USE OF HOST-SPECIFIC PROBIOTICS IN ANIMAL FEED

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Introduction

The increasing demand for sustainable and efficient animal production has resulted in extensive research into alternative strategies to enhance livestock health and performance. Probiotics represent a potential alternative for promoting gut health, improving nutrient utilization and mitigating antibiotic use in animal production systems (Fuller, 1989). Probiotics are defined as live microorganisms which, when administered in appropriate amounts, benefit the host by modulating the gut microbiota, enhancing immune response, and improving well-being (Ouwehand et al., 2002).

Traditional probiotics from human or environmental sources may not be ideal for the gut environment of various animal species. Interest in host- specific probiotics has been on the rise- those derived from the same species in which they will be used (Markowiak and Śliżewska, 2018). Host-specific probiotics are more suited for the physiological and microbial environments of their respective host species than non-specific probiotics (Gao et al., 2017). Host-specific probiotics are believed to colonize better, establish a more optimal microbiota, and confer better health than non-specific probiotics (Gao et al., 2017).

The tenet of host specificity in probiotics is based upon the premise that different animal species have different gut microbiota compositions which is influenced by diet, physiology, and environmental factors (Guerra-Ordaz et al., 2014). By utilizing probiotics that have a natural adaptation to the host species, investigators and the industry are pursuing a more predictable and efficacious method of promoting animal health and production (Ducatelle et al., 2015). Host-specific probiotic regimens have shown a variety of benefits, including improved adhesive properties to intestinal epithelial cells, greater resistance to gastric and bile acids, and enhanced interactions with the derived microbiota (Bajagai et al., 2016). These benefits promote a more stable gut ecosystem rich in beneficial microbiota which in turn reduce the risk of pathogenic infections, improve digestive efficacy, and promote overall growth performance in farm animals (Kenny et al., 2011).

The increasing concern about antibiotic resistance and sustainable production in livestock has stimulated interest in the use of host-specific probiotics as an alternative to traditional growth promoters and methods of disease prevention (Broom, 2017). This review outlines how host-specific probiotics can work, their potential benefits, and how they can be used in animal diets, by discussing their effects on improving feed efficiency, enhancing immune function, and reducing disease across several livestock animals.

Sources of Host-Specific Probiotics

Host-specific probiotics are often isolated from the gastrointestinal tracts of healthy members of a given species to benefit similar types of individuals. Such material can be alone or in a mixture, and may come from the gut microbiota of livestock, or from fermented animal-derived products, or through geographic or targeted isolation of particular microbes from fecal samples or intestinal mucosa (e.g., Gao et al., 2017).

Isolation from Gut-microbiota

The most reliable source of host-specific probiotics is gut microbiota from healthy animals that have been isolated from digesta. Recovery of putative probiotics from healthy animals has relied primarily on advantageous bacteria like Lactobacillus, Bifidobacterium, or Enterococcus, isolated from livestock digesta and analyzed for probiotic potential (e.g., Uyeno et al., 2015). Strains are selected based on factors such as their ability to endure gastric conditions, their capacity to adhere to gut epithelial tissues and their potential to generate antimicrobial products against pathogen bacteria (e.g., Markowiak and Śliżewska, 2018).

Fermented Animal-derived Products

Some fermented animal-derived products, including fermented milk products or silage, might serve as natural locations where host-specific microbes reside. For example, species of dairy-derived probiotics, such as Lactobacillus casei and Lactobacillus plantarum, have been used in ruminants to increase digestive efficiency and improve milk quality (Nocek and Kautz, 2006). Such probiotics are isolated from traditional dairy fermentations and adapted for use as feed additives (e.g., Chaucheyras-Durand and Durand, 2010).

Fecal and Intestinal Mucosal Sampling

Probiotics can also be sourced from fecal samples and intestinal mucosa of healthy animals. Scientists employ microbial culture techniques and molecular sequencing to identify and select beneficial strains capable of conferring health benefits. This approach ensures that the isolated probiotics are naturally adapted to the host's gut environment, enhancing their efficacy in modulating gut microbiota and preventing enteric infections (Guerra-Ordaz et al., 2014).

Biotechnology- based Microbial Selection

Biotechnological advancements, including metagenomics and microbial genome sequencing, allow for accurate identification and selection of host-specific probiotics (Bajagai et al., 2016). Researchers can identify bacterial strains with the greatest probiotic potential through the composition of microbiota associated with diverse species of animals. Genetic modification and strain engineering can increase the survivability of these probiotics when used in animal nutrition (Ducatelle et al., 2015).

Benefits of Using Host-Specific Probiotics

Enhanced Colonization and Adaptability

One of the most significant benefits of host-specific probiotics is that they can establish themselves and survive in the gastrointestinal tract easier than generic probiotics. Probiotics that are referred to as host-specific originate from the species of the host they are being used in, which increases their potential to survive in the digestive tract of that host (Markowiak and Śliżewska, 2018). An example in poultry; *Lactobacillus salivarius*, isolated from chickens, adhered better to intestinal epithelial cells and persisted for a longer duration to inhibit pathogens when compared to generic probiotics (Gao et al., 2017). An example from swine; *Lactobacillus reuteri*, isolated from the digestive tract of pigs, improved colonization and nutrient absorption efficiency (Guerra-Ordaz et al., 2014).

Improved Gut Microbiota Balance

Probiotics which are host-specific have been shown to stabilize gut microbiota, which positively shifts the microbial community in a way that supports digestion and immune function. Host-specific or species-specific probiotics can increase the number of beneficial microbes while also reducing some opportunistic pathogens (Bajagai et al., 2016). The therapeutic use of probiotics is of particular significance in younger or stressed animals since gut microbiota dis-equilibrium is often expected in these populations. For example, using *Lactobacillus johnsonii* with swine has reduced pathogenic *Escherichia coli* prevalence, lower incidence of diarrhea, and improved efficiency of feed conversion (Guerra-Ordaz et al., 2014).

Enhanced Immune Modulation

Host-specific probiotics are known to more effectively interact with their host's immune system, modulating both innate and adaptive immunity. They stimulate the production of immunoglobulin A (IgA), thereby enhancing mucosal immunity to enteric pathogens (Broom, 2017). Probiotics also stimulate immune adaptation by inducing the expression of tight junction proteins in intestinal epithelium resulting in a stronger gut barrier that will prevent the entry of pathogenic bacteria (Ducatelle et al., 2015). In poultry, *Lactobacillus acidophilus* probiotics that had been isolated from chickens have been shown to stimulate immune responses and reduce intestinal inflammatory responses (Gao et al., 2017).

Pathogen Exclusion and Antimicrobial Effects

Host-specific probiotic strains also demonstrate beneficial competitive exclusion properties as they protect the gut from subsequent colonization by pathogenic bacteria by attaching to adherence sites and competitively assimilating nutrients more efficiently than the pathogenic bacteria. Furthermore, many of these probiotics also produce antimicrobial metabolites, such as bacteriocins, organic acids, and hydrogen peroxide, that inhibit the growth of pathogenic bacteria (Markowiak and Śliżewska, 2018). In ruminants, host-adapted *Lactobacillus plantarum* strains have been shown to reduce the occurrence of Salmonella and *Clostridium perfringens* infections and improve health and production (Kenny et al., 2011).

Improved Digestive Efficiency and Nutrient Absorption

One more significant advantage of host-specific probiotics is their contribution to digestive process improvement and nutrient uptake. Probiotics help facilitate the digestion of dietary fibers, starches, and proteins, enhancing the bioavailability of important nutrients (Ducatelle et al., 2015). For instance, a host-specific strain of Bacillus subtilis has been demonstrated to improve gut enzyme activity, which resulted in improved digestibility and feed efficiency in poultry (Dowarah et al., 2017). In ruminants, probiotics also enhance fermentation processes in the rumen which increases production of volatile fatty acids; key components of energy metabolism (Markowiak and Śliżewska, 2018).

Reduction in Antibiotic Use and Resistance Concerns

With increasing concerns regarding antibiotic resistances, host-specific probiotics provide a natural, alternative method of antibiotic growth promoters. Probiotics support gut health and immunity to reduce the frequency of bacterial infections, and therefore the need for antibiotics (Bajagai et al., 2016). This also enhances the sustainability of animal production systems and relates to global concerns regarding antimicrobial resistance (Broom, 2017).

Economic and Environmental Benefits

Host-specific probiotics provide valuable economic benefits to animal producers through improved feed efficiency, decreased losses due to disease, and improved productivity. Improved nutrient efficacy reduces feed costs, and healthier animals mean fewer medical costs (Guerra-Ordaz et al., 2014). Probiotics also provide environmental benefits by reducing nitrogen and phosphorus excretion in the manure of animals, contributing to sustainable livestock farming (Ducatell et al., 2015).

Mechanism of Action of Host-Specific Probiotics

Colonization and Competitive Exclusion

Probiotics that are specific to particular hosts colonize the gastrointestinal tract by adhering to intestinal epithelial cells and competing for nutrients and attachment sites with pathogenic microorganisms (Markowiak and Śliżewska, 2018). This colonization is further enhanced by adaptations specific to the species of the probiotic strains that enable them to thrive within the gut environment of their hosts. For example, *Lactobacillus reuteri* isolated from pigs appears to have superior adhesion characteristics in swine intestines than that of non-host specific strains (Guerra-Ordaz et al., 2014). Host-specific probiotics prevent, or reduce the likelihood of, pathogenic microorganisms colonizing the intestinal mucosa, such as *Escherichia coli* and Salmonella, by occupying attachment sites (Gao et al., 2017). The competitive exclusion of pathogen colonization reduces pathogen load and decreases risk for GI infections which improves animal health and performance (Bajagai et al., 2016).

Modulation of the Gut Microbiota

Host-specific probiotics can influence the gut microbiota's composition and function by facilitate beneficial microbes and suppress harmful microbes (Broom 2017). These probiotics produce antimicrobial factors including organic acids, hydrogen peroxide, and bacteriocins, leading to reductions in the growth of pathogens (Markowiak and Śliżewska, 2018). *Lactobacillus salivarius* strains that were isolated from chickens have been shown to increase the population of beneficial Bifidobacteria and decrease the populations of Clostridium perfringens, which is associated with necrotic enteritis, in poultry (Ducatelle et al., 2015). Because probiotics can adjust the microbiota composition, they can improve digestive efficiency and reduce the incidence of subsequent diseases, leading to increased gut health (Guerra-Ordaz et al., 2014).

Enhancement of Intestinal Barrier Function

Role of host specific probiotics in facilitating gut barrier integrity as a first line defence against pathogenic bacteria and toxins has emerged as a significant function (Bajagai et.al. 2016). Probiotic strains have been shown to upregulate the expression of tight junction proteins, like ccluding and claudin, which help maintain gut epithelial integrity (Gao et.al. 2017). In swine, *Lactobacillus johnsonii* has been shown to improve gut barrier function by upregulating mucin production and permeability (Ducatelle et.al. 2015). When gut barrier integrity is improved, health status is improved and the need for antibiotic intervention is lowered (Broom, 2017).

Immunomodulation and Anti-Inflammatory Effects

Host-specific probiotics utilize the host immune system to modify immune responses and increase disease immunity. They induce the production of secretory immunoglobulin A (sIgA), which provides mucosal immunity against enteric pathogens (Bajagai et al., 2016). Additionally, probiotics can alter cytokine production, leading to reduced inflammation and increased immune tolerance (Markowiak and Śliżewska, 2018). For instance, poultry research shows that a

Lactobacillus acidophilus from chickens decreased gut inflammation through regulation of the ratio of pro-inflammatory and anti-inflammatory cytokines, resulting in improved gut health and performance (Gao et al., 2017). Furthermore, in cattle studies, *Lactobacillus plantarum strains* improved immune responses and reduced enteric infection susceptibility (Kenny et al., 2011).

Production of Beneficial Metabolites

Probiotics specific to particular hosts generate necessary metabolites, including short-chain fatty acids (SCFAs), such as acetate, propionate, and butyrate (Bajagai et al., 2016). SCFAS are utilized as energy sources by intestinal epithelial cells and support gut health and dampen pathogenic bacteria growth, in part by decreasing gut pH (Ducatelle et al., 2015). In ruminants, *Bacillus subtilis* strains specific to a certain host are able to improve ruminal fermentation, resulting in increased volatile fatty acid production and energy utilization (Markowiak and Śliżewska, 2018). In livestock, this means better feed efficiency and productivity (Broom, 2017).

Effect of Host-Specific Probiotics on Poultry

Host-specific probiotics have demonstrated significant benefits in poultry production by improving gut health, enhancing growth performance, reducing pathogenic infections, and optimizing feed efficiency. Given the poultry industry's economic importance, incorporating host-specific probiotics into feed formulations has emerged as a sustainable strategy for improving productivity while minimizing the use of antibiotics (Gao et al., 2017).

Improvement in Gut Health and Microbiota Composition

Poultry-specific probiotics, such as *Lactobacillus salivarius* and *Lactobacillus acidophilus*, play a crucial role in modulating the gut microbiota by promoting beneficial bacteria while inhibiting the growth of pathogenic microorganisms (Ducatelle et al., 2015). These probiotics produce organic acids, hydrogen peroxide, and bacteriocins, which create an unfavorable environment for pathogens like *Salmonella*, *Escherichia coli*, and *Clostridium perfringens* (Bajagai et al., 2016). By enhancing microbial diversity and stability, host-specific probiotics help maintain intestinal homeostasis, reducing incidences of enteric diseases such as necrotic enteritis and colibacillosis (Guerra-Ordaz et al., 2014). A balanced gut microbiota also improves nutrient absorption, leading to better overall health and performance in poultry (Markowiak and Śliżewska, 2018).

Enhanced Growth Performance and Feed Efficiency

The administration of host-specific probiotics has been shown to improve growth rates and feed conversion ratios (FCR) in poultry by optimizing digestion and nutrient assimilation (Gao et al., 2017). Probiotics enhance enzyme production, such as amylase, protease, and lipase, which break down feed components more efficiently, ensuring better nutrient utilization (Ducatelle et al., 2015). For example, supplementation with *Lactobacillus fermentum* in broilers has been reported to significantly increase body weight gain and improve FCR by enhancing gut morphology and nutrient absorption capacity (Broom, 2017). Additionally, probiotics contribute to the production of short-chain fatty acids (SCFAs), such as butyrate, which provide energy to intestinal cells and promote overall gut health (Kenny et al., 2011).

Reduction of Pathogenic Infections and Disease Prevention

Host-specific probiotics enhance the immune system by stimulating the production of immunoglobulins, such as secretory IgA (sIgA), and modulating cytokine responses (Bajagai et al., 2016). This immune-boosting effect helps poultry combat common pathogens, reducing the need for antibiotic treatments (Markowiak and Śliżewska, 2018). For instance, studies have shown that broilers supplemented with *Lactobacillus reuteri* exhibit lower mortality rates due to bacterial infections, such as *Salmonella enterica* and *Clostridium perfringens*, compared to control groups (Gao et al., 2017). The ability of host-specific probiotics to prevent infections translates into improved flock health and reduced production losses (Ducatelle et al., 2015).

Enhancement of Intestinal Barrier Function

Host-specific probiotics strengthen the intestinal barrier by increasing the expression of tight junction proteins, such as ccluding and claudin, which prevent pathogen translocation and systemic infections (Broom, 2017). Improved barrier integrity reduces the risk of leaky gut syndrome, a condition that negatively affects nutrient absorption and immune function (Guerra-Ordaz et al., 2014). For example, supplementation with *Lactobacillus plantarum* in layer hens has been shown to enhance mucin production and reduce gut permeability, leading to a healthier digestive tract (Markowiak and Śliżewska, 2018). This results in better overall welfare and sustained egg production performance in laying hens (Bajagai et al., 2016).

Positive Impact on Egg Production and Quality

In laying hens, host-specific probiotics have been associated with improvements in egg production, shell quality, and yolk composition (Gao et al., 2017). Probiotics enhance calcium absorption, which contributes to stronger eggshells and reduced incidences of cracked or broken eggs (Ducatelle et al., 2015). Additionally, dietary supplementation with *Lactobacillus casei* has been reported to improve yolk color and omega-3 fatty acid content, making eggs nutritionally superior for human consumption (Markowiak and Śliżewska, 2018). These benefits underscore the potential of host-specific probiotics in improving both production efficiency and product quality in the poultry industry.

Animal	***Probiotics level (%) in kg feed***	***Strain of probiotics used***	***Effects***	***References***
Broiler	*1* *5 × 10^9 CFU/g*	*Lactobacillus acidophilus, Lactobacillus casei, and Bifidobacterium*	*Increase in growth rate, antioxidant quality*	*Wang et al. (2018)*
Broiler	*1*	*Lactobacillus acidophilus*	*Improved weight gain by 5–10% and FCR by 7–12%.*	*Yousefi and Karkoodi (2007)*
Broiler	*0.5*	*Lactobacillus acidophilus*	*Improvement in weight gain by 8% and nitrogen retension.*	*Mohan et al. (1996)*

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Effect of Host-Specific Probiotics on Swine

Swine production benefits significantly from host-specific probiotics, as they enhance gut microbiota balance, improve feed efficiency, support immune function, and reduce gastrointestinal diseases (Gao et al., 2017).

Gut Microbiota Modulation and Disease Prevention

Swine-specific probiotics, such as *Lactobacillus reuteri* and *Bifidobacterium thermophilum*, help establish a healthy microbial balance in the pig gut by outcompeting pathogenic bacteria like *Escherichia coli* and *Salmonella* (Guerra-Ordaz et al., 2014). These probiotics produce antimicrobial compounds, such as bacteriocins and organic acids, which inhibit pathogen growth and enhance intestinal health (Ducatelle et al., 2015).

Improved Growth Performance and Feed Utilization

Host-specific probiotics enhance digestion by promoting enzyme secretion and nutrient absorption. Supplementation with *Lactobacillus plantarum* has been shown to improve feed conversion ratios and daily weight gain in weaned piglets by optimizing gut morphology and enhancing villi development (Markowiak and Śliżewska, 2018).

Strengthening of Immune Function

Probiotics stimulate the production of immunoglobulins and modulate cytokine expression, leading to improved immune responses in pigs (Bajagai et al., 2016). Studies indicate that weaned piglets supplemented with *Lactobacillus casei* exhibit enhanced resistance to enteric infections, reducing the need for antibiotic interventions (Kenny et al., 2011).

Reduction of Post-Weaning Diarrhea

Post-weaning diarrhea is a major challenge in swine production. Host-specific probiotics help stabilize gut microbiota and reduce intestinal inflammation, minimizing the incidence of diarrhea in piglets (Gao et al., 2017). *Lactobacillus reuteri* has been particularly effective in reducing diarrhea severity and improving gut integrity (Broom, 2017).

Effect of Host-Specific Probiotics on Ruminants

Ruminant production also benefits significantly from host-specific probiotics, particularly in enhancing rumen fermentation, improving feed digestibility and boosting immune responses (Uyeno et al., 2015).

Animal	Probiotics level (%) in kg feed	Strain of probiotics used	Effects	References
Layer	0.02% 1×10^9 CFU/g	C. Butyricum and Brevibacillus	Enhanced egg weight, egg production rate, eggshell quality, Haugh unit, thick albumen content, and albumen height.	Obianwuna *et al*.(2022)
Layer	0.05%	*Clostridium butyricum, Saccharomyces boulardii and Pediococcus acidilactici*	Increased FCR, Egg quality improved.	Xiang *et al.(*2019)
Layer	10^8 CFU/kg	*P. acidilactici*	Improved Eggshell thickness, egg weight and reduced the cholesterol level in egg yolk	Mikulski *et al*. (2012)
Layer	1×10^8 CFU/kg	*Bacillus subtilis*	positive influence on egg quality, performance, and the cholesterol levels of the yolk	Sobczak and Kozłowski, (2015)

Enhancement of Rumen Fermentation

Ruminant-specific probiotics, such as *Saccharomyces cerevisiae* and *Megasphaera elsdenii*, improve fiber digestion and volatile fatty acid (VFA) production, leading to better energy utilization (Chaucheyras-Durand and Durand, 2010).

Improved Milk Production and Composition

Probiotic supplementation in dairy cows has been linked to increased milk yield, improved fat and protein content, and better udder health. Cows supplemented with 5×10^9 CFU of *Enterococcus faecium* and 2×10^9 CFU *Saccharomyces cerevisiae* cells enhanced milk production by 2.3 L per cow each day (Nocek and Kautz, 2006).

Reduction in Metabolic Disorders

Host-specific probiotics help prevent conditions such as acidosis and ketosis by stabilizing rumen pH and enhancing microbial balance (Uyeno et al., 2015). Supplementation of Lactobacillus acidophilus, Lactobacillus salivarius, and Lactobacillus plantarum at a pace of $10^7 – 10^8$ CFU/g bring down the occurrence of diarrhea in juvenile calves (Signorini et al., 2012).

Challenges in the Use of Host-Specific Probiotics

Despite their numerous benefits, the application of host-specific probiotics in animal nutrition faces several challenges. These include strain selection and stability, regulatory approval, scalability of production, variations in gut microbiota among individuals, storage and viability concerns and cost implications (Markowiak and Śliżewska, 2018).

Strain Selection and Stability: Identifying and maintaining viable probiotic strains that consistently deliver health benefits can be challenging.

Regulatory Approval: Different countries have varying regulations, making it difficult to commercialize probiotics globally.

Scalability of Production: Large-scale production without loss of viability and functionality remains a hurdle.

Gut Microbiota Variability: Differences in microbiota composition across individuals may lead to inconsistent effects.

Storage and Viability: Maintaining probiotic stability in feed formulations is crucial for efficacy.

Cost Implications: The high cost of isolating, characterizing, and producing host-specific probiotics can limit widespread adoption.

Summary and conclusion

Probiotics that are specific to a host are a potential method of improving nutrition in poultry, swine and ruminants, gut health, feed efficiency and diseases. Probiotics can be tailored to a specific strain that most effectively colonizes the microbial ecosystem of a host species to support digestive efficiency and immune modulation. However, challenges with strain selection, regulations and costs must be resolved for these probiotic products to gain market acceptance in animal nutrition. Areas for future research include longer-term effects of host-specific probiotics on the health and productivity of livestock, as well as novel methods of improving probiotic formulation and delivery.

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