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Review Article

Role of Probiotics in Increasing Meat and Egg Production in Poultry: A Review

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Abstract

Antibiotics have been used as growth promotors to enhance poultry's growth performance and feed efficiency. However, their use leads to various side effects like antimicrobial resistance (AMR), destruction of beneficial bacteria, and microbes in the gut, and dysbiosis with time. Various alternatives have been used over the years to overcome the poultry problems and these are necessarily required to replace antibiotics to prevent these side effects. Among alternatives, probiotics are the best option because of their unique pharmacological and therapeutic properties. They are living and non-pathogenic microbes that have health benefits for the host. In poultry diets, they are used as feed additives. They help in proper feed digestion to make beneficial nutrients available for more feed intake and faster growth. They play a significant role in the host by modulation of the host's immune response thus protecting the host from many infections. They contribute to health by offering anti-mutagenic, anti-carcinogenic, anti-hypertensive, hypocholesterolemic, and immune-modulating effects. They help to enhance the production and quality of poultry meat and eggs. The selection of suitable probiotic strains is of great concern to achieve all optimal effects of probiotics. Therefore, this review explores probiotics, their properties, mode of action, and effects on commercial egg and meat production.

Keywords: Alternatives, Growth promotors, Immune-modulator, Hypocholesterolemic effects, Quality eggs, Meat

Introduction

The poultry industry plays a key role in economic progress and fulfilling the food requirements of the human population in the country [1]. There is a huge demand for food products from the poultry industry with time across the globe. Feed additives and nutritional supplements have become a crucial need in the poultry field because these have a wide range of useful activities, like increasing growth, production, and health protection by improving the immune system [2]. There is a huge progress in the poultry production system after obtaining advancements in genetic makeup, good management, and nutrition. They are commonly used as growth promotors and enhance the growth of broilers and egg production in layers [3]. This increase in production and growth rate is related to the productive role of antibiotics. Yet they have led to an imbalance in the intestinal bacterial population, resulting in alterations of the gastrointestinal tract (GIT) and the immune response. Multiple undesirable effects have been noticed, especially affecting the determination of antimicrobial resistance (AMR) genes. AMR appears due to the misuse and overuse of antibiotics during disease control and it is a predominant issue, currently prevailing around the globe [4].

With the emergence of AMR, the focus on searching out substitutes for antibiotics has increased [5]. Feed additives like probiotics have the potential to minimize enteric

disorders and contamination of poultry products. The term "probiotic" is derived from two Greek words 'pro' which means 'for' and 'biotic' which means 'life' [6]. It was used very first time in 1965 as a growth promotor produced from a ciliate protozoan that enhances the growth of another ciliate [7]. Elie Metchnikoff was the first person who worked on probiotics at the Pasteur Institute in Paris. He observed the existence of an increased survival rate by consuming a large amount of soured milk in Bulgarian peasants [2]. Many scientists have worked during the period of this discovery, from 1953 to this date. Probiotic microbes have led to valuable effects like immunomodulation and modulation of local microbiota during in-vivo trials followed by high success in the field as developed by *in-vitro* testation. They include microorganisms that have positive effects on the host by improving the properties of intestinal microflora. They are live non-pathogenic microorganisms mixed into the diet of both humans and animals. They include microorganisms like bacteria, yeast, or fungi. *Lactobacillus*, *Enterococcus*, *Pediococcus*, and *Bacillus* are bacterial strains used in manufacturing probiotics [8]. They are obtained by isolation from milk, fermented foods, gut microbes, and feces of different animals.

The addition of probiotics in the poultry diet results in improving the performance and some egg quality traits [9]. Yeast probiotics enhance egg weight, eggshell-breaking strength, nutrition utilization, and feed conversion ratio (FCR) [10]. They play a critical role in maintaining the natural balance in the digestive system as they are involved in the regulation of gut microbes and increase the activity of digestive enzymes [11]. They increase poultry production by reducing the risk of illness and enhancing the efficiency of poultry birds. The efficiency of probiotics is affected by different ways like selecting efficient strains, gene modification, the interaction between strains, and the synergistically acting components of probiotics. Therefore, the main objective of this review is to explain the role of probiotics in raising meat and egg production in poultry due to their beneficial effects along with their limitations and future use

Probiotics

Probiotics were first introduced by Lilly and Stillwell in 1965 to explain factors required for improving growth and performance [7,12]. As described earlier probiotics mean microorganisms for life. Different scientists gave different definitions for them. Parker defined it as microbes contributing to intestinal microbial balance and Crawford defined it as a culture of specific living microbes that are involved in setting up the intestinal population of useful microorganisms [13]. In 1989, the FDA (Food and Drug Administration) needed producers to operate the term direct-fed microbial (DFM) instead of probiotics. The FDA described DFM as a source of naturally present live animals like bacteria *(Lactobacillus, Streptococcus),* yeast, and fungi [14].

Microorganisms that are used as probiotics are mostly bacteria except some yeast and fungus *(Aspergillus oryzae* and *Candida pintolopesii).* Bacterial probiotics include many species of *Lactobacillus*, *Bifidobacterium*, *Bacillus*, and *Enterococcus* as shown in *Fig. 1* [15]. However, the properties, benefits, and aims of these microbes as probiotics are not similar but rather specific to each one as shown in *Table 1* which is given below after the properties of probiotics.

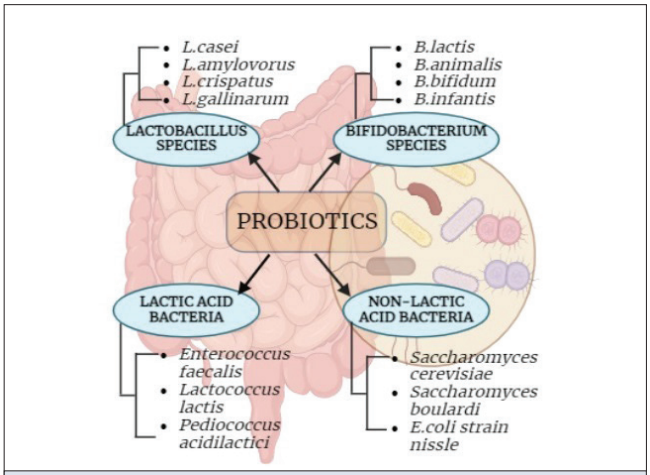

Fig 1. Various strains of bacteria and fungi used as probiotics (Retrieved from Biorender)

Properties of Probiotics Regarding Meat and Egg Production

Assessment of the quality of eggs and meat is mostly dependent on the diet's nutritional makeup. A diet that has a balanced proportion of vital elements promotes better nutrition utilization and overall quality [4]. An imbalanced diet causes more protein breakdown by acquiring extra energy in the form of ATP which in turn leads to a reduction of fat deposition in the live poultry birds [16]. To overcome the situation, probiotics have been used as an alternative in the poultry sector to enhance meat and health rates by decreasing disease load. Probiotics can be used alone or in combination with other additives, generally regarded as a safe alternative. The fundamental aim of using probiotics in poultry feed is to reduce intestinal bacterial pathogens and infections. Probiotics maintain the intestinal microbial population and improve the feed intake [16]. Probiotics may improve digestion, promote general health, and provide defense

against harmful bacteria and pathogens by maximizing the microbial balance in the gastrointestinal tract of chicken hosts when given in appropriate quantities. Additionally, it can help reduce environmental contamination and improve food safety in general. Furthermore, they can increase the activity of glutathione peroxidase, superoxide dismutase, and other chemicals in the animal body [17]. As so, they successfully reduce reactive oxygen species (ROS) levels. This decrease in ROS level is essential for reducing the harmful effects on phospholipid-containing muscle cell membranes [18]. Consequently, it helps to maintain the freshness of myoglobin in fresh meat for a longer time, which results in notable improvements in meat color [17].

The use of probiotics also leads to the modulation of the immune system to protect poultry birds from fatal diseases. Thus, these are safe to use as they are non-pathogenic. They do not lead to AMR by preventing the transfer of antibiotic resistance genes and regulating genetic stability [5]. Different properties of probiotics are described below and also labeled in *Fig. 2*.

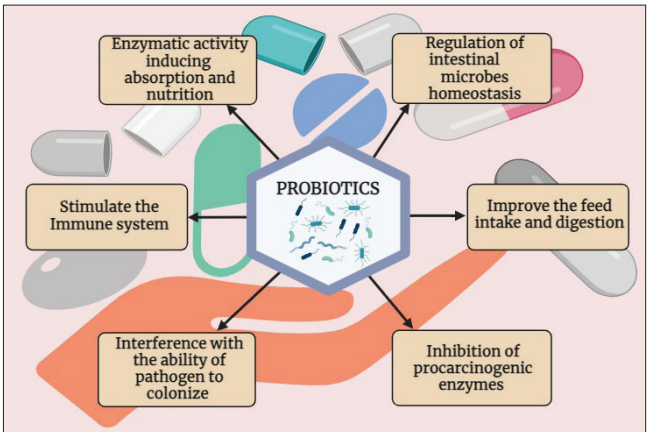

Fig 2. Properties of probiotics regarding meat and egg production (Retrieved from Biorender)

Enzymatic Activity Inducing Absorption and Secretion

Probiotics produce certain enzymes to improve digestion in the host. These enzymes such as protease and lipase are involved in improving and enhancing the absorption of proteins and lipids in the digestive system respectively, which leads to better growth and development of chick [17]. They increase the surface area of the intestinal villi thus causing an increase in the absorption of food material in the digestive tract [18]. Protease enzyme causes hydrolysis of peptide bonds of proteins and lipase causes the breakdown of ester linkages present in lipids. In this way, these enzymes break these compounds into smaller sub-units to improve their absorption and play an important role in increasing the growth rate and production of meat.

Stimulation of Immune Response

Probiotics stimulate the immune system of the host against pathogens. Exposure of the intestine to various kinds of antigens like bacteria, proteins, and other components of probiotics in feed additives causes an immune response by the host immune system [19]. They cause the growth of certain useful microbes that lower the risk level of gastrointestinal diseases resulting in healthy growth of birds with more meat and egg production [20]. They also have beneficial effects like anti-mutagenic, anti-hypertensive, and anti-osteoporosis.

Interference with the ability of the Pathogen to Colonize

Probiotics reduce the colonization of infectious pathogens like *Salmonella* and *Campylobacter* in the intestines of poultry birds [21]. These pathogens are zoonotic and lead to zoonotic diseases like necrotic enteritis and coccidiosis in developing countries. These microbes decrease the infection rate in this way and lead to more production of meat and eggs by improving the growth of poultry birds [22]. The healthy and useful microorganisms supplied by probiotics colonize the intestinal mucosa and stop the colonization of pathogens in the intestinal mucosa.

Regulation of Intestinal Microbial Homeostasis

Probiotics maintain the homeostasis of intestinal micro-organisms. These useful microbes decrease the number of harmful organisms and reduce the risk level of many diseases in the host causing healthy chickens. Probiotic microbes are part of the natural microbiota and maintain the population of useful microbes in the intestines [23]. The probiotic microbes improve intestinal health by regulating intestinal epithelial function [24]. This leads to intestinal mucosal homeostasis resulting in better growth and more meat production [25].

Improve the Feed Intake and Digestion

As poultry products are the major source of food so high production in the poultry is needed. In this regard, probiotics increase the growth rate of chickens and control different diseases. Probiotics cause an increase in feed and water intake by chickens and improve the digestion of feed by the production of useful enzymes like lipase and protease. Thus, leads to the effective digestion of lipids and protein ingredients in poultry feed and improves the overall health of poultry birds [26].

Inhibition of Pro-carcinogenic Enzymes

An imbalance in the population of intestinal microbes results in disruption of homeostasis and this imbalance leads to a pro-inflammatory immune response along with several other diseases in poultry. Moreover, such a type of response leads to different diseases including cancer [27].

Table 1. *Probiotics and their effects on meat and egg production*

Probiotics	Dose	Bacterial/ Fungal	Properties	Action	Effect on Meat Production	Effect on Egg Production	References
Lactobacillus casei	1 million-1 billion CFU	Bacterial	Acts as a growth promotor and anti-carcinogenic agent	Improves feed intake and feed conversion ratio	Increases meat production	N/A	[29]
Lactobacillus amylovorus	1-10 billion CFU	Bacterial	Promotes the growth	Improves meat quality by promoting the immune system, FCR, and gastrointestinal tract	Increases meat production and quality	Improves egg quality and production	[30,31]
Lactobacillus gallinarum	1-5 billion CFU	Bacterial	Increases immune response, weight gain, and organ health. It has hypocholesterolemic effects	Increases immune function to improve immune response and overall health.	Results in better meat production.	Increases egg production.	[32,33]
Lactobacillus crispatus	1-5 billion CFU	Bacterial	Acts as a growth enhancer and improves overall health.	Performs its action by improving and balancing gut microbiota	Enhances the meat quality	Shows positive effects on eggshell production and egg quality but up to a limit	[34,35]
Lactobacillus lactis	1-10 billion CFU	Bacterial	Acts as a growth promotor	Balances the gut microbiota and improves feed intake	N/A	Potentially enhances egg production	[36]
Bifidobacterium lactis	1-3 billion CFU	Bacterial	Acts as a growth promotor.	Maintains and improves the gut microbiota.	N/A	Enhances the egg quality and production	[37]
Bifidobacterium animalis	1-10 billion CFU	Bacterial	Accelerates the FCR and improves growth	Performs its action by improving gut microbiota and increasing FCR	Enhances the meat quality and meat production	Increases the egg production and improves quality	[38]
Bifidobacterium bifidum	1-5 billion CFU	Bacterial	Improves feed intake and has hypocholesterolemic effects on poultry products	Increases growth by improving feed intake and growth performance	Gives more meat production with good quality	Results in more egg production with good characteristics	[39]
Bifidobacterium infantis	0.5-2 billion CFU	Bacterial	Acts as a growth promotor	Improves the gut microbes which enhances nutrient absorption and utilization	Enhances growth performance and better meat production	Results in more egg production with better quality	[40]
Enterococcus faecalis	10^8-10^{10} CFU	Bacterial	Useful for growth and feed efficiency	Increases growth performance by improving feed efficiency	Increases meat production with better characteristics	Some strains like *E. faecalis* UGRA 10 maintain egg production while some other strains can decrease egg production	[41]
Lactococcus lactis	1-10 billion CFU	Bacterial	Lowers the cholesterol level in poultry products, improves gut health, and reduces mortality	Improves gut microbiota and increases growth performance to increase poultry production	Results in more meat production with good quality	N/A	[42]

Table 1. *Probiotics and their effects on meat and egg production (continued)*

Probiotics	Dose	Bacterial/ Fungal	Properties	Action	Effect on Meat Production	Effect on Egg Production	References
Pedicoccus acidilactici	0.5-1 g per bird per day	Bacterial	Enhances the growth of poultry birds	Shows its effects by improving FCR	N/A	Significantly increases the egg-laying rate with good quality	[42]
Saccharomyces cerevisiae	0.5-5 g per kg of feed	Fungal	Acts as a growth promotor and enhances the overall health of poultry birds	Enhances growth performance by improving, feed conversion, gut health, utilizing minerals, and absorbing nutrients	This microbe results in more meat production with better quality	Increases egg production	[43]
*Escherichia coli (*nissle*)*	10^6-10^8 CFU	Bacterial	Exhibits a preventive measure against agents resulting in foodborne diseases and acts as a growth promotor	Maintains the gut microbial population and reduces the *Campylobacter jejuni* colonization inside the caecum of birds to improve growth performance	Causes more meat production by improving growth performance	Decrease in egg production in poultry birds due to inflammatory reaction during *E. coli* infection	[44]
Aspergillus oryzae	0.1-1% of feed	Fungus	Acts as a growth promotor and improves the overall health of hens	Performs its function by improving gut microbiota and modulating the immune system of poultry birds	N/A	Indirectly increases egg production in laying hens by modulation of the immune system and improving gut health	[45]
Cyberlindera jadinii	1-5g per kg of feed	Fungus	Increases the nutritional quality of poultry products	Improves protein quantity in poultry products like meat to enhance its nutritional quality	Produces meat with better quality enriched in proteins and various vitamins	N/A	[46]
Debaromyces hansenii	1-10 billion CFU	Fungus	Stimulates the immune system, digestive system, and cell proliferation	Performs its activities as a probiotic by releasing enzymes known as β-D-glucan	Produces more meat with high free fatty acids and amino acid levels	N/A	[47]

Probiotics deactivate carcinogenic agents like N-nitrous and heterocyclic aromatic amines (HCA) by two major methods known as deactivation and binding [28]. In this way, probiotics protect from cancer by maintaining homeostasis through these methods, resulting in more growth and enhanced production of poultry products (meat and eggs).

Limitations and Future Prospectives

Probiotics can proficiently enhance the beneficial intestinal microorganisms and enhance their effectiveness in terms of health and growth in poultry birds. They also reduced the disease burden by lowering the level of hazardous microbes such as *Staphylococcus aureus* [21]. However, researchers have found varying results about the advantages of using them, with other studies indicating no apparent effect [48]. There are many obstacles to overcome when choosing the best probiotic for improving the quality of poultry meat and eggs. In reality, only a few probiotics fulfill these requirements. For instance, only *Pediococcus pentosaceus* 62781-3, 46035-1, and 46035-4, along with *Mesenteria leuconostoc* 14324-8, showed promising results as probiotics out of 42 isolated strains [26]. Additionally, the expression of virulence genes, antibiotic resistance, the existence of biogenic amines and enterotoxins, and the manufacture of related hazardous compounds should all be taken into account when choosing appropriate probiotic strains. In another study, it was discovered that probiotics extracted from milk samples have been found to have β-hemolytic activity [22].

Probiotics, however, are often found to have poor thermal stability, and heat treatment of meat products may threaten their vitality. The effective concentration of probiotics in birds' gastrointestinal tracts declines as a result of this decline in viability [27]. Additionally, probiotics, such as *Bacillus* species, have been shown to provide inconsistent

outcomes occasionally having no impact at all. For example, it was found that *B. subtilis* supplementation did not affect the hens' growth performance as measured by the average daily feed intake (ADFI), average daily gain (ADG), and FCR indices [42].

Similarly in another study, it was found that addition of probiotic such as *B. coagulans* did not show any growth-promoting and preventative impact on broiler chicks that was attained with antibiotic. It has been demonstrated that, in addition to *B. cereus*, several strains of *Bacillus*, including *B. subtilis, B. pumilus,* and *B. licheniformis*, can produce both entero and emetic toxins [40]. The potential for antibiotic-resistance genes to be passed on to pathogens is another issue. Their use in animal feed may result in a drug-resistant reservoir that people can contract. Furthermore, resistance genes may be transferred to animal pathogens that can infect humans through food products and transcend the species barrier [12].

Studies on the use of probiotics in chicken production are steadily growing, despite adoption barriers [49]. Before probiotics may be regarded as a full replacement for antibiotic growth promoters, much more research needs to be done. It is possible that applying technologies like next-generation sequencing will improve our current comprehension of the underlying mechanisms. More laboratory research that can be verified *in vivo* is required for multiple-mode probiotic development and consortium studies. By doing so, time and money could be saved by identifying biochemical characteristics in the laboratory and choosing strong candidates for field testing. By combining them with nanotechnology, we can improve their form and distribution systems, improve their necessary actions in the body, and shield probiotics from various harms as they travel to the site of action [50]. To determine the best circumstances for probiotics to work better and to generate healthier and higher-quality poultry meat, more studies on the use of probiotics in poultry diets are still needed [51,52]. Furthermore, more investigation is needed on the form, delivery, and mechanisms of action of probiotics as feed additives for poultry.

Additionally, little is known about the formulation of probiotic products and the suitable carriers that should be included in them, even though these aspects affect the stability of probiotic performance and shelf life. The main factors influencing broader industry interest and adoption will be improved cost-benefit ratios, more stringent regulations, and proven effectiveness on an industrial scale. The expense and limits of conventional probiotics continue to be issues for the industry, but future demand for more natural poultry production will make alternatives to AGP more appealing. Because of increased studies on the genus, there seems to be more evidence that probiotics are safe to use for poultry birds.

Conclusion

The increasing world population is alarming and the demand for more meat, eggs, and animal products is increasing day-by-day. Initially, antibiotics were used as growth promotors to increase production but their use stopped with the emergence of AMR and was replaced by probiotics. They have a large number of useful benefits for poultry production. They enhance the growth rate, feed intake, FCR, increase meat and egg production, and have hypocholesterolemic on poultry products. However, few probiotics have significant effects on feed intake, egg production, and growth performance. They are live microbes that affect host animals by maintaining intestinal microbes. Probiotics are of many kinds and they are different in their actions and effects on poultry production. They are used to treat various infections. Although, they are commonly used in poultry farming; still, the determination of the optimal dose remains an issue that needs to be solved. Probiotics are used in different dosages and can be given by mixing them with water. There are various microbial infections such as *Campylobacter*, *C. perfringes*, and *Salmonella*. Many antibiotics are extensively used to enhance poultry production and treat infections. However, this leads to the presence of antibiotic residues in poultry products like meat and eggs, followed by antibiotic resistance. As antibiotic resistance becomes more critical, the use of probiotics and prebiotics gains prominence. Poultry farmers increasingly incorporate probiotics into feed as nutritional supplements, benefiting from their positive effects on growth, egg quality, immune function, and overall health.

Declarations

Competing Interests: The authors have shown no conflict of interest

Declaration of Generative Artificial Intelligence (AI): We Declare that the main manuscript, tables, and figures were not written/created by AI and AI-assisted technologies

Authors Contributions: AR, RZA, OK, AMAK: conceptualization, design, planning, investigation, writing the original draft. AR, MZK, NM, AQ, AH revised and edited. KPK finalized the manuscript. All authors read and approved the final manuscript.

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