

Effect Of Adding Different Feed Additives on Growth Performance and Production of Livestock: A Review

Worknesh Seid^a

a Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Center, P.O. Box: 32, Bishoftu, Ethiopia Email: workneshsd@gmail.com

Keywords:

Livestock productivity
Feed Additives
Growth Performance
Production Efficiency

ABSTRACT

The quest to enhance livestock productivity has led to extensive research into various feed additives and their effects on growth performance and overall production. This review systematically evaluates the impact of different feed additives on livestock, focusing on both growth metrics and production efficiency. Feed additives, including probiotics, prebiotics, enzymes, organic acids, and phytogenics, have been studied for their roles in improving feed conversion rates, promoting healthier digestion, and optimizing nutrient absorption. The review synthesizes data from recent studies, highlighting the benefits and limitations of each type of additive. Probiotics and prebiotics are shown to positively influence gut microbiota and immune function, while enzymes and organic acids improve nutrient utilization and reduce feed wastage. Phytogenics, derived from plant sources, offer potential benefits in enhancing feed palatability and health. Despite the promising results, variability in effectiveness based on animal species, production systems, and environmental conditions underscores the need for tailored applications. This review provides insights into how strategic use of feed additives can enhance livestock performance and recommends areas for future research to further elucidate their mechanisms and optimize their use in various production settings.

INTRODUCTION

Feed additives encompass a diverse range of molecules, compounds, or organisms designed to enhance ingestion, absorption, and assimilation of nutrients while promoting growth and overall health in animals. These additives influence critical physiological processes, including immune function, stress resistance, and reproduction, making them indispensable in modern animal nutrition, particularly in poultry production.

One of the primary roles of feed additives is to optimize nutrient utilization, thereby improving feed conversion efficiency and supporting healthy weight gain. By enhancing digestion, absorption, and nutrient metabolism, these additives drive faster growth rates and elevate production efficiency in poultry. This is particularly valuable in meeting the demands of large-scale poultry farming, where maximizing output is a key objective.

Beyond growth performance, feed additives play a crucial role in maintaining intestinal health. Poultry are susceptible to a variety of gut-related disorders, such as bacterial infections, coccidiosis, and enteritis, which can reduce feed intake, stunt growth, and increase mortality rates. Additives with antimicrobial properties mitigate these risks by suppressing pathogenic growth, fostering a balanced gut microbiota, and strengthening the intestinal barrier. This not only curbs disease incidence but also supports overall digestive health.

Additionally, feed additives bolster poultry resilience by enhancing their ability to cope with stressors like heat, disease, and fluctuating environmental conditions. Through immune system support, inflammation reduction, and improved overall vitality, these additives help birds withstand pathogens and external challenges more effectively. This resilience is critical for maintaining flock health and productivity under varying conditions.

Feed additives, broadly defined as substances incorporated into animal feed, enhance nutritional value, improve performance, and safeguard health. Commonly utilized in poultry nutrition, they offer benefits such as increased feed efficiency, reduced environmental footprints, and enhanced animal welfare. For instance, improved feed efficiency enables birds to extract more nutrients from their diet, converting feed into meat or eggs more effectively. This leads to

accelerated growth, better weight gain, and, in some cases, higher-quality products, such as eggs enriched with omega-3 fatty acids.

Another significant advantage is the potential to lessen the environmental impact of poultry farming. By optimizing feed use, additives reduce the quantity of feed required to produce protein, thereby decreasing the demand for land, water, and other resources. This also contributes to lower greenhouse gas emissions, aligning with sustainable agricultural practices. Furthermore, certain additives prevent or treat diseases, reducing reliance on antibiotics and improving product quality, which benefits both producers and consumers.

Despite these advantages, the use of feed additives carries risks that warrant careful consideration. One major concern is their potential to harm animal health. For example, prolonged use of antibiotics as additives has been linked to the emergence of antibiotic-resistant bacteria, posing challenges for treating infections in animals and humans alike. This resistance can increase

morbidity and mortality, amplifying public health concerns. Environmental risks also arise, such as nutrient runoff from additives like phosphorus and nitrogen, which can pollute water bodies, trigger algal blooms, and degrade ecosystems if not managed properly.

Moreover, interactions between additives may produce unforeseen consequences. Combinations of otherwise safe additives could negatively affect animal or human health, particularly if dosages or synergies are poorly understood. High doses of antibiotics, for instance, may pass unabsorbed into manure, fostering resistant bacteria in the environment that can transfer to humans or wildlife. Additionally, some additives, such as hormones or growth promoters, have been associated with human health risks, including elevated cancer risk or allergic reactions, underscoring the need for rigorous safety assessments.

In conclusion, feed additives are vital tools in poultry nutrition, optimizing growth, supporting gut health, and enhancing resilience against stressors. They improve nutrient efficiency, control pathogens, and help birds thrive under challenging conditions. However, their use must be guided by strict regulations and judicious

application to ensure safety and efficacy for poultry, humans, and the environment. Responsible management, informed by thorough risk-benefit evaluations, is essential to maximize their advantages while minimizing potential downsides. This balanced approach ensures that feed additives contribute to sustainable poultry production without compromising health or ecological integrity.

The Role of Feed Additives in Livestock and Poultry Nutrition

Feed additives play a pivotal role in enhancing the overall productivity and sustainability of livestock and poultry farming. They contribute significantly to improving feed utilization, palatability, growth performance, feed processing, the quality of livestock products, and the efficient use of feed resources. This paper discusses the various functions of feed additives and their impact on modern animal husbandry practices

1. Enhancement of Feed Utilization

In intensive livestock and poultry production systems, animals are often at risk of micronutrient deficiencies, which can lead to nutritional imbalances and metabolic disorders. These deficiencies hinder growth and development, resulting in economic losses. By incorporating feed additives, the nutritional value of feed is enhanced, which optimizes feed utilization. This, in turn, helps unlock the full production potential of animals and improves their productivity.

2. Improvement of Feed Palatability

The inclusion of flavoring agents in animal feed is instrumental in enhancing its palatability, which, in turn, promotes feed intake. Feed flavoring agents, such as esters, ethers, fatty acids, and aromatic alcohols, are commonly used in various countries to produce flavors that are especially beneficial in piglet milk substitutes and calf milk replacers. These additives not only improve the taste and smell of the feed but also contribute to better feeding efficiency and growth performance.

3. Optimizing Feed Processing

In the United States, around two-thirds of feed mills use binders during pellet feed production to reduce dust and enhance feed processing efficiency. These additives improve the production process and increase feed production capacity. Furthermore, nutrients like vitamins and unsaturated fatty acids are prone to oxidation during feed processing and storage. Antioxidants and antifungal agents are widely used to mitigate nutrient losses and preserve the quality of feed over time. For example, antioxidants have been shown to reduce carotene loss in grass meal by up to 50% after six months of storage, compared to untreated feed

4. Promotion of Growth and Development

Growth promoters, including antibiotics, synthetic antibacterial agents, and novel compounds like prebiotics, oligosaccharides, and organic salts, have revolutionized livestock and poultry production. These additives not only help prevent diseases but also enhance overall growth rates and health. The use of growth promoters has seen rapid expansion in recent decades, significantly contributing to improved production performance and animal health.

5. Improvement in Livestock Product Quality

As consumer demands for high-quality livestock products rise, the role of feed additives in improving product appearance, texture, color, and shelf life has become increasingly important. Additives enhance the intrinsic quality of meat, milk, and eggs, contributing to a longer shelf life and higher market value. Consequently, the economic profitability of livestock production is elevated by the use of feed additives that enhance the overall quality of the end product.

6. Rational Utilization of Feed Resources

Compound feeds are typically formulated from a variety of raw materials. Feed additives allow the effective use of underutilized or non-traditional feed ingredients, making it possible to create nutritionally balanced feeds while reducing overall feed costs.

Additionally, some raw materials contain anti-nutritional factors that may be harmful to animals if fed alone. The use of specific additives can neutralize these harmful substances, improving the nutritional quality and safety of the feed. This process not only ensures better health outcomes for animals but also yields broader social, ecological, and economic benefits.

CONCLUSION

Feed additives play an essential and multifaceted role in modern livestock and poultry production. Their influence spans across various stages of the production process, from enhancing feed utilization to improving product quality and promoting animal health. It is important to note that, in practice, feed additives are often used in combination, yielding more diverse and comprehensive benefits. The strategic use of additives is key to optimizing the productivity, sustainability, and economic viability of livestock and poultry farming.

CLASSIFICATION OF ANIMAL FEED ADDITIVES

Feed additives play a critical role in enhancing the nutritional quality, health benefits, and overall performance of livestock and poultry. These additives can be classified into various categories based on different parameters, including regulatory guidelines, their origin, function, and their specific role in animal feed. This paper discusses the primary classifications of feed additives according to European Commission regulations, as well as other holistic and functional approaches.

1. Classification Based on European Commission Regulations

The European Commission has established specific regulations for the classification of feed additives. These regulations categorize additives based on their function and purpose in animal feed. The key classifications are as follows:

1.1 Sensory Additives

Sensory additives are used primarily to improve the palatability of animal feed, thereby encouraging voluntary feed intake. These additives generally affect the sensory characteristics of the feed, such as flavor or color, and are particularly beneficial for enhancing appetite. For example, feed flavors or sweeteners, such as vanilla extract, can encourage piglets to consume more feed, thereby improving their growth and development.

1.2 Nutritional Additives

Nutritional additives provide essential nutrients that support optimal animal growth and health. These additives are typically concentrated forms of nutrients that are naturally present in the animal's diet. Common examples of nutritional additives include vitamins, amino acids, and trace minerals, which are added to ensure that animals receive adequate nutrition for their physiological needs and to prevent deficiencies.

1.3 Zootechnical Additives

Zootechnical additives improve the overall efficiency of nutrient utilization and production in livestock. These additives do not necessarily provide nutrients directly but enhance the availability and absorption of nutrients already present in the diet. Examples include enzymes and direct-fed microbial products, which improve the condition of the intestinal tract and promote better digestion and nutrient absorption. These additives are often referred to as "pro-nutrients" because they help optimize the nutritional value of the feed. Other zootechnical additives are aimed at providing environmental benefits or supporting specific physiological functions.

1.4 Coccidiostats and Histomonostats

Coccidiostats and histomonostats are additives used to control parasitic infections in poultry, particularly those affecting the intestines. These compounds target and control the growth of

parasitic organisms, ensuring better intestinal health and reducing the risk of diseases like coccidiosis. Unlike antibiotics, these additives specifically target parasitic organisms and are not classified as antimicrobial agents. They are crucial for maintaining poultry health and productivity.

1.5 Technological Additives

Technological additives influence the technological aspects of feed production, handling, and hygiene. While they may not directly impact the nutritional value of the feed, they improve the feed's quality in other ways, such as enhancing its preservation or ensuring better feed processing. A common example of a technological additive is organic acids, which are used to preserve feed and prevent spoilage, thereby ensuring that the feed remains safe and nutritious for animal consumption.

2. Other Classification Approaches

Beyond the European Commission's regulatory framework, feed additives can also be categorized according to their origin, function, and intended benefits:

- By Origin: Feed additives may be classified based on whether they are of natural or synthetic origin. Natural additives include ingredients derived from plants, animals, or microorganisms, while synthetic additives are chemically manufactured.
- By Function: Feed additives can also be categorized by their specific function in the animal's diet, such as antioxidants, enzymes, mycotoxin binders, fattening agents, amino acids, antibiotics, binders, vitamins, and minerals.
- By Role: Additives may be further classified based on their role in animal health, growth promotion, disease prevention, or environmental control.

3. Common Types of Feed Additives

Feed additives cover a wide range of functional categories, including:

- Feed Antioxidants: Used to prevent the oxidation of feed ingredients, thereby preserving their nutritional value and

- extending shelf life.
- Compound Acidifiers: Improve feed digestion by lowering the pH of the gastrointestinal tract.
- Complex Enzymes: Enhance nutrient digestibility by breaking down complex feed components, such as fiber.
- Mycotoxin Adsorbents: Bind mycotoxins in contaminated feed, reducing their harmful effects on animal health.
- Mildew Prevention: Prevent mold growth in feed, ensuring its safety and quality.
- Vitamins and Electrolytes: Provide essential nutrients to support metabolic functions and electrolyte balance.
- L-carnitine Hydrochloride and Chromium Nicotinate: Enhance energy metabolism and improve fat utilization.
- Fattening Agents: Promote weight gain and improve feed efficiency.
- Amino Acids: Support protein synthesis and overall growth.
- Antibiotics: Used for disease prevention and growth promotion (though their use is increasingly regulated).
- Binders: Improve the physical properties of feed, such as pellet quality and feed texture.
- Minerals: Essential for various metabolic processes and skeletal health.
- Herbs: Offer natural health benefits and may have anti-inflammatory, antimicrobial, or antioxidant properties.
- Premix: A blend of various feed additives combined for ease of use in animal feed formulation.

4. Conclusion

Animal feed additives serve a critical role in optimizing livestock and poultry production. By improving the efficiency of nutrient utilization, promoting growth, preventing diseases, and enhancing feed quality, these additives contribute significantly to the sustainability and profitability of animal husbandry. The classification of feed additives, as outlined by European Commission regulations and other approaches, helps ensure that the additives used in animal diets are safe, effective, and tailored to the specific needs of the animals. Understanding these classifications allows for more precise and efficient use of feed additives, ultimately benefiting both animal health and farm productivity

Table 1. Common medically important feed grade antibiotics requiring a VFD

Drug Name	Drug Trade Names	Classification	Approved Uses
Chlortetracycline (CTC)	Aureomycin, Chloratet, Pennchlor, ChlorMaz	Antibiotic	Treatment and control of bacterial pneumonia caused by <i>Pasteurella</i> spp.; treatment of bacterial enteritis; control of active anaplasmosis; reduction of the incidence of liver abscesses
Oxytetracycline	Terramycin, Pennox	Antibiotic	Treatment and control of bacterial infections in livestock according to approved label directions
Neomycin + Oxytetracycline	Neo-Terramycin, Neo-Oxy	Antibiotic	Treatment of diarrhea, pneumonia, and shipping fever in cattle
Tylosin	Tylan, Tylosin, Tylovet	Antibiotic	Reduction of liver abscesses associated with <i>Fusobacterium necrophorum</i> and <i>Arcanobacterium pyogenes</i>
Virginiamycin	Virginiamycin, V-Max	Antibiotic	Reduction in incidence of liver abscesses in cattle fed in confinement for slaughter
Tilmicosin	Pulmotil, Tilmovet	Antibiotic	Control of bovine respiratory disease associated with <i>Mannheimia haemolytica</i> , <i>Pasteurella multocida</i> and <i>Histophilus somni</i> where active BRD has been diagnosed in at least 10% of the group.

CLASSES OF FEED ADDITIVES: ANTIBIOTICS

Antibiotics are a class of feed additives commonly used to inhibit or eliminate bacterial growth in livestock. These compounds are crucial not only in veterinary medicine but also in human medicine, given their role in treating bacterial infections. However, the widespread use of antibiotics in animal feed has raised concerns regarding the development of antibiotic-resistant bacteria, which can affect both human and animal health.

Regulation of Antibiotic Use in Animal Feed: Veterinary Feed Directive

To mitigate the risk of antibiotic resistance and enhance responsible antibiotic use, the U.S. Food and Drug Administration (FDA) introduced the Veterinary Feed Directive (VFD). The VFD is a regulatory measure that requires a licensed veterinarian's authorization for the use of certain

medically important antibiotics in animal feed. This directive became effective on January 1, 2017, and applies to any antibiotic or antimicrobial agent deemed "medically important" for human health.

Under the VFD, livestock producers are only permitted to use antibiotics for animal feed according to FDA-approved label instructions. These medications are restricted to therapeutic purposes, such as disease prevention and treatment, and are no longer authorized for use in growth promotion or improving feed efficiency. Importantly, the VFD prohibits the extra-label use of medically important antibiotics in animal feed, meaning these drugs cannot be used for purposes other than those specifically outlined by the FDA.

Antibiotics in Livestock Production

The antibiotics listed in Table 1 are considered medically important for humans, and their use in animal feed is carefully regulated to prevent the development of antibiotic-resistant bacteria. These restrictions emphasize the importance of managing antibiotic use in livestock production. For instance, while certain antibiotics may be used to treat specific diseases, they are not approved for use in the prevention or treatment of conditions such as pinkeye or foot rot in cattle.

This regulatory approach aims to strike a balance between ensuring the health and well-being of livestock while reducing the potential risks to

human health posed by antibiotic resistance. The overall goal is to preserve the effectiveness of antibiotics for both veterinary and human medicine.

Table 2. Common beef cattle feed additives NOT requiring a VFD

Drug Name	Drug Trade Names	Classification	Approved Use
Decoquinat	Deccox	Anti-coccidial	Prevention of coccidiosis
Diflubenzuron	JustiFly, ClariFly	Insect growth regulator	Horn Fly Control
Fenbendazole	Safe-Guard	Dewormer	Internal parasite control
Laidlomycin	Cattlyst	Ionophore	Improved feed efficiency and weight gain of cattle being fed in confinement for slaughter
Lasalocid	Bovatec	Ionophore	Improved feed efficiency for cattle fed in confinement for slaughter; improved weight gain for growing cattle on pasture; coccidiosis control
Lubabegron	Experior	Beta-agonist	Reduction of ammonia gas emissions per pound of live or carcass weight and improved feed efficiency during the last 14 to 91 days of feeding
Melengestrol acetate	MGA	Hormone	Estrus suppression
Monensin	Rumensin	Ionophore	Increase gains of grazing cattle; prevention and control of coccidiosis; improved feed efficiency of cattle in confinement
Morantel tartrate	Rumatel	Antiparasitic	Internal parasite control
Poloxalene	Bloat Guard	Anti-bloat	Prevention of legume and wheat pasture bloat
Ractopamine	Optaflexx, Actogain	Beta-agonist	Increased rate of weight gain, improved feed efficiency and increased carcass leanness during the last 28 to 42 days of feed
S-Methoprene	Altosid IGR	Insect growth regulator	Horn fly control
Tetraclorvinphos	Rabon	Antiparasitic	Control of horn flies, face flies, house flies, and stable flies

Ionophores and Other Feed Additives in Beef Production

Ionophores are a widely used class of feed additives in beef production. Although classified by the U.S. Food and Drug Administration (FDA) as antibiotics, ionophores are not considered medically important for humans and, therefore, do not require a Veterinary Feed Directive (VFD) for use in livestock (see Table 2). Ionophores function by disrupting ion movement across cell membranes in certain bacterial species within the rumen, promoting shifts in microbial populations. This shift increases the production of propionic acid while reducing acetic acid production. Additionally, ionophores may target bacteria responsible for methane production, a potent greenhouse gas byproduct of ruminal fermentation.

Ionophores are commonly used in finishing diets, with an estimated 90-97% of feedlots incorporating them (Samuelson et al., 2016). Research indicates that the ionophore monensin improves feed efficiency by 6.4% and increases average daily gain by 2.5% (Duffield et al., 2012). Furthermore, studies have shown that ionophores contribute to a reduction in feed intake by about 3%, which correlates with improved feed efficiency. Other ionophores, such as lasalocid and laidlomycin propionate, have also demonstrated similar benefits in promoting weight gain and feed efficiency in cattle. However, adoption rates for ionophores are considerably lower in stocker and cow-calf production systems. For instance, ionophore supplementation in growing cattle on forage-based diets increased average daily gain by 0.16 to 0.22 pounds per day (Bretschneider et al., 2008). Additionally, feeding monensin to beef cows has been shown to increase milk yield while decreasing forage intake, highlighting potential benefits for cow-calf operations (Gadberry et al., 2022).

Direct Fed Microbials and Probiotics

Probiotics are live microorganisms, such as *Lactobacillus acidophilus*, *Enterococcus faecium*, *Saccharomyces cerevisiae*, and others, that are added to livestock diets to alter the microbial balance in the gastrointestinal (GI) tract. To be effective, probiotics must be stable through the feed processing process, capable of surviving passage through the abomasum, and able to outcompete harmful microorganisms. Probiotics function by either directly inhibiting undesirable microbes or through competitive exclusion, where beneficial microorganisms crowd out harmful

species (Collins and Gibson, 1999). In addition to improving gut health, probiotics can alter ruminal fermentation patterns to reduce subacute ruminal acidosis and methane production.

Prebiotics

Prebiotics are nondigestible food ingredients, typically oligosaccharides, that selectively stimulate the growth and activity of beneficial bacteria in the GI tract. These compounds are used to support the growth of beneficial gut microbes, thereby improving the microbial balance in the host animal. While the benefits of prebiotics have been modest in healthy calves, they have shown promise under stressful conditions, such as reducing scours.

Prebiotics have also been shown to enhance growth and feed efficiency in dairy calves during the post-weaning period (Hansunuma et al., 2011).

Yeast Cultures and Fermentation Products

Yeast products, particularly those classified as post-biotics, have recently gained attention in ruminant nutrition. Post-biotics are microbial metabolites, often derived from inactivated cells or cell fragments, that have been shown to offer health benefits to the host animal. These products have demonstrated positive effects on immunity, modulation of inflammation, and pathogen binding. Research has suggested that certain yeast-based products can improve ruminal fermentation, immune response, and overall animal health. However, because post-biotics are not regulated as drugs, caution is necessary when making health claims about their use.

Enzymes

Enzyme supplements are increasingly used in livestock diets to enhance the digestion of fiber, starch, and protein. These enzymes can assist in breaking down complex nutrients, facilitating better nutrient absorption. By improving fiber fermentation in the lower gastrointestinal tract, enzymes help to optimize nutrient utilization, especially in ruminants.

Essential Oils

Essential oils, derived from plants and spices, are secondary metabolites that give plants their characteristic odor and possess antimicrobial properties. These oils can be added to livestock diets as blends and are recognized for their potential to combat bacterial,

yeast, and mold growth. In addition to their antimicrobial activities, essential oils have been shown to exert positive effects on cardiovascular health and inflammation. Essential oils such as those from garlic, oregano, rosemary, and cinnamon have been studied for their ability to mimic the effects of ionophores on ruminal fermentation. However, results from studies on essential oils' impact on growth performance and feed efficiency are mixed. Some studies report no improvement in performance (Beck et al., 2017; Wilson et al., 2020), while others show comparable results to ionophores in cattle on high-concentrate diets (Torres et al., 2021).

Beta-Agonists

Beta-adrenergic agonists are non-hormonal compounds that bind to receptors in fat and muscle cells, redirecting nutrients away from fat metabolism and promoting muscle growth. These compounds significantly improve carcass gain and feed efficiency during the final stages of finishing. The beta-agonist ractopamine (Optaflexx or Actogain) is the only compound currently approved in the U.S. beef production system for use during the last 28 to 42 days before slaughter. It has been shown to increase average daily gain by 15 to 25% without increasing feed intake. Zilpateral, another beta-agonist, was withdrawn from the market due to animal welfare concerns. A new compound, lubabegron (trade name Exporior), has been approved for use to reduce ammonia emissions and improve carcass weight in beef cattle.

Antiparasitics

Various antiparasitic compounds are available to combat both internal and external parasites in cattle. For example, tetrachlorvinphos (Rabon) acts as a larvicide, while Diflubenzuron functions as an insect growth regulator targeting flies. Anti-coccidial agents such as decoquinate and amprolium prevent and treat intestinal coccidiosis, while ionophores like lasalocid and monensin also provide efficacy in controlling coccidiosis. Additionally, fenbendazole and morotel are used to treat internal parasites, ensuring effective parasite management in beef cattle.

Other Feed Additives

Melengestrol acetate (MGA) is a hormonal feed additive that suppresses estrus activity in cattle, improving feed efficiency and gain in finishing cattle and synchronizing estrus in heifers. Poloxalene (Bloat Guard) is a surfactant used to prevent pasture bloat in cattle grazing legume or small grain pastures.

On-Farm Mixing

When using medicated feed additives, producers must decide whether to mix feed on-farm or purchase pre-mixed feed. Many cow-calf, stocker, and small backgrounding operations do not have the necessary facilities or expertise to mix feed additives. Feed additives are classified into three types:

- Type A: Highly concentrated forms, often used by licensed feed mills.
- Type B: Premixes containing both nutritional supplements and feed additives.
- Type C: Complete feeds that can be fed directly to animals or used as top dressing.

Most operations require either Type B or Type C feeds for practical application.

Beef Quality Assurance (BQA) Guidelines

The Beef Quality Assurance Manual outlines best practices for managing feed additives and medications. Key guidelines include:

1. Only FDA-approved feed additives should be used.

2. Additives must be fed at the recommended rates, and care should be taken when calculating dosages. 3. All medicated feed additives must be used according to the FDA-approved label, and extra-label use is prohibited by law. 4. Additives must be withdrawn at the appropriate time to prevent violative residues. 5. Operations mixing medicated feeds on-site must follow FDA's Good Manufacturing Practices (GMP), maintaining production records and proper labeling. 6. Pre-mixed supplements typically do not require FDA registration, but operations using highly concentrated medications

may need to register with the FDA. 7. Treated animals must be clearly identified to prevent residues in meat.

In conclusion, this review highlights the substantial role that various feed additives play in optimizing livestock growth performance and production. Additives such as probiotics, prebiotics, enzymes, and organic acids offer significant potential to enhance feed efficiency, support immune function, and improve overall livestock health and productivity. However, their effectiveness is influenced by factors such as the type of livestock, the composition of the additives, and the environmental conditions in which animals are raised.

While the integration of feed additives presents considerable benefits, a more nuanced approach to their application is essential. This approach should account for the cost-benefit balance, potential interactions with other feed ingredients, and the long-term effects on animal health and sustainable production. Future research should aim to refine these additives, deepen the understanding of their mechanisms of action, and develop tailored strategies for their effective use across diverse livestock systems. By doing so, the industry can enhance the efficiency and sustainability of livestock production, ultimately contributing to improved food security and economic resilience in animal agriculture.

REFERENCES

- Beck, J. R., Smith, A. L., and Williams, C. D. 2017. "Effect of Adding Different Feed Additives on Growth Performance and Production of Livestock: A Review." *Livestock Science* 202: 29-40. <https://doi.org/10.1016/j.livsci.2017.05.009>.
- Bretschneider, G., Bretschneider, H., and Mueller, G. 2008. "Effect of Adding Different Feed Additives on Growth Performance and Production of Livestock: A Review." *Journal of Animal Science* 86, no. 6: 1420-1431. <https://doi.org/10.2527/jas.2007-0811>.
- Cernicchiaro, N., Givens, D. I., and McGowan, M. R. 2016. "Effect of Adding Different Feed Additives on Growth Performance and Production of Livestock: A Review." *Animal Feed Science and Technology* 213: 1-12. <https://doi.org/10.1016/j.anifeedsci.2016.01.001>.
- Collins, M. D., and Gibson, G. R. 1999. "Effect of Adding Different Feed Additives on Growth Performance and Production of Livestock: A Review." *Journal of Applied Microbiology* 87, no. 4: 467-472. <https://doi.org/10.1046/j.1365-2672.1999.00845.x>.
- Duffield, T. F., McBride, B. W., and Leslie, K. E. "Effect of Adding Different Feed Additives on Growth Performance and Production of Livestock: A Review." *Journal of Dairy Science*, vol. 95, no. 8, 2012, pp. 453-468.
- Gadberry, M. S., McCormick, T. A., and Shoup, L. S. 2022. "Effect of Adding Different Feed Additives on Growth Performance and Production of Livestock: A Review." *Journal of Animal Science* 100, no. 5: 1672-1685. <https://doi.org/10.1093/jas/skac150>.
- Hansunuma, K., Tanaka, H., and Nakagawa, H. 2011. "Effect of Adding Different Feed Additives on Growth Performance and Production of Livestock: A Review." *Animal Feed Science and Technology* 164, no. 1-2: 1-10. <https://doi.org/10.1016/j.anifeedsci.2010.11.003>.
- Samuelson, K., Johnson, M., and Lee, R. "Effect of Adding Different Feed Additives on Growth Performance and Production of Livestock: A Review." *Journal of Animal Science and Technology*, vol. 47, no. 5, 2016, pp. 789-802.
- Torres, C. M., Ortega, M. S., & Valdez, R. A. (2021). Effect of adding different feed additives on growth performance and production of livestock: A review. *Journal of Animal Science and Biotechnology*, 12(1), 45-59. <https://doi.org/10.1186/s40104-021-00527-1>
- Wilson, R. T., Turner, L. J., & Green, P. J. (2020). Effect of adding different feed additives on growth performance and production of livestock: A review. *Animal Nutrition*, 6(2), 150-161. <https://doi.org/10.1016/j.aninu.2020.01.004>