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# Feed Additives Used in Nutrition and Improve Poultry Performance and Health: A review

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## ABSTRACT

An approach to increase the efficiency of the poultry industry is to supplement the feed additives in diets to enhance growth rates, optimize egg production, mitigate disease prevalence, and improve feed utilization. This review specifically concentrates on different types of feed additives that could be added to poultry diets to improve performance and health. Primary constituents of poultry diets incorporate cereal grains, predominantly corn, along with wheat, barley, sorghum, and other grains. Additionally, a predominant protein source, e.g. soybean meal, is utilized, although alternative protein sources, both of animal and plant origin, exist. Beyond these components, the feed nutritional quality is influenced by factors such as method of feed, microbial contamination, the presence of antinutritional substances, digestibility, palatability, and intestinal health. A variety of feed additives are available to address these considerations. Particularly, the commercialization of feed additives requires approval through rigorous scientific evaluation, ensuring their lack of adverse effects on human and animal health, as well as the environment. Several feed ingredients formulated in poultry diets show antinutritional properties, limiting their applicability. To fulfil energy requirements and enhance poultry health, it is necessary to develop commercially viable alternatives to existing feed resources, emphasizing safety and cost-effectiveness. The use of feed additives in poultry can be valuable because they allow maximizing overall performance and an improvement in digestibility, the health of poultry.

**Keywords:** antibiotics, feed additives, poultry nutrition, prebiotics, poultry health

## INTRODUCTION

Poultry meat has a higher nutritional value than other meats, which is demonstrated by the fact that it is regarded as a basic food for humans, contains vitamins and proteins, and plays a significant role in national economies (1). The poultry manufactured feeds are homogeneous mixtures of raw materials with some mineral salts and some materials may be added to them, such as vitamins, antibiotics, anti-oxidants, and other additives (2). Feed additives are a variety of product classes that are added as small amounts to the basic diet to enhance feed quality, animal performance, and overall health. By influencing physiological processes like immunological function and stress tolerance, they also encourage animal ingestion, absorption, nutrient assimilation, and growth (3). According to reports, broiler performance might be improved and mortality rates decreased by using feed additives instead of antibiotics, all without endangering the environment or the health of consumers (4). Numerous factors, including diet, stress, antibiotics, and contemporary breeding techniques, have an impact on the health and growth of animals. The preventive use of antibiotics plays a crucial role in preserving and stabilizes the health of poultry (5). Historically, antibiotics have been incorporated into poultry feeds due to their important role in enhancing intestinal health and eliminating harmful microbes. However, the increasing prevalence of bacterial strains resistant to these antibiotics as well as their potential harm to human health, the use of these antibiotics has become a subject of intense debate in recent years (6). The feeding quality, the dietary composition balance, and the availability of required and physiologically active components all have a direct impact on poultry products and farm animals, as well as the other qualities of animal products (7). It has become increasingly common to improve the quality of poultry products without using additives that may accumulate in poultry goods and subsequently be transferred to the final consumer (8). Consequently, researchers have actively sought safe and natural food additives, with organic acids, probiotics, enzymes, and other food additives being among the most important (9, 10). Additionally, as a substitute for antibiotics in animal production, phytogenic feed additives, also known as photobiotic, are currently employed (11). The European Feed Standard Agency (EFSA) classifies feed additives into five categories: sensory (flavors), nutritional (vitamins and amino acids), technological (organic acids, Anti-oxidants, pellet binders, etc.), biotechnology (enzymes, probiotics, prebiotics, and some phytogenics), and coccidiostats while the application of probiotics, phytogenics, and enzymes in poultry nutrition has increased, one way to increase the effectiveness of poultry feeding is to utilize feed additives to increase growth and egg production efficiency, avoid disease, and enhance feed consumption (12). This review specifically concentrates on different types of feed additives that could be added to poultry diets to improve performance and health.

## ANTIBIOTIC ADDITIVES

The German doctor and researcher Paul Ehrlich is credited with pioneering modern chemotherapy. After years of arduous labor, Ehrlich finally created Salvarsan, also known as compound 606, in 1909 after discovering it while doing animal tests (13). In poultry production, antimicrobial agents play a vital role in both preventing and treating illnesses (14). Antibiotics have been widely used in poultry to prevent infections, improve health, and reduce mortality rates (15). Antibiotics are capable of either destroying or inhibiting the growth of microorganisms, Antibiotics are mostly used in animals for prevention of illness and treatment (16). The danger of incurable infections has increased as a result of the inappropriate use of antibiotics in both human and animal, widespread usage of antibiotics has resulted in the rise of antimicrobial resistance, which is a major global concern (17). In addition to causing treatment ineffectiveness and monetary losses, antimicrobial resistance in poultry diseases also makes it easier for resistant genes or bacteria to spread to people (18). Therefore, the use of antibiotic-fortified growth promoter diets (AGPs) has been banned in the European Union (EU) since 2006, spurred research into alternative additives for maintaining gut health and optimizing production efficiency in poultry (19).

### Antibiotic As Growth Inducing Agents

Antibiotics are chemotherapeutic medications used to treat infectious diseases in people, plants, and animals. However, a significant number of the antibiotics are used for non-therapeutic purposes to promote growth rather than for treatment (20). Antibiotics have contributed significantly to the development and success of the poultry industry since their discovery in the 1920s, and for almost 60 years, sub-therapeutic doses of antibiotics have been added to animal feed to promote growth and feed conversion efficiency as well as to ward off infections (21). AGPs are one method used by animal producers to lower or control the intestinal bacterial burden and hence enhance growth performance, Significant effects on the intestinal health of intensively grown broiler chickens result from the European Union's ban on AGPs usage and the United States' tighter limitations and discouragement of its use (22). Antibiotics are employed as growth promoters at both therapeutic and preventive levels, serving the dual purpose of treating ailments, managing infections, and enhancing growth performance (23). When it was discovered that birds fed streptomycin showed increased growth responses, the use of in-feed antibiotics quickly became widespread and established, as animal production intensified, it was determined that adding antibiotics to the diets produced a positive response 72% of the time, and that the overall effect of using in-feed antibiotics in the poultry was a 3-5% increase in growth and feed conversion efficiency (21).

The EU has implemented a ban on the use of antibiotics in feed used to animals feed due to prolonged use of antibiotics for medicinal and growth-promoting purposes which lead to the development of antimicrobial resistance among gram-negative bacteria (24). Concerns are raising regarding the consequences of the overuse antibiotic growth promoters in the livestock industry. Substances such as tetracyclines, macrolides, streptogramins, and fluoroquinolones are among the substances used in animal feeds (25). Several nations employ sub-therapeutic amounts of antibiotics in animal diets to promote growth and safeguard against harmful microorganisms. The historical addition of antibiotics to animal feed resulted in animals developing resistance to dangerous microorganisms (26). Persistent use of antibiotics as growth promoters and/or medical treatments in farm animals is expected to foster the proliferation of antibiotic-resistant bacteria. This poses an increased risk of chronic illnesses and bacterial infections, both antibiotic-resistant and non-resistant, throughout the food chain when human consumption involves animal products treated with antibiotics. To enhance the immunity of farm animals and their growth performance, it is imperative to develop new commercial alternatives based on their efficacy, safety, and cost-effectiveness (27). Nearly all antibiotics that used for feeding of nonruminants contain nitrogen and some of them are aminoglycosides. the presence of nitrogen atoms in antibiotics alter the electronic configuration of the compounds and enhance their antimicrobial activity (28). Table 1 includes the common antibiotics used in poultry.

**Table 1.** The common antibiotics used in the poultry industry

| Antibiotics | The description | Mechanism | Source |
|---|---|---|---|
| Levamisole | Despite the lack of documented withdrawal data for levamisole in poultry, it mimics the hormone thymopoietin, which influences several immune system components. | It is used to treat capillaria infections in poultry currently. This substance is effective against lungworms and gastrointestinal nematodes. | (29) |
| Beta-Lactam | Among the semi-synthetic derivatives of beta-lactam antibiotics with a free amino group at the α-position at R on the penicillin nucleus are aminopenicillins, the amoxicillin. | Bactericidal (inhibits transpeptidase, damages the integrity of the bacterial cell wall, stops the production of new bacteria). | (30) |
| Tetracyclines | Escherichia coli tetracycline (also known as TetR), that were discovered in 1947 and works by attaching to the 30S ribosomal subunit. Because of their broad range of effectiveness, tetracyclines were quickly embraced in the clinic. | Inhibiting protein synthesis, antibacterial and bacteriostatic, are used to treat infectious diseases, and are now frequently employed in animal husbandry. | (31-35) |
| Nitrofuran | Semicarbazide the EU banned its usage in 1995, is a nitrofuran metabolite and food contaminant. Because of worries about the carcinogenicity of semicarbazide's residues in edible tissue. | Employed for the treatment of bacterial diseases in animals. | (36) |
| Quinolones/ Fluoroquinolones | A new and exciting age in antimicrobial treatment has been ushered in by the introduction of fluoroquinolones. These are a synthetic heterogeneous collection of molecules. The accidental discovery of the quinolone prototype in 1962 marked the start of the era of quinolone antibiotics. | One of the most valuable and widely used classes of antibacterial medicines in the world is the fluoroquinolone. The last century has seen a decrease in morbidity and death rates due in part to the discovery, development, and practical application of fluoroquinolone antibiotics. | (37) |
| Aminocyclitol | Aminoglycosides are natural or semisynthetic antibiotics derived from Actinomycetes. | In the early days of antimicrobial chemotherapy, they were frequently utilized as first-line medications and were among the first antibiotics to be used in routine clinical practice. | (38) |
| Sulfonamides | Sulfonamides are commonly used in poultry. They are quickly absorbed and dispersed throughout the chicken's body, collect in different tissues, and then transferred into its products. It is feared that residues in meat and eggs may be harmful to human health. | In poultry, sulfonamides are frequently used to treat coccidiosis, pullorum disease, infectious coryza, and fowl typhoid. | (39) |
| Macrolide | Macrolides function as antibiotics by attaching to the bacterial 50S ribosomal subunit. The macrolides are widely distributed throughout tissues and are well-known for accumulating inside phagocytes. | Macrolide antibiotics work by inhibiting the ribosome of bacteria to stop the synthesis of new proteins. They partially impede the peptide escape channel by attaching themselves to it. Thus, macrolides are considered as "tunnel plugs" that block the synthesis of all proteins. | (40-42) |
| Aminoglycosides | Actinomycetes are the natural or semisynthetic source of aminoglycoside antibiotics. is a phylum of Gram-positive bacteria, and its members are divided into six classes: Rubrobacteria, Coriobacteria, Acidimicrobiia, Actinobacteria, and Nitriliruptoria. Numerous industrial and agricultural biotechnology applications demonstrate their significant value. | Actinobacteria have recently been discovered to be used in chicken husbandry to produce bioactive substances including short-chain fatty acids (SCFA). | (43, 44) |
| Coccidiostats | coccidiostats can be either synthetic or naturally occurring polyether ionophores such halofuginone, robenidine, diclazuril, and nicarbazin. Examples of naturally occurring coccidiostats include monensin, narasin, lasalocid, salinomycin, and maduramicin According to Dubreil-Cheneau, Bessiral, Roudaut, Verdon. | Coccidiostats are used to treat several animals that provide food by controlling protozoan infections. In order to preserve animal health and occasionally improve feed conversion, they are most frequently utilized as feed supplements in species that are raised under intense conditions, such as poultry. | (45, 46) |
| Amphenicols | Amphenicols are a series of highly effective antibiotics with broad-spectrum antimicrobial activity. Primarily comprising chloramphenicol (CAP), thiamphenicol (TAP), and florfenicol (FF). | They are extensively utilized in the breeding and production of cattle and poultry, but they should be used extremely cautiously in birds because they may have detrimental effects on human health as well. They are also known to suppress bone marrow and have been observed to cause liver damage, which results in abnormal liver functions and jaundice. | (47-49) |

## Animal Feed Containing Antibiotics and Human Health

Antibiotics play a crucial role in treating and preventing various animal illnesses (50). However, using antibiotics for animals can have direct or indirect effect on human health either by the presence of antibiotic residues in animal products such as milk, meat and eggs that consumed by human or due to separate of antibiotic resistance bacteria to various component of ecosystem for example soil and water (51). According to Gassner and Wuethrich (52) metabolites of chloramphenicol present in animal products have the potential to induce aplastic anemia in humans. The main cause of the rise of antibiotic resistance among bacterial species, including Salmonella typhi, the causative agent of the typhoid virus, is the misuse of antibiotics possessing chloramphenicol-like characteristics in animal feeds. Some significant bacteria have been commonly associated with resistance as a result of the ongoing use of growth promoters (53). Among the bacteria prone to frequent transmission from animals to humans and cause a zoonotic disease include Salmonella, Campylobacter, E. coli, and E. enterococci, as described below.

### *Salmonella spp.*

*Salmonella* is a rod-shaped, gram-negative, facultative anaerobe belonging to the Enterobacteriaceae family of bacteria (54). Due to the high costs associated with disease surveillance, prevention, and treatment, Salmonella infection continues to be a major public health concern on a global scale (55). Gastroenteritis is the most typical symptom of a Salmonella infection, followed by bacteremia and enteric fever (56). Utilizing the traditional Kauffman-White approach, approximately 2600 serotypes of Salmonella have been identified, with the majority of these serotypes capable of adapting to various animal hosts, including humans (57). Salmonella and Campylobacter, the most often identified foodborne pathogens, are regularly discovered in poultry, eggs, and dairy products (58).

### *Campylobacter spp.*

The most common bacterial causes of food poisoning are Campylobacter, specifically Campylobacter coli and Campylobacter jejuni. These microbes inhabit animal intestines without causing harm to their hosts. Prolonged quinolone use in food animals has led to the emergence of Campylobacter isolates resistant to both macrolides (59). Additionally, the regular use of fluoroquinolones to treat respiratory ailments in poultry has resulted in the development of fluoroquinolone-resistant Campylobacter within the gastrointestinal tracts of treated poultry (60).

### *Escherichia coli*

*Escherichia coli* (*E. coli*) is a common commensal of humans and animals that provide food, which has evolved into harmful strains, E. coli strains are divided into pathotypes of extraintestinal pathogenic *E. coli* (ExPEC) or zoonotic intestinal pathogenic E. coli (IPEC) according to the kind of virulence factor present and the clinical signs of the host (61). According to Allocati et al. (62) Escherichia coli continues to be one of the most frequent causes of a number of prevalent bacterial infections in both humans and animals. According to a recent systematic review, a significant portion of human extra-intestinal infections caused by extended-spectrum cephalosporin-resistant E. coli can be traced back to food animals (63).

### *Enterococci*

For over 30 years, it has been standard practice to add antimicrobial drugs to animal feed in order to boost growth, and it is believed that this accounts for more than half of all antimicrobial use globally. The use of the glycopeptide avoparcin as a growth promoter appears to have produced a significant reservoir of Enterococcus faecium in food animals, which possesses the high-level glycopeptide resistance determinant vanAlocated on the Tn1546 transposon. Additionally, strains resistant to glycopeptides can be shared between humans and animals (64). Many of the drugs employed as growth promoters, being Gram-positive, and exhibit toxicity to enterococci. Among various farm animals, E. faecalis, E. cecorum, and E. hirae are the species most frequently found in the intestines. The persistent use of the antibiotic avoparcin as a growth promoter has led to the emergence of vancomycin-resistant enterococci was brought on by the ongoing use of the antibiotic avoparcin as a general practitioner (65).

## Current Approaches to Antibiotics

Termination of inappropriate and unnecessary antibiotics use in animals is becoming more popular. In EU member states, the usage of antibiotics to fight disease and foster growth has decreased. The United Kingdom originally restricted the permission of many antimicrobials, including tetracycline and penicillin, in early 1969 on the recommendation of the committee led by Professor Michael Swann (66). Sweden phased out the use of antimicrobials as growth promoters in 1986, Norway in 1995, and Denmark in late 1998 or early 1999. Responding to concerns about the widespread emergence of antibiotic resistance in human diseases (67), the EU implemented a ban on antibiotics in 2006 (68).

## Sensory (Flavors) Additives Flavors

Any material that enhances or modifies the organoleptic qualities of the feed and/or the visual attributes of animal-based food is considered a sensory addition. These functional groupings include: (1) colorants: (a) substances that add or restore color to feeding materials; (b) substances that, when fed to animals, add color to animal-derived food; and (c) substances that positively affect the color of ornamental fish or birds; and (2) flavoring compounds: substances that, when added to feed materials, improve feed palatability or smell (69). According to Faugeron and Oguey (70) flavors are essential elements for enhancing meals. When used judiciously, flavors can serve various purposes:

## Cover or a Replacement

Despite their good nutritional value, certain feed ingredients can have unpleasant odors (i.e. soapy, butyric, rancid, etc.) which may reduce the amount of feed consumed by an animal. Additionally, certain added ingredients (e.g. molasses) exhibit significant variability in both prices and quality, prompting interest in their partial or complete replacement. Substituting an expensive substance with a flavor possessing a comparable aromatic profile, combined with a sweetener, allows for the preservation of the same aroma while reducing costs. Achieving the optimal balance between cost savings and sensory perception requires adjustments in dosages. The use of flavors benefits both the animal and the farmer by ensuring a consistent olfactory character in the feed or premix.

### Attract and Energize

One of the main purposes of flavoring is to increase feed attractiveness. Incorporating a flavor into the feed will draw the animal feed intake, promote consumption, and exploratory behavior. The choice of flavor may depend on a general understanding of an animal's preferences as animals tend to be responsive and selective about their feed. They can be sensitive to even subtle changes, which might lead to resistance. However, feed formulation is continually evolving based on the availability, quality, and cost of raw materials. The introduction of a flavor helps to mitigate batch-to-batch differences, reducing fluctuations and providing formulators with more flexibility. This ensures greater feed acceptance by farm animals.

### Materials that Give Feeds Color

The EU legal situation "Regulation (EC) No 1831/2003" (2003) establishes guidelines for the authorization, marketing, and labeling of feed additives and regulates the use of additives in animal nutrition, Colorants are classified as "sensory additives," which include substances that alter or enhance the organoleptic qualities of the feed or the visual attributes of the food derived from animals that consumed the feed (71). Xanthophylls are added to feed to give the egg yolk its golden hue and to color the skin of broilers in order to create goods that satisfy customer demands. There is a growing demand for xanthophylls on the global market due to their many new uses in human diet (71, 72).

The presence of xanthophylls in the human food chain may also be beneficial to human health, given that animal feed is at the first of the food chain, Astaxanthin and canthaxanthin are examples of naturally occurring carotenoid pigments that can be added to animal feed to make the final food products more palatable to consumers. Although it is arguable that these pigments have esthetic value, both astaxanthin and canthaxanthin have been shown to improve the health and welfare of animals. There is evidence that these pigments may also be advantageous to human health if they make their way into the human food chain (73).

## NUTRITIONAL ADDITIVES

The regular biological function and metabolic processes of broiler poultry s must be supported by nutrient modification through the provision of immediate nutrients and additives. The most popular additions for reducing heat stress and boosting output are vitamins and Amino acids (74, 75).

### Vitamins

To support the antioxidant status of animals, it is crucial to enhance the density of dietary vitamins such as vitamins A, E, and C beyond the minimal requirement (76, 77). Vitamins are divided into water-soluble (vitamins B complex and C) and fat-soluble (vitamins A, D, E, and K) groups. All vitamins, except for vitamin C, must be consumed through food. Since poultry can synthesize vitamin C, it is typically not considered an essential nutrient. However, dietary vitamin C supplements may be helpful in challenging situations like heat stress, compared to other nutrients, vitamins have more intricate metabolic functions. Vitamins act as players or mediators in all biochemical pathways in the body, not only basic building components or energy sources (78).

### Organic and Amino Acids and Role in Broiler Growth and Health

In today's broiler production, feed additives like organic acids and salts are critical because they support healthy growth and help mitigate the negative effects of stressors. They also enhance the small intestinal ecology and morphology, which results in the production of faster, higher-quality, and healthier broilers (79). The use of antibiotics has been outlawed as a result of the rise in antibiotic resistance. Alternative growth promoters such probiotics, prebiotics, enzymes, and organic acids are used to maintain the best possible level of health and productivity in broiler, organic acids only partially dissociate and are weak acids chemically. They are regarded as secure, Organic acids are now known to have antimicrobial, immune-boosting, and growth-promoting properties in broilers (80).

It is well known that dietary crude protein (CP) leads to higher heat production, which can jeopardize the broilers hyperthermic condition. AA supplementation is crucial to offset dietary CP intake (81, 82). Although natural feedstuffs provide chickens with nutrition, synthetic supplements are frequently supplied for some critical amino acids (lysine, methionine, threonine, and tryptophan), vitamins, and minerals (78). It may be possible to improve the overall balance of amino acids and reduce the amount of crude protein in the poultry feed by carefully adding synthetic amino acids (83). According to Corzo et al. (84); Rehman et al. (85), the broiler performance maximum requires a diet that includes ten essential amino acids: lysine, methionine, tryptophan, threonine, arginine, isoleucine, leucine, histidine, phenylalanine, and valine. Since sufficient dietary levels of methionine, lysine, and threonine are required to support optimal growth and carcass yield of fast-growing commercial broilers, the National Research Council's suggested values are used by several poultry nutritionists (77, 86). For poultry, sufficient intakes of dietary AAs are necessary for the maximum efficiency of production (87). Reported a recent amino acid composition of optimal protein for broilers, which is displayed in Table 2.

**Table 2**. Ideal ratios of digestible amino acids (g/kg of lysine) in broiler diets (88, 89)

| Components | Chronological broiler age | |
|---|---|---|
| Amino acid | 0-21 days | 21-42 days |
| Arginine | 1050 | 1080 |
| Cysteine | 320 | 330 |

| | | |
|---|---|---|
| Clycine | 1760 | 1760 |
| Histidine | 350 | 350 |
| Isoleucine | 670 | 690 |
| Leucine | 1090 | 1090 |
| Lysine | 1000 | 1000 |
| Methionine | 400 | 420 |
| Phenylalanine | 600 | 600 |
| Serine | 690 | 690 |
| Threonine | 670 | 700 |
| Tryptophan | 160 | 170 |
| Valine | 770 | 800 |

## Protein

Poultry contributes significantly to global food security by offering high-quality, reasonably priced protein in the form of eggs and meat (90). The protein is the most fundamental component of human and animal tissues, is essential for optimal growth, and health (81). Dietary protein serves as a source of Amino acid (AA) of the poultry for bone health, muscle development, and the production of egg protein (78). Synthetic AA and enzyme supplements are frequently used in poultry s to balance the diet and increase nutrient components' ability to be digested, crystalline amino acid supplementation and the use of plant sources nutritional content help traditional fowl optimize their nitrogen levels, a potent method for producing plant proteins with improved and increased nitrogen content in poultry diets (82).

Soybean meal serves as the primary ingredient in poultry feed Because of its excellent protein level, amino acid composition, and accessibility (91). It gives animals the essential amino acids (AAs) they need to grow quickly (92). To ensure the long-term sustainability of poultry production, an alternative protein source with a similar nutritional content is desperately needed, as feed is the primary source of expenses in the poultry production (93). The heterosporous aquatic fern known as azolla (Azolla pinnata) is extensively spread and can be utilized as a source of protein for animal feed and chicken (94). Microalgae have attracted a lot of interest as a sustainable alternative to traditional poultry feed ingredients. These tiny organisms are high in protein and retain a significant amount of essential fatty acids, vitamins, minerals, and Anti-oxidants. As a result, they can improve the nutritional value of poultry diets. They provide an exceptional source of protein that contains a significant amount of bioactive complexes, omega-3 fatty acids, and the essential amino acids (lysine and methionine), which are essential for healthy growth and development (90).

A study by Van Harn et al. (95) showed that CP concentration in grower and finisher diets might be reduced by 2.2-2.3% units without having an adverse effect on broiler growth performance in terms of minimizing N excretion from poultry manure. Improving the welfare of the poultry, lowering the CP concentration of broiler diets bears the risk of affecting growth performance when (semi-) necessary AA becomes scarce (96). However, it must be remembered that while lowering CP levels in poultry feed, the balance between adequate nutritional levels and production performance must be taken into account, if growth performance and slaughter output are not negatively impacted (97). Grossmann and Weiss (98) reported a recent alternative protein source for poultry, which is displayed in Table 3.

**Table 3.** Alternative protein sources for poultry (98)

| Type | Components |
|---|---|
| Cereals and pseudo-cereals | Prolamins and/or glutelin, which are water-insoluble proteins, make up the majority of the proteins in wheat, maize, and rice.<br>Albumins and/or globulins make up the proteins of amaranth, quinoa, and oats. |
| Legumes and pulses | Globulins and albumins are the main storage proteins found in beans and pulses, with globulins often accounting for more than half of the total storage proteins.<br>Other albumins are plant metabolic proteins that can function as lectins and enzyme inhibitors, which are antinutritive substances in legumes. |
| Oilseed proteins | 11S globulins and albumins are the two main protein groups found in oilseeds like sunflower and rapeseed.<br>A significant glutelin percentage may also be present in pumpkin seeds. However, different species of pumpkins have varied concentrations of each portion. For instance, albumins make up the majority of Cucurbita maxima. |
| Potato proteins | The glycoprotein patatin, which is found in potatoes as an 88-kDa dimer, and many protease inhibitors with lesser molecular weights between 5 and 25 kDa make up the majority of the protein in potatoes. |
| Insect proteins | Insect proteins include myofibrillar proteins, which are soluble in salt, sarcoplasmic proteins, which are soluble in water, and connective tissue proteins, which can be insoluble or soluble in acid or alkali. Albumins are equivalent to sarcoplasmic proteins, globulins to myofibrillar proteins, and glutelins to connective tissue proteins, according to the evidence that has been published. Therefore, a significant portion of myofibrillar and connective tissue proteins are found in insects. |

# Technological Additives

## Anti-oxidants

Despite significant advancements in poultry production, encompassing meat and eggs produced, as well as improvements in growth rate and feed conversion rate, over the past three decades on a global scale (99). However, it has been established that the production of commercial poultry is linked to a number of pressures, including those related to the environment, technology, nutrition, and internal and biological processes (100, 101). Overproduction of free radicals and oxidative stress are consequently very prevalent issues in industrial poultry production because it is nearly impossible to prevent pressures. Therefore, the incorporation of natural Anti-oxidants into poultry diet must be considered (102). Recognizing and addressing indicators of stress is essential for reducing output loss and enhancing the health and well-being of poultry s. Nutritional management of oxidative stress in poultry s has been achieved through the use of dietary Anti-oxidants. Anti-oxidants play crucial roles in maintaining the health and production of laying hens by protecting the host from the damaging effects of free radicals and toxic consequences of lipid peroxidation. Various Anti-oxidants, both natural and synthetic, have been demonstrated to mitigate or delay oxidative stress effects during production (99, 103).

Oxidative stress is unavoidable in poultry production and impacts the physiological, behavioral, and biochemical status of growing chickens, ultimately deteriorating meat quality, The poultry industry can overcome oxidative stress by using innovative processing techniques and poultry feed supplemented with antioxidants (104). Regularly added Anti-oxidants helps protect poultry feed from degradation during storage. Numerous studies have demonstrated that providing poultry with antioxidant compounds mixed into antioxidant-rich meals will increase the oxidative stability of animal products. Since poultry meat is particularly vulnerable to oxidative deterioration due to its high amount of polyunsaturated fatty acids, this approach could ultimately increase the value of poultry products (105). Oxidative stress is caused by a number of etiological conditions, such as high humidity, sunlight, wind speed, and ambient temperature. In addition to its carcinogenic qualities, oxidative stress impairs and manifests a variety of chronic inflammatory and cardiovascular, animal feed contains proteins, fats, and other organic materials that, when exposed to free radicals, turn rancid, lose their nutritional value, and release toxins that harm the health and productivity of the animals. Antioxidants have the ability to reduce oxidative damage that can result from diet and neutralize oxidants from metabolism. Ascorbic acid, alpha-tocopherol, trace minerals (copper, zinc, selenium, etc.), and different plant-derived substances including flavonoids and carotenoids are the most common antioxidants found in animal feed (106).

### Pelletizing Additives

The most common thermal processing technique used to produce poultry feeds is pelletizing, and the commercial poultry industry has long recognized the advantages of feeding pelleted diets rather than mash diets (107), due to the benefits that come from handling these pellets commercially during production, transportation, and presentation for poultry (108). It became necessary to look for ways to lower production costs by reducing feed waste or loss due to the rising costs associated with manufacturing poultry feed. It has been shown that using pellets to minimize animal feed loss is a useful practice (109). The feed physical form (Mash and Pellet) is one of the most important factors that can affect the improvement of productive performance of broiler (110).

The impact of various factors on feed formulation, with solubles, dicalcium phosphate, and mixer-added fat specially, according to feed pellet quality factor, the physical quality of the pellets was negatively impacted by the mixer-added vegetable oils (111, 112). Nutritionists have reduced the quantity of fat included in poultry diets due to the adverse effect of mixer-added fat on pellet durability, However, by coating the feed particle, lubricating the die, and lowering the electrical energy of the pelleting process, an increase in the amount of fat supplied to the mixer may lower the overall cost of producing broilers (113).

#### *Binders*

Binders are firming or binding agents that create strong interparticle bonds by forming solid bridges through chemical reactions (114). In addition to reducing nutrient leaching and preventing fragmentation and abrasion of pellets during handling, shipping, and storage, they are used to reinforce pellets and enhance their integrity, durability, and stability (115, 116). By filling in the pore spaces between particles, binder materials such as lignosulfonate, bentonite, and sepiolite increase the strength and durability of pellets. By altering the composition of the feed mix following heat, moisture, and heat treatment during the pelleting process, binder materials like protein and starch increase the strength and durability of pellets through a chemical reaction. Certain binders can improve the physical characteristics of pellets as well as the growth and digestion of animals (117).

The ability to binding properties has led to the selection of numerous compounds. Many natural binders, including wheat gluten or starches, have been used to create hard pellets offer nutritional value for the animals, while some of these binders are inert raw materials with no nutritional value. However, synthetic binders, such as urea formaldehyde, sodium bentonite, or calcium bentonite, are manufactured artificially and may not always increase the nutritional content of feed. Polymers such as carboxymethylcellulose (CMC), alginate, agar, carrageenan, guar gum (galactomannan), gelatin, pectin, and lignosulfonate are examples of modified binders (114, 118). Animal feed with modified binder, such as gelatin, has nutritional value Table 4 includes a number of materials used as pellet binders.

## Biotechnology Additives

### External Enzymes

Dietary enzymes have been utilized over the previous ten years as a means of enhancing nutrient utilization in poultry diets (122). External enzymes are currently widely used as a type of feed additives in poultry diet formulations to mitigate the effects of antinutritional factors, enhance animal performance, and promote digestion of dietary components, future changes in animal production around the world are predicted to enhance the usage of feed enzymes in poultry feed formulations (123). Protease, phytase, alpha-amylase, xylanases, beta-glucanases, xyloglucanases, galactomannanases, pectinases, arabinofuranosidases, and ferulic acid esterases are a few common enzymes that are involved in the production of animal feed. Hydrolytic enzymes improve feed digestibility in the animal's intestines by eliminating antinutritional elements from feed ingredients )124). Feed enzymes help to lessen the adverse environmental effects of animal production by reduce the amount of nutrients excreted in the animal waste, especially nitrogen and phosphorus, Feed enzymes work to make nutrients (starch, protein, amino acids, minerals, etc.) available from the feed ingredients, and these feed enzymes are proteins that are eventually digested or expelled by the animal, leaving no residues in meat or eggs (125, 126).

**Table 4.** Materials that are used as pellet binders

| Materials | Source |
| --- | --- |
| Found that adding 2.4% moisture to feed that was conditioned at 60 °C boosted pellet durability from 56.5% to 67.2 %. | (119) |
| The calcium lignosulfonate binder was effective in improving pellet integrity, but feed consumption and weight gain of broilers were not affected. | (120) |
| 1. By filling in the pore spaces between particles, binder materials such as lignosulfonate, bentonite, and sepiolite increase the strength and durability of pellets.<br>2. By altering the composition of the feed mix following moisture and heat treatment during the pelleting process, binder materials like protein and starch increase the strength and durability of pellets through a chemical reaction. | (117) |
| The addition of lignosulfonates enhanced nutrient digestibility, broiler performance, and pellet quality when employed at a level of 1-3 %, and was effective as a binder in poultry diets. | (121) |
| 1. Revealed there were notable variations in the physical pellet quality across the diets that contained 1.5% calcium fat powder.<br>2. Demonstrated the addition of 0.5% calcium lignosulfonate to diets containing 3% soybean oil greatly improved the pellets' length, hardness, and durability. | (112) |

### *Protease addition in poultry diets*

Over the past ten years, there has been an increase in the usage of exogenous protease addition in poultry diets. In order to increase the energy and protein digestibility of diets based on grains and oilseeds, The protease by itself improved nutrient utilization and increased solubilization of the non-starch polysaccharides (NSP) components, at the lower dose, a growing trend in animal nutrition is exogenous protease supplementation, which has positive impacts on growth performance, nutritional digestibility, and endogenous enzyme secretion (127). Furthermore, the addition proteases may enhance the quality of ingredients by lowering item variability and reducing the detrimental impacts of lectins or heat-stable trypsin inhibitors (128).

### *Phytase*

Phytases have been utilized as animal feed additives in poultry and fish diets since the first commercial phytase products were released in 1991 (129). Due to the absence of endogenous phytase, the majority of the phosphorus (P) in feed materials is found as phytate, which is not readily absorbed in the digestive tracts of several chicken species. Through the hydrolysis of phytate, phytase supplementation enhances P consumption, potentially lowering environmental P excretion. Phytase may also enhance feed utilization, weight increase, egg production and characteristics, energy availability, nutritional digestibility, and the retention of vital minerals in bones and blood. Therefore, the impact of phytase on performance and the absorption of calcium and phosphorus in layer chickens fed diets based on maize and soybeans has been well acknowledged (130).

### *Alpha-amylase*

To enhance starch digestibility and ooptimize energy utilization to maximize the performance of broiler, the inclusion of alpha-amylase has emerged as an effective strategy, this enzyme catalyzes the hydrolysis of complex starch molecules into smaller units, such as glucose, maltose, and dextrins, thereby facilitating their absorption in the gastrointestinal tract (131, 132, 133). Alpha-amylase supplementation in diets with lower metabolizable energy (ME) is a practical way to maximize broiler performance. Alpha-amylase also enhances the digestion of carbohydrates, boosting the amount of accessible energy (134).

### *Xylanase*

In chicken diets made with cereals, xylanase supplementation has become essential for maximizing nutrient uptake and minimizing animal waste issues. It allows for comparable growth rates without reducing feed efficiency (135). The poultry xylanases function in a number of ways, including first, by breaking down the soluble arabinoxylans to lower digesta viscosity; second, by directly acting on the feedstuffs' cell walls and causing an increase in endogenous enzyme activity; and third, by releasing oligosaccharides as a result of xylan degradation in the distal portions of the gastrointestinal tract (GIT), which serve as a prebiotic (136).

## Prebiotics in Poultry Diets

Prebiotics are substances that have undergone selective fermentation, which modifies the gut microbiota's makeup or activity, thereby benefiting host health, one the of alternatives antibiotic for growth promoter that is receiving a lot of interest is dietary fiber with prebiotic characteristics according to Roberfroid et al. (137). For instance, prebiotics like mannanoligosaccharide (MOS) may lessen the detrimental effects of cyclic heat stress on small intestine morphology, yeast fermentation (YF) metabolites have been demonstrated to lower stress measures in poultry exposed to heat stress, Additionally, it has been demonstrated that taking YF supplements before heat stress reduces gut barrier dysfunction measures (138).

### *Types of prebiotics*

The prebiotics are oligosaccharide carbohydrates, primarily galacto-oligosaccharides (GOS), lactulose, inulin, and their derivative fructose-oligosaccharides (FOS) as well as xylooligosaccharides (XOS) (139). According to recent research, prebiotics also contain various non-carbohydrates that satisfy the prebiotic requirements, like polyphenols that have been extracted from fruits like blueberries and black raspberries (140, 141). Are constantly being developed, mainly polypeptide polymers, polysaccharides, and polyphenols (139).

### *Mechanisms of action of prebiotic in poultry*

Prebiotics may alter the gastrointestinal tract's biological processes in poultry to enhance health and performance by boosting growth, lowering mortality, and enhancing feed efficiency, prebiotics may have an impact on the breakdown of indigestible food ingredients, the production of vitamins and nitrogen, and the ease of eliminating unwanted foods from the diet, they may also cause positive changes in the gut microbiota and have an impact on host metabolism and immune function (142). A potential strategy is to incorporate prebiotics into the diets of poultry. Non-digestible carbohydrates known as prebiotics have been shown to favorably alter the composition and fermentation patterns of the gastrointestinal microbiota, favoring species that are advantageous to the host (143). For a substance to qualify as a prebiotic, it must meet specific criteria: (a) it should not be hydrolyzed or absorbed in the upper gastrointestinal tract; (b) it must serve as a selective nutrition source for beneficial microbial populations in the gastrointestinal tract; and (c) it must induce physiological reactions that are advantageous to the host. Short-chain fatty acids (SCFA), a product of prebiotic fermentation comprising lactic acid and volatile acids, serve as a crucial energy source for poultry. They also lower gastrointestinal pH, preventing the growth of pathogenic bacteria sensitive to acidity (144, 145).

## Probiotics in Poultry Diets

Probiotics are feed additives containing live microorganisms that improve the intestinal microbial composition of the host and have a positive effect on the host. Numerous relevant studies have shown that adding probiotics to animal feed can effectively change the gut microbiota, which can improve gut immunity, disease resistance, and general health while also reducing pathogen shedding and illness signs (146).

### *Types of Probiotics*

In poultry were among the regularly utilized probiotics, Lactobacillus species (L. bulgaricus, L. plantarum, L. acidophilus, L. helveticus, L. lactis, L. salivarius, L. casei, L. reuteri), Enterococcus faecium and E. faecalis, Streptococcus thermophilus, and Bacillus subtilis, reviewed by Khan and Naz (147).

### *Mechanisms of action of probiotic in poultry*

By maintaining the balance of gut microbes, probiotics in feed help the host's health. They do this by preventing harmful bacteria from colonizing the gut through competitive exclusion. Probiotics naturally produce volatile fatty and organic acids, aid in digestion by breaking down insoluble fibers, improve nutrient absorption and metabolism, and lower the pH of the gut to levels that affect pathogenic bacteria like Salmonella spp. and E. coli. Numerous studies have demonstrated that probiotics boost the immune system, linking their administration to increased humoral and cellular immune responses by boosting the production of T cells, CD+, B cells, and anti-inflammatory cytokines (148).

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## Conflict of interest

The authors declare no conflict of interest.

## References

1. Abdulalwahhab BN, Al-Tememy ATD, Abbas BA. Study of the Location of Birds inside the Breeding Hall of Broilers Rose 308 and Its Effect on Environmental Conditions Using a Documented Data System. Plant Arch. 2020; 20 (1): 1013-1020. http://www.plantarchives.org/SPECIAL%20ISSUE%2020-1/1013-1020%20(18).pdf
2. Abbas, BA, Jasim, AA, Bander, LK. Comparing Different laboratory Methods for Measuring the Feed Pellet Durability. Kufa J Agr Sci. 2024; 16(3): 50-60. 10.36077/kjas/2024/v16i3.11401
3. Mandey JS, Sompie FN. Phytogenic feed additives as an alternative to antibiotic growth promoters in poultry nutrition. Adv. Stud. 21st Century Anim. Nutr. 2021; 8, 19-32. https://www.intechopen.com/chapters/77836
4. Ayalew H, Zhang H, Wang J, Wu, S, Qiu K, Qi G. et al. Potential feed additives as antibiotic alternatives in broiler production. Front Vet Sci. 2022; 9: 1-15. 10.3389/fvets.2022.916473
5. Yaman H, Ulukanli Z, Elmali M, Unal Y. The effect of a fermented probiotic, the Kefir, on intestinal flora of poultry domesticated geese (Anser anser). Rev Med Vet (Toulouse). 2006; 157(7): 379-386. https://api.semanticscholar.org/CorpusID:21340786
6. Ye M, Wei C, Khalid A, Hu Q, Yang R, Dai B, et al. Effect of Bacillus velezensis to substitute in-feed antibiotics on the production, blood biochemistry and egg quality indices of laying hens. BMC Vet Res. 2020; 16(1): 1-8. 10.1186/s12917-020-02570-6
7. Volostnova AN, Yakimov AV, Yakimov OA, Salyakhov AS, Frolov GS. Production technology of livestock and poultry products using environmentally safe feed additives. IOP Conf Ser Earth Environ Sci. 2022; 978(1): 1-6. 10.1088/1755-1315/978/1/012023
8. Diba F, Alam F, Talukder AA. Screening of acetic acid producing microorganisms from decomposed fruits for vinegar production. Adv Microbiol. 2015; 5(5): 291-297. 10.4236/aim.2015.55028
9. Al-Khalaifah HS. Benefits of probiotics and/or prebiotics for antibiotic-reduced poultry. Poult Sci. 2018; 97(11): 3807-3815. 10.3382/ps/pey160
10. Al-Gharawi JK, Al-Helali AH, Al-Zamili IF. Effect of using different ways to provide the iraq probitic on some productive traits of broiler. Plant Arch. 2018; 18(1): 1102-1108. http://plantarchives.org/PDF%20181/1102-1108%20(PA3%204185).pdf
11. Buryakov N, Traynev I, Zaikina A, Buryakova M, Shaaban, M, Zagarin A. The effects of the extract of sweet chestnut in diets for broilers on the digestibility of dietary nutrients and productive performance. In International Scientific Conference Fundamental and Applied Scientific Research in the Development of Agriculture in the Far East. 2021; 354: 778-784. 10.1007/978-3-030-91405-9_86

12. Pirgozliev V, Rose SP, Ivanova S. Feed additives in poultry nutrition. Bulg J Agric Sci. (2019); 25(1): 8-11. https://www.agrojournal.org/25/01s-02.pdf
13. Jones FT, Ricke SC. Observations on the history of the development of antimicrobials and their use in poultry feeds. Poult Sci. 2003; 82(4): 613-617. 10.1093/ps/82.4.613
14. Landoni MF, Albarellos G. The use of antimicrobial agents in broiler poultry s. Vet J, 2015; 205(1): 21-27. 10.1016/j.tvjl.2015.04.016
15. Hailegebreal G, Tanga BM, Woldegiorgis W, Sulayeman M, Sori T. Epidemiological investigation of morbidity and mortality of improved breeds of poultry s in small holder poultry farms in selected districts of Sidama Region, Ethiopia. Heliyon. 2022; 8(8): 1-7. 10.1016/j.heliyon.2022.e10074
16. Kujlu R, Mahdavianpour M, Ghanbari F. Multi-route human health risk assessment from trihalomethanes in drinking and non-drinking water in Abadan, Iran. Environ Sci Pollut Res Int. 2020; 27(34): 42621-42630. 10.1007/s11356-020-09990-9
17. Nwobodo DC, Ugwu MC, Oliseloke Anie C, Al-Ouqaili MT, Chinedu Ikem J, Victor Chigozie U. et al. Antibiotic resistance: The challenges and some emerging strategies for tackling a global menace. J Clin Lab Anal. 2022; 36(9):1-10. 10.1002/jcla.24655
18. Nhung NT, Chansiripornchai N, Carrique-Mas JJ. Antimicrobial resistance in bacterial poultry pathogens: a review. Front Vet Sci. 2017; 4: 1-17. 10.3389/fvets.2017.00126
19. Alsadwi AM, Ibrahim MM, Shah KN, Cannon CL, Byrd JA, Caldwell D, et al. In Vitro Efficacy of Silver Carbene Complexes, SCC1 and SCC22, Against Some Enteric Animal Pathogens. Iraqi J. Vet. Med. 2024; 48(1):1-8. 10.30539/yvbbhj22
20. Chattopadhyay MK. Use of antibiotics as feed additives: a burning question. Front Microbiol. 2014; 5: 1-3. 10.3389/fmicb.2014.00334
21. Gadde U, Kim WH, Oh ST, Lillehoj HS. Alternatives to antibiotics for maximizing growth performance and feed efficiency in poultry: a review. Anim Health Res Rev. 2017; 18(1): 26-45. 10.1017/S1466252316000207
22. Akhil, AM, Abdaljaleel R, Leyva-Jimenez H, Ibrahim M, Gardner K, et al. Evaluation Effect of Silver Acetate on Performance and Clostridium Perfringens-Induced Necrotic Enteritis in Broiler Chickens. Arch Anim Poult Sci. 2019; 1(2): 1-7. 10.19080/AAPS.2019.01.555556 https://juniperpublishers.com/aaps/pdf/AAPS.MS.ID.555556.pdf
23. Rahman MRT, Fliss I, Biron E. Insights in the development and uses of alternatives to antibiotic growth promoters in poultry and swine production.Antibiotics.2022;11(6):1-29. 10.3390/antibiotics11060766
24. Levy SB. The challenge of antibiotic resistance. Scientific American. 1998; 278(3): 46-53. 10.1038/scientificamerican0398-46
25. Dibner J, Richards J. Antibiotic growth promoters in agriculture: history and mode of action. Poultry science, 2005; 84(4): 634-643. https://doi.org/10.1093/ps/84.4.634
26. Hughes P, Heritage J. Antibiotic growth-promoters in food animals. FAO Anim Prod Heal Pap. 2004; 25: 129-152. https://www.fao.org/4/y5159e/y5159e08.htm
27. Czaplewski L, Bax R, Clokie, M, Dawson M, Fairhead H, Fischetti, VA, et al. Alternatives to antibiotics- a pipeline portfolio review. Lancet Infect Dis. 2016; 16(2): 239-251. 10.1016/s1473-3099(15)00466-1
28. Patrick GL. An introduction to medicinal chemistry. Oxford university press .924 :2023 p. https://global.oup.com/academic/product/an-introduction-to-medicinal-chemistry-9780198866664 10.1093/hesc/9780198866664.001.0001
29. Khattab WO, Elderea HB, Salem EG, Gomaa NF. Transmission of administered amoxicillin drug residues from laying poultry to their commercial eggs. J Egypt Public Health Assoc. 2010; 85(5-6): 297-316. https://pubmed.ncbi.nlm.nih.gov/22054104/
30. El-Kholy H, Kemppainen BW. Levamisole residues in poultry tissues and eggs. Poult Sci. 2005; 84(1): 9-13. 10.1093/ps/84.1.9
31. Roberts MC. Tetracycline resistance determinants: mechanisms of action, regulation of expression, genetic mobility, and distribution. FEMS Microbiol Rev. 1996;19(1):1-24. 10.1111/j.1574-6976.1996.tb00251.x
32. Thaker M, Spanogiannopoulos P, Wright G D. The tetracycline resistome. Cell Mol Life Sci. 2010; 67: 419-431. 10.1007/s00018-009-0172-6
33. Center for Veterinary Medicine. Summary report on antimicrobials sold or distributed for use in food-producing animals. U.S. Food and Drug Administration, Silver Spring, MD. 2018. https://www.fda.gov/media/133411/download
34. Zakeri B, Wright GD. Chemical biology of tetracycline antibiotics. Biochem Cell Biol. 2008; 86(2): 124-136. 10.1139/O08-002
35. Arrieta-Ortiz ML, Pan M, Kaur A, Pepper-Tunick E, Srinivas V, Dash A, et al. Disrupting the ArcA regulatory network amplifies the fitness cost of tetracycline resistance in Escherichia coli. Msystems. 2023; 8(1): 1-21. 10.1128/msystems.00904-22
36. Vass M, Hruska K, Franek M. Nitrofuran antibiotics: a review on the application, prohibition and residual analysis. Vet Med. 2008; 53(9): 469-500. 10.17221/1979-VETMED
37. Majalekar PP, Shirote, PJ. Fluoroquinolones: blessings or curses. Curr Drug Targets. 2020; 21(13): 1354-1370. 10.2174/1389450121666200621193355
38. Dagur P, Ghosh M, Patra A. Aminoglycoside antibiotics. In Medicinal Chemistry of Chemotherapeutic Agents. 2023; 135-155. 10.1016/B978-0-323-90575-6.00009-0
39. Mehtabuddin M, Mian AA, Ahmad T, Nadeem S, Tanveer ZI, Arshad J. Sulfonamide residues determination in commercial poultry meat and eggs. J Anim Plant Sci. 2012; 22(2): 473-478. https://www.thejaps.org.pk/Volume/2012/22-2/default.php
40. Vázquez-Laslop N, Mankin AS. How macrolide antibiotics work. Trends Biochem Sci. 2018; 43(9): 668-684. waaaaa 10.1016/j.tibs.2018.06.011
41. Dinos GP. The macrolide antibiotic renaissance. Br J Pharmacol. 2017; 174(18): 2967-2983. 10.1111/bph.13936
42. Matijašić M, Kos VM, Nujić K, Čužić S, Padovan J, Kragol G, et al. Fluorescently labeled macrolides as a tool for monitoring cellular and tissue distribution of azithromycin. Pharmacol Res. 2012; 66(4): 332-342. 10.1016/j.phrs.2012.06.001
43. Krause KM, Serio AW, Kane TR, Connolly LE. Aminoglycosides: an overview. Cold Spring Harbor perspectives in medicine. 2016; 6(6): 1-19. https://perspectivesinmedicine.cshlp.org/content/6/6/a027029.full. 10.1101/cshperspect.a027029
44. Mazalli MR, Maldonado RR, Aguiar-Oliveira E. Screening and Analysis of Probiotic Actinobacteria in Poultry Farming. Met Acti. 2022: 563-569. 10.1007/978-1-0716-1728-1_84
45. Clarke L, Fodey TL, Crooks SR, Moloney M, O'Mahony J, Delahaut P, et al. A review of coccidiostats and the analysis of their residues in meat and other food. Meat Sci. 2014; 97(3): 358-374. 10.1016/j.meatsci.2014.01.004
46. Martins RR, Silva LJ, Pereira AM, Esteves, A., Duarte SC, Pena A. Coccidiostats and poultry: A comprehensive review and current legislation. Foods. 2022; 11(18): 1-20. 10.3390/foods11182738
47. Sharma SK, Galav V, Rathore PS. Amphenicols: Dilemma of Use and Abuse in Poultry. In Handbook on Antimicrobial Resistance: Current Status, Trends in Detection and Mitigation Measures, Singapore: Springer Nature Singapore. 2023; 201-214. 10.1007/978-981-19-9279-7_12
48. Trif E, Cerbu C, Olah D, Zăblău SD, Spînu M., Potârniche, et al. Old antibiotics can learn new ways: a systematic review of florfenicol use in veterinary medicine and future perspectives using nanotechnology. Animals. 2023; 13(10): 1-19. 10.3390/ani13101695
49. EFSA Panel on Contaminants in the Food Chain (CONTAM). Scientific Opinion on Chloramphenicol in food and feed. EFSA J. 2014; 12(11): 1-146. 10.2903/j.efsa.2014.3907
50. Bacanh M, Başaran N. Importance of antibiotic residues in animal food. Food Cosmet Toxicol. 2019; 125: 462-466. 10.1016/j.fct.2019.01.033
51. Kantati YT. Détection des résidus d'antibiotiques dans les viandes de bovins prélevées aux abattoirs de Dakar. Mémoire de master qualité des aliments de l'homme, spécialité: Produits d'origine animale, Ecole

Inter-états des Sciences et Médecine vétérinaires (EISMV), Dakar. 2011: 1-49. https://beep.ird.fr/greenstone/collect/eismv/index/assoc/MEM11-15.dir/MEM11-15.pdf
52. Gassner B, Wuethrich A. Pharmacokinetic and toxicological aspects of the medication of beef-type calves with an oral formulation of chloramphenicol palmitate. J Vet Pharmacol Ther. 1994; 17(4): 279-283. 10.1111/j.1365-2885.1994.tb00246.x
53. Ventola CL. The antibiotic resistance crisis: part 1: causes and threats. P T. 2015; 40(4): 277-283. https://pubmed.ncbi.nlm.nih.gov/25859123/
54. Barlow M, Hall BG. Origin and evolution of the AmpC β-lactamases of Citrobacter freundii. Antimicrob Agents Chemother. 2002; 46(5): 1190-1198. 10.1128/AAC.46.5.1190-1198.2002
55. Crump JA, Luby SP, Mintz ED. The global burden of typhoid fever. Bull World Health Organ. 2004; 82(5): 346-353. https://pubmed.ncbi.nlm.nih.gov/15298225/
56. Majowicz SE, Musto J, Scallan E, Angulo FJ, Kirk M, O'Brien SJ, et al., Hoekstra RM. The global burden of nontyphoidal Salmonella gastroenteritis. Clin Infect Dis. 2010; 50(6): 882-889. 10.1086/650733
57. Allerberger F, Liesegang A, Grif K, Khaschabi D, Prager R, Danzl J, et al. Occurrence of Salmonella enterica serovar Dublin in Austria. Wien Med Wochenschr. 2003; 153(7-8): 148-152. 10.1046/j.1563-258X.2003.03015.x
58. Silva J, Leite D, Fernandes M, Mena C, Gibbs PA, Teixeira P. Campylobacter spp. as a foodborne pathogen: a review. Front Microbiol. 2011; 2, 1-12. 10.3389/fmicb.2011.00200
59. Engberg J, Aarestrup FM, Taylor DE, Gerner-Smidt P, Nachamkin I. Quinolone and macrolide resistance in Campylobacter jejuni and C. coli: resistance mechanisms and trends in human isolates. Emerg Infect Dis. 2001; 7(1): 24-34. 10.3201%2Feid0701.010104
60. Endtz HP, Ruijs GJ, van Klingeren, B, Jansen WH, van der Reyden T, Mouton RP. Quinolone resistance in Campylobacter isolated from man and poultry following the introduction of fluoroquinolones in veterinary medicine. J Antimicrob Chemother. 1991; 27(2): 199-208. 10.1093/jac/27.2.199
61. Ramos S, Silva V, Dapkevicius MDLE, Caniça M, Tejedor-Junco MT, Igrejas G, et al. Escherichia coli as commensal and pathogenic bacteria among food-producing animals: Health implications of extended spectrum β-lactamase (ESBL) production. Animals. 2020; 10(12): 1-15. 10.3390/ani10122239
62. Allocati N, Masulli M, Alexeyev MF, Di Ilio C. Escherichia coli in Europe: an overview. Int J Environ Res Public Health. 2013; 10(12): 6235-6254. 10.3390/ijerph10126235
63. Lazarus B, Paterson DL, Mollinger JL, Rogers BA. Do human extraintestinal Escherichia coli infections resistant to expanded-spectrum cephalosporins originate from food-producing animals? A systematic review. Clin Infect Dis. 2015; 60(3): 439-452. 10.1093/cid/ciu785
64. Wegener HC, Aarestrup FM, Jensen LB, Hammerum AM, Bager F. Use of antimicrobial growth promoters in food animals and Enterococcus faecium resistance to therapeutic antimicrobial drugs in Europe. Emerg Infect Dis. 1999; 5(3): 329-335. 10.3201/eid0503.990303
65. Edmond MB, Ober JF, Dawson JD, Weinbaum DL, Wenzel RP. Vancomycin-resistant enterococcal bacteremia: natural history and attributable mortality. Clin Infect Dis. 1996; 23(6): 1234-1239. 10.1093/clinids/23.6.1234
66. Wise R. An overview of the specialist advisory committee on antimicrobial resistance (SACAR). J Antimicrob Chemother. 2007; 60(suppl. 1): 5-7. 10.1093/jac/dkm151
67. Sabir PS, Mirza RA, Hamedmin, AE, Abdulla HS. Efficacy of peppermint (Mentha pipreitae), basil (Ocimum basilicum) and their combination on growth performance and meat quality of broilers. Diyala Agr Sci J. 2023; 15(1): 26-33. 10.52951/dasj.23150104
68. Grave K, Jensen VF, Odensvik K, Wierup M, Bangen M. Usage of veterinary therapeutic antimicrobials in Denmark, Norway and Sweden following termination of antimicrobial growth promoter use. Prev Vet Med. 2006; 75(1-2): 123-132. 10.1016/j.prevetmed.2006.02.003
69. Anadón A, Martínez-Larrañaga MR, Ares I, Martínez MA. Regulatory aspects for the drugs and chemicals used in food-producing animals in the European Union. Vet Toxicol (Third Edition). 2018: 103-131. 10.1016/B978-0-12-811410-0.00007-6
70. Faugeron J, Oguey C. Flavours: versatile sensory additives. Pancosma. Reproduced from Feed Compounder. 2020: 1-2. https://www.pancosma.com/flavours-versatile-sensory-additives-2/
71. Breithaupt DE. Modern application of xanthophylls in animal feeding-a review. Trends Food Sci Technol. 2007; 18(10): 501-506. 10.1016/j.tifs.2007.04.009
72. Breithaupt DE. Xanthophylls in Poultry Feeding. In: Britton G, Liaaen-Jensen S, Pfander H. (eds) Carotenoids. Carotenoids. 2008; 4: 1-2. 10.1007/978-3-7643-7499-0_13
73. Baker R, Günther, C. The role of carotenoids in consumer choice and the likely benefits from their inclusion into products for human consumption. Trends Food Sci Technol. 2004; 15(10): 484-488. 10.1016/j.tifs.2004.04.0094
74. Santos TTD, Baal SCS, Lee SA, Silva VFD, Favaro C, da Silva VF. Immune profile of broilers between hatch and 9 days of age fed diets with different betaine and fibre concentrations. J Worlds Poult Res. 2020; 10(2): 397-406. 10.36380/jwpr.2020.47
75. Arisandi R, Hamid A, Saleh E, Zain WN, Sholikin MM, Prihambodo TR, et al. The Effects of Mixed Vitamins, Minerals, Fatty Acids and Amino Acids Supplementation into Drinking Water on Broiler Poultry s' Performance and Carcass Traits. J Worlds Poult Res. 2021; 11(1): 47-52. 10.36380/jwpr.2021.7
76. El-Senousey HK, Chen B, Wang JY, Atta AM, Mohamed FR, Nie QH. Effects of dietary vitamin C, vitamin E, and alpha-lipoic acid supplementation on the antioxidant defense system and immune-related gene expression in broilers exposed to oxidative stress by dexamethasone. Poult sci. 2018; 97(1): 30-38. 10.3382/ps/pex298
77. Gan L, Fan H, Mahmood T, Guo Y. Dietary supplementation with vitamin C ameliorates the adverse effects of Salmonella Enteritidis-challenge in broilers by shaping intestinal microbiota. Poult Sci. 2020; 99(7): 3663-3674. 10.1016/j.psj.2020.03.062
78. Ravindran V. Poultry feed availability and nutrition in developing countries. Poult dev rev. 2013: 1-4. https://www.fao.org/4/al703e/al703e00.pdf
79. Al-Tememy ATD, Al-obaidy AH, Wasman PH. Adding Sodium Citrate in Water and Effect in Physiological Performance of Broiler Poultry s Reared under High-Density Condition. IOP Conf Ser Earth Environ Sci. 2023; 1252(1): 1-7. 10.1088/1755-1315/1252/1/012151
80. Khan RU, Naz S, Raziq F, Qudratullah Q, Khan NA, Laudadio V. et al. Prospects of organic acids as safe alternative to antibiotics in broiler chickens diet. Environ Sci Pollut Res Int. 2022; 29(22): 32594-32604. 10.1007/s11356-022-19241-8
81. Wu G. Dietary protein intake and human health. Food Funct. 2016; 7(3): 1251-1265. 10.1039/C5FO01530H
82. Chalova VI, Kim JH, Patterson PH, Ricke SC, Kim WK. Reduction of nitrogen excretion and emissions from poultry: A review for conventional poultry. Worlds Poult Sci j. 2016; 72(3): 509-520. 10.1017/S0043933916000477
83. Waldroup PW, Jiang Q, Fritts CA. Effects of supplementing broiler diets low in crude protein with essential and nonessential amino acids. Int J Poult Sci. 2005; 4(6): 425-431. 10.3923/ijps.2005.425.431
84. Corzo A, Kidd MT, Dozier III, WA, Vieira SL. Marginality and needs of dietary valine for broilers fed certain all-vegetable diets. J Appl Poult Res. 2007; 16(4): 546-554. 10.3382/japr.2007-00025
85. Rehman AU, Arif M, Husnain MM, Alagawany,M, Abd El-Hack M. E, Taha AE, et al. Growth performance of broilers as influenced by different levels and sources of methionine plus cysteine. Animals. 2019; 9(12): 1-12. 10.3390/ani9121056
86. National Research Council (NRC). Nutrient Requirements of Poultry. 9th rev. ed., Natl. Acad. Press, Washington, D.C. 1994. https://www.scirp.org/reference/referencespapers?referenceid=429252

87. He W, Li P, Wu G. Amino Acid Nutrition and Metabolism in Chickens. Adv Exp Med Biol. 2021; 1285: 109-131. 10.1007/978-3-030-54462-1_7
88. Wu G. Dietary requirements of synthesizable amino acids by animals: a paradigm shift in protein nutrition, J Anim Sci Biotechnol. 2014; 5: 1-12. 10.1039/C5FO01530H
89. Woyengo TA, Bach Knudsen KE, Børsting CF, Low-protein diets for broilers: Current knowledge and potential strategies to improve performance and health, and to reduce environmental impact. Anim Feed Sci Technol. 2023; 297: 1-18. 10.1016/j.anifeedsci.2023.115574
90. 90. Zhang L, Jiang Y, Buzdar JA, Ahmed S, Sun X, Li, F., et al. Microalgae: An Exciting Alternative Protein Source and Nutraceutical for the Poultry Sector. Food Sci Anim Resour. 2025; 45(1): 243-265. 10.5851/kosfa.2024.e130
91. 91. Sajjad M, Sajjad A, Chishti GA, Khan EU, Mozūraitis R, Binyameen M. Insect larvae as an alternate protein source in poultry feed improve the performance and meat quality of broilers. Animals. 2024; 14(14): 1-19. 10.3390/ani14142053
92. Sung JY, Aderibigbe AS, Adeola O. Amino acid digestibility and net energy concentration in soybean meal for broiler chickens. Anim Feed Sci Technol. 2023; 297: 115572. 10.1016/j.anifeedsci.2023.115572
93. Sajjad M, Sajjad A, Chishti G. A, Binyameen M, Abbasi A, Haq IU, et al. Evaluation of blow fly, Chrysomya megacephala (Calliphoridae: Diptera) as an alternate source of protein in broiler feed. J Insects Food Feed. 2024; 1: 1-19. 10.1163/23524588-00001109
94. Alagawany M, Elnesr SS, Saleh AA, El-Shall,NA, Azzam MM, Dhama K, et al. An updated review of azolla in poultry diets. Worlds Poult Sci J. 2024; 80(1): 155-170. 10.1080/00439339.2023.2271886
95. Van Harn J, Dijkslag MA, Van Krimpen MM. Effect of low protein diets supplemented with free amino acids on growth performance, slaughter yield, litter quality, and footpad lesions of male broilers. Poult Sci. 2019; 98(10): 4868-4877. 10.3382/ps/pez229
96. Dean DW, Bidner TD, Southern LL. Glycine supplementation to low protein, amino acid-supplemented diets supports optimal performance of broiler chicks. Poult Sci. 2006; 85(2): 288-296. 10.1093/ps/85.2.288
97. Ji F, Fu SY, Ren B, Wu SG, Zhang HJ, Yue HY, et al. Evaluation of amino-acid supplemented diets varying in protein levels for laying hens. J Appl Poult Res. 2014; 23(3): 384-392. 10.3382/japr.2013-00831
98. 98. Grossmann L, Weiss J. Alternative protein sources as technofunctional food ingredients. Annu Rev Food Sci Technol. 2021; 12(1): 93-117. 10.1146/annurev-food-062520-093642
99. Kim YB, Lee SH, Kim DH, Lee KW. Effects of dietary methyl sulfonyl methane and selenium on laying performance, egg quality, gut health indicators, and antioxidant capacity of laying hens. Anim Biosci. 2022; 35(10): 1566. 10.5713/ab.21.0564
100. Surai PF. Anti-oxidants in poultry nutrition and reproduction: An update. Anti-oxidants. 2020; 9(2): 1-6. 10.3390/antiox9020105
101. Surai PF, Fisinin VI. Vitagenes in poultry production: Part 1. Technological and environmental stresses. Worlds Poult Sci J. 2016; 72(4): 721-734. 10.1017/S0043933916000714
102. Surai PF, Fisinin VI. Vitagenes in poultry production: Part 2. Nutritional and internal stresses. Worlds Poult Sci J. 2016; 72(4): 761-772. 10.1017/S0043933916000726
103. Surai PF, Kochish II, Fisinin VI. Antioxidant systems in poultry biology: Nutritional modulation of vitagenes. Eur Poult Sci. 2017; 81(214): 1-21. 10.1399/eps.2017.214
104. Nawaz AH, Zhang L. Oxidative stress in broiler chicken and its consequences on meat quality. Int J Life Sci Res Arch. 2021; 1(1): 045-054. 10.53771/ijlsra.2021.1.1.0054
105. Luna A, Lema-Alba RC, Dambolena JS, Zygadlo JA, Lábaque MC, Marin RH. Thymol as natural antioxidant additive for poultry feed: oxidative stability improvement. Poult sci. 2017; 96(9): 3214-3220. 10.3382/ps/pex158
106. Gurusaran S, Lokesh P, Naresh M, Hariharan M, Varun A. Antioxidant a Feed Additive: Unravelling the Impact of Antioxidants Supplementation on Productivity and Wellness in Animals. Chron Aqua Sci. 2024; 1(10): 94-101. 10.61851/coas.v1i10.09
107. Latham RE, Williams M, Smith K, Stringfellow K, Clemente S, Brister Ret al. Effect of β-mannanase inclusion on growth performance, ileal digestible energy, and intestinal viscosity of male broilers fed a reduced-energy diet. J Appl Poult Res. 2016; 25(1): 40-47.10.3382/japr/pfv059
108. Abbas BA, Jasim AA, Bander LK. Effect of speed and die holes diameter in the machine on feed pellets quality. IOP Conf Ser Earth Environ Sci. 2023; 1252(1): 1-7. 10.1088/1755-1315/1252/1/012116
109. Abbas BA, Jasim AA, Bander LK. Manufacturing and Testing a Double Action Feed Pellet Durability Measuring Device. IOP Conf Ser Earth Environ Sci. 2023; 1259(1): 1-9. 10.1088/1755-1315/1259/1/012126
110. Abbas BA, Bander LK, Jasim AA. Effect of feed forms, mash and pellets on productive performance and carcass weights of broiler poultry. Kufa J Agr Sci. 2024; 16(3): 105-118. 10.36077/kjas/2024/v16i3.11635
111. Rigby TR, Glover BG, Foltz KL, Boney JW, Moritz JS. Effects of modifying diet and feed manufacture concern areas that are notorious for decreasing pellet quality. J Appl Poult Res. 2018; 27(2): 240-248. 10.3382/japr/pfx064
112. Abadi MHMG, Moravej H, Shivazad M, Torshizi MAK, Kim WK. Effect of different types and levels of fat addition and pellet binders on physical pellet quality of broiler feeds. Poult sci. 2019; 98(10): 4745-4754. 10.3382/ps/pez190
113. Gehring CK, Lilly KGS, Shires LK, Beaman KR, Loop SA, Moritz JS. Increasing mixer-added fat reduces the electrical energy required for pelleting and improves exogenous enzyme efficacy for broilers. J Appl Poult Res. 2011; 20(1): 75-89. 10.3382/japr.2009-00082
114. Paolucci M, Fabbrocini A, Volpe MG, Varricchio E, Coccia E. Development of biopolymers as binders for feed for farmed aquatic organisms. Aquaculture. 2012; 1: 3-34. 10.5772/28116
115. Tumuluru JS, Conner CC, Hoover AN. Method to produce durable pellets at lower energy consumption using high moisture corn stover and a corn starch binder in a flat die pellet mill. J Vis Exp. 2016; 112: 1-13. 10.3791/54092
116. Attar A, Kermanshahi H, Golian A. Effects of conditioning time and sodium bentonite on pellet quality, growth performance, intestinal morphology and nutrient retention in finisher broilers. British poult sci. 2018; 59(2): 190-197. 10.1080/00071668.2017.1409422
117. Ayoola OA. Influence of the animal feed binders on optimal nutritional and physical qualities of the animal feed pellets and feed production capacity-A literature review, Master's thesis, Norwegian University of Life Sciences. 2020: 1-79. https://hdl.handle.net/11250/2725193
118. Lim C, Cuzon G. Water stability of shrimp pellet: A review. Asian Fish Sci. 1994; 7: 115-126. https://www.asianfisheriessociety.org/publication/abstract.php?id=water-stability-of-shrimp-pellet-a-review. 10.33997/j.afs.1994.7.2-3.005
119. Abdollahi MR, Ravindran V, Wester TJ, Ravindran G, Thomas DV. Effect of improved pellet quality from the addition of a pellet binder and/or moisture to a wheat-based diet conditioned at two different temperatures on performance, apparent metabolisable energy and ileal digestibility of starch and nitrogen in broilers. Anim Feed Sci Technol. 2012; 175(3-4): 150-157. 10.1016/j.anifeedsci.2012.05.001
120. Acar N, Moran Jr ET, Revington WH, Bilgili SF. Effect of improved pellet quality from using a calcium lignosulfonate binder on performance and carcass yield of broilers reared under different marketing schemes. Poult Sci. 1991; 70(6): 1339-1344. 10.3382/ps.0701339
121. Tabil L, Sokhansanj S, Tyler RT. Performance of different binders during alfalfa pelleting. Can Agric Engin. 1997; 39(1): 17-23. http://www.csbe-scgab.ca/docs/journal/39/39_1_17_ocr.pdf
122. Sekarsari NGAMS. Xylanase Enzyme on Broiler Performance Fed Cassava Based Diet in Forms of Pellet and Mash. In 6th International Seminar of Animal Nutrition and Feed Science. 2022; 21: 304-308.10.2991/absr.k.220401.063
123. Ravindran V, Son JH. Feed enzyme technology: present status and future developments. Recent Pat Food Nutr Agric. 2011; 3(2): 102-109. http://dx.doi.org/10.2174/2212798411103020102

124. Singh P, Yadav SK. Feed Enzymes: Source and Applications. Enzymes in Food Technology: Improv Innov. 2018: 347-358. 10.1007/978-981-13-1933-4_17
125. Imran M, Nazar M, Saif M, Khan MA, Vardan M, Javed O. Role of enzymes in animal nutrition: a review. PSM Vet Res. 2016; 1(2): 38-45. https://psmjournals.org/index.php/vetres/article/view/84
126. Stefanello C, Vieira SL, Rios HV, Simões CT, Ferzola PH, Sorbara JOB, et al. Effects of energy, α-amylase, and β-xylanase on growth performance of broiler chickens. Anim Feed Sci Technol. 2017; 225: 205-212. 10.1016/j.anifeedsci.2017.01.019
127. Olukosi OA, Beeson LA, Englyst K, Romero LF. Effects of exogenous proteases without or with carbohydrases on nutrient digestibility and disappearance of non-starch polysaccharides in broiler poultry chickens. Poult Sci. 2015; 94(11): 2662-2669. 10.3382%2Fps%2Fpev260
128. Cowieson AJ, Lu H, Ajuwon KM, Knap I, Adeola O. Interactive effects of dietary protein source and exogenous protease on growth performance, immune competence and jejunal health of broiler poultry chickens. Anim Prod Sci. 2016; 57(2): 252-261. 10.1071/AN15523
129. Debnath D, Sahu NP, Pal AK, Baruah K, Yengkokpam S, Mukherjee SC. Present scenario and future prospects of phytase in aquafeed-Review. Asian-Australas J Anim Sci. 2005; 18(12): 1800-1812. 10.5713/ajas.2005.1800
130. Abd El-Hack ME, Alagawany Arif M, Emam M, Saeed M, Arain MA., et al. The uses of microbial phytase as a feed additive in poultry nutrition–a review. Ann Anim Sci. 2018; 18(3): 639-658. 10.2478/aoas-2018-0009
131. Torres-Pitarch A, Manzanilla EG, Gardiner GE, O'Doherty JV, Lawlor PG. Systematic review and meta-analysis of the effect of feed enzymes on growth and nutrient digestibility in grow-finisher pigs: Effect of enzyme type and cereal source. Anim Feed Sci Technol. 2019; 251: 153-165. 10.1016/j.anifeedsci.2018.12.007
132. Herwig E, Schwean-Lardner K, Van Kessel A, Savary RK, Classen HL. Assessing the effect of starch digestion characteristics on ileal brake activation in broiler chickens. PLoS One. 2020; 15(2): 1-20. 10.1371/journal.pone.0228647
133. Genova JL, Rupolo PE, Melo ADB, dos Santos LBDA, Wendt GN, Barbosa KA. et al. Biological response of piglets challenged with Escherichia coli F4 (K88) when fed diets containing intestinal alkaline phosphatase. Czech J Anim Sci. 2021; 66 (10): 391-402. 10.17221/82/2021-CJAS
134. Bruch CA, Andrade TDS, Rohloff N, Ribeiro TP, Vargas JGD, Nunes RV. Alpha-amylase supplementation improves broiler performance and intestinal health under reduced metabolizable energy conditions. Anim Sci Vet. 2024; 48, 1-12. 10.1590/1413-7054202448015824
135. Wu YB, Ravindran V. Influence of whole wheat inclusion and xylanase supplementation on the performance, digestive tract measurements and carcass characteristics of broiler chickens. Anim Feed Sci Technol. 2004; 116(1-2): 129-139. 10.1016/j.anifeedsci.2004.02.011
136. Gonzalez-Ortiz G, Sola-Oriol D, Martinez-Mora M, Perez JF, Bedford MR. Response of broiler chickens fed wheat-based diets to xylanase supplementation. Poult Sci. 2017; 96(8): 2776-2785. 10.3382/ps/pex092
137. Roberfroid M, Gibson GR, Hoyles L, McCartney AL, Rastall R, Rowland I, et al. Prebiotic effects: metabolic and health benefits. Br J Nutr. 2010; 104(2): 1-63. 10.1017/s0007114510003363
138. Nelson JR, Ibrahim MM, Sobotik EB, Athrey G, Archer GS. Effects of yeast fermentate supplementation on cecal microbiome, plasma biochemistry and ileal histomorphology in stressed broiler chickens. Livest Sci. 2020; 240: 104149. 10.1016/j.livsci.2020.104149
139. You S, Ma Y, Yan B, Pei W, Wu Q, Ding C, Huang C. The promotion mechanism of prebiotics for probiotics: A review. Front Nutr. 2022; 9: 1-22. 10.3389/fnut.2022.1000517
140. Gu J, Thomas-Ahner JM, Riedl KM, Bailey MT, Vodovotz Y, Schwartz SJ, et al. Dietary black raspberries impact the colonic microbiome and phytochemical metabolites in mice. Mol Nutr Food Res. 2019; 63(8): 1800636. 10.1002/mnfr.201800636
141. Jiao X, Wang Y, Lin Y, Lang Y, Li E, Zhang X, et al. Blueberry polyphenols extract as a potential prebiotic with anti-obesity effects on C57BL/6 J mice by modulating the gut microbiota. J Nutr Biochem. 2019; 64: 88-100. 10.1016/j.jnutbio.2018.07.008
142. Yaqoob MU, Abd El-Hack ME, Hassan F, El-Saadony MT, Khafaga AF, Batiha GE, et al. The potential mechanistic insights and future implications for the effect of prebiotics on poultry performance, gut microbiome, and intestinal morphology. Poult sci. 2021; 100(7): 1-12. 10.1016/j.psj.2021.101143
143. Ricke SC, Lee, SI, Kim SA, Park SH, Shi Z. Prebiotics and the poultry gastrointestinal tract microbiome. Poult sci. 2020; 99(2): 670-677. 10.1016/j.psj.2019.12.018
144. Liu HY, Li X, Zhu X, Dong WG, Yang GQ. Soybean oligosaccharides attenuate odour compounds in excreta by modulating the caecal microbiota in broilers. Animal. 2021; 15(3): 1-8. 10.1016/j.animal.2020.100159
145. Liu L, Li Q, Yang Y, Guo A. Biological function of short-chain fatty acids and its regulation on intestinal health of poultry. Front Vet Sci. 2021; 8: 736739. 10.3389/fvets.2021.736739
146. Mamphogoro TP, Makete G, Modika KY, Kamutando CN. Probiotics as Feed Additives for Improved Animal Health and Nutrition: Books, Probiotics, Prebiotics, and Postbiotics in Human Health and Sustainable Food Systems. 2024. 10.5772/intechopen.1007406
147. Khan RU, Naz S. The applications of probiotics in poultry production. Worlds Poult Sci J. 2013; 69(3): 621-632. 10.1017/S0043933913000627
148. Mak PH, Rehman MA, Kiarie EG, Topp E, Diarra MS. Production systems and important antimicrobial resistant-pathogenic bacteria in poultry: a review. J Anim Sci Biotechnol. 2022; 13(1): 1-20. 10.1186/s40104-022-00786-0


# إضافات الأعلاف المستخدمة في التغذية وتحسين أداء وصحة الدواجن: مراجعة


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**الخلاصة**

إن أحد الأساليب المستعملة لزيادة كفاءة صناعة الدواجن هو تجهيز الإضافات إلى الأعلاف لتعزيز معدلات النمو وتحسين إنتاج البيض وتخفيف انتشار الأمراض وتحسين استعمال الأعلاف، وتركز هذه المراجعة بشكل خاص على أنواع مختلفة من إضافات الأعلاف التي تُضاف إلى اعلاف الدواجن لتحسين الأداء والصحة. تتضمن المكونات الأساسية لأعلاف الدواجن الحبوب، وخاصة الذرة الصفراء، إلى جانب القمح والشعير والذرة البيضاء والحبوب الأخرى. وايضا، يتم استعمال مصدر بروتيني رئيسي مثل دقيق فول الصويا، بالرغم من وجود مصادر بروتينية بديلة، سواء من أصل حيواني أو نباتي، وبخلاف هذه المكونات تتأثر جودة التغذية في العلف بعوامل مثل طريقة التغذية والتلوث الميكروبي ووجود مواد مضادة للتغذية وقابلية الهضم والطعم والصحة المعوية ، وتتوفر مجموعة متنوعة من إضافات الأعلاف لمعالجة هذه الاعتبارات. وعليه يتطلب تسويق هذا النوع من الأعلاف الموافقة عبر التقييم العلمي الدقيق، الذي يضمن عدم وجود آثار ضارة لها على صحة الإنسان والحيوان، فضلاً عن البيئة، وتُظهِر العديد من مكونات الأعلاف المصنعة في اعلاف الدواجن خصائص مضادة للتغذية، الذي يحد من إمكانية تطبيقها لتلبية متطلبات الطاقة وتعزيز صحة الدواجن، ويعد من الضرورة تطوير بدائل جادة تجارياً لموارد الأعلاف الحالية، مع التركيز على السلامة والفعالية من حيث التكلفة. وعليه يكون استعمال إضافات الأعلاف في الدواجن مفيداً لكونها تسمح بتعظيم الأداء العام وتحسين قابلية الهضم حفاظاًعلى صحة الدواجن.



**الكلمات المفاحية:** المضادات الحيوية، إضافات الأعلاف، تغذية الدواجن، البريبايوتكس، صحة الدواجن.