administration/Dosage	Duration	Outcome	Ref.
Broiler	Chicks (1 day old)	Mixed: *B. subtilis* (CPB 011, CPB 029, HP 1.6, and D014) *B. velezensis* (CBP 020 and CPB 035)	1×10^9 CFU/g feed	35 days	↑LW and FCR	(Ramlucken et al., 2020)
Broiler	Chicks (1 day old)	Mixed: *L. bulgaric* *L.plantarum* *S. faecium* *B. Bifidum* *S. cerevisiae*	100 g/ton starter 50 g/ton finisher	42 days	No improvement	(Sarangi et al., 2016)
Broiler	Chicks (1 day old)	Mixed: *L.acidophilus* *L. casei* *E. faecium* *B. thermophilus*	10^9 CFU/g of feed	42 days	↑FI and LW	(Cengiz et al., 2015)
Layer	Hens (15 months old)	*B. licheniformis*	10^7 CFU/g of feed	12 days	↑Egg production	(Deng et al., 2012)
Bovine	Calves (8 days old)	Single: *L. plantarum* GF103 Mixed: *L. plantarum* F103 *B. subtilis*	Oral 1.7×10^{10} CFU/day 1.7×10^{10} CFU/day 1.7×10^8 CFU/day	83 days	↑FCR and CP digestibility	(Zhang et al., 2016)
Bovine	Calves (10 days old)	Mixed: *L. casei* DSPV 318T *L. salivarius* DSPV 315T *P. acidilactici* DSPV 006T	Oral 10^9 CFU/kg LW/day	35 days	↑LW	(Frizzo et al., 2010)
Porcine	Piglets (36 days old)	Single: *L. plantarum* GF103 Single: *B. subtilis* B27 Mixed: *L. plantarum* GF103 *B. subtilis* Mixed: *L. plantarum* GF103 and *B. subtilis*	8.6×10^9 CFU/kg feed 2.0×10^8 CFU/kg feed 4.3×10^8 CFU/kg feed 1.0×10^8 CFU/kg feed	35 days	All treatments ↑FCR	(Dong et al., 2014)
Porcine	Piglets (1 month old)	Mixed: *L. reuteri* ZJ625 *L. reuteri* VB4 *L. salivarius* ZJ61 *S. salivarius* NBRC 13956	Oral (10 mL)/week. 6.8×10^9 CFU/mL 5.5×10^{10} CFU/mL 5.5×10^{10} CFU/mL 2.9×10^{10} CFU/mL	30 days	↑GP	(Dlamini et al., 2017)
Porcine	Piglets (35 days old)	Mixed: *L. amylovorus* *E. faecium*	Oral (3 mL)/day 1×10^8 CFU/mL	35 days	↑FI and FE	(Ross et al., 2010)

FCR = feed conversion ratio; CP = crude protein; FI = feed intake; FE = feed efficiency; LW = live weight; GP = growth performance; (↑) increase in respective outcome; (*) study did not include age of the animal.

The early postnatal period is considered a "critical window" for altering the gut microbiota because the microbiome is more susceptible to both internal and external influences during this time. This is shown in germ-free animals that are reared and housed in a sterile atmosphere, where their immune systems are undeveloped because of not being exposed to germs 94. According to Jørgensen et al. (2016), probiotic supplementation was most sensitive to the pigs throughout their growth and weaning stages, but less successful during the finishing stages. The same study also showed that probiotic supplementation worked best for pigs fed a lower-energy diet, supporting the notion that an animal's nutritional condition should be considered when assessing the effectiveness of probiotic supplementation. It has also been demonstrated that dietary probiotics increase the quantity and quality of milk and eggs produced. During feeding, the inclusion of *Bacillus subtilis* and *Bacillus licheniformi* greatly increased the milk's protein and fat content. In a similar vein, adding Aspergillus oryzae culture to dairy cow feed raised the milk's protein and dry fat-free solids percentages. Probiotic supplements not only appear to improve the quality of milk but have also been linked to increased milk output in nursing cows, sows, ewes, and does (Ma et al., 2020). Xu et al. (2017) found that dairy cows treated with *Lactobacillus casei* and *Lactobacillus platarum* had a 37% increase in milk output. Alhussien and Dang (2018) linked the lower incidence of mastitis and inflammation of the mammary glands to the probiotic-supplemented dairy animals' higher milk output. Probiotics *Bacillus licheniformis* and *Bacillus subtilis* reduced cholesterol in egg yolks by 35% and enhanced egg production by 3% in laying hens. Additionally, laying hens' diets supplemented with 10^7 CFU/g of probiotic Bacillus licheniformis reduced the negative effects of heat stress, as seen by increased egg production, greater feed intake, and improved immunological response (Mia et al., 2023).

Effect of probiotics on meat quality

The general phrase "meat quality" refers to characteristics that affect consumers' decisions to buy and how they eat (Glogovețan and Pocol, 2024). These characteristics include meat's water-holding capacity (WHC), color, and texture (Kawsar et al., 2006; Tushar et al., 2023; Torun et al., 2023). These traits are impacted by the animal's life cycle as well as by the processes involved in harvesting, processing, and preparing the finished meat product (Sarker et al., 2022). Probiotics have been shown to enhance both the quality of fresh and processed meat products, as well as the development and production capacities of animals (Trabelsi et al., 2019; Bis-Souza et al., 2020). Improvements in product quality and safety, shelf-life extension, the imparting of distinctive sensory attributes, and health advantages are a few examples of these impacts (Kumar et al., 2017; Sarker et al., 2021). Meat color is thought to be the most significant quality factor influencing consumers' decisions to buy. This is because customers interpret color as a sign of a meat product's general freshness and wholesomeness. The amount and pace of pH fall that occurs after death are closely related to the variance in flesh color, which is affected by care of the animal and corpse both before and after death (Matarneh et al., 2017). pH typically decreases with time, starting at 7.2 and ending at about 5.6. Dark, firm, and dry (DFD) meat, in which the final pH stays relatively high (pH > 6.0), might result from abnormal pH drop. By contrast, pale, soft, and exudative (PSE) meat defect develops when there is a sudden drop in pH while the carcass temperature is still high. In this instance, the flesh releases water and proteins that are soluble in water, such myoglobin, giving the finished product a bland, pale look. Researchers have looked into the possibility of using probiotics to raise the pH and color stability of meat in recent years. Zheng et al. (2014) found that broilers treated with Enterococcus faecium had a higher pH in the pectoralis major muscle 45 minutes postmortem. Redder pectoralis flesh was linked to a pH rise. In a similar vein, research revealed that probiotic-supplemented pigs had meat that was redder and darker. It's yet unknown how probiotic supplementation and postmortem pH drop are related. Nonetheless, it appears that the kind of microbe employed and the mode of administration have an impact on the final pH (Popova, 2017). Research revealed that broilers given *Bacillus cereus* IP 5832 had higher breast ultimate pHs than broilers fed a diet containing *Streptococcus faecium* cernelle 68, which was linked to lower ultimate pHs. Additionally, studies showed that adding probiotics to the diet differed from drinking water in terms of final pH. Overall, probiotic usage may be able to assist in resolving this problem that has been ailing the hog and poultry sectors by slowing down the rate of pH fall in the early postmortem period. Meat's capacity to hold onto water often rises when the meat's final pH rises. A rise in pH is frequently linked to an increase in the WHC of the meat, which produces a final product that is thought to be more firm, juicy, and tender within the standard range of ultimate pH (5.4–5.8). Probiotic usage has reportedly been demonstrated to enhance WHC and meat softness (Liu et al., 2017). According to Cramer et al. (2018), probiotic treatment may also lessen harmful meat abnormalities in animals who have experienced oxidative stress in addition to improving tenderness (Mia et al., 2023). Studies on meats from animals fed with probiotics have demonstrated an increase in antioxidant capacity (Sadakuzzaman et al., 2023; Bai et al., 2017), as well as a decrease in lipid oxidation (Kim et al., 2016) and reactive oxygen species (Bai et al., 2016). Researchers are looking at different ways to incorporate these microorganisms into meat products as evidence for the positive benefits of probiotics on meat quality grows. Researchers have lately focused on the use of fermented meat products as a source of probiotics for human consumption, in addition to the advantages of employing probiotic cultures in fresh meat products. It may be possible to enhance human health and prevent the formation of harmful and spoiling microbes in food products by utilizing fermented meat as a carrier for these advantageous cultures (Sidira et al., 2014). Fermented meat products require little to no heat treatment during manufacturing, which makes them good carriers for living cultures. In contrast, fresh meat products are often cooked before eating. To ensure that the bacteria can withstand the high salt content, low pH, and water activity of fermented meat products, the right strain of microorganisms must be chosen. Due to their capacity to acidify meat, which aids in its preservation, Lactobacilli are the most significant probiotic bacteria in fermented meat products (Rahman et al., 2023; Sultana et al., 2023; Das et al., 2022). Numerous investigations have demonstrated the potential application of probiotic Lactobacillus strains, including *Lactobacillus plantarum, L. curvatus, and L. sakei,* in fermented meat products. According to several studies, using probiotic cultures of *Lactobacillus rhamnosus* GG, LC-705 & E-97800 inhibits the growth of E. coli 0157:H7 in dry sausage while producing high-quality sausage with no negative effects on its technological or sensory qualities (Alam et al., 2024a). Similar to this, when *Lactobacillus rhamnosus* GG was added at 10^5 and 10^7 CFU/g, it inhibited the growth of Enterobacteriaceae during the fermentation process. Lipid oxidation is a serious issue in fresh and fermented beef products because it degrades the product's sensory appeal, which in turn affects customer acceptance of the product. In both fresh and fermented meats, free fatty acids are the primary precursors of lipid oxidation (Slima et al., 2018). Because probiotics may create bacteriocins, which prevent lipolytic microorganisms from generating free fatty acids, they have the potential to be used as preventive agents against lipid oxidation (Smaoui et al., 2017). According to Özer et al. (2016), compared to control samples, the addition of *Lactobacillus plantarum* at 10^5 CFU/kg to fermented sucuk resulted in noticeably decreased levels of thiobarbituric acid reactive substances (TBARS), a marker of lipid peroxidation. Trabelsi et al. (2019) came to a similar result when they observed reduced TBARS in minced beef that had received a Lactobacillus plantarum inoculation. Likewise, the incorporation of Bifidobacterium lactis and Lactobacillus acidophilus decreased the incidence of lipid oxidation and enhanced the organoleptic properties of fermented sausage (Dong et al., 2024; Simion et al., 2014). As cutting-edge technologies are on rise in the meat industry such as hybrid cultured meat (Alam et al., 2024b), umami enhancement in meat (Hossain et al., 2024), plant-based meat (Kumari et al., 2023), reconstructed meat (Samad et al., 2024), etc., value addition through the addition of microflora could be promising as functional foods for the consumers. Application of spectroscopy (Hashem et al., 2022) and multivariate analysis could be useful in identifying the meat characteristics in the probiotic treated functional foods as well.

Conclusions

The conclusion that employing probiotics in animal food and fresh and processed meat products has various benefits may be drawn from this study, which compiles a number of prior studies. Probiotic use appears to enhance immunological response, animal development, meat quality, nutritional absorption and digestibility, and gut microbial composition. Probiotics have also been shown in several studies to enhance the sensory qualities and quality of fermented meat products. This clarifies some of the complexities around the use of probiotics, even if there were certain instances when their inclusion in animal meals and meat products had no discernible impact. Therefore, greater research defining particular strains, determining the ideal dose, and comprehending the web of interactions between probiotics and the gut microbiota may aid in the development of more potent probiotic mixes for use in meat products and animal feed.

Conflict of Interest

There are no conflicts of interest among the authors.

References

Abdel-Azeem M. 2013. Do probiotics affect the behavior of turkey poults? J. Vet. Med. Anim. Health., 5: 144-148.

Alam AN, Hashem MA, Matar AM, Ali MS, Monti JA, Hossain MJ, Mia N. 2024a. Cutting edge technologies for the evaluation of plant-based food and meat quality: A comprehensive review. Meat Research, 4:1.

Alam AN, Kim CJ, Kim SH, Kumari S, Lee SY, Hwang YH, Joo ST. 2024b. Trends in Hybrid Cultured Meat Manufacturing Technology to Improve Sensory Characteristics. Food Science Animal Research, 44(1):39. https://doi.org/10.5851/kosfa.2023.e76

Alhussien MN, Dang AK. 2018. Milk somatic cells, factors influencing their release, future prospects, and practical utility in dairy animals: An overview. Vet. World, 11: 562.

Azad MAK, Rahman MM, Hashem MA. 2022. Meat microbiota: A conceptual review. Meat Research, 2: 2, Article No. 20. https://doi.org/10.55002/mr.2.3.20

Bai K, Huang Q, Zhang J, He J, Zhang L, Wang T. 2017. Supplemental effects of probiotic *Bacillus subtilis* on growth performance, antioxidant capacity, and meat quality of broiler chickens. Poult. Sci., 96:74–82.

Bai WK, Zhang FJ, He TJ, Su PW, Ying XZ, Zhang L, Wang T. 2016. Dietary probiotic Bacillus subtilis strain fmbj increases antioxidant capacity and oxidative stability of chicken breast meat during storage. PLoS ONE, 11: e0167339.

Bis-Souza C, Penna ALB, da Silva Barretto C. 2020. Applicability of potentially probiotic Lactobacillus casei in low-fat Italian type salami with added fructooligosaccharides: In vitro screening and technological evaluation. Meat Sci., 168: 108186.

Bonder MJ, Kurilshikov A, Tigchelaar EF, Mujagic Z, Imhann F, Vila AV, Deelen P, Vatanen T, Schirmer M, Smeekens SP. 2016. The effect of host genetics on the gut microbiome. Nat. Genet., 48: 1407–1412.

Cengiz Ö, Köksal BH, Tatlı O, Sevim Ö, Ahsan U, Üner AG, Ulutas PA, Beyaz D, Büyükyörük, S, Yakan A. 2015. Effect of dietary probiotic and high stocking density on the performance, carcass yield, gut microflora, and stress indicators of broilers. Poult. Sci., 94: 2395–2403.

Chen C, Chen S, Wang H. 2017. Effect of supplementation of yeast with bacteriocin and Lactobacillus culture on growth performance, cecal fermentation, microbiota composition, and blood characteristics in broiler chickens. Asian Australas. J. Anim. Sci., 30: 211.

Conlon MA, Bird R. 2015. The impact of diet and lifestyle on gut microbiota and human health. Nutrients, 7: 17–44.

Cramer T, Kim H, Chao Y, Wang W, Cheng H, Kim Y. 2018. Effects of probiotic (*Bacillus subtilis*) supplementation on meat quality characteristics of breast muscle from broilers exposed to chronic heat stress. Poult. Sci., 97: 3358–3368.

Das A, Hashem MA, Azad MAK, Rahman MM. 2022. Edible oil marination in broiler meat for short term preservation. Meat Research, 2:(3).

Dasriya VL, Samtiya M, Ranveer S, Dhillon HS, Devi N, Sharma V, Puniya AK. 2024. Modulation of gut-microbiota through probiotics and dietary interventions to improve host health. Journal of the Science of Food and Agriculture.

Deng W, Dong X, Tong J, Zhang Q. 2012. The probiotic Bacillus licheniformis ameliorates heat stress-induced impairment of egg production, gut morphology, and intestinal mucosal immunity in laying hens. Poult. Sci., 91: 575–582.

Dlamini Z, Langa R, Aiyegoro O, Okoh A. 2017. Effects of probiotics on growth performance, blood parameters, and antibody stimulation in piglets. S. Afr. J. Anim. Sci., 47: 765–776.

Dong S, Li L, Hao F, Fang Z, Zhong R, Wu J, Fang X. 2024. Improving quality of poultry and its meat products with probiotics, prebiotics, and phytoextracts. Poultry Science, 103(2): 103287.

Dong X, Zhang N, Zhou M, Tu Y, Deng K., Diao Q. 2014. Effects of dietary probiotics on growth performance, faecal microbiota and serum profiles in weaned piglets. Anim. Prod. Sci., 54: 616–621.

Elghandour MM, Abu Hafsa SH, Cone JW, Salem AZ, Anele UY, Alcala-Canto Y. 2024. Prospect of yeast probiotic inclusion enhances livestock feeds utilization and performance: An overview. Biomass Conversion and Biorefinery, 14(3):2923-2935.

Frizzo L, Soto L, Zbrun M, Bertozzi E, Sequeira G, Armesto RR, Rosmini M. 2010. Lactic acid bacteria to improve growth performance in young calves fed milk replacer and spray-dried whey powder. Anim. Feed Sci. Technol., 157: 159–167.

Glogoveţan AI, Pocol CB. 2024. The Role of Promoting Agricultural and Food Products Certified with European Union Quality Schemes. Foods, 13(6): 970.

Hashem MA, Islam MR, Hossain MM, Alam AM, Khan M. 2022. Prediction of chevon quality through near infrared spectroscopy and multivariate analyses. Meat Res, 2 (6). https://doi.org/10.55002/mr.2.6.37

Hildebrandt MA, Hoffmann C, Sherrill-Mix SA, Keilbaugh SA, Hamady M, Chen YY, Knight R, Ahima RS, Bushman F, Wu GD. 2009. High-fat diet determines the composition of the murine gut microbiome independently of obesity. Gastroenterology, 137: 1716–1724.

Hossain MJ, Alam AM, Lee EY, Hwang YH, Joo ST. 2024. Umami Characteristics and Taste Improvement Mechanism of Meat. Food Sci Anim Res 44: 3. https://doi.org/10.5851/kosfa.2024.e29

Huang J, Sheng Y, Xue P, Guan P, Ren J, Qian W. 2024. Characteristics of bacterial community and volatile fatty acids in the gastrointestinal tract of Tarim wapiti. Italian Journal of Animal Science, 23(1): 259-274.

Jäger R, Purpura M, Farmer S, Cash HA, Keller D. 2018. Probiotic Bacillus coagulans GBI-30, 6086 improves protein absorption and utilization. Probiotics Antimicrob. Proteins, 10: 611–615.

Jonkers DM. 2016. Microbial perturbations and modulation in conditions associated with malnutrition and malabsorption. Best Pract. Res. Clin. Gastroenterol., 30: 161–172.

Jørgensen JN, Laguna JS, Millán C, Casabuena O, Gracia MI. 2016. Effects of a Bacillus-based probiotic and dietary energy content on the performance and nutrient digestibility of wean to finish pigs. Anim. Feed Sci. Technol., 221: 54–61.

Kawsar SM, Rahman MM, Rahman SME, Hossain MM, Huq MA. 2006. Growth, carcass and non-carcass traits of Black Bengal goats due to urea molasses block supplementation. International Journal of Bio-Resources. 2 (1): 1-5.

Khatun A, Das SC, Ray BC, Ahmed T, Hashem MA, Khairunnesa M, Roy BC. 2023. Effects of feeding phytobiotics on growth performance, breast meat quality, blood biochemical indices, and liver enzymes of broiler chickens. European Poultry Science/Archiv für Geflügelkunde, 374.

Kim H, Yan F, Hu J, Cheng H, Kim Y. 2016. Effects of probiotics feeding on meat quality of chicken breast during postmortem storage. Poult. Sci., 95: 1457–1464.

Kraimi N, Dawkins M, Gebhardt-Henrich SG, Velge P, Rychlik I, Volf J, Creach P, Smith A, Colles F, Leterrier C. 2019. Influence of the microbiota-gut-brain axis on behavior and welfare in farm animals: A review. Physiol. Behav, 210: 112658.

Kumar P, Chatli M, Verma AK, Mehta N, Malav O, Kumar D, Sharma N. 2017. Quality, functionality, and shelf life of fermented meat and meat products: A review. Crit. Rev. Food Sci. Nutr.,57: 2844–2856.

Kumari S, Alam AN, Hossain MJ, Lee EY, Hwang YH, Joo ST. 2023. Sensory Evaluation of Plant-Based Meat: Bridging the Gap with Animal Meat, Challenges and Future Prospects. Foods. 28;13(1): 108. https://doi.org/10.3390/foods13010108

Liu H, Zhang J, Zhang S, Yang F, Thacker P.A, Zhang G, Qiao S, Ma X. 2014. Oral administration of Lactobacillus fermentum I5007 favors intestinal development and alters the intestinal microbiota in formula-fed piglets. J. Agric. Food Chem., 62: 860–866.

Liu L, Ni X, Zeng D, Wang H, Jing B, Yin Z, Pan K. 2017. Effect of a dietary probiotic, Lactobacillus johnsonii BS15, on growth performance, quality traits, antioxidant ability, and nutritional and flavour substances of chicken meat. Anim. Prod. Sci., 57: 920–926.

Ma ZZ, Cheng YY, Wang SQ, Ge JZ, Shi HP, Kou JC. 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. J. Anim. Physiol. Anim. Nutr., 104: 44–55.

Majidi-Mosleh A, Sadeghi A, Mousavi S, Chamani M, Zarei A. 2017. Ileal MUC2 gene expression and microbial population, but not growth performance and immune response are influenced by in ovo injection of probiotics in broiler chickens. Br. Poult. Sci, 58:40–45.

Matarneh SK, England EM, Scheffler TL, Gerrard DE. 2017. The conversion of muscle to meat. In Lawrie' s Meat Science; Elsevier: Amsterdam, The Netherlands, pp. 159–185.

Meng HYH, Mak CCH, MakWY, Zuo T, Ko H, Chan FKL. 2022. Probiotic supplementation demonstrates therapeutic potential in treating gut dysbiosis and improving neurocognitive function in age‑related dementia. European Journal of Nutrition, 61: 1701–1734. https://doi.org/10.1007/s00394-021-02760-4

Mi L, Yang B, Hu X, Luo Y, Liu J, Yu Z, Wang J. 2018. Comparative analysis of the microbiota between sheep rumen and rabbit cecum provides new insight into their differential methane production. Front. Microbiol, 9:575.

Mia N, Rahman MM, Hashem MA. 2023. Effect of heat stress on meat quality: A review. Meat Research, 3:(6).

Nyathi N, Ndhlovu D, Rabvukwa E, Ndudzo A. 2024. Improving Antimicrobial Stewardship in Human Health Using Probiotics and their Derivatives.

Okumura R, Takeda K. 2017. Roles of intestinal epithelial cells in the maintenance of gut homeostasis. Exp. Mol. Med, 49: e338.

Özer CO, Kılıç B, Kılıç GB. 2016. In-vitro microbial production of conjugated linoleic acid by probiotic L. plantarum strains: Utilization as a functional starter culture in sucuk fermentation. Meat Sci, 114: 24–31.

Popova T. 2017. Effect of probiotics in poultry for improving meat quality. Curr. Opin. Food Sci., 14: 72–77.

Prajapati K, Bisani K, Prajapati H, Prajapati S, Agrawal D, Singh S, Goswami D. 2024. Advances in probiotics research: mechanisms of action, health benefits, and limitations in applications. Systems Microbiology and Biomanufacturing, 4(2): 386-406.

Rahman MM, Hashem MA, Azad MAK, Choudhury MSH, Bhuiyan MKJ. 2023. Techniques of meat preservation-A review. Meat Research,3:(3).

Ramlucken U, Ramchuran SO, Moonsamy G, Lalloo R, Thantsha MS, van Rensburg CJ. 2020. A novel Bacillus based multi-strain probiotic improves growth performance and intestinal properties of Clostridium perfringens challenged broilers. Poult. Sci., 99: 331–341.

Ran T, Gomaa W, Shen Y, Saleem A, Yang W, McAllister T. 2019. Use of naturally sourced feed additives (lactobacillus fermentation products and enzymes) in growing and finishing steers: Effects on performance, carcass characteristics and blood metabolites. Anim. Feed Sci. Technol., 254: 114190.

Rios Galicia B. 2024. Novel bacterial species from the chicken gastrointestinal tract and their functional diversity.

Ross GR, Gusils C, Oliszewski R, De Holgado SC, González SN. 2010. Effects of probiotic administration in swine. J. Biosci. Bioeng., 109: 545–549.

Sadakuzzaman M, Rahman MM, Hashem, M. A. 2023. Irradiation of meat with synthetic and natural antioxidant: A review on quality aspect of meat. Meat Research, 3:(4).

Samad A, Alam AM, Kumari S, Hossain MJ, Lee EY, Hwang YH, Joo ST. 2024. Modern Concepts of Restructured Meat Production and Market Opportunities. Food Sci Anim Res 44(2): 284-98. https://doi.org/10.5851/kosfa.2024.e18

Sarangi NR, Babu L, Kumar A, Pradhan C, Pati P, Mishra J. 2016. Effect of dietary supplementation of prebiotic, probiotic, and synbiotic on growth performance and carcass characteristics of broiler chickens. Vet. World, 9: 313.

Sarker MAH, Hossain ME, Habib M, Hashem MA, Ali MS. 2022. Comparison of meat yield and physicochemical characteristics of indigenous, cockerel and Sonali chicken. Meat Research, 2: (6).

Sarker MIA, Hashem MA, Azad MAK, Ali MS, Rahman MM. 2021. Food grade vinegar acts as an effective tool for short-term meat preservation. Meat Research. 1 (1): Article No. 05.

Schoonakker MP, van Peet PG, an den Burg EL, Numans ME, Ducarmon QR, Pijl H, Wiese M. 2024. Impact of dietary carbohydrate, fat, or protein restriction on the human gut microbiome: a systematic review. Nutrition Research Reviews, 1-47.

Sidira M, Karapetsas A, Galanis A, Kanellaki M, Kourkoutas Y. 2014. Effective survival of immobilized Lactobacillus casei during ripening and heat treatment of probiotic dry-fermented sausages and investigation of the microbial dynamics. Meat Sci, 96: 948–955.

Simion AMC, Vizireanu C, Alexe P, Franco I, Carballo J. 2014. Effect of the use of selected starter cultures on some quality, safety and sensorial properties of Dacia sausage, a traditional Romanian dry-sausage variety. Food Control, 35: 123–131.

Slima SB, Ktari N, Triki M, Trabelsi I, Abdeslam A, Moussa H, Makni I, Herrero AM., Jiménez-Colmenero F, Ruiz-Capillas C. 2018. Effects of probiotic strains, *Lactobacillus plantarum* TN8 and *Pediococcus acidilactici*, on microbiological and physico-chemical characteristics of beef sausages. LWT, 92: 195–203.

Smaoui S, Ennouri K, Chakchouk-Mtibaa A, Karray-Rebai I, Hmidi M, Bouchaala K, Mellouli L. 2017. Relationships between textural modifications, lipid and protein oxidation and sensory attributes of refrigerated turkey meat sausage treated with bacteriocin BacTN635. Food Bioprocess Technol, 10: 1655–1667.

Su ACY, Ding X, Lau HCH, Kang X, Li Q, Wang X, Yu J. 2024. Lactococcus lactis HkyuLL 10 suppresses colorectal tumourigenesis and restores gut microbiota through its generated alpha-mannosidase. Gut.

Sultana N, Islam R, Bhakta S, John AS, Sinza SI, Hashem MA. 2023. Role of Clove and Tulsi on broiler health and meat production. Saudi Journal of Biological Sciences, 30(6): 103654.

Trabelsi I, Slima SB, Ktari N, Triki M, Abdehedi R, Abaza W, Moussa H, Abdeslam A, Salah RB. 2019. Incorporation of probiotic strain in raw minced beef meat: Study of textural modification, lipid and protein oxidation and color parameters during refrigerated storage. Meat Sci., 154: 29–36.

Tushar ZH, Rahman MM, Hashem MA. 2023. Metmyoglobin reducing activity and meat color: A review. Meat Research, 3:5. Article No. 67.

Xu H, Huang W, Hou Q, Kwok LY, Sun Z, Ma H, Zhao F, Lee YK, Zhang H. 2017. The effects of probiotics administration on the milk production, milk components and fecal bacteria microbiota of dairy cows. Sci. Bull., 62: 767–774.

Yeoman CJ, White BA. 2014. Gastrointestinal tract microbiota and probiotics in production animals. Annu. Rev. Anim. Biosci, 2:469–486.

Yi Y, Zhang Z, Zhao F, Liu H, Yu L, Zha J, Wang G. 2018. Probiotic potential of Bacillus velezensis JW: Antimicrobial activity against fish pathogenic bacteria and immune enhancement effects on Carassius auratus. Fish Shellfish. Immunol., 78: 322–330.

Zhang R, Zhou M, Tu Y, Zhang N, Deng K, Ma T, Diao Q. 2016. Effect of oral administration of probiotics on growth performance, apparent nutrient digestibility and stress-related indicators in Holstein calves. J. Anim. Physiol. Anim. Nutr., 100: 33–38.

Zheng A, Luo J, Meng K., Li J, Zhang S, Li K, Liu G, Cai H, Bryden WL, Yao B. 2014. Proteome changes underpin improved meat quality and yield of chickens (Gallus gallus) fed the probiotic Enterococcus faecium. BMC Genom, 15: 1167.