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Various Prebiotics and Probiotics, Their Usage and Importance in Maintaining Normal Microflora in Animal

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ABSTRACT
Maintaining balanced microflora in animals is essential for health, immunity, and productivity, particularly considering the increasing global demand for antibiotic-free animal products. This review examines the contributions of prebiotics and probiotics, separately and in combination as synbiotics, to gastrointestinal health and the enhancement of animal performance. This review consolidates contemporary data regarding these therapies' mechanisms, uses, and advantages, highlighting their capacity to foster microbial stability, improve nutrient absorption, and augment immunological responses across diverse animal species, including poultry, swine, ruminants, and aquaculture. Key themes, including the effectiveness of prebiotic and probiotic strains, and discrepancies in the literature concerning doses, combinations, and species-specific treatments are examined. The review additionally analyzes the synergistic effects of synbiotics, which enhance the advantages of these chemicals. This review examines the current research landscape, identifies significant knowledge gaps, and provides insights into the difficulties and potential for enhancing microbial-based techniques in animal production systems. The results underscore the promise of prebiotics and probiotics as sustainable substitutes for antibiotics, enhancing animal welfare and production while mitigating the environmental effects of livestock systems. The review culminates with essential recommendations for future research, highlighting the necessity for longitudinal investigations, established methodology, and the investigation of innovative microbiological possibilities. It enhances the comprehension and implementation of microbial-based therapies, providing a basis for superior health management and sustainable practices in animal agriculture.

INTRODUCTION
Maintaining normal animal microflora is crucial in veterinary research, animal nutrition, and sustainable livestock production. The gut microbiota is essential for animal health, affecting immunity, nutrition absorption, and disease resistance. With the increasing global demand for antibiotic-free animal products, attention has turned to other techniques, like prebiotics and probiotics, to sustain a healthy microbial equilibrium (Shehata et al., 2022). These chemicals, whether used individually or as synbiotics, have shown significant potential in fostering intestinal health and improving productivity in several animal species, including poultry, swine, ruminants, and aquaculture (Ringseis & Eder, 2022). This review consolidates existing literature to elucidate the function of prebiotics and probiotics in sustaining animal microbiota, emphasizing their utilization, processes, and applications in contemporary animal production systems (Ji et al., 2023).

Recent studies have highlighted the advantages of prebiotics and probiotics in improving gut health and alleviating microbial imbalances. Research indicates that Lactobacillus and Saccharomyces cerevisiae strains greatly enhance animal growth performance and immunological function (Kaur et al., 2023). Nonetheless, significant deficiencies persist in comprehending these substances' ideal mixes, doses, and species-specific utilizations. The variability in experimental methodologies and inconsistencies in outcome reporting further restrict the generalizability of findings. Rectifying these deficiencies is essential for promoting the application of microbial-based therapies as sustainable substitutes for antibiotics (Barathan et al., 2024). This review methodically examines the current literature to address these deficiencies, providing an enhanced understanding of the effectiveness of prebiotics and probiotics and their combined effects as synbiotics (Nugusa & Kasa, 2024).

This review aims to rectify shortcomings in prior research by consolidating findings to clarify the mechanisms, applications, and advantages of prebiotics and probiotics in sustaining animal microbiota (Ke et al., 2021). The review emphasizes the integration of these chemicals in many animal systems, revealing new insights into their potential to enhance health, productivity, and sustainability (Reddy et al., 2023). This review rectifies discrepancies in current research while pinpointing prospects for future progress, providing a fundamental paradigm for academics, policymakers, and practitioners in animal nutrition and health (Bo et al., 2023).

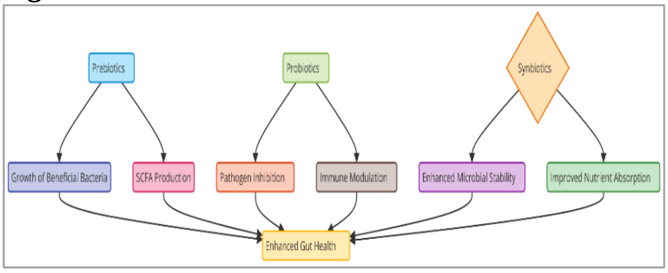
Overview of Microflora in Animals

Role of Normal Microflora in Animal Health

The term "microflora" denotes the varied assemblage of microorganisms, encompassing bacteria, fungus, and archaea, which reside in different areas of an animal's body, especially the gastrointestinal (GI) tract. These microorganisms are essential for sustaining their host's health and physiological processes, establishing a symbiotic relationship that advantages both the germs and the mammal (Zhou et al., 2024). Comprehending the function and makeup of normal microflora is essential for recognizing their significance in overall animal health. Normal microflora contributes to maintaining animal homeostasis by executing various essential roles. Their primary function is to assist in the digestion and fermentation of complex polysaccharides and other food elements the host cannot enzymatically degrade (Isiaka et al., 2024). In ruminants, including cows and sheep, the bacteria in the rumen aids in cellulose digestion and the synthesis of volatile fatty acids, which serve as key energy sources for these animals (Jiang et al., 2022).

Besides facilitating digestion, the microflora is a defensive barrier against pathogenic germs. This is accomplished by competitive exclusion; wherein advantageous bacteria surpass detrimental pathogens in securing resources and adhesion sites inside the gastrointestinal tract (Wang et al., 2023). Moreover, the synthesis of antimicrobial agents, including bacteriocins and organic acids, by helpful microorganisms further suppresses pathogen proliferation (Reitano et al., 2021). Microflora significantly influences the immune system. The interplay between the host's immune cells and gut microbiota facilitates the formation and regulation of the immune response. Commensal bacteria, for instance, promote the synthesis of immunoglobulin A (IgA) and additional immunological components that safeguard the intestinal lining against infections. Furthermore, the gut microbiota's capacity to affect systemic immune responses highlights their significance beyond the gastrointestinal tract (Vaga et al., 2020). The Figure 1 provides a visual representation of how prebiotics, probiotics, and synbiotics interact to improve gut health through various biological mechanisms.

Figure 1



This flowchart illustrates the interconnected mechanisms of prebiotics, probiotics, and synbiotics in promoting gut health. Prebiotics enhance beneficial bacteria's growth and stimulate short-chain fatty acids (SCFAs), while probiotics inhibit pathogens and modulate the immune system. Synbiotics combine these effects, improving microbial stability and nutrient absorption. Together, these processes enhance overall gut health, fostering a balanced and resilient gut microbiome essential for well-being.

Factors Affecting Microflora Balance

Normal microflora balance is a dynamic condition affected by numerous factors, such as nutrition, age, environment, and antibiotic usage (Chen et al., 2020). Diet significantly influences microbial composition. High-fiber diets encourage the proliferation of beneficial microorganisms, but diets abundant in fats and simple carbohydrates may support potentially harmful species (Zhen et al., 2022). Likewise, incorporating feed additives, including prebiotics and probiotics, might beneficially influence microbiota composition, improving animal health (Oswari et al., 2021).

Age is an additional factor influencing microbiota composition. In neonatal animals, the gastrointestinal system is initially devoid of microorganisms; however, colonization commences immediately postnatally, determined by the delivery method and ambient exposure (Diao et al., 2021). With time, the microbial community achieves stabilization, resulting in a resilient and equilibrated environment. Nevertheless, older animals frequently see a reduced microbial diversity, potentially resulting in health complications (Liu et al., 2021). Environmental factors, such as stress and hygienic conditions, can disrupt the delicate equilibrium of microflora. Factors such as transportation, overcrowding, and severe temperatures have been demonstrated to modify microbial makeup, frequently leading to dysbiosis, a condition of microbial imbalance. Likewise, indiscriminate antibiotic usage can significantly diminish microbial diversity, eradicating pathogenic and beneficial microorganisms. This disturbance may render animals more vulnerable to opportunistic infections (Tsekhmistrenko et al., 2020).

Prebiotics: Characteristics and Applications

Types of Prebiotics and Their Sources

Prebiotics are non-digestible carbohydrates that evade enzymatic breakdown in the host's gastrointestinal system, arriving in the large intestine where they act as a substrate for beneficial bacteria (Davani-Davari et al., 2019). Examples include inulin, fructooligosaccharides (FOS), galactooligosaccharides (GOS), and resistant starches. These substances are prevalent in foods such as chicory root, garlic, onions, bananas, and whole grains, providing a natural means of promoting intestinal health (Augustin et al., 2020). Prebiotics such as mannan oligosaccharides (MOS) sourced from yeast cell walls and xylooligosaccharides (XOS) obtained from hemicellulose are extensively utilized in animal feed. These targeted prebiotics are formulated to enhance the growth of beneficial microbial communities in cattle, poultry, and aquaculture systems (Ng & Rosman, 2019). Prebiotic selection is contingent upon the specific animal species and intended results, such as promoting fiber-degrading bacteria in ruminants or stimulating Lactobacilli proliferation in poultry and swine to mitigate infections like Salmonella and Escherichia coli (Naumann et al., 2019).

Mechanisms of Action in Supporting Microflora

Prebiotics improve gut health via specific and diverse processes. They serve as a fermentable substrate, promoting the proliferation of beneficial bacteria that generate short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate (Davani-Davari et al., 2019). These SCFAs are essential for energy synthesis in intestinal epithelial cells and significantly contribute to reducing gut pH, inhibiting the growth of detrimental bacteria (Biswas et al., 2019).

Prebiotics promote a beneficial microbial equilibrium and aid in immune modulation by increasing the synthesis of bioactive metabolites. Short-chain fatty acids (SCFAs) are recognized for enhancing gut barrier integrity, diminishing inflammatory reactions, and regulating immune cell activity. This is especially crucial for animals recuperating from stress or infections, as prebiotics facilitate the restoration of intestinal homeostasis (Bogusławska-Tryk et al., 2021). Competitive exclusion constitutes another fundamental process. Prebiotics enhance the prevalence of advantageous microbes, which surpasses pathogenic organisms in acquiring nutrition and adhesion sites within the gastrointestinal tract. Moreover, specific prebiotics, like MOS, directly adhere to pathogens, obstructing their adhesion to intestinal walls and aiding in expulsion from the host organism (Park et al., 2021).

Using prebiotics in animal nutrition has produced significant advantages, including improved intestinal health, increased nutrient absorption, and less disease occurrence. Prebiotic addition in poultry diets has been described to enhance weight gain, improve feed conversion ratios, and reduce intestinal infections (Biswas et al., 2019). Incorporating fructooligosaccharides (FOS) or galactooligosaccharides (GOS) in swine has been associated with superior growth performance, greater gut integrity, and improved immunological responses (Siddiqui et al., 2024). As research advances, the application of prebiotics is increasingly broadening, providing sustainable methods to enhance animal productivity and welfare while diminishing reliance on antibiotics. This method corresponds with contemporary trends in advocating natural, health-focused animal dietary solutions (Shanmugasundaram et al., 2019).

Probiotics: Characteristics and Applications

Commonly Used Probiotics in Animals

Probiotics are live bacteria that, when provided in sufficient quantities, offer health advantages to the host by favorably altering the makeup of gut microbiota. They are extensively employed in animal nutrition to promote gastrointestinal health, augment immunity, and enhance overall productivity (Fabia et al., 2021). The predominant animal probiotic strains are from the genera Lactobacillus, Bifidobacterium, Bacillus, Enterococcus, and Saccharomyces. Every probiotic strain demonstrates unique functions. Lactobacillus species are recognized for their capacity to generate lactic acid, which reduces gut pH and establishes an inhospitable environment for pathogenic bacteria (Li et al., 2024). Bacillus species are esteemed for their capacity to create spores, which guarantees their survival in extreme settings, such as elevated temperatures during feed processing and the acidic milieu of the stomach (Qiu et al., 2022).

Probiotic strain selection is contingent upon the specific species targeted and the intended result. Lactobacillus acidophilus and Bacillus subtilis are commonly employed in chickens to mitigate enteric infections, including Salmonella and Clostridium perfringens (Khan et al., 2019). In pigs, probiotics such as Enterococcus faecium and Saccharomyces cerevisiae improve nutritional absorption and reduce post-weaning diarrhea (Tazehabadi et al., 2021). Ruminants derive advantages from probiotics like Propionibacterium and Megasphaera elsdenii, which contribute to rumen stability and the prevention of acidosis (Johnson et al., 2023).

Probiotic Efficacy in Promoting Gut Health

Probiotics offer advantages through multiple pathways, with competitive exclusion being one of the most significant. Probiotics adhere to the intestinal mucosa, occupying binding sites and restricting the colonization of harmful microorganisms. This competitive mechanism inhibits pathogenic bacteria from initiating infections, improving gut integrity (Siddique et al., 2021). Probiotics facilitate the synthesis of antimicrobial agents, including organic acids, hydrogen peroxide, and bacteriocins, which suppress the proliferation of pathogenic microorganisms. Moreover, several probiotic bacteria generate enzymes that facilitate the digestion of complex nutrients, enhancing feed efficiency and nutrient absorption (Siddique et al., 2021).

A vital feature of probiotics is their capacity to regulate the host's immunological response. Probiotics promote the synthesis of immunological components, including cytokines, bolsters the host's fight against infections. They also facilitate the formation of gut-associated lymphoid tissue (GALT), an essential immune system element (Pell et al., 2021). Probiotics enhance innate and adaptive immunity, enabling animals to combat illness threats more effectively. Studies have consistently demonstrated the advantages of probiotics in enhancing animal health and productivity. Supplementation with Lactobacillus reuteri in poultry diminishes intestinal lesions induced by coccidiosis and improves feed conversion ratios (Chen et al., 2022). The application of Saccharomyces cerevisiae in dairy cattle has been associated with enhanced milk production and rumen health. In aquaculture, probiotics have been reported to mitigate disease outbreaks by improving water quality and strengthening fish immune systems (Knobloch et al., 2022).

Incorporating probiotics into animal feed signifies a sustainable method for enhancing gut health and mitigating increasing apprehensions regarding antibiotic resistance. Probiotics enhance animal welfare by fostering a balanced microbiome, improving animal-derived products' safety and quality (Do Carmo et al., 2019). As research progresses, identifying new probiotic strains and their specific applications is anticipated to improve the effectiveness of these advantageous microbes in animal nutrition (Kaur et al., 2020).

Combined Use of Prebiotics and Probiotics (Synbiotics)

Synergistic Effects on Microflora Stability

Integrating prebiotics and probiotics, termed synbiotics, signifies a novel strategy for improving gut health and overall animal welfare. The diverse applications and benefits of synbiotics across various animal species, including poultry, swine, ruminants, and aquaculture, are summarized in Table 1, illustrating their significant role in enhancing health, productivity, and disease resistance in animal production systems. Synbiotics function synergistically, utilizing the distinct advantages of prebiotics as substrates and probiotics as living helpful bacteria. This combination enhances the viability and activity of the administered probiotic strains while augmenting their beneficial effects on the indigenous gut flora (Chi et al., 2021).

Synbiotics enhance the colonization potential of probiotics, hence stabilizing microbiota. Prebiotics, including fructooligosaccharides (FOS) and galactooligosaccharides (GOS), serve as a selective energy source for administered probiotics, facilitating their survival and growth in the host's gastrointestinal tract. This focused assistance enhances microbial equilibrium, diminishing the likelihood of dysbiosis induced by pathogenic microorganisms or environmental stresses (Sergeev et al., 2020). Furthermore, synbiotics enhance the formation of short-chain fatty acids (SCFAs). The fermentation of prebiotics by probiotics produces short-chain fatty acids (SCFAs), including acetate and butyrate, which reduce gut pH and suppress pathogenic microorganisms. The increased generation of SCFAs supplies energy to intestinal epithelial cells, enhancing gut barrier function and mitigating inflammation (Sergeev et al., 2020). Synbiotics have demonstrated efficacy in alleviating diarrhea and enhancing gut health in weaning pigs, where the preservation of microbial stability is essential for growth and immunological development (Jačan et al., 2020).

Case Studies on Synbiotic Applications in Animals

The utilization of synbiotics has been thoroughly investigated across multiple animal species, confirming their effectiveness in improving health and production. In chicken, synbiotics have demonstrated enhancements in performance indicators, including weight increase, feed conversion ratios, and disease resistance. An exemplary case is using Lactobacillus strains in conjunction with FOS, which diminished Salmonella colonization and improved intestinal architecture and nutritional absorption (Sapsuha et al., 2023). In swine production, synbiotics have proven helpful in mitigating issues related to weaning stress. The combination of Enterococcus faecium and mannan oligosaccharides (MOS) has enhanced intestinal integrity and mitigated post-weaning diarrhea, a prevalent concern in piglets (Acharya et al., 2024). These advantages stem from the increased proliferation of bacteria, such as Lactobacilli, and the inhibition of detrimental pathogens like Escherichia coli (Shanmugasundaram et al., 2020).

Ruminants additionally gain advantages from synbiotic nutrition. Research has demonstrated that using Saccharomyces cerevisiae with inulin in dairy cows enhances rumen fermentation efficiency, increasing milk output and enhancing feed utilization. Synbiotics have effectively alleviated rumen acidosis, a disease frequently associated with high-grain diets in cattle (Nisar et al., 2021). In aquaculture, synbiotics are becoming recognized for their contribution to enhancing fish health and disease resistance. The amalgamation of Bacillus subtilis and dietary prebiotics has demonstrated the capacity to augment gut microbiota diversity, increase growth rates, and diminish mortality in aquacultured fish species. These advantages are especially significant in aquaculture systems, where water quality and disease outbreaks pose crucial concerns (Szczypka et al., 2021).

The synergistic effect of synbiotics provides a comprehensive method for enhancing animal health by integrating prebiotics and probiotics. Their capacity to augment gut microbiota stability, promote nutritional absorption, and elevate immune function highlights their potential as a sustainable substitute for antibiotics in animal production systems. With the rising demand for antibiotic-free animal products, the utilization of synbiotics is set to be crucial in the future of livestock and aquaculture management (Atela et al., 2019).

Table 1

Summary of Prebiotic and Probiotic Applications Across Animal Species

Animal Species	Key Benefits	Examples of Applications
Poultry	- Improved growth performance	- *Lactobacillus* and *Bacillus subtilis* reduce *Salmonella* colonization and enhance intestinal morphology.
	- Enhanced immune response	- *Saccharomyces cerevisiae* mitigates coccidiosis and improves feed conversion ratios.
	- Reduced disease incidence	- Prebiotics like MOS lower *Clostridium perfringens*-induced necrotic enteritis.
Swine	- Improved feed efficiency	- *Enterococcus faecium* reduces post-weaning diarrhea and enhances nutrient absorption.
	- Enhanced gut integrity	- FOS supports beneficial *Lactobacilli*, suppressing *Escherichia coli*.
	- Better recovery from stress	- Synbiotics help maintain microbial balance during weaning.
Ruminants	- Enhanced fiber digestion	- *Propionibacterium* and *Saccharomyces cerevisiae* improve rumen health and milk production.
	- Prevention of metabolic disorders	- Probiotics mitigate rumen acidosis caused by high-grain diets.
	- Increased productivity	- Inulin supplementation leads to higher milk yields and better nutrient utilization.
Aquaculture	- Improved survival and growth rates	- *Bacillus subtilis* combined with prebiotics increases gut microbiota diversity and reduces mortality.
	- Enhanced resistance to disease	- Synbiotics improve immune function and water quality in aquaculture systems.
	- Reduced environmental stress	- Prebiotics support gut health under high-density farming conditions.

Impact of Prebiotics and Probiotics on Animal Health and Productivity

Benefits in Disease Prevention and Recovery

Prebiotics and probiotics are crucial for disease prevention and recovery by enhancing immune response, strengthening gut barrier integrity, and reducing pathogen colonization. Their ability to influence microbial communities in the gastrointestinal tract makes them valuable tools for mitigating common diseases in livestock and other animals. Probiotics, such as Lactobacillus and Bifidobacterium, produce antimicrobial agents such as lactic acid and bacteriocins that inhibit the growth of harmful bacteria, including Salmonella, Escherichia coli, and Clostridium perfringens (Chlebicz-Wójcik & Śliżewska, 2020). Conversely, prebiotics promote the growth of beneficial bacteria by providing fermentable substrates, enhancing the protective advantages of the gut microbiota (Zhaxi et al., 2020).

Including prebiotics, such as mannan oligosaccharides (MOS), in poultry has been linked to a reduction in enteric diseases, including necrotic enteritis and coccidiosis. These prebiotics impede pathogenic adhesion and bolster the avian immune response. Probiotics like Bacillus subtilis have effectively reduced gastrointestinal disorders' severity and enhanced recovery rates (Donovan et al., 2021). In swine, prebiotics and probiotics successfully mitigate post-weaning diarrhea, a condition often caused by E. coli infections. These vitamins reduce inflammation and enhance the piglet's healing ability by promoting a healthy microbial balance and improving gut integrity (Guevarra et al., 2023). Furthermore, in ruminants, probiotics such as Saccharomyces cerevisiae have demonstrated the ability to reduce the risk of acidosis, a metabolic disorder that can considerably impact productivity (Chae et al., 2019).

Influence on Animal Growth and Feed Efficiency

Applying prebiotics and probiotics has significantly enhanced animal growth performance and feed efficiency, rendering them essential in contemporary livestock management. These supplements improve nutritional digestion, absorption, and utilization by enhancing gastrointestinal health and stabilizing microbial communities. Probiotics enhance feed conversion efficiency by increasing enzyme activity and decomposing complex nutrients into readily absorbable forms (Seifi et al., 2019). Bacillus subtilis has been demonstrated to enhance the availability of amino acids and other vital elements in poultry diets, resulting in accelerated growth rates and increased body weights. In ruminants, probiotics like Propionibacterium augment the rumen's fiber digestion, enhancing milk production and weight gain (Araújo & Botelho, 2022).

Prebiotics enhance feed efficiency by promoting the proliferation of beneficial bacteria that digest dietary fibers into short-chain fatty acids (SCFAs). These SCFAs not only furnish supplementary energy to the host but also encourage the formation of intestinal villi, hence augmenting the surface area for food absorption (Behrouz et al., 2020). In swine, adding fructooligosaccharides (FOS) has been linked to enhanced growth performance and increased feed efficiency (Olas, 2020).

The advantages of prebiotics and probiotics in aquaculture are manifest in enhanced growth and survival rates. The synergistic application of Bacillus spp. and dietary prebiotics in aquaculture has enhanced feed efficiency and reduced feed expenses, along with improved disease resistance (Sharma et al., 2019). The influence of prebiotics and probiotics transcends growth performance, encompassing enhanced product quality. Probiotic supplementation in dairy cows has been correlated with increased milk outputs and improved milk composition, whilst, in poultry, it has been associated with elevated egg production and enhanced shell quality (Segura-Badilla et al., 2020).

CONCLUSION

This review emphasizes the vital importance of prebiotics and probiotics in sustaining a balanced microbiota crucial for animal health, immunity, and production. Prebiotics, as non-digestible substrates, preferentially promote beneficial bacteria, whereas probiotics introduce live microorganisms that improve gut health and inhibit harmful colonization. Their synergistic application as synbiotics enhances these advantages, fostering microbial stability, immunological regulation, and enhanced nutrient absorption, with notable implications in poultry, swine, ruminants, and aquaculture systems. These findings illustrate their capacity to diminish antibiotic reliance, tackling worldwide antimicrobial resistance issues while conforming to customer preferences for natural, health-focused animal products. Nonetheless, deficiencies in the research remain, especially with a standardized methodology for assessing efficacy across species, heterogeneity in doses and delivery, and the intricate connections among gut microbiota, host genetics, and environmental variables. Future research must focus on long-term studies investigating species-specific requirements, optimal combinations, and delivery methods of prebiotics and probiotics while utilizing advancements in multi-omics technologies to identify new microbial candidates and pathways. Research on their systemic effects, especially regarding immunological and metabolic activities, is essential for expanding their applications. This review is constrained by the variability of available data and an emphasis on extensively researched chemicals, possibly neglecting developing candidates. Notwithstanding these constraints, the results highlight the transformative capacity of microbial-based interventions in fostering sustainable, health-oriented animal production systems. Addressing existing knowledge deficiencies could transform animal agriculture, improving productivity, animal welfare, and global food security while reducing the environmental effect of livestock systems. This study establishes a basis for future research and underscores the vital role of prebiotics and probiotics in influencing sustainable animal production practices.

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