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Potential effects of probiotics on animal production and health; Evaluating practical aspects with its status

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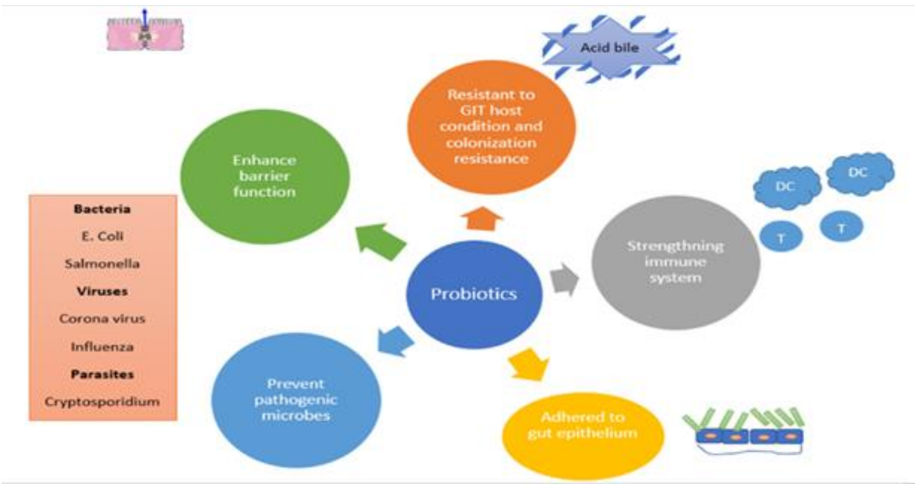
Abstract: Probiotics have gained importance in recent years as a viable substitute to antibiotics for boosting livestock performance. A detailed literature review was collected through retrieved data from online sources like MEDLINE, PubMed, ScienceDirect, and Google Scholar. Along with enhanced nutrient digestibility and immunomodulation, probiotics have reflected an enormous reduction in gastrointestinal tract infection through in-feed usage. Although each of the novel probiotic strains could not be presumed to be part of a perspective of historical safety with standard typical strains. Harmful effects of probiotics can be dependent on prevailing immunological conditions, strain-specific, along with the physiological conditions of the host. The most important consideration is the strain's strength. Probiotics state an effective chance of replacing antibiotics in animals; their safety measures should have been adhered to for safety concerns.
Keywords: Probiotics, antibiotics, livestock performance, animal production

1. Introduction

Population growth is posing a challenge to the world by exponential growth exceeding 9 billion by 2050, which is a threat to food security, mainly among developing countries. Additionally, livestock demand is increased by economic growth, that pressurizes the livestock sector to generate more with limited resources. However, this sector is known to be the fastest-growing agricultural zone that contributes almost 40% of total agricultural production, which supports food security and livelihoods of more than 1.3 billion people (Boaventura et al., 2012). This livestock is also a major source of disposable income for the marginal and stressed population living in developing countries by providing them with an opportunity to fight against poverty.



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Moreover, being an effective source of nutrition and income, livestock offers draught manure and power to be utilized as a fertilizer and fuel.

Presently, a rigorous production system is playing a vital role in the livestock sector globally, although this peak also needs to ensure that animal welfare issues are also considered (Markowiak & Śliżewska, 2018). Despite an increase in livestock production in different ways, public health concerns are also raised.

2. Challenges of probiotics

Among these challenges, the first one is that their use is banned in different countries, including the European Union, because of the possibility of developing antibiotic resistance among microbes linked with animal diseases. Another one is that this event of zoonotic diseases like campylobacteriosis, salmonellosis, and pathogenic E. coli infectious disease led to serious health concerns and economic loss globally. This led to the need for an alternative as a directly fed microbial system, which gained importance in the area of research as a substitute to antibiotic growth promoters (AGP).

Probiotics are currently being utilized in animal feed for the purpose of productivity and growth if animals and to prevent them from pathogens. Probiotics are globally being utilized as a source of animal nutrition, with the growing concern of AGP in animal feed, along with the role of the microbial ecology of the gastrointestinal tract in evaluating animal productivity (Corcionivoschi et al., 2010).

Probiotics are termed as living microbes that are utilized in suitable amounts to deliberate positive health effects on the host. In other words, they are classified as live feed supplements of microbes that have benefits on host animals by boosting the equilibrium of microorganisms. They were originally found to enhance the health of animals through the variety of intestinal microbiota. Some of the valuable effects of consuming probiotics include enhanced intestinal health through microbiota regulation, along with growth and stimulation of the immune system, improved bioavailability of nutrients, fewer lactose-resistant symptoms, and a chance of disease occurrence.

Though there is a need to evaluate the effects and possible side effects of probiotics because research in this area has increased in recent years, which has led to the formation of new strains with disease-specific functions. This can be effective in investigating the use of probiotics with respect to disease-specific response and time (Gaggìa et al., 2010).

2.1. Species involved in probiotics

There are diverse microbial species being utilized in the probiotics, among which the major ones are Clostridium, Eubacterium, Bacteroides, Bifidobacterium, Enterobacteriaceae, Propionibacterium, Lactobacillus, and Streptococcus. They are utilized in monogastric animals like rabbits, pigs, and chickens.

While others in poly-gastric animals like lamb, cow, and sheep, the fiber-degrading group in the microbial ecosystem has rumen that belongs to Bacteroides, Fibrobacter, and Ruminococcus, which, in mixture, forms a group of Streptococcus, Prevotella, Selenomas, Megasphaera, and Lactobacillus. There is a list of probiotic species being utilized in different studies to evaluate the health status, in Table 1 (Mukhammadiev et al., 2021).

2.2. Historical perspectives of probiotics

Research dates back to 1974 as the use of probiotics in correspondence to feed supplements, and the antiquity goes to thousands of years in terms of live microorganism feed supplements. The first reported food containing living microbes was fermented milk that was recorded in the Old Testament (Herman et al., 2014). Studies have tracked Metchnikoff as the godfather of probiotics, which is referred to as Ezema 209, that reflects his studies where he wrote a book named 'Essais optimistes'.

This book has literature including beliefs, philosophy, as well as the factor of aging with description. He had a minor descriptive portion of views on lower gut flora along with the beneficial properties of fermented milk on health. He has concluded this section as; Humans are facing unhappy and precocious old age, which is because of the toxins in tissues that come mostly from the infinite microbes inhabiting the large intestine. It reflects the concept that agents that arrest intestinal putrefaction must be ameliorated and postpone old age.

Table 1: Probiotics used for animal species (Depoorter et al., 2015)

Microbes utilized as probiotics	Animal targeted in the life phase	Health effects
E. faecium		Enhanced milk quality,
E. faecalis		colostrum quality
B. licheniformis		Reduced diarrhea risk
	PIGS	
L. reuteri		Less constipation
L. acidophilus		Lesser stress level
L. johnsonii		Enhanced feed efficiency
S. faecium		Lesser mortality
L. acidophilus		More body weight
E. faecium	POULTRY	Enhanced bone quality
L. reuteri		More carcass quality
B. pseudolongum		More feed efficiency, milk yield
L. animalis	VEAL CALF	Lower pathogen risk
L. paracasei		Limited shedding of pathogens
L. acidophilus	Horse	Lesser diarrhea risk
L. rhamnosus		More diet digestibility
L. plantarum		Avoiding disorders in the hindgut

It has been stated in literature that an adult's gut microflora could be exaggerated by antibacterial drugs, diet, and worry. The utilization of probiotic supplements is aimed at treating these deficits. Its use is often stimulated by the misleading public on antibiotics like therapeutic agents, along with growth promoters, with the goal of filling this gap. Lately, the interest in probiotics for the purpose of enhancing the health status of animals and productive performance has been revived by legislation to restrain the use of antibiotics in order to achieve these purposes (Nagpal et al., 2012).

Historically, the characteristics of a good probiotic were explained, which include;

1. It should be a strain that has the ability to exert valuable effects on host animals, like enhancing the resistance to disease and growth rate.
2. It should also be non-toxic and non-pathogenic
3. They should be feasible and available in large amounts
4. Having a capacity to metabolize and survive in a gut environment, such as resistance to organic acid and lower pH
5. It should be able to remain sustainable during the storage period or field conditions

Their advantages are stated as

1. Intestinal probiotics, mainly bacteria, play an effective role in understanding the digestive mechanism and overall health status among animals
2. Growth improvement in farm animals
3. Host protection from an intestinal infection
4. Lactose elevation is alleviated
5. Nutrient bioavailability and synthesis
6. They control urinary and vaginal tract infections
7. They have an effect on protein sparing, and an immunostimulatory effect which enhances the animal's health
8. Their benefits are also dependent on the numerous factors that include the level of consumption, the selected strain, frequency of exposure, and the animal's physiological conditions (Asml et al., 2015).

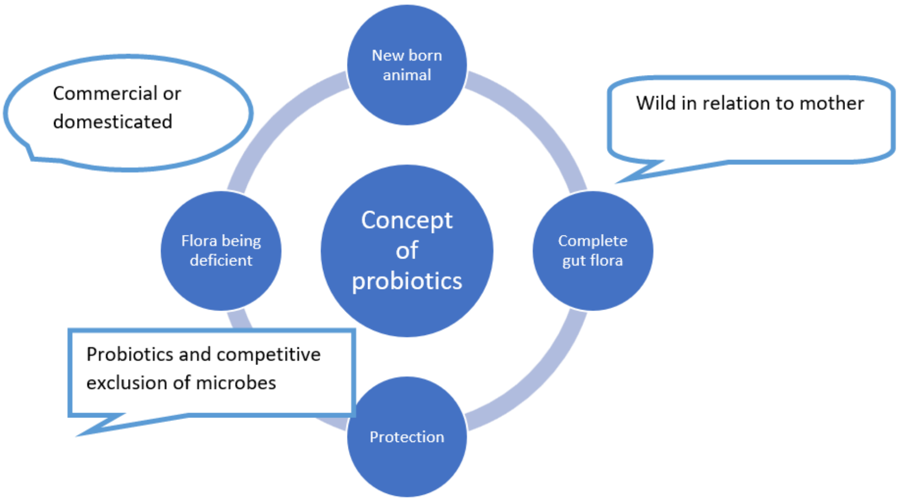
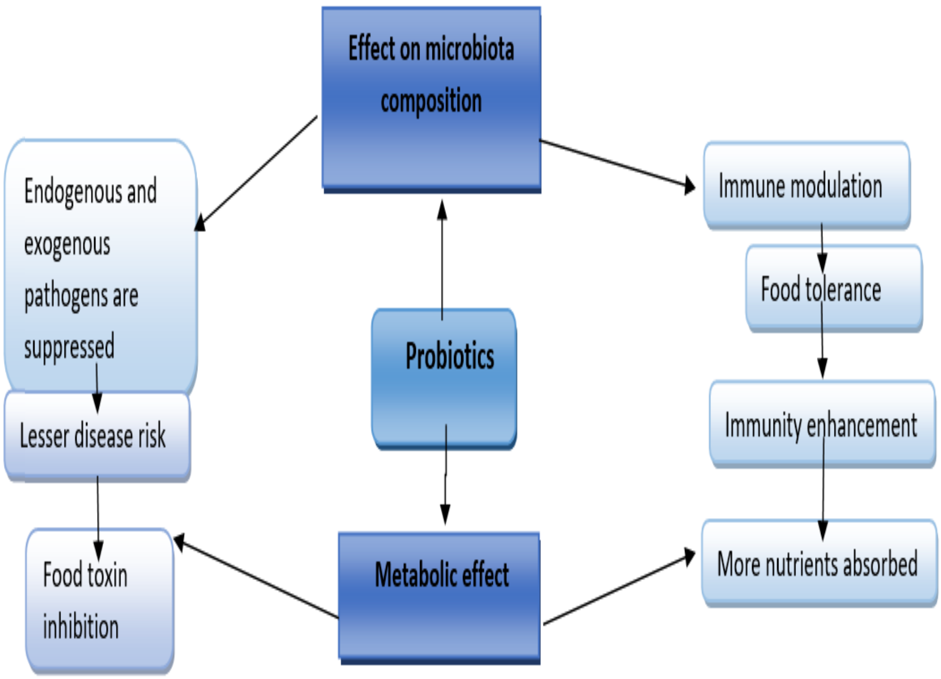


Figure 1: Probiotics hypothetical effect on animals

3. Methods

Probiotic strains have different functions and survival rates in the gut of a mammalian host, due to which their mode of action can not be fully understood. Their effects are classified as:

1. Probiotic microbial gut epithelium interaction; a grip to mucosal epithelial cells, spur of mucus secretion, restricting grip of pathogenic constituents as a probiotic hindering intestinal receptor, thus eliminating pathogens, impeding and enterotoxins propagation of the pathogenic characteristics, contesting with pathogens for essential nutrients, as release of antitoxin and antimicrobial substances which impacts the replication and establishment of pathogens in the gastrointestinal tract.
2. Probiotic immune system interaction; it includes immune variation inherited along with systemic ways, improving and strengthening the gut hindering and integrity functions, finally decreasing inflammatory and secretory molecules against infection of microbes. Its general mechanism can be categorized into several types in which probiotics have an effect, including antitoxic impact, linking activity to the mucosal epithelium, variation of the immune system, construction of competitive and antimicrobial materials, excluding among probiotic and pathogenic bacteria (Alayande et al., 2020).



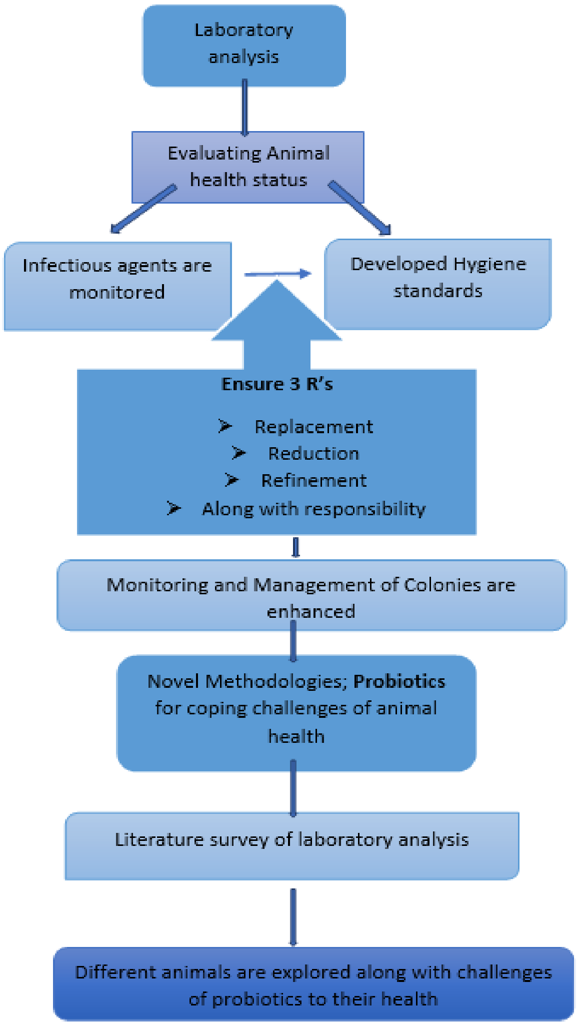


Figure 2: Probiotics and their positive outcomes on animals

4. Results

In these mechanisms, the advances are listed below with detailed description; the selection conditions for existing and emerging probiotics were the gripping capacities of the intestinal mucosa, which leads to interconnect the host concerned to the ability of strains to varying immune functions and probiotic strains. The most commonly observed among the researchers was the effective interaction and gripping mechanism of probiotics that have been recognized in several intestinal mucosa model systems. Lactic acid bacteria are represented by various surface determinants through the interaction of mucus and intestinal epithelial cells with lactic acid bacteria. This mechanism of averse adhesiveness by the probiotics can be because of carbohydrate receptor degradation through a complex of glycoprotein, which establishes a biofilm, leading to the formation of receptor referents and stimulation of biosurfactants. Additionally, this gel is formed of free proteins, lipids, salts, and immunoglobulins (Zimmermann et al., 2016).

The definite link reflects the possible connection between the probiotic bacteria's surface protein and the reasonable omission of pathogens from the mucus. Mucus-binding protein is the most dominant adhesin targeting mucus; this protein of Lactobacillus reuteri is either inserted in the cell wall or fastened to the membrane by a lipid moiety. Other forms of mucous-bond-enhancing protein from L. Fermentum, along with L. Reuteri, influence the association of these probiotics with mucous. The other linkage of pathogenic E. Coli, Clostridium, and Salmonella strains to the intestinal mucus of pic can be reduced in the presence of MUC3 from the Bifidobacterium lactis Bb12 of probiotics or Lactobacillus rhamnosus. Mucus binding with probiotics is affected by fermentum, mainly MUC2 and MUC3 mucins from L. Plantarum, restricting the adhesion of enteropathogenic E. Coli through overlaying glycocalyx in the intestinal epithelium and boosting mucous layers along with the binding sites of microbes that act as a defensive mechanism against pathogens. Moreover, the outcome of INT407 on B. Coagulans over the line of an intestinal cell has shown the adherence of intestinal epithelium, which was observed by other authors as well (Naito et al., 2011).

On the other hand, another in vivo study has suggested transitory colonization, B. Coagulans vanishes after 7 days of administration, so its regular direction can be a requirement for effectiveness. The mixture of VSL3 with probiotics has shown an improvement in the mucin surface cell synthesis along with the modification of mucin gene expression in a model of bacterial cell adhesion to the intestinal epithelium. Additionally, some of the qualitative variations are caused by probiotics in the intestinal mucins that aid in restricting pathogen binding. Plenty of researchers have demonstrated that the probiotic strains and mixtures being evaluated have shown the ability to prevent, compete, and displace pathogens. Despite this, it is considerable to note the higher specificity of these procedures to be investigated throughout in consent of molecular approaches for adhesion and resistance in mucus, and cell lines for categorizing the strain properties. Its best strain is effectively considered and selected for animal trials in order to treat and control infection caused by any specific pathogen (Alayande et al., 2020).

4.1. Effect of antitoxin observed

Diarrhea among mammals is mainly caused by bacterial toxins that affect bacterial virulence. There are several probiotics that are capable of protecting the central organism against pollutants, inducing diarrhea by inhibiting the mechanism of illustration in pathogenic constituents. For example, the expression of Shiga toxin in Coli O157:H7 strains is restricted by Yakult Bifidobacterium pseudocatenulatum DSM20439 and Bifidobacterium breve in mice and in an in vitro model. This reflects the higher concentration of the Yakult strain forming acetic acid, that is responsible for inhibiting the expression of Shiga toxin. Gnotobiotic mice is protected from O157:H7 strain of enterohaemorrhagic E. Coli by clostridium butyricum strain named as MIYAIRI, that was a Shiga poison embedded infection all overproduction of lactic and butyric acid. It has been observed that butyric acid has shown an enterohaemorrhagic E. Coli feasibility decline after neutralization. Moreover, the strains of probiotic Lactobacilli decrease Shiga toxin 2A expression, through the generation of bacteriocidal amounts of organic acids for E. Coli with the O157:H7 strain (Paliy et al., 2020).

Alongside the ability to bind mycotoxins along with aflatoxins is observed in bacterial toxins, probiotics Lactobacillus rhamnosus strain GG and LC-705. The rat observation of the GG strain of Lactobacillus rhamnosus has shown a modification in intestinal absorption resulting in enhanced aflatoxin fecal excretion, causing a lower toxicity ratio, showing a silver injury. In another case of cell culture, this strain led to decreasing aflatoxin B1 uptake, reducing both damage to DNA and the membrane. Conclusively, there was effective protection observed in an animal model with Vibrio or enterotoxigenic E. Coli, which was by designed probiotics holding receptor for cholera pollutants or those of heat-tolerant enterotoxin of enterotoxigenic E. Coli. While, according to some theories, bacterial-referred killed-formaldehyde has effective protection as far as the frequency of applicability is enhanced (Mukhammadiev et al., 2021).

4.2. Immune system variation

It has been observed that DNA, metabolites, and cell wall constituents of the probiotics could stimulate the immune system by dendritic and epithelial cell interaction along with lymphocytes and macrophages through immune responses, either adaptive or innate methods, that could be restricted to stimulation of gut immunity and local or systemic immunity. DNA or peptidoglycan fragments derived from probiotics, along with immune-modulatory effects, can be used to target dead bacteria in the animal body system. Probiotics are often recognized in host receptor cells through the adhesion phenomenon among epithelial and gut-interacting immune systems. These feathers are recognized in the gut immune system, like the intestinal microbes, through a pattern recognition receptor, such as Toll-like receptors. Research has shown that activation of toll-like receptors leads to triggering the signaling cascade that leads to the immune system of animals. These signaling force in the epithelial cells or in immune cells that are aroused by the soluble factors has an effect on the immune system. Basically, the M and dendritic cells in the gut have an influential role in direct and indirect contact with probiotics, incorporating it into the gut, and T naïve cells. This leads to activating T cells and differentiation in them that results in secreting IgA in the gut by plasma cells, that affect the IL-10 expression in the dendritic cells (Ezema & Ugwu, 2015).

5. Discussion

5.1. Relevance of probiotics in livestock: Pigs and probiotics

Environmental factors, mainly controlling methods, diet, and others, can impact swine production, leading to a discrepancy in intestinal variety, causing a risk of pathogenic infection. The period of halting and post-weaning is a hectic situation in viable porcine generation, causing a fleeting drop in feed intake, negatively affecting the immune function, restricting the growth performance, and balance of intestinal microbiota that consequently leads to infections, more susceptibility for gut disorders, and diarrhea in pigs. After the ban of antibiotics in feed, the utilization of probiotics has increased, followed by an enormous reduction in zinc and copper incorporation by the European Union. Most of the researchers have shown a positive health effect of probiotics when applied to piglets. This led to boosting the ratio of intestinal valuable bacteria, decreasing the pathogenic load of microbes, influencing more activity of IgA, IgM against pathogenic constituents, then regulating, increasing protective mechanism towards pathogenic incorporation, and enhancing villi function and morphology. Most useful probiotics in bacteria Enterococcus spp, Lactobacillus, Bifidobacterium spp, Pediococcus spp, and Bacillus spp, yeasts such as Saccharomyces boulardii, among monogastric animals targeting the hindgut that ports a diverse and profuse quantity of microbes that are formed of archaea and bacteria (Ezema, 2013).

In pigs, a Bacillus species is also utilized as a probiotic, which has shown different results. Its incorporation in the feed resulted in decreasing scours in weaned pigs. They are challenged against K88-positive enterotoxigenic E. Coli along with Bacillus Subtilis and B. licheniformis, decreasing the mortality and morbidity among weaned piglets and enhancing the performance parameters of fattening pigs and enhancing carcass quality (Valiullin et al., 2020). Furthermore, the utilization of other species like Bacillus Cereus-based probiotics has shown varied results of decreasing chances of diarrhea, but they have to maintain their weight and eat less food (Jeong et al., 2015). Other amusing effects observed in pigs of the Korean population have shown results of probiotic supplements, such as good meat color, tenderness, marbling, and good flavor. Besides this, sensitive gut colonization is more observed from birth to the post-weaning period by pesticides like Cryptosporidium and Isospora, and bacteria such as Clostridium spp, Salmonella spp, and E. Coli, or viruses like Rotavirus or Coronavirus. They are observed to be responsible for lower growth and causing diarrhea. Therefore, studies have suggested the use of probiotics during this period and have recommended it because of its efficiency (Ezema, 2012).

In contrast to poultry, an effective elimination culture has not been comprehensively studied in the pig. Known culture of good exclusion from porcine decreased the shedding of enterotoxigenic E. Coli and mortality rate in neonatal pigs, along with sheltering considerably lower pathogens after challenging Salmonella enteric serovar choleraesuis in neonatal pigs (Musa et al., 2009). Selected colicin-producing E. Coli targeting the strain of K-88 inoculated from environmental sources established an important and valuable effect on activity, diarrhea among weaning piglets infected with an E. Coli K88. While Enterococcus faecalis and faecium are continuously being utilized in plenty of clinical trials, though they have not been anticipated for EU status in QPS. In another interdisciplinary study, the healthy sows and piglets with E. faecium reduce the load of pathogenic bacteria (Ezema & Ugwu, 2015).

The species that is commonly utilized for humans is Bifidobacterium, but its blend with Lactobacillus is held in pigs mainly. Its administration has decreased the prevalence and severity of necrotizing enterocolitis, along with decreased colonization ratio of the potential pathogen Clostridium perfringens, suddenly after birth. Its combination in swine intestinal mucosa as a probiotic Lactobacillus rhamnosus and Bifidobacterium has independently decreased resistance of E. Coli, Clostridium, and Salmonella. So, their assemblage has decreased gripping and is more efficient.

Microbes residing in the gut are capable of affecting the phenotypic characteristics of intestinal neurons of the gut's nervous system. It has been observed that the dietary probiotics influence the chemical coding of swine myenteric activity in human separated smooth muscle strips. Another study has reflected in pig cecum and ileum for a quantitative evaluation of neural groups in myenteric and submucosal plexuses, which has shown particular variation in enteric and neuronal glial cells in porcine evaluated with dietary P. Acidilactici. It has suggested variations in the intestinal microbial population that are linked to dietary probiotic supervision, which might support enteric neuronal plasticity, conceptually (Callaway et al., 2021).

5.2. Effecting poultry

In advanced practices of broiler production, there are several features that has a contributory role to stressing like imbalance in feed, more stocking ratio, transport, and procedures at the hatchery. That influences the colonization of the gastrointestinal tract during post-hatching duration, through bacterial pathogens because of the unhealthy immune system, posing a challenge to food safety and birds health. Infection of hens and chickens by Clostridium perfringens and Salmonella Campylobacter jejuni are observed to be increasing the risk of polluting the food chain consequently harming the poultry as well. This shows that probiotics act as the biological substitutes in preharvest control of Salmonella, Campylobacter, and E. Coli.

5.3. Probiotics and hens

Probiotics can be an effective strategy for preventing pathogen shedding and resulting in the successful revealing the impact of intestinal microbiota on disease control and intestinal properties (Barba-Vidal et al., 2019). While in the production system of poultry, the probiotics utilization is firmly directed with the theory of competitive exclusion, in which 1-d-old chick could be protected from Salmonella's incorporating infection through increasing the formation of complex and defensive microflora. There are plenty of exclusion cultures available on market in effective commercial competitive elimination against Clostridium perfringens and Campylobacter. There was an accelerated competitive exclusion culture observed that was formed from free-range chickens on an owned farm in comparison to commercial farm chickens (Seal et al., 2013).

Followed by the prevention of food-borne pathogens among the poultry gut, the chosen probiotic cultures, specifically Lactobacillus spp., might enhance production activity considerations; in the poultry farmers with an objective of increased feed conversion, growth rate, and quality of meat, which are primarily important. In a thorough study in chickens and turkeys, commercial researchers have invented proper management of probiotics composition with lower cost, more performance, along with efficient reduction in abdominal fat deposition. It has been reported that the main factor in probiotic preparation efficiently depends on time and way of monitoring.

In concern of probiotic application, egg production was being evaluated, a mixed culture of Lactobacillus casei, Enterococcus faecium, L. Acidophilus, and Bifidobacterium thermophilus the cost was decreased and egg size was increased in laying hens. Furthermore, Enterococcus faecium and Bifidobacterium thermophilus has enhanced the egg quality and production.

In poultry, the advantages of yeast probiotic supplements are established in broilers production activity and enhanced protection of chickens to enteric pathogenic disease. Moreover, the supplanting along yeast usage notably reduced the prevalence of Salmonella colonization to less than pre-stressing stage, while non-supplement birds were with more Salmonella colonization. Probiotics can enhance the productivity and feed efficacy of laying hens (Li et al., 2020).

5.4. Effect on young calves

The remarkably advantageous effects of probiotics have been discovered when probiotics were a part of animal diet through specifically stressing the duration of animals. Because of the unformed rumen in young pre-ruminants, Bacillus spores and lactic acid bacteria probiotics with Enterococcus spp, Lactobacillus, and Bifidobacterium spp were normally aimed at the small intestine to stabilize the gut microorganisms and reduce the risk of enteric pathogenic colonization (Duarte et al., 2020).

Calves fed milk agitated with either lactic acid bacteria or S. Cerevisiae NCDC49 or L. Acidophilus was found to reduce the prevalence of diarrhea. Additionally, doable E. Coli strain Nissle directed to calves has a transient beneficial impact on treatment and prophylaxis of neonatal calf diarrhea. Laboratory results have described a study that was conducted, followed by the treatment of calf feces of Bacillus coagulans spores that were added to feed in a form of probiotics. All over the trail, the number of spores was notably increased in the treated population as compared to the control one. Additionally, the recovered group was known to retain their properties of acid production, survival in the presence of bile, and in artificial gastric juice. The outcomes further clarify the fate of spore formers directed to calves, which will be effective in the development of new species with specified nutritional strategies. While the observations of few days after birth have shown that the live yeast has shown microbial colonization in an effective way by calf administration along with setting up fermentative ability among rumens. Among the young calf population, integrating live yeast into grain has decreased the diarrhea level (Paliy et al., 2020).

5.5. Effect on horses

Probiotic impact on the horses in their digestive track particularly the caecum-colon, is explained. The supplements of live yeast in their population resulted in increasing fiber digestibility in their colon and changed the equilibrium of the hindgut bacterial population, which resulted in reducing the risk of lactic acidosis. Another administration of *S. Cerevisiae* is documented in mature horses with a higher fiber diet, which led to enhancing the apparent nutrient digestion ratio. Another perspective of increased apparent digestion rate was notably observed in treated horses with the organic and dry matter as compared to the control ones. while the most concerning difference in the experimental population was referred to by the beneficial impact of the live yeast over the fibrous fraction, like acid or neutral detergent fiber (Mukhammadiev et al., 2021).

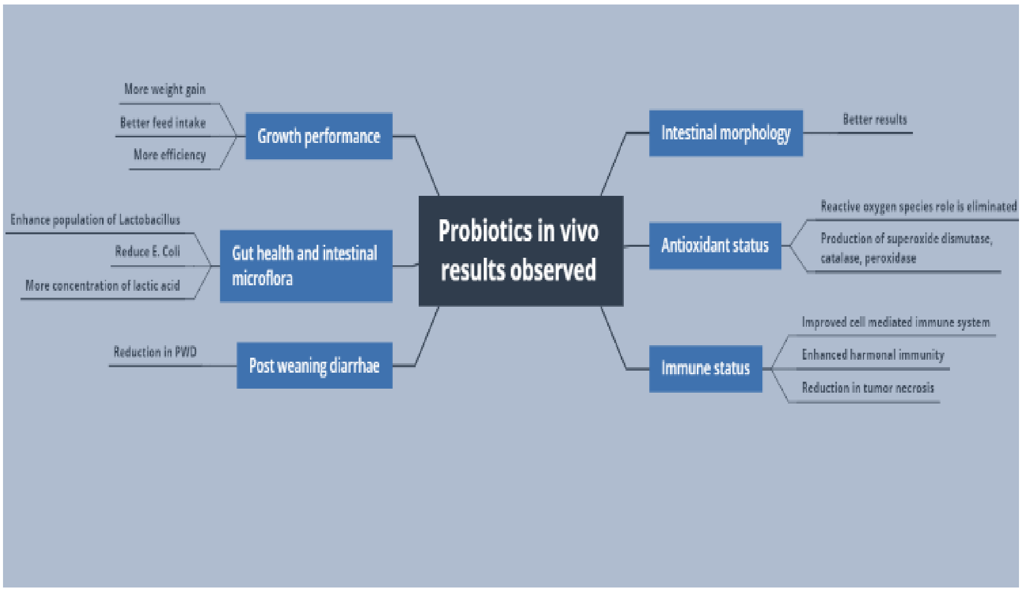


Figure 3: Resulting probiotics and animal health effects

6. Conclusion

The majority of the probiotic strains that are marketed presently are basically chosen for their superiority in a diversity of easily measurable phenotypes, instead of their distinctive ability to confer health benefits. There are a few cases reporting opportunistic infection probability, which is dependent on the host. Its safer protocols are demonstrated for utilizing it for animal husbandry, due to its tremendous beneficial effects on animal health.

CRediT authorship contribution statement

Zainab Tahir contributed to conceptualization, study design, and overall supervision of the review. Qaiser Farid Khan was involved in literature collection and preparation of the original draft. Hamid Majeed and Nabaa Azhar contributed to data curation, visualization, and manuscript drafting. All authors contributed to writing the review and editing, approved the final manuscript, and agreed to be accountable for the content of the work.

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Declaration of competing interests

The authors declared no conflict of interest.

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