Understanding and Application of Phytogenic Feed Additives in Livestock Nutrition, Health and Production

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Abstract

The application of antibiotic agents in livestock production causes great animal and public safeguard concerns without any side effects. They are more economical and easily available. Therefore, their supplementation to animals is an imperative need as potential substitutes for antibiotics. Numerous antibiotic substitutes such as enzymes, probiotics, inorganic acids, medicinal plants, immunostimulants, and managing systems have been applied in the livestock industry to improve livestock health and production performance. In recent years, feed additives derived from herbs have been extensively evaluated as alternatives for antibiotics in livestock farming systems due to their manifold biological roles and less resistance development. This chapter abridges the investigation in past, classification, major functions, potential mechanisms, and bioactive compounds, effects on animal health, growth, production, and reproduction parameters, mitigating energy losses, reducing toxicity and environmental pollution, affecting elements, and possible adverse effects of these additives. In addition, some challenges in introducing viable, innocuous, and reasonable plant-derived antibiotic alternatives for application in livestock production have been highlighted.

Keywords: Classification; Feed additives; Herbal extracts; Phytogenic substances, Mechanisms, Production performance

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Introduction

Feed additives are edible constituents added to animal feed to improve feed efficiency, metabolism, health, and productive performance of the livestock. Among feed additives, the most abundantly used are prebiotics, probiotics, enzymes yeast, natural herbs, vitamins, amino acids, minerals, and antibiotics (Mobashar, 2024). Antibiotics as growth promoters have long been applied to improve animal productive efficiency (Hashami and Dawoodi, 2011). However, prolonged use of antibiotics may cause accumulation of their residues in animal products such as meat and meat products, which come in the consumption of human beings, showing resistance to antibiotics against certain diseases. Due to some hazardous effects of antibiotics, the European Union banned their use as growth promoters in livestock two decades ago. A developed country like China which is an advanced technological country developed some regulatory policies regarding a ban on antibiotic use in livestock farming systems. Recently, livestock products without antibiotic residues have boosted market value and have shown exponential growth (Gadde et al., 2017).

In addition to antibiotic alternatives mentioned in the above paragraph, several other alternatives like acids of inorganic nature, herbs with medicinal properties, immune stimulants, and managing strategies are being practiced across the globe for improved livestock health and performance. Phytogenic substances are a group of natural herbal growth promoters or non-antibiotic growth promoters used as feed additives, derived from herbs, spices, or other plants. They have biologically variable activities and are thought to possess certain growth-promoting effects like antibiotics (Rossie et al., 2020). Various herbs along with their products have been validated to be beneficial due to anti-microbial, anti-oxidant, anti-inflammation, and immunomodulation properties, with no negative effects on growth and feed efficiency. (Kuralakar and Kuralakar, 2021). There is a growing tendency to use natural herbal products due to their no negative effects. The Emerging and using herbal feed additives has attained attention on research in animal nutrition and is significant for livestock husbandry and product quality.

Feed additives of phytogenic nature are bioactive herbal compounds with potential to improve livestock health, growth performance, and production and reproduction performance, product quality and to reduce emissions and toxicity. These are also called herb-based feed additives and are preferred due to their economically affordability, easy accessibility and preparation. Likewise, they generate less residual mass and have no toxic effects on livestock productivity and hence they are safe for human beings. Antimicrobial activity, immune-modulatory activity; antioxidant property and intestinal microbiota regulation are the known mode of actions of phytogenic feed additives. Using tools related metagenomics, transcriptomics, proteomics, and network pharmacology may illuminate the functions and acting modes of these additives and establish some inexpensive methods to practice these additives as alternatives for antibiotics in livestock production systems. Present chapter recapitulated description on classification, functions; potential factors and mechanism of these additives. We

intended to provide information comprehensively on present research status on the impact of phytogenic feed additives as a novel nutritional strategy in term of animal health and growth parameters and their application.

1.2. Research Framework of Phytogenic Feed Additives

Phytogenic feed additives, also known as phytochemicals and or pharmacological components are herbal-derived compounds, herbal extracts, or natural bioactive compounds with the potential to modify animal feed properties, enhance livestock production efficiency, and, improve the quality of l product (Hashami and Dawoodi, 2011; Mobashar, 2024). In the literature, different terminology has also been used for phytogenic substances like Chinese feed additives and extracts of herbal nature. Due to beneficial effects, outdated and or traditional herbs as medicines in the public sector, for more than 3000 years (Huang et al., 2017) and livestock sector for more than two thousand years (Goeng et al., .2014) have been used. Producers and different companies dealing with manufacturing herbal-based products have revealed the advantageous prospects of these additives on growth and productive performance of livestock (Shakeel et al., 2023). Later on, scientists from different disciplines of agriculture, medicine, and animal sciences exposed the properties of anti-microbial, anti-viral, anti-fungal, anti-oxidant, and anti-inflammation aspects. Their multi-functionality in curbing intestinal health, nutrient metabolism, and immune responses of animals has been well documented in the application of these substances (Hashemi and Davoodi, 2011; Yang et al., 2015a). With the development in extraction techniques, and the identification of bioactive components in these substances, extensive novel studies on the application of herbs and or their different parts as antibiotics alternatives in livestock feed have increased.

Herbs have broad application potential in livestock production as they are non-toxic, economical, and eco-friendly; therefore, currently, most of animal feed manufacturers include phytogenic feed additives in poultry, swine and ruminant feed products.

1.3. Classification of Phytogenic Feed Additives Concerning Composition

Traditional herbal medicines have various ingredients and exert complex, low-specific pharmacological effects. A clear and standard classification of phytogenic feed additives is lacking. However, these are categorized according to composition (Figure 1) (Hashemi and Davoodi, 2011).

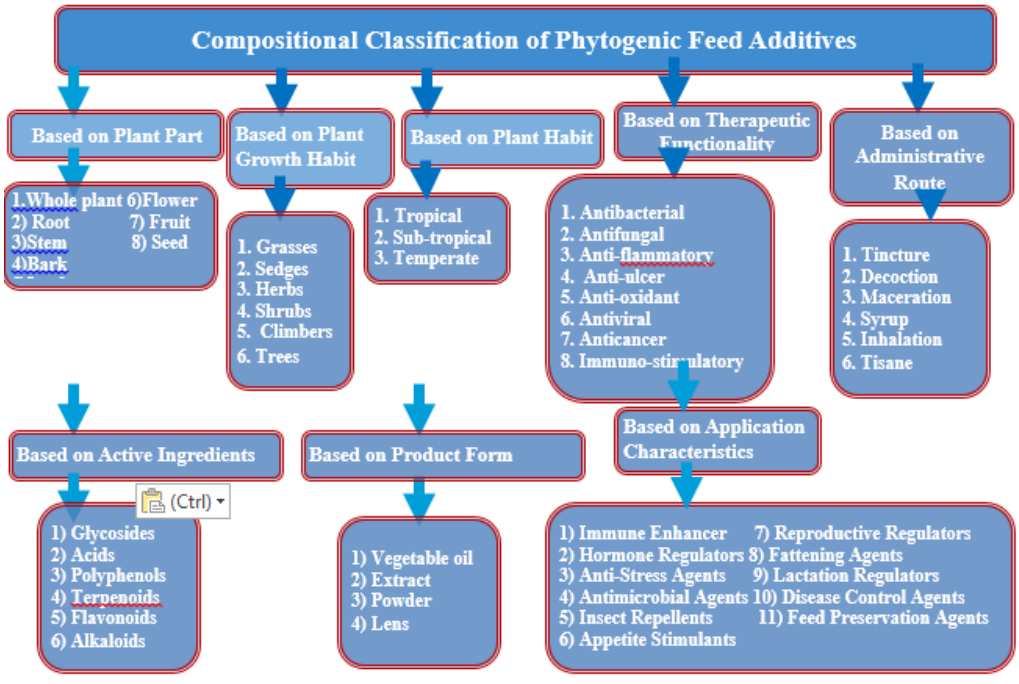

Fig. 1: Compositional Classification of Phytogenic Feed additives

Due to the physiological properties of natural herbal products, they can be applied as feed additives. They can be fed to animals through dietary supplementation in dried, crushed, or extract form or they can be offered to animals as green fodders. Moreover, multiple herbal products or extracts can be used in combination for multi-beneficial effects. They exert an integrated influence through synergism among their bioactive components (Albino and Arma, 2022). Various research is being importantly planned to look at blends of bioactive components as compared to a single compound, however, the significance of an individual ingredient and or bioactive component cannot be underestimated.

1.4. Importance of Phytogenic Feed Additives in Livestock

Application of phytogenic or herbal origin feed additives in animal nutrition is of greater significance, particularly their role in animal health, growth and reproductive parameters, and product quality. They also reduce methane, and ammonia emissions, and toxicity due to mycotoxins and heavy metals and antibiotic restudies in products (Rossi et al., 2020).

1.4.1. Impact on Growth and Production Performance of Livestock

Application of antibiotics as growth promoters because of antibiotic resistance has been frequently banned (Hashemi and Davoodi, 2011). At present, phytogenic feed additives of phytogenic nature are broadly applied in farming systems of livestock.

Effects on Swine

A mixture of phytogenic substances composing ginger, buckwheat, thyme, curcuma and black pepper has been applied in growing pigs and investigated significant increase in feed intake and improvement in growth performance (Yan et al., 2011a).

No effect of *Cinnamomumzeylanicum* and *Trachyspermumcopticum* essentialoils, *Mikania micrantha* and *Garcinia lanceifolia* blend was reported on growth performance, however, it showed an improvement in lipid profile, immunity and gut integrity in piglets (Samanta et al., 2021).

Phytogenic feed additive commercially available when feed to sows during transition period enhanced size of litter and birth rate as well as caused modulation in composition and bioactivity of colostrum-milk (Nowland et al., 2021).

Effects on Poultry

Several comprehensive studies have been conducted on these additives in poultry and demonstrated improved performance, digestibility coefficient and efficacy. Dietary supplementation of digestion containing about 30 essential oils and bioactive contents, significantly showed ideal performance, in broiler.

Herbal extracts of *Cinnamomumverum*, *Alliumsativum*, *Zingiberofficinale*) and *Origanumvulgare* significantly boosted gain in body weight and FCR in turkey and quails (Gernat et al., 2021). Feeding peppermint leaves to laying hen improved egg number and weight.

Effects on Ruminants

Using phytogenic feed additives in many studies on ruminants have been focused on production performance, rumen fermentation and mastitis prevention and or treatment.

Offering leaves of poplar and eucalyptus in buffaloes enhanced milk production, yield of fat-protein-corrected milk in addition to DM, OM, and NDF digestibility (Dey et al., 2021). Calf starter composing mainly thyme, eucalyptus, and oil have been investigated in growing calves and reported an improved growth performance.

1.7. Impact on Livestock Health Defense

Different herbs and their extracts are rich source of remedies, nutrients and therapeutics and therefore exert health benefits, in public and livestock sector. These have been found to improve health of livestock.

Health of intestine is of greater significance in defense system which mostly determines overall livestock health and production. Herbs and their extracts have useful effects on animal digestive tract. Phytogenic additives increase the villus height related to healthy gut, digestibility and absorption (Line et al., 2020). Mucosa of intestine is responsible for absorption and protection of epithelium against pathogenicity.

Among the herbal feed additives, Chinese feed additives show optimistic effects on animal health indicators such as serum biochemical parameters. These feed additives influence synthetic and metabolic process of protein, physiology of liver, immune system and health of pancreas and kidney in swine, contributing their role in sustainability of healthy requirements of host and therefore, parameters of growth (Line et al., 2020).

Similarly, thymol and cinnamaldehyde extracted oils reduced inflammation in weaning pigs by mediating interleukin (IL)-6 levels and enhanced lymphocyte proliferation ad phagocytic rate, and IgA and IgM levels in the plasma (Li et al., 2012a).

It is very important to mention that assessment of livestock health status based on phytogenic feed additives is not sufficient. Application and efficacy of these additives as a potential substitute for antibiotics have to be explored for all kinds of farm animals.

1.8. Improving Animal Product Quality

Effects on Meat Quality Parameters

Due to larger range of effects and vast mode of actions of phytogenic feed additives, their significance in improving quality of pork, white meat, beef and mutton cannot be overlooked. It has been investigated that administration of herbal feed additives has improved the flavor and quality of milk, meat and eggs. Consuming pork from pigs fed on Chinese herb feed additives reduced drip loss, and improved protein contents in muscle (Lin et al., 2020). Several phytogenic feed additives like photobiotic have shown an increase in overall and particular breast weight in addition to reduction in fat content, and yellow color in broiler chickens, probably thru the modulation in pathways related with antioxidant activity and stress.

Herbal products and or their components like thyme, rosemary leaf, and licorice extract diminish lipid oxidation and therefore, better-quality meat parameters of ruminants. Moreover, their different parts and or their extracts mitigate negative effects on meat quality due to transport stress. A study conducted on broilers revealed that phytogenic additives have induced green herb flavor in broiler poultry breasts (Orlowski et al. 2018). Similarly, feeding fermentable and unfermentable Yupingfeng, Baizhu, and FangFeng to Qingyuan black goats enhanced the meat-related flavor of acids. Dietary supplementation of Yizhi improves flavor and causes high nutritive value of meat. Phytogenic feed additives have the potential to change the intestinal microbial composition and modulate stress and antioxidant-related pathways responsible for muscle flavor and taste (Ji et al., 2022). Due to health implications, consumers are interested in fatty acid composition of meat.

1.9. Effects on Egg Quality Parameters of Laying Hens

Supplementation of phytogenic feed additives like YGF251 in laying hens affect thickness of eggshell, strength of egg and Haugh unit expectedly due to increased level of insulin like growth factor-1 in layers (Dang et al., 2021).

Inclusion of extract of *Yuca schiedigera* at 100 mg/kg in laying hen presented quadratic improvement in thickness, weight and egg count (Alagawany et al., 2016). Improved egg yolk pigmentation and egg sensory attributes have been reported in layers fed on C*onfusa* and Astragali extract (Xie et al., 2019). Contradictions on effects on egg quality parameters need to be investigated and demand intensive research on impact of phytogenic feed additives on egg quality parameters. Importance of phytogenic feed additives cannot be ignored in the production of healthy eggs in term of low cholesterol and high yolk phospholipids levels.

Dietary supplementation of layers poultry with 1% mixture of Chinese herb composing pine needle by seventy and Artemisia annua by thirty percent causes reduced cholesterol while increased phospholipid contents in eggs (Li et al., 2016). Similarly phytogenic substances like black cumin, garlic, and turmeric when supplemented in diets of White Leghorns resulted reduced triglyceride levels in eggs.

1.10. Impact on Milk Yield and Composition and Functional Properties and Fatty Acid Profile of Milk

Phytogenic supplementation in the diet of Friesian cows improves milk yield and composition. Extract addition of shatavari in milk causes improved functional properties, stability, decreased pH, longer rennet coagulation time, and increased acidity, viscosity, and heat stability (Veena et al., 2015). Supplementation of mustard and cumin seeds or cumin seed and mustard extract in goat diet reduces milk fatty acids (saturated) while enhancing total conjugated linoleic acid contents in dairy products. Secondary metabolites of cumin exert an antimicrobial impact on bacterial species. These are responsible for bio-hydrogenation in the rumen, causing the accumulation of bio-hydrogenated substances and increasing polyunsaturated fatty acid and conjugated linoleic acid composition in milk (Morsy et al., 2018).

1.11. Improvement in Reproductive Efficiency of Livestock

Effects on the Female Reproductive System

In livestock industry, reproduction efficacy is the key factor for computing economy of animal production. Long ago and also recently, different herbs because of their medicinal potential have been used to mitigate reproductive diseases and disorders in public and livestock sector. Many traditional phytogenic substances have beneficial effects on uterine contractions and reestablishment of oestrus cycle in heifers (Tripathi, 2015). Supplementation of Murraya koenigii alone and or combined with Aegle marmelos results in increased ovulation and conception rate and therefore improved fertility in buffalo heifers. Furthermore, dietary supplementation of *Tinospora cordifola* plus Cassia fistula bark leaves increases postpartum anestrus in cattle. A conventional herbal mixture of *RaidixAngelicai Sinensis*, *RhisomaLigustici*, *SemenPersicai*, *RhizomaZingberis*, and *Radix Glycyrhizae*, reduces the occurrence of retained placenta during puerperium in cattle.

Effects on the Male Reproductive System

Different herbs play a vital role in the male reproductive system. Semen quality in addition to sex libido is improved in boars when fed on an extract of *Euriycoma longifola*, *Tribulus terrestrs*, and *Leuza carthamodes* (Frydrychova et al., 2011). Moringa olefera extract increases semen quantity, viscosity and motility in rams (ElDesoky et al., 2017). Likewise, *T. cordifolia* in diet of Muzzafarnagari rams enhanced triglycerides, SOD, and CAT concentration in semen. Based on this fact, we hypothesize that its supplementation may play role in cryopreservation and therefore, it improves animal fertility (El-Desoky et al., 2017).

Several studies applying different herbal extracts on fertility of male reproductive systems of pigs, sheep and cattle have been conducted on semen preservation via refrigeration and cryopreservation (Ros-Santaella and Pintus, 2021). It was concluded that these extracts have potential to sperm characteristics, mainly due to antioxidant enzyme activity and play role in storage of semen (Carrera-Chavez et al., 2020). Based on above research studies and their outcomes, application of herbal extracts can be an efficient preservative technology for storage of semen.

1.12. Importance of Phytogenic Feed Additives in Mitigating Energy Losses and Reducing Environmental Pollution

In ruminants, rumen fermentation and or feed degradation up to a larger extent and intestinal fermentation up to a smaller extent in all farm animals result in energy losses and environmental pollution via gas emission mainly methane and ammonia. Efficient energy utilization from these sources in animal bodies for different physiological activities and reduction in environmental pollution via methane and ammonia emission are the major challenges of the day. Herbal products have been found to have a greater potential in this respect. Results of different studies show that herbs and their extracts enhance fermentation by suppressing deamination and reducing ammonia and methane production, which are considered major energy loss (Sun et al., 2021).

CO2 and methane are greenhouse gases produced from feed during fermentation in the rumen, accounting for 80 and 12% of energy losses, respectively. An *in vitro* study on phytogenic feed substances like thyme, thymol, and carvacrol showed that these active components cause modification in rumen fermentation pattern by overwhelming methanogen bacteria and therefore, methane production (Zhou et al., 2020 and Ma et al., 2020). *In vitro,* the results of these phytogenic components have been validated by studies on various ruminants regarding the mitigation of gas emissions (Wanapat et al., 2014). A very important mechanism of Cypsum, Amur cork, and Patchouli, which are feed additives is to reduce methane production volume, signifying attribution in methane gas reduction (Wang et al., 2019). A commercial product (Mootral) of phytogenic nature composing extracts of citrus and garlic decreased methane production. An *in vitro* study on the effect of defaunation of ruminal protozoa on gas production was conducted. It was concluded by the study that not only the bacteria but also rumen protozoa are linked with gas production mainly, methane, CO_2 and H_2 via the hydrogenotrophic pathway (Mobashar et al., 2019). Extract from licorice, mulberry and moringa has also been reported to mitigate methane production (Ramos-Morales et al., 2018).

Ammonia is not only an environmental pollutant but also prolong exposure of poultry and young animals to high ammonia level may cause stress conditions and toxicity in these animals. Therefore, a control strategy for ammonia production will be viable for the health of livestock and the quality of the environment. Herbs like Yucca and or its extract mainly containing saponins reduce ammonia emission and

fecal odor in poultry birds and porcine (Chen et al., 2021), it might be due to reduced enzymatic activities in the intestine. These active components are used to minimize ammonia emission and odor in feed industry. Moreover, application of carvacrol, thymol and cinnamaldehyde in young pigs inhibited ammonia loss which seems to be related with hindering protease and urase activities and improving nitrogen retention.

Methane and ammonia emissions are the animal energy losses in addition to their emissive odor affecting farm workers; therefore, application of herbal products would be a wise strategy to utilize these emissions as an energy source in the animal body to maintain quality atmosphere around and to improve human and animal health and livestock productivity.

Table 1: Modes of actions and effects of phytogenic feed additives in animals

Herbs/Phytogenic substances	Active Components	Mode of Actions	Potential Effects Observed	Type of Animal	References
Poplar (Populus deltoides) and eucalyptus (Eucalyptus citriodora) leaves	Phenolic compounds,tannins (condensed), and phytochemicals	Improve milk yield production and immune system	Increased milk yield and milk composition, improved digestibility and antibody titer against Pasteurella multocida	Buffaloes	(Dey et al. 2021)
Cinnamon (*Cinnamomum verum*)	Hexenol, berneol, linalool, nonanol, caryophyllene oxide, spathulenol	Enhance growth performance, improve meat quality via antioxidant properties	Better growth performance, increased water holding capacity	Quails	(Mehdipour and Afsharmanesh, 2018)
Thymole and cinnamaldehyede	Essential oils	Improve growth performance, digestibility and immunity and flora	Increased digestibility, lymphocyte proliferation and microflora	Pigs at weaning stage	(Li et al., 2012a)
Digestarom	Essential oils and phytogenic compounds	Improve growth parameters, improve digestive physiology and gut microbes	Enhance, gain in body weight, villus height, reduce crypt depth; improve digestibility of DM, CP, EE and decrease total coliform	Broiler poultry	(Murugesan et al., 2015)
Peppermint (Mentha piperita L.)	Menthol, menthone, iso menthone, menthyl acetate, cineol	Enhance egg production, antimicrobial and antioxidant properties	improved egg quality and quantity parameters	Hens at laying stage	(Abdel-Wareth and Lohakare, 2014)
Oregano, anise and citrus	Anethol, carvacrol and limonene	Modify intestinal morphology and mucin composition	Improved mucin composition, and intestinal morphology	Broiler poultry	(Tsirtsikos et al. 2012)
T. vulgaris	Essential oils of eugenol, thymol, and piperine	Decreased goblet cells count, small intestine and colon relative weights and decreased Escherichia-Shigella and Campylobacteria	Improved growth performance and nutrients and gut health	Piglets at weaning stage	(Silva Júnior et al. 2020)
Brazilian red pepper (*Schinus terebinthifolius Raddi*)	Carotenoids, capsaicinoids, phenolics (flavonoids), vitamin C, vitamin E and fatty acids	Modulate microbiota and histology, improved performance and organ weight	Reduced villi density, higher Lactobacillus counts, reduced Enterobacteria counts and diarrhea	Weaning pigs	(Cairo et al. 2018)
Greek Origanum vulgare subsp. hirtum; Sophora japonica L	Oregano essential oil; quercetin	Reduce oxidative stress due to transportation, improve meat quality	Improved BW, carcass and dressing percentage	Pigs at the finished stage	(Zou et al. 2016)
Yucca schidigera powder	Steroids, saponins, glycocomponents	Improve bod weight gain and reproductive performance, regulate metabolic disturbances, maintain homeostatic balance, and improve productive efficiency	Increased BW, fertility rate, decrease oestrus resumption, decrease cholesterol, urea and glucose	Lactating goats	(Khalifa et al. 2014)
Moringa oleifera leaf extract	carotenoids, phenolic compounds, alkaloids, glucosinolates, isothiocyanates, folates, tannins, saponins, and fatty acids	Enhance tolerance against heat, and improve oxidative status and semen quality in the hot season	Reduced rectal temperature, increased serum albumin, antioxidant capacity, male reproductive functions	Rabbit bucks	(El-Desoky et al., 2017)

Albizia harveyi	Myricetin, quercetin, and kaempferol glycoside	Mitigate damage to cryopreserved semen during the frozen-thawing process, and enhance antioxidant activities.	Improved male reproductive functions	Bull semen	(Sobeh et al., 2017)
Murtilla (Ugni molinae Turcz)	Gallic acid, catechin, quercetin-3-b-Dglucoside, myricetin, quercetin, kaempferol	Antioxidant potential, improve sperm motility, reduce membrane damage	Decreased lipid peroxidation and increased sperm motility	Boar semen	(Jofre et al., 2019)
Moringa oleifera seed	Ascorbic acid, flavonoids, polyphenolics, carotenes	Improve the outcome of semen cryopreservation used as an antioxidant.	Increased male reproductive efficiency and antioxidant activity	Ram semen	(Carrera-Chavez et al., 2020)
Mangosteen peel powder	Tannins and saponins	Mitigate methane formation by reducing rumen methanogenic bacteria	Increased organic acid, and enhanced total bacteria population and microbial protein synthesis	Swamp buffaloes	(Wanapat et al., 2014)
Mulberry leaf	Flavonoids	Improve the OM digestibility, reduce CH_4 output, and reduce methanogenic bacteria	Enhanced digestibility and VFA and reduced fecal and urinary, nitrogen, and CH_4 losses	Ewes	(Wang et al. 2019)
Yucca schidigera extract	Resveratrol and saponin	Improve growth performance, and nutrient digestibility, and reduce ammonia emission in sows	Reduced birth of dead fetuses, weak piglets, mortality and loss of urea and ammonia nitrogen diarrhea and increased digestibility	Sows	(Chen et al. 2021)

1.13. Role of Phytogenic Substances in Toxicity Control in Animals

Toxic substances like heavy metals, antibiotics, toxic pesticides and mycotoxins via feed and water can cause health hazards in livestock. Exposure to high level of lead (Pb) reduced the feed intake and growth performance in addition to other harmful effects on different organs in livestock (Taha et al., 2019). Yucca, coriander, Bitter cola, and Garlic, which are natural herbs protect livestock against lead toxicity and play a role in growth and blood parameters (Osemwegie et al., 2017). This reduced Pb toxicity may be due to the antioxidant and chelating activity of active components present in these herbs. Similarly, dietary supplementation with Turmeric mitigated toxicity in poultry due to salinomycin (Sayrafi et al., 2017). Furthermore, dietary inclusion of extracted oil from thymus vulgaris mitigated toxicity in catfish induced by thiamethoxam. This protection is related to its immune-stimulatory, antioxidant, apoptotic, and anti-inflammatory mechanisms.

Mycotoxins are secondary metabolites of toxigenic fungi which mostly occur as common feed contaminants (Shakeel et al., 2023). Generally, feed contamination with mycotoxin affects animal health, productive performance and immune responses, and even causes death with prolonged exposure. Herbal extracts like licorice extract reduced hepatotoxicity in poultry caused by aflatoxin B1, mainly due to reduced enzymatic activities.

1.14. Phytogenic Feed Additives and Their Modes of Action

Due to the complex composition of phytogenic products and or substances, it is very difficult to explore their potential modes of action in different animals and different organs. Some of the herbs along with their modes of actions, effects, and sources are given in Table 1.

Conclusion

This chapter describes phytogenic feed additives as potential alternatives in livestock production for antibiotics. Considering the economic impact, reduced resistance development, and other factors, phytogenic feed additives being natural herbal products have numerous advantages over other feed additives predominantly antibiotics. Multi-functions of Phytogenic feed additives like beneficial effects on improved health, growth and production, reproduction performance, reduced energy losses, and toxicity in farm animals have been presented. Considering the effect of the manufacturing process and variable batches, evaluation of natural herbs and their extracts is needed in the future. Regarding quality control standards, precautionary measures and unpredictable results, further *in vitro* and in vivo investigations are warranted. Numerous potential modes of action of phytogenic feed additives like growth promoters, antioxidants, antimicrobials, immunity modulators, antioxidants, intestinal flora, and gut integrity have been well described and established. Investigation into phytogenic products to understand their mechanisms involved in epigenetic regulation, TRP channel activation, and quorum sensing is not fully established, which needs further research. Phytogenic feed additives are Inexpensive and more effective therefore their biological mechanisms need to be explored, evaluated, and standardized comprehensively due to the large range of variety in extracts and formulas, which will enable their application on a commercial scale in the livestock sector. In conclusion, phytogenic feed additives can potentially replace antibiotics in livestock feeds, however more research is needed to understand and utilize them to improve animal health and production and reproductive performance.

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