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Herbal and Phytogenic Compounds in Veterinary Therapy: Efficacy, Mechanisms of Action, and Regulatory Challenges

Prasanna Godbole[1*], Anjali Arya[2] and Subhasish Sahu[3]

[1]Department of Veterinary Pharmacology and Toxicology, M. B. Veterinary College, (RAJUVAS) -314001 (Rajasthan), India
[2]Department of Livestock Production Management, M. B. Veterinary College, (RAJUVAS) -314001 (Rajasthan), India
[3]Department of Livestock Production Management, CVSc & AH, OUAT, BBSR, India.

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*Corresponding Author
Prasanna Godbole*

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INTRODUCTION

Phytotherapy, or the administration of medicinal plants, has been the backbone of traditional systems of medicine for centuries. In veterinary medicine, the employment of herbal and phytogenic molecules is re-acquiring popularity in response to a growing demand for natural, residue-free treatment, particularly in food-producing animals. The excessive use and abuse of man-made drugs, especially antibiotics and antiparasitic drugs, have resulted in worldwide health issues like antimicrobial resistance (AMR). Moreover, contamination of milk, meat, and eggs with chemical residues has prompted both producers and consumers to find safer, more environmentally friendly alternatives. Herbal treatments, with their bountiful pharmacological potential and minimal toxicity, provide a suitable complementary or alternative method of treatment in veterinary medicine.

Efficacy and Safety of Widely Used Herbs

Several herbs have been scientifically researched for their therapeutic action in animals, and some are already in practical application in various regions.

Widely Used Herbs and Their Applications

Neem (*Azadirachta indica*) is widely employed due to its antimicrobial, antiparasitic, and cicatrisant activities. It has efficacy in ectoparasite control like ticks and lice and demonstrated antimicrobial action against a variety of pathogens. Tulsi (*Ocimum sanctum*), commonly called "holy basil," contains antiviral, immunomodulatory, and anti-stress properties, which make it useful in poultry and small ruminant management. Garlic (*Allium sativum*) has significant antibacterial, antifungal, and antiparasitic activity, and turmeric (*Curcuma longa*), which is rich in curcumin, is well known for its strong anti-inflammatory and antioxidant activities. Fenugreek (Trigonella foenum-graecum) is utilized to stimulate digestion and lactation, whereas Aloe vera is also preferred for wound healing as well as gastrointestinal advantage. *Withania somnifera* (ashwagandha), which is an adaptogen, is generally utilized for immune system support as well as stress reduction in animals.

Clinical Efficacy

Experimental research and field studies have established clinical efficacy of these herbs. For instance, curcumin supplementation in dairy cows has decreased somatic cell count and inflammatory cytokines in mastitis. Neem oil preparations have exhibited strong larvicidal activity against prevailing parasitic nematodes in goats. Tulsi extracts have exhibited promising antiviral activity against poultry diseases, particularly respiratory pathogens. Fenugreek seeds have enhanced milk production and feed conversion ratios in lactating animals. In spite of these favorable results, there is usually variability in outcomes owing to differences in species of plant, conditions of growth, and extraction. Safety Profile

Herbs are largely safe, particularly when they are applied in traditional types and dosages. Toxicity is, however, caused by inappropriate dosing or chronic consumption. For example, excessive intake of garlic has been linked to oxidative injury and hemolytic anemia in canines. Aloe vera, if not well processed, can lead to gastrointestinal upset from the anthraquinones present in the latex. Also, the possibility of herb-drug interactions cannot be ignored, especially when herbal preparations are combined with orthodox drugs. Thus, toxicological studies and standardization of doses are essential for safety in clinical practice.

Mechanisms of Action

Herbal substances act via a plethora of pharmacological mechanisms through several active components that act synergistically.

Antimicrobial Effects

Numerous herbs contain bioactive phytochemicals in the form of alkaloids, flavonoids, and essential oils that interfere with microbial membranes, suppress enzyme systems, or hinder microbial adhesion and proliferation. Allicin of garlic, for example, inhibits bacterial cell wall synthesis and has broad-spectrum antimicrobial activity. Likewise, neem-derived azadirachtin interferes with microbial metabolism and reproduction.

Anti-inflammatory and Antioxidant Actions

Curcumin from turmeric blocks the cyclooxygenase (COX) and lipoxygenase (LOX) pathways, which are pivotal to the inflammatory response. Most herbs are also antioxidants, clearing free radicals and calming oxidative stress in tissues. Such dual anti-inflammatory and antioxidant effect is particularly useful in diseases like arthritis, mastitis, and metabolic disease in ruminants.

Immunomodulatory Properties

A number of herbs, such as Ocimum sanctum and Withania somnifera, are immunomodulators that activate immune mechanisms by increasing phagocytosis, inducing antibody synthesis, and controlling cytokine expression. These immunomodulatory actions are especially beneficial for the treatment of viral diseases, chronic inflammation disorders, and immune augmentation post-vaccination.

Antiparasitic Activity

Herbal anthelmintics like neem and garlic are effective for treating a range of internal and external parasites. They work by inhibiting the nervous system of the parasite, interfering with metabolism, or destroying the egg and larval forms. These plants provide a natural substitute for synthetic anthelmintics, which are increasingly encountering resistance problems.

Regulatory Challenges

Although they have therapeutic potential, the extensive use of herbal drugs in animal medicine is confronted by various regulatory and practical challenges.

Lack of Standardization and Quality Control

One of the key limitations is variability in quality and concentration of active ingredients owing to differences in plant material, harvesting periods, storage conditions, and method of processing. In contrast to synthetic medicines, herbal products are not necessarily subject to rigorous standardization, influencing efficacy as well as safety.

Limited Scientific Validation

Although traditional lore validates much use of herbs, modern scientific confirmation by controlled clinical trials is generally absent. Studies are mostly confined to in vitro testing or small field trials. It is urgently needed that more rigorous, evidence-based research substantiates therapeutic claims and sets standards for dosages.

Inconsistent Regulatory Frameworks

Worldwide, the regulation of veterinary herbal products differs enormously. In the United States, the Center for Veterinary Medicine of the FDA regulates animal

supplements, although most herbal products are sold as feed additives with less regulation. In the European Union, the EMA mandates herbal veterinary medicinal products to be assessed in the Committee on Herbal Medicinal Products. In India, although AYUSH regulates traditional medicine, detailed veterinary phytotherapy regulation is underdeveloped.

Concerns on Residues and Interactions

Even regarded as safer, herbal products applied to food animals must be screened for possible residues in meat, milk, and eggs. Since there are no Maximum Residue Limits (MRLs) set for these substances, approval by the regulatory agencies continues to be a problem. In addition, combined usage with traditional drugs can cause unexpected interactions, hence the necessity for more extensive pharmacovigilance.

Future Prospects and Recommendations

In order to fully take advantage of herbal and phytogenic compounds in veterinary medicine, some strategic actions need to be taken. First, the appropriate research infrastructures have to be built to facilitate phytochemical analysis, clinical trials, and toxicological studies. Second, international standardization procedures for the production of herbal medicine—such as Good Agricultural and Collection Practices (GACP)—need to be established. Third, veterinary education programs need to incorporate education in ethnoveterinary practices and phytopharmacology. Lastly, the regulatory authorities need to come together to formulate standard guidelines that ensure safe and effective use while securing animal and public health.

CONCLUSION

Herbal and phytogenic compounds are a very promising aspect in the development of veterinary pharmacology. Their wide range of therapies, safety profile, and environmental compatibility make them the best fit for incorporation within preventive as well as curative animal health routines. Yet, if such natural remedies are to gain acceptance in addition to mainstream pharmaceuticals, higher scientific confirmation, regulatory transparency, and product standardization are necessary. With proper regulation and ongoing studies, herbal medicine can be a useful addition to sustainable and integrative veterinary medicine.