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Review Article

Medicinal Plants in Veterinary and Wildlife Health: Therapeutic Applications, Disease Management and Conservation Perspectives

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Abstract

Antimicrobial resistance, strict regulations on the use of antibiotics in livestock and consumer preference for sustainable livestock products have once again drawn attention to the role of medicinal plants as complementary or alternate means of treatment in the veterinary field. This review consolidates evidence from 151 peer-reviewed articles in order to critically analyze the possibilities in the use of phytomedicines in the context of One Health through an analysis of its therapeutic possibilities, disease management roles and even the conservation aspect. The history and ethnobotany behind the use of plants in animal therapy is explored, along with the pharmacology behind the major bioactive principles alkaloids, flavonoids, terpenoids, essential oils and tannins discussing their mode of action that include cell membrane disruption, efflux-pump inhibitors, quorum-sensing inhibitors and immune modulation. Specific examples exist from studies involving species across livestock, companion and aquatic animals as well as captive and free-ranging wildlife that show antimicrobial, antiparasitic anti-inflammatory and wound healing properties, among others, with multi-target effects suggesting a possible approach for minimizing resistance development. The review highlights the trade-offs associated with the exploitation of botanical resources, focusing on conservation practices through cultivation efforts and community management, as well as current barriers to the development of plant medicine, which include lack of standardization, pharmacokinetic information, clinical studies and regulation. The review highlights that for moving forward from using veterinary phytotherapeutics in an empirical way to applying them scientifically, there is a need for concerted efforts toward conducting proper clinical trials, pharmacology research on animals, toxicity testing and regulation of the use of medicinal plants.

Keywords: Ethnobotany, Phytotherapy, Antimicrobial stewardship, Zoopharmacognosy, Bioactive compounds, Nanoencapsulation, Sustainable cultivation, Wildlife pharmacology, One Health.

1. INTRODUCTION

The current scenario of animal health globally is being significantly transformed due to rising cases of AMR, increasing restrictions on the usage of antibiotics in animals for health maintenance purposes, and increased consumer demands for sustainable production of animal products (Lillehoj *et al*., 2018; Murugaiyan *et al*., 2022). It has been observed that medicinal plants are gaining momentum as viable alternative options to veterinary drugs and exhibit multifaceted pharmacological effects (Álvarez-Martínez *et al*., 2020; Angelini, 2024). WHO and WOAH have recognized that there is an urgent need for an alternative approach towards antimicrobial stewardship in the field of animal health, wherein the concept of phytomedicine plays a significant role.

The application of plants in the treatment of animal illnesses through ethnoveterinary medicine is among the most ancient forms of therapy that have existed throughout different cultural and geographic locations (Aziz *et al*., 2018; McGaw & Abdalla, 2019). Communities from all over the world have developed complex systems of treatment of animal diseases by using medicinal plants, which remain important sources of treatment in areas where there are no veterinary treatments available (Eiki *et al*., 2021; Assefa & Bahiru, 2018). Reviving the ancient knowledge of this field alongside scientific studies has brought unique possibilities of creation of effective phytotherapy solutions for veterinarians.

One Health is an important theoretical perspective that needs to be used in examining the mutual advantages of phytomedicine for animals. Through the provision of animal health care using plants, this method is effective in lowering antibiotic use in foods, minimizing zoonoses risk factors, and facilitating environmental conservation (Dafale *et al*., 2020; Ghai *et al*., 2022). Therefore, medicinal plants work in the context of the interrelationship between human health, animal health, and ecological sustainability as key features of the One Health concept (Shin & Park, 2018; Kelly *et al*., 2020).

New developments in the fields of analytical chemistry, molecular biology, and computation science have greatly increased our understanding of how phytochemicals work, allowing us to identify which bioactive molecules cause the effects we observe (Varghese *et al*., 2025). Essential oils, tannins, flavonoids, alkaloids and terpenoids have shown themselves to be highly effective at killing microbes, parasitic organisms, reducing inflammation, and immunological modulation in different animal species (Jubair *et al*., 2021; Huang *et al*., 2022). In addition, new technological innovations like nano-technology based delivery systems and computer assisted drug discovery are helping bring traditional knowledge to modern veterinary medicine applications (Kazemi, 2025).

This exhaustive review intends to assess the existing body of knowledge concerning medicinal plants used in veterinary and wildlife medicine through synthesis of the latest scientific evidence from peer-reviewed literature to create a definitive source of information that can benefit researchers, veterinarians, wildlife biologists, conservationists, and decision-makers.

The particular purposes of the review include:

(i) Discussion of the concepts of ethnoveterinary medicine and its history
(ii) Investigation of bioactive compounds found in medicinal plants and their modes of action
(iii) Assessment of the medicinal use of medicinal plants among different animal species
(iv) Evaluation of the potential of medicinal plants in dealing with antibiotic resistance problem
(v) Consideration of the conservation aspects of using medicinal plants
(vi) Recognition of the limitations and problems associated with the contemporary research
(vii) Identification of the modern technologies and promising areas for future research.

2. Ethnoveterinary Medicine: Concepts and Historical Perspectives

Ethnoveterinary medicine refers to the knowledge systems associated with the use of medicinal plants in the treatment of animals by indigenous people and their communities (Abo-EL-Sooud, 2018). This knowledge system is a collection of observations passed down from generation to generation over many years of practice and is deeply rooted in the local culture, spirituality, and environment (Aziz *et al*., 2020; McGaw & Abdalla, 2019). Unlike veterinary medicine, which is based on the standardized use of pharmaceutical products, ethnoveterinary medicine employs holistic methods that recognize the interrelated nature of animal health and environmental factors.

The development of ethnoveterinary medicine is based on the mutual evolution of agriculture among humans and the use of plants as medicine. Evidence from archaeological sites suggests that there was an early use of medicinal plants to cure animal diseases from 3000 BCE in the cultures of ancient Egypt, Mesopotamia, and China (McGaw & Abdalla, 2019). TCVM and Ayurveda are some examples of well-known systems of medicine that have played a significant role in shaping current phytotherapy (Xiong & Long, 2020; Gao *et al*., 2024). Medicinal plants are classified in these systems of medicine on the basis of energetic, taste, and therapeutic characteristics.

Contemporary ethnoveterinary research has documented traditional plant usage across diverse geographical regions. In Africa, comprehensive ethnobotanical surveys have identified hundreds of medicinal plant species used for treating livestock diseases in Ethiopia (Oda *et al*., 2024; Hankiso *et al*., 2024; Wendimu *et al*., 2024), Nigeria (Adeniran *et al*., 2020), Cameroon (Dzoyem *et al*., 2020), and South Africa (McGaw *et al*., 2020). Asian studies have similarly documented rich ethnoveterinary traditions in Pakistan (Aziz *et al*., 2018; Khan *et al*., 2023; Rafique Khan *et al*., 2021), China (Xiong & Long, 2020; Gao *et al*., 2024), and Turkey (Erarslan & Kültür, 2019). Latin American (Suffredini *et al*., 2023) and Pacific Island (Bakare *et al*., 2020) studies have further contributed to the global inventory of ethnoveterinary medicinal plants.

The pharmacological substantiation of ethnoveterinary medicines has become one of the most pressing issues in research today. Bioassay-guided fractionation of widely used herbal medicines has shown that many medicinal plants have proved their antimicrobial, antiparasitic, and anti-inflammatory properties (Wasihun *et al*., 2023; Amber *et al*., 2018). Still, the majority of described ethnoveterinary techniques are not sufficiently clinically validated, and there is a problem with standardization and safety that hinders the use of ethnomedicine in combination with veterinary practices (Meena *et al*., 2024).

There is an unprecedented danger that faces the preservation of ethnoveterinary knowledge, including modernization, cultural homogeneity, environmental degradation, and reduction in the transfer of traditional knowledge to succeeding generations (Khan *et al*., 2019; Batool *et al*., 2025). Documentation and preservation need to take place to ensure that this invaluable source of knowledge is not lost, especially in areas undergoing socioeconomic development. This can be achieved through digital documentation, community-level preservation schemes, and research collaboration between traditional practitioners and scientific organizations (Kour *et al*., 2026).

3. Bioactive Phytochemicals and Mechanisms of Action

The secondary metabolites contained in medicinal plants have different functions that protect them from pathogens, herbivores, and other forms of stress. The bioactive components of phytochemicals like alkaloids, flavonoids, terpenoids, tannins, phenolics, and essential oils form the most significant bioactive agents that are responsible for the pharmacological actions seen while treating animals with veterinary treatments (Othman *et al*., 2019; Huang *et al*., 2022; Ferdes, 2018). Information regarding their structural complexities is very crucial for the development of effective treatments.

3.1 Alkaloids

Alkaloids represent a large class of nitrogen-containing substances with considerable pharmacological effects. The most common alkaloids in veterinary practice are berberine in plants of Berberis genus, quinine obtained from Cinchona bark and several types of tropane alkaloids from Solanaceae plants (Othman *et al*., 2019). Berberine stands out because of its high antibacterial effect on MRSA and E. coli resistant to various medications due to inhibition of bacteria cell division protein FtsZ and prevention of bacterial biofilm development (Jubair *et al*., 2021). Quinine and other cinchona alkaloids show significant antiprotozoal activity on Babesia and Theileria protozoa in domesticated livestock. Nevertheless, such alkaloids are highly restricted for use because of the existence of narrow therapeutic index and potential toxicity of substances (Shin & Park, 2018). Alkaloids inhibit nucleic acid synthesis, protein synthesis, and energy metabolism of cells.

3.2 Flavonoids

Flavonoids constitute one of the most extensively studied groups of polyphenolic compounds, displaying remarkable structural diversity and broad-spectrum bioactivities. This class includes flavones, flavonols, flavanones, isoflavones, and anthocyanins, all sharing a characteristic C6-C3-C6 skeleton (Shamsudin *et al*., 2022). Quercetin, rutin, kaempferol, and epigallocatechin gallate (EGCG) represent flavonoids with documented veterinary applications. The antibacterial mechanisms of flavonoids involve inhibition of bacterial energy metabolism through ATP synthesis disruption, interference with cell wall synthesis, and inhibition of nucleic acid synthesis (Huang *et al*., 2022). Additionally, flavonoids exhibit potent anti-inflammatory activity through inhibition of pro-inflammatory enzyme systems including cyclooxygenase-2 (COX-2) and lipoxygenase, modulation of nuclear factor-kappa B (NF-κB) signaling pathways, and reduction of reactive oxygen species production (Williams *et al*., 2020). The immunomodulatory effects of flavonoids make them particularly valuable for managing inflammatory conditions in companion animals and livestock.

3.3 Terpenoids and Essential Oils

Terpenoids form the largest group of secondary metabolites in plants and include monoterpenes, sesquiterpenes, diterpenes, triterpenes, and tetraterpenes. Essential oils, which are volatile mixtures of terpenoid and phenolic compounds, have been found to be among the most promising candidates for use in veterinary medicine because of their broad spectrum of antimicrobial action, low toxicity, and favorable environmental properties (Nehme *et al*., 2021; Zhai *et al*., 2018). Carvacrol and thymol contained in essential oils of Origanum vulgare (oregano) and Thymus vulgaris (thyme) demonstrate strong antibacterial effects against a wide range of bacteria responsible for the majority of animal diseases, such as Salmonella enterica, Escherichia coli O157:H7, Staphylococcus aureus, and Campylobacter jejuni (Cui *et al*., 2024; Matte & Luciano, 2023). The mode of action is based on the disturbance of membrane integrity caused by the interaction of antibacterial compounds with phosphol.

Eugenol from clove (Syzygium aromaticum) and cinnamaldehyde from cinnamon (Cinnamomum verum) demonstrate significant antifungal activity against Candida albicans and dermatophyte species affecting companion animals (Ebani & Mancianti, 2020). Tea tree oil (Melaleuca alternifolia) containing terpinen-4-ol exhibits potent antibacterial and acaricidal properties, finding applications in poultry ectoparasite control and companion animal dermatological conditions (Puvača *et al*., 2019). The anti-inflammatory and immunomodulatory properties of 1,8-cineole from eucalyptus oil and α-bisabolol from chamomile further expand the therapeutic applications of terpenoids in veterinary medicine (Vercelli *et al*., 2025).

3.4 Tannins and Phenolic Compounds

Tannins represent high molecular weight polyphenols, which may be subdivided into hydrolyzable tannins (HTs) and condensed tannins (CTs), demonstrating strong antimicrobial, antilayering, and antibiofilm properties. The tannins of Castanea sativa (sweet chestnut) and Quercus genus and tannins of Acacia, Mimosa, and quebracho genera show very high activities against enterotoxigenic Escherichia coli and other pathogenic microorganisms attacking the gastroenteric tract of domestic animals (Huang *et al*., 2024). The mechanism of action of tannins is connected with the formation of complexes with proteins and lipids of the bacterial cell wall resulting in the increase in membrane permeability and ultrastructural alterations detectable by electron microscopy. In addition to their direct bacteriostatic and/or bactericidal effects, tannins can prevent the adhesion and biofilm formation via the interaction with adhesins, pili, and fimbriae (Vercelli *et al*., 2025).

The anti-inflammatory and astringent nature of tannins offers other medicinal advantages for treating gastrointestinal conditions in animals. The use of tannins has proven useful in reducing the duration of diarrhea cases, decreasing the shedding of pathogens in feces, and altering the microbe flora in the gut by moving the community away from pathogenic overgrowth while retaining beneficial microbes (Tedeschi *et al*., 2021). Nevertheless, high tannin consumption will lead to poor palatability and digestion of feed.

3.5 Mechanisms of Action and Synergistic Interactions

However, phytochemicals are much more complex in action compared to conventional antibiotics since phytochemicals act on multiple targets while conventional antibiotics act on single target sites. This is one of the reasons for the decreased chances of developing resistance due to phytochemical drugs since it is not easy for a single microorganism to develop mutations in all target sites (AlSheikh *et al*., 2020; Khare *et al*., 2021).

Some of the important mechanisms involved in the process of phytochemical activity include:

(i) Membrane disruption through the interaction with phospholipid bilayer.
(ii) Efflux pump inhibition which is part of multidrug resistance.
(iii) Quorum sensing and biofilm formation inhibition.
(iv) Redox state modulation via acting as antioxidants and pro-oxidants.
(v) Immune regulation through cytokine and phagocyte effects (Jubair *et al*., 2021; Shin & Park, 2018).

One of the most promising techniques in overcoming bacterial resistance to the above drugs can be the synergism between natural plant substances and antibiotics. Combination of essential oils with antibiotics proved to be more effective approach in fighting resistant bacteria for several reasons such as increased permeability of the cell membranes by antibiotics, inhibition of the efflux pump, and blocking the metabolic pathway (Alvarez-Martínez *et al*., 2020). Synergism or addition was observed in treating Pseudomonas aeruginosa bacteria with carvacrol and gentamicin, MRSA bacteria with thymol and tetracycline, and Salmonella with eugenol and fluoroquinolones (Vercelli *et al*., 2025).

4. Therapeutic Applications in Veterinary Health

Medicinal plants have varied uses in therapy in the field of veterinary medicine that includes antibacterial, antiviral, antifungal, antiparasitic, anti-inflammatory, wound healing, and immunomodulatory actions. The following section discusses the various medicinal uses of plants, which range from those with established uses to those that need further research.

4.1 Antibacterial Applications

The antibacterial activity of the used herbs in their medical application has been extensively researched. It can be stated that it is the most common application of natural remedies in veterinary medicine. The extract and essential oils from the herbs possess antibacterial activity in relation to various kinds of bacteria causing diverse diseases in the farm animals and pets such as Staphylococcus aureus (including MRSA), Escherichia coli (including ESBL producing strains), Salmonella enterica, Pseudomonas aeruginosa, and Campylobacter spp. (Vercelli *et al*., 2025; Mala *et al*., 2021). Essential oil from oregano (Origanum vulgare) and the active components of it – carvacrol and thymol – showed MIC values of 0.19-1.56 mg/mL in relation to the listed bacteria. The oregano is one of the most effective antibacterial herbs thanks to those features (Auezov *et al*., 2024). Garlic (Allium sativum) extract possessing allicin and ajoene has shown a broad-spectrum antibacterial activity due to the inhibition of thiol-dependent enzymes and the destruction of the bacterial cell membrane (Ogbuewu *et al*., 2019).

Moreover, high-level antibacterial properties have been recorded for Calpurnia aurea extracts against Staphylococcus aureus and Streptococcus agalactiae (Wasihun *et al*., 2023); ginger (Zingiber officinale) extracts against Bacillus cereus and Pseudomonas aeruginosa (Aleem *et al*., 2020); and Syzygium cumini leaf extracts against multiple mastitis pathogens (Tambe *et al*., 2021). Despite this, converting in vitro antibacterial effectiveness into clinically applicable success presents difficulties owing to various issues such as bioavailability problems, chemical instability, and the complicated interplay of phytochemicals and host physiology.

4.2 Antiviral and Antifungal Applications

Medicinal plant-based antiviral drugs have received much interest due to the outbreak of coronavirus disease 2019 and zoonotic viruses. Plants contain antiviral agents that act via various ways such as direct virucidal effect, preventing the attachment and entrance of virus, interfering with viral replication enzyme, and immunomodulation (Kang *et al*., 2019). The essential oil extracted from oregano, thyme and cinnamon has been proved to be effective against avian influenza viruses, whereas the extracts from Artemisia annua have been proved effective against bovine viral diarrhea virus. Nonetheless, there is lack of evidence on their clinical effectiveness as antiviral medications for veterinary use.

An antifungal effect of the following oils: tea tree oil (Melaleuca alternifolia), lavender oil (Lavandula angustifolia), and eucalyptus oil (Eucalyptus globulus) on dermatophytes, Candida species, and Aspergillus species has been established. Essential oils lead to destruction of the structure of the fungal cell membrane owing to the influence on ergosterol and the prevention of cell wall synthesis (Ebani & Mancianti, 2020). Essential oil shampoos have demonstrated their clinical efficacy in the treatment of Microsporum canis infection in felines, but the period needed to eliminate infections varies from one patient to another (Vercelli *et al*., 2025). An antifungal effect of medicinal plants on novel fungal pathogens affecting wildlife, such as Batrachochytrium dendrobatidis in amphibians and Pseudogymnoascus destructans in bats, is a crucial perspective for the future study.

4.3 Antiparasitic Applications

Some uses of medicinal plants in antiparasitics therapy involve the treatment of endoparasites like nematodes, coccidia, and protozoans, and ectoparasites including ticks, mites, fleas, and lice. Some of the essential oils with a high level of efficacy in vitro against acaricide of ticks and fleas in dogs include citronella oil, clove oil, peppermint oil, and Zanthoxylum limonella. It has been noted to be tolerated in dilution on the skin (Vercelli *et al*., 2025; Alimi *et al*., 2021). The mode of action includes the toxicity of the nerve system of the arthropods through acetylcholinesterase and octopamine receptors, and cuticle.

Regarding the control of gastrointestinal nematodes, especially the barber's pole worm Haemonchus contortus in small ruminants, secondary metabolites of plants such as condensed tannins, sesquiterpene lactones, and alkaloids have shown considerable anthelmintic activity based on disrupting the parasites' energy metabolism, neuromuscular function, and egg hatching (Matte & Luciano, 2023). Nevertheless, the creation of plant-derived antiparasitics effective clinically as current anthelmintics is difficult since of issues related to bioavailability and the rapid metabolism of the active ingredients in ruminant digestion systems.

4.4 Anti-inflammatory, Wound Healing, and Immunomodulatory Effects

Anti-inflammatory effects of the medicinal plants have many uses in treatment of musculoskeletal diseases, dermatologic conditions, and gastrointestinal inflammation in the veterinary cases. Extracts of Boswellia serrata which consist of boswellic acids block 5-lipoxygenase and formation of leukotrienes, which result in clinical improvement of osteoarthritis in dogs (Nicotra *et al*., 2025). Curcumin found in Curcuma longa possesses strong anti-inflammatory effects by blocking NF-κB pathway and can be effective in the management of inflammatory bowel disease in the companion animals. Essential oils from chamomile, lavender, and eucalyptus prevent inflammation locally by blocking prostaglandin synthesis and altering cytokine formation (Vercelli *et al*., 2025).

Medicinal plants for wound healing benefit from the synergistic effects of the antimicrobial, anti-inflammatory, and regenerative nature of the phytochemicals. The use of Aloe Vera gel, plant extract containing honey-based ointments, and essential oil-containing preparations has been shown to improve wound contraction, increase collagen synthesis, and heal wounds faster than control (Santos *et al*., 2026). The effect of the immune system-modulating properties of the plant extracts such as increasing phagocytosis, increased cytokine secretion, and antibody reactions contributes to resistance against diseases and vaccine efficiency in livestock and companion animals (Elumalai *et al*., 2020; Nazeemashahul *et al*., 2023).

5. Medicinal Plants in Livestock Disease Management

Medicinal plants used for the treatment of livestock diseases constitute the most economically important and well-studied area in veterinary phytotherapy. In light of the ban on antibiotic growth promoters in Europe and their growing restrictions in North America and Asia, phytogenic feed additives have become the main replacement products in promoting animal welfare and efficiency (Callaway *et al*., 2021; Salman *et al*., 2026). The current subsection will analyze the species-specific uses in various livestock types.

5.1 Cattle

The application of medicinal plants in treating bovine mastitis is the most economically viable application of medicinal plants for treating cow diseases. Numerous studies have demonstrated the antibacterial properties of extracts of plants with respect to the bacteria responsible for causing bovine mastitis like Staphylococcus aureus, Streptococcus agalactiae, and Escherichia coli (Ajose *et al*., 2022; Kaseke *et al*., 2023). Ethanolic extracts of Nauclea latifolia and Ocimum gratissimum have proven to be effective against mastitis-causing organisms that are resistant to treatments (Abdulsalam *et al*., 2023). Teat disinfectants made from essential oils consisting of cloves, citronella, and sweet basil have been developed (Aiemsaard *et al*., 2023).

Beyond mastitis applications, oregano and thyme essential oils have shown promise for controlling bovine respiratory disease complex (BRDC) through their activity against Mannheimia haemolytica, Pasteurella multocida, and Histophilus somni (Rajamanickam *et al*., 2019; Alkheraije, 2025).

It is well documented that phytochemical feed additives exert a considerable influence on rumen fermentation profiles, nutrient digestion, and methane emissions from cattle. Essential oils, tannins, and saponin additions to feed change rumen microbiota, leading to an increase in propionate concentration at the expense of acetate and methane concentrations (Tedeschi *et al*., 2021; Tsiplakou *et al*., 2023). The meta-analysis evidence proves that essential oil inclusion into cattle feed positively impacts their feeding efficiency and average daily gain while lowering the environmental impact of beef production (Torres *et al*., 2021; Orzuna-Orzuna *et al*., 2022). Nonetheless, the effects of phytochemical additives on rumen fermentation processes are highly dependent on the diet composition, cattle breed, and rumen microbiota profile.

5.2 Poultry

In the poultry industry, the use of plant-based feed additives to replace antibiotics is highly advanced because of the immense pressure on production and tough regulations. The growth promotion, improvement in the feed efficiency, and immunostimulatory properties of essential oils obtained from oregano, thyme, rosemary, and cinnamon have all been confirmed for broiler chickens (Puvaca *et al*., 2022; Movahedi *et al*., 2024). The antimicrobial potential of these plants towards Salmonella enterica, Campylobacter jejuni, and Clostridium perfringens tackles food safety issues as well as decreases the bacterial colonization of the intestinal tract (Zhai *et al*., 2018). The use of oregano essential oil at a dose rate of 300-600 mg/kg feed has been found to increase body weight by 5-12% over control birds as well as reduce Salmonella counts in the cecum (Cui *et al*., 2024).

Apart from essential oils, prebiotics such as inulin extracted from chicory (Cichorium intybus), fructooligosaccharides (FOS) from different sources of plants have the ability to foster the colonization of beneficial microbes within the gut, while at the same time reducing the growth of pathogens (Zhao *et al*., 2025). Medicinal herbs such as Astragalus membranaceus, Echinacea purpurea, and Glycyrrhiza glabra are some of the herbs that have been found to offer an improved antibody response to vaccines, alongside increased resistance against diseases like infectious bursal disease and Newcastle disease in commercial poultry farms.

5.3 Small Ruminants, Companion Animals, and Aquaculture

Anthelmintic activity against H. contortus, which is the most economically important nematode in sheep and goat production systems, has been reported among condensed tannin-containing forages such as birdsfoot trefoil (Lotus corniculatus) and sulla (Hedysarum coronarium) in small ruminants (Matte & Luciano, 2023). Forage containing high amounts of tannins reduce egg counts by 30-60% compared to control diets; however, the effect is mediated through direct anthelmintic activity and enhancement of protein nutrition of the host. Thyme and oregano essential oil also showed in vitro anthelmintic activity, but due to bioavailability problems in the rumen, in vivo effectiveness is compromised.

The field of companion animal medicine has experienced tremendous growth in the use of phytomedicines due to the owners' desire for natural remedies. Extracts of milk thistle (Silybum marianum), which contain silymarin, have been commonly employed in liver protection for canines and felines (Tedesco & Guerrini, 2023), while extracts of Boswellia serrata, turmeric (Curcuma longa), and green tea (Camellia sinensis) have been utilized for osteoarthritis, skin diseases, and cognitive dysfunction in elderly pets (Guo *et al*., 2024; Ciarcia *et al*., 2025). The rising popularity of pet nutraceuticals has fueled efforts toward species-specific formulations and dosing regimens despite poorly developed regulations of veterinary herbal products in most places.

Aquaculture is a new frontier where medicinal plants can be used as an option due to the growing demand for alternative treatments of fish and shrimp against antibiotics (Abdel-Latif & Yilmaz, 2023; Nik Mohamad Nek Rahimi *et al*., 2022; Ather *et al*., 2026). Extracts of Allium sativum, *Azadirachta indica* and some other Chinese medicinal herbs have been shown to exhibit immunostimulation, antiparasite and antibacterial properties in various fish such as carps, tilapia, catfish, and salmonids (Li *et al*., 2022; Sumana *et al*., 2025). Herbal immunomodulators boost non-specific immunity in fish by improving lysozyme activity, complement concentrations, and respiratory bursts, thus offering protection from aquatic pathogens such as *Aeromonas hydrophila, Vibrio* species, and Streptococcus agalactiae (Elumalai *et al*., 2020; Jeyavani *et al*., 2022). Nevertheless, issues regarding stability of compounds in an aqueous environment, the best means of delivery, and possible water quality changes need further research (Qasim *et al*., 2025).

6. Medicinal Plants in Wildlife Health Management

Pharmacological usage of medicinal plants for managing the health of wildlife is an underdeveloped field of great importance where the principles of conservation medicine and traditional pharmacology intersect each other. As opposed to veterinary practices for livestock and companion animals, wildlife pharmacology needs to take into account specific physiology of wildlife, ecology of diseases, conservation status of target species and of the sources of medicinal plants, and overall principle of minimizing human intervention into wildlife (Inatimi *et al*., 2022; Chaganti *et al*., 2024).

Control measures for wildlife diseases now include herbal medication approaches that aim at the management of the diseases afflicting the threatened species. For instance, treatment of gastrointestinal disorders in African elephants (Loxodonta africana) and crab-eating macaques using Triticum aestivum L. and Theobroma cacao L. respectively is an illustration of possible inter-species application of herbal medication approaches based on proven phytotherapeutics (Shin & Park, 2018). Topical use of tea tree oil and chamomile extracts in the treatment of dermatological disorders in chlamydial-infected koalas (Phascolarctos cinereus) is another example.

Captive animal health care in zoos, aquariums, and rescue centers is one of the most sophisticated applications of phytomedicine in non-domesticated animals. Phytomedicine is becoming increasingly common in the treatment of chronic diseases like gastro-intestinal problems, inflammations, and behavioral issues in captive wild animals (Rahman *et al*., 2022). Chinese veterinary medicine compounds have also found an application in exotic cats, elephants, and reptiles with positive effects on managing their musculoskeletal diseases and geriatric health care. However, the pharmacodynamics of phytochemicals in non-domesticated animals are still unknown, and the dosage calculations based on domesticated animals involve substantial risks.

The incorporation of medicinal plants in conservation medicine is one strategy that presents unique ways of solving wildlife health problems in tandem with the aim of biodiversity conservation efforts. Community conservation programs that involve sustainable harvesting of medicinal plants together with the protection of the habitat of wildlife provide complementary motivation for ecological stewardship (Gbogbo & Daniels, 2019; Wani *et al*., 2021). The recording of traditional knowledge about the use of self-medications among wildlife animals known as zoopharmacognosy can reveal information on plant species with therapeutic effects and help design new phytotherapy drugs for wildlife animals. Nevertheless, the harvesting of medicinal plants for use by wildlife should be properly controlled.

7. Medicinal Plants and Antimicrobial Resistance

The increasing concern about the worldwide antimicrobial resistance issue has raised more attention to medicinal plants as a potential alternative to regular antibiotics for veterinary purposes. Antimicrobial Resistance is regarded by the World Health Organization as one of the biggest threats to the world's population and agricultural antibiotics have been listed as one of the factors that facilitate the formation of resistance in zoonotic pathogens (Dafale *et al*., 2020; Murugaiyan *et al*., 2022). There are a number of benefits of using plant-based substances in the fight against AMR: spectrum activity, multi-target mechanisms limiting the risk of resistance development, antibiotic synergy, and immunomodulation (Gupta & Sharma, 2022; Helmy *et al*., 2023).

The modes by which phytochemicals act against antibiotic-resistant pathogens are very different from that of traditional antibiotics. Traditional antibiotics usually target one aspect of cellular metabolism like enzymes involved in synthesis of cell walls, ribosomes subunits, or nucleic acid polymerases, but phytochemicals act on multiple targets of the cellular metabolism (Jubair *et al*., 2021; Angelini, 2024). The chances of developing resistance are greatly reduced since acquiring mutations in multiple targets is less likely statistically. Essential oils act by compromising membrane integrity by acting on phospholipid bilayers of the bacteria and also inhibit the multidrug efflux pump systems (Vercelli *et al*., 2025). The tannins form complexes with the bacterial cell wall proteins, inhibit extracellular enzymes, and prevent biofilm formation via anti-adhesive properties (Huang *et al*., 2024). The flavonoids interfere with bacterial energy metabolism, inhibit nucleic acid synthesis, and disrupt the functioning of quorum sensing systems involved in virulence factor secretion and biofilm formation (Shamsudin *et al*., 2022).

Several studies show that phytochemicals can be effective against multidrug-resistant bacteria in veterinary practice. Carvacrol oil showed a strong antimicrobial effect on multidrug-resistant strains of staphylococci, isolated from sick animals and people (Abed *et al*., 2021), while cinnamon oil is effective against the pan-drug-resistant and extensively drug-resistant Pseudomonas aeruginosa isolates due to its antibacterial and anti-efflux pump properties (Abdelatti *et al*., 2023). In combination with traditional drugs, the use of plant extracts can be considered an especially effective method to prolong the life span of antibiotics and decrease their consumption (AlSheikh *et al*., 2020; Fik-Jaskółka *et al*., 2024). A combination of cinnamaldehyde with fluoroquinolones, eugenol with tetracyclines, and thymol with aminoglycosides shows enhanced efficacy due to multiple mechanisms including the increased permeability of bacterial membranes and efflux pump inhibition.

Although promising in vitro results were observed, various problems hamper the use of plant AMR solutions in practice in veterinary medicine. The lack of bioavailability, instability in biological fluids, fast metabolism, elimination, and differences in phytochemical content in the batches of plant extracts create great difficulties in formulating such products (Hotea *et al*., 2022; Lillehoj *et al*., 2018). It is difficult to standardize phytochemical formulations because of the complicated chemical composition of plant extracts and the influence of the environment, extraction methods, and other processes on the levels of active compounds. Moreover, high concentrations necessary for in vivo efficiency in some experiments cause doubts regarding palatability, feed consumption, and possible toxicity. Proper pharmacokinetic research, quality control, and clinical trials are necessary preconditions for the widespread use of phytochemicals as an AMR problem solution in veterinary medicine.

8. Conservation Perspectives

Sustainable exploitation of medicinal plants in veterinary practice is closely related to the goals of biodiversity conservation in general. Around 70 percent of the world's population uses traditional medicines as the basis for health care systems, and medicinal plants form the backbone of these traditional medicine systems (Wani *et al*., 2021; Kadam & Pawar, 2020). The growing commercial demand for medicinal plant materials for the veterinary and human phytomedicine sectors poses considerable risks for wild plant species because of over-exploitation and habitat loss (Zaman *et al*., 2025; Shukla, 2023).

Climate change is one of the threats posed to medicinal plant biodiversity. Changes in climate in terms of precipitation and temperature changes, more extreme weather phenomena, and disease vector migration pose great danger to many medicinal plants because they compromise their niches, especially if they have small geographical ranges and habitat-specific needs (Zaman *et al*., 2025). Climate changes have threatened the distribution of some important medicinal plants, such as various species of Berberis, Aconitum, and Picrorhiza found in mountainous areas which are used for both traditional veterinary and human medicinal purposes. It has been projected that as much as 15-30% of medicinal plant species might have their ranges reduced by 50% by 2050, depending on the current climate change scenarios.

The conservation of medicinal plants requires an equilibrium between the requirements of therapy and ecological sustainability. In situ conservation by setting up protected areas and habitat restoration is the ideal conservation method for preserving the genetic diversity and ecosystem interactions needed for species survival (Kadam & Pawar, 2020; Kaur *et al*., 2022). Seed banks, botanical gardens, and cryopreservation can be used as forms of ex situ conservation that serve as insurance against extinction as well as facilitating research and propagation. CITES is an international treaty that ensures that international trade of endangered species of medicinal plants is regulated.

Sustainable harvesting and cultivation play very important roles in conservation measures for medicinal plants. GACP guidelines, which have been developed by the WHO, offer guidance for the sustainable wild harvesting and commercial cultivation of medicinal plants (Alum, 2025).

Successful cultivation programs aimed at high demand species such as Artemisia annua, Calendula officinalis, and Matricaria chamomilla have been achieved through reduction in pressures on natural populations, and also in securing regular supply and quality for veterinary use. Community-based management strategies that encourage the participation of all relevant stakeholders in the process of conservation, distribution of benefits, and monitoring of these programs have been shown to be more successful compared to top-down regulatory approaches (Wani *et al*., 2021; Targe *et al*., 2022). Integrating plant conservation into one health strategies allows consideration of the connectedness between plants, animals, and human beings.

9. Challenges and Limitations

Although there have been many advancements in veterinary phytomedicine research, several problems limit the transition from promising results obtained in laboratories to proven therapeutics. Such problems cut across different sectors, including science, regulations, economics and others.

Questions concerning standardization form the primary concerns surrounding veterinary phytomedicines. Plant extracts differ from pharmaceutical products in that they consist of mixtures of various bioactive substances in varying amounts depending on genetic variability, environment of growth, time of collection, and post-harvesting processing (Alum *et al*., 2025; Hotea *et al*., 2022). The difficulty with standardization is due to the chemical nature of plant extracts where bioactivity may come from the interaction of several substances and not just a single one. Available technologies such as HPLC, GC-MS, and NMR spectroscopy allow for phytochemical profiling of substances contained in the extracts; however, there is still no standard reference material available for some of the relevant plants.

Issues relating to dosage and dosage optimization form one of the major practical challenges that arise during the use of phytochemicals in veterinary medicine. There is little information on the pharmacokinetics of phytochemicals in various animal species, which means that allometric scaling from data derived from experimental animals or humans may fail to predict the dose necessary for effective use of phytochemicals in veterinary medicine (Lillehoj *et al*., 2018; Vercelli *et al*., 2025). The physiology of digestion, metabolism and excretion in various species affects the bioavailability and effectiveness of phytochemicals. In ruminants, for instance, the ruminal metabolism of many compounds in essential oils necessitates higher doses compared to monogastrics.

Although the risk of toxicity is lower than artificial drugs, it needs due attention for veterinary use. Although plant extracts are natural substances, yet there can be serious toxic consequences of the use of essential oils even in high concentrations, which include mucosal irritations, hepatotoxicity, neurotoxicity, and reproductive toxicity (Vercelli *et al*., 2025; Tedesco & Guerrini, 2023). Tea tree oil has caused some neurotoxicity (weakness, ataxia, tremors) in both dog and cats, when used at high concentrations. There is the need for caution in dosing of some alkaloids, including that of the genus Datura and Aconitum due to the small therapeutic window of action. Interaction of phytochemicals with normal veterinary drugs may change pharmacokinetics or pharmacodynamics.

Lack of clinical validations is among the major impediments that prevent medicinal plants from gaining acceptance in the mainstream practice of veterinarians. Although some in vitro experiments and few in vivo studies have shown encouraging outcomes, most studies that have been carried out in this field are characterized by insufficient sample sizes, poor control groups, short-term follow-up period, and lack of standardized criteria (Meena *et al*., 2024; Kaseke *et al*., 2023). The lack of well-conducted clinical trials similar to those done in the development of drugs hinders the availability of sufficient information to make decisions regarding clinical practices. Moreover, there is the problem of publication bias because negative findings are rarely published.

However, regulatory limitations differ greatly between regions; thereby creating a dilemma for producers and end-users. In the USA, veterinary botanical preparations could be regulated as drugs, feed additives, or supplements based on the nature of their usage, with each one having its own set of regulations (Guo *et al*., 2024). In the European Union, there have been more elaborate regulations on veterinary phytogenic products, although these regulations are not entirely harmonized within member states. Many developing countries do not have any specific regulatory framework in place for veterinary herbal products, leading to inconsistencies in the quality control of such products as well as their marketing claims. International regulatory guidelines for veterinary phytomedicines could help in market growth while ensuring product safety and efficacy.

10. Emerging Technologies and Future Trends

Integration of modern technologies with the knowledge of phytomedicine has been revolutionizing veterinary phytomedicine by turning it from a trial-and-error technique into a science. Technologies such as nanotechnology, artificial intelligence, metabolomics, and drug delivery systems have helped to resolve some of the long-existing problems of bioavailability and standardization.

Herbal preparations developed using nanotechnology are among the most innovative technologies within the field of veterinary phytomedicine. Nanoformulation of essential oils, polyphenols, and other natural ingredients via encapsulation in liposomes, polymeric nanoparticles, solid lipid nanoparticles, and nanoemulsions is very beneficial from the viewpoint of increasing their water solubility, stability, bioavailability, and targeted delivery (Kazemi, 2025; Danchuk *et al*., 2023). Essential oils incorporated into nanoemulsions possess increased antimicrobial properties and thus pose less risk of toxic effects. Nanoencapsulation preserves the bioavailability of the phytochemicals against any possible degradation during the preparation of feed and digestion in the gut. In a study conducted by (Liu *et al*., 2022), it was found that garlic essential oil nanoemulsions produced using high-power ultrasonication possessed considerably better antibacterial properties against MRSA from pork than traditional products. The combination of titanium dioxide nanoparticles with extracts of herbs has also been effective for wound healing in animals (Pangprasit *et al*., 2023). However, the effects on the environment and biology need to be analyzed properly.

The application of artificial intelligence (AI) and machine learning (ML) is changing the field of phytomedicines' discovery and development through fast detection, prediction of activity, and formulation design (Varghese *et al*., 2025; Paerhati *et al*., 2026). Algorithms based on AI could assess big databases of phytochemical composition, biological activities, and pharmacokinetics, helping in identifying new bioactive compounds and designing their extraction process. The use of deep learning models to analyze metabolomics data helps in fast identification and quantitation of phytochemicals (Kalita *et al*., 2025). Synergy in interactions between phytochemicals and existing antibiotic drugs has been assessed using machine learning techniques, which can speed up the discovery of combination therapies to combat resistant bacteria. Combining AI and ethnobotanical databases makes it possible to systematically screen for traditionally used plant species that have a high likelihood of producing bioactive components (Kour *et al*., 2026).

Genomics and metabolomics have provided an unprecedented level of knowledge about the biosynthesis, mechanism of action, and therapeutic utility of phytochemicals. The use of metabolomics for the standardization of traditional medicines allows for a full profile of phytochemicals that correlate their presence with biological activity and resolve quality problems associated with herbal medicines (Alum *et al*., 2025). Transcriptomics and proteomics elucidate the mechanism by which phytochemicals affect host-pathogen interactions. Mining of the genome of medicinal plants along with their associated microbes facilitates the discovery of biosynthetic gene clusters for the biosynthesis of bioactive compounds, thus allowing metabolic engineering to achieve improved yields and the discovery of new compounds. The combination of omics data and AI-based prediction modeling is an effective strategy for developing veterinary phytomedicine.

The use of precision medicine techniques that take into account the genetics of an animal, its microflora, and disease biomarkers opens the way to personalized use of plant-derived remedies. Awareness that individual animals have different responses to phytochemicals depending on their polymorphisms related to drug metabolism, microflora that affects the biotransformation of compounds, and their immune status opens doors for personalized treatment protocols (Chihomvu *et al*., 2024). Nutrigenomics studies the way that plant chemicals react with certain genetic makeups to affect health status. This allows for tailored dietary suggestions to improve animal well-being based on an individual's genetic makeup. With further development in precision medicine strategies, animal phytomedicine will evolve from making broad recommendations into designing individualized treatment protocols based on different animal populations.

11. Research Gaps and Future Priorities

Even with considerable advancements that have been made in the study of phytotherapy in veterinary medicine, there are still many limitations that need to be overcome before its full potential can be achieved. The following section outlines some of the key research areas that require attention.

The issue of conducting controlled clinical trials is an important research agenda at hand. Although there is enough proof from in vitro and some in vivo tests regarding their efficacy, the majority of studies performed have not been methodologically strong to warrant clinical applications (Kaseke *et al*., 2023; Meena *et al*., 2024). Well-designed randomized, placebo-controlled trials with standardized preparations and outcome measures and enough follow-up periods and power calculations are necessary to establish evidence-based guidelines for treatment. These studies should be performed in a variety of animal species and production systems, as well as geographic areas, to generalize the results. Collaborative networks of researchers from different universities and veterinary practices may make it possible to conduct multicenter clinical trials effectively and share the cost.

There is an urgent need for research into medicinal plants for wildlife animals considering the recent realization that animal health is an integral part of biodiversity conservation and prevention of zoonotic infections. Almost nothing is known about pharmacokinetics of medicinal plants in non-domestic animals and safe dose levels to apply on such animals (Inatimi *et al*., 2022; Chaganti *et al*., 2024).

Priorities in research are

(i) Pharmacodynamics/pharmacokinetics studies specific to each particular species in common use in medicine
(ii) Efficiency studies of managing new infectious diseases in endangered species
(iii) Self-medication (zoopharmacognosy) practices as an indicator of medicinal value of plants
(iv) Devising suitable means for drug administration to free-living wild populations. Formation of a multidisciplinary network between wildlife vets, conservationists and herbal medicine scientists will greatly facilitate this process.

It is important to undertake long-term safety studies that can help solve the problems related to continuous use of phytochemicals as feed supplements and therapeutics. Presently, safety studies tend to emphasize acute toxicity but lack any assessment of subchronic or chronic toxicity, reproductive toxicity, genotoxicity, and carcinogenicity (Vercelli *et al*., 2025; Tedesco & Guerrini, 2023). It is necessary to carefully evaluate the risk of bioaccumulation of lipophilic phytochemicals like essential oils in animal tissue as well as in food products, especially taking into account the fact that consumers are worried about chemical residues in animal-derived food products. It is important to evaluate the impact of phytochemicals on the environment.

Developing phytomedicine through a conservation lens is a new priority area that merges conservation concerns and therapeutic discovery efforts. Development of sustainable cultivation systems for valuable medicinal plants is a need so as to ease pressure on wild populations and provide constant quality and supply (Zaman *et al*., 2025; Alum, 2025). Exploring other sources of medicinal plants, like agriculture waste products and invasive plants, may allow increasing the biomass stock while alleviating the conservation burden (Qasim *et al*., 2026). Using cell culture and bioreactor technology to produce bioactive compounds independent from cultivation of the entire plant can be helpful to meet the market demands without posing threat to wild populations. Moreover, medicinal plant conservation in the context of climate change adaptation is a research area.

Studies on regulatory science are required in order to establish proper criteria of evaluation and approval of botanical medicines used in animals. The present methodologies borrowed from the evaluation of drugs used in human medicine may not be optimal in assessing multi-component drugs and other assessment strategies which include chemical profiling and biological activity need to be validated (Guo *et al*., 2024; Hotea *et al*., 2022). It will be easier to trade such products if there is harmonization of the regulatory requirements in international markets. There should also be research into proper methods of quality control and stability tests of the products.

12. CONCLUSIONS

The following review, in a detailed manner, has critically reviewed the existing body of knowledge on the use of medicinal plants for veterinary and wildlife medicine, analyzing data derived from 151 scientific papers in order to present an authoritative evaluation of the use of medicinal plants for therapeutic purposes, disease management approaches and conservation perspectives. As has been identified in this paper, there is great potential in the application of medicinal plants in solving critical problems in the management of animal health.

The body of knowledge relating to veterinary phytomedicine has increased greatly over the last decade with proven antimicrobial, antiparasitic, anti-inflammatory and immunomodulatory activities observed in several different animal species. Essential oils especially those that contain carvacrol, thymol, and eugenol possess significant antimicrobial properties against important veterinary pathogens and even multi-drug-resistant types. Tannins display special anti-biofilm and anti-adhesive properties that enhance the treatment offered by antibiotics. Flavonoids and alkaloids possess wide-spectrum bioactivity properties including immunomodulatory ones that assist the defense mechanism of the host.

Nevertheless, several challenges need to be overcome in order to turn promising scientific results into clinically tested veterinary medicines. First, there are problems associated with standardization of plant preparations, as their chemical composition is highly diverse and can vary depending on environmental conditions. Species-specific studies on the dosage need to be conducted, which have not been conducted for most animals yet. Clinical testing of medicines should be done, however, at the moment it is still limited in scope and methodology. It is necessary to develop regulatory measures in order to guarantee the quality of products and help them to enter the market. Finally, it is important to make sure that sources of these medicines will be available in the future.

Nanotechnology is one area that holds tremendous promise when it comes to tackling the issues discussed above. Nanotechnology offers better drug delivery techniques by increasing the bioavailability of the drugs as well as ensuring targeted delivery of phytochemicals. Artificial intelligence will help with discovering new compounds as well as their activities and formulations. Genomic and metabolomics technologies will give a better understanding of the underlying mechanisms while helping with standardizing quality control measures.

Among the future areas of research needed are controlled clinical trials in veterinary species, wildlife pharmacological trials, safety testing, and development programs focusing on conservation. The combination of medicinal plants' research into One Health approach that considers human health, animal health, and conservation is the best way to develop sustainable therapeutics. Through the use of traditional knowledge, science, and new technologies, the practice of veterinary phytomedicine could make important contributions to global health security while promoting biodiversity conservation and sustainable agriculture development. It is time to act internationally in this field.

Table 1: Major Medicinal Plants Used in Veterinary Medicine, Active Compounds and Therapeutic Functions

Plant Species	Common Name	Major Active Compounds	Therapeutic Applications	Target Species
Origanum vulgare	Oregano	Carvacrol, Thymol	Antibacterial, Antifungal, Antiparasitic	Cattle, Poultry, Swine
Thymus vulgaris	Thyme	Thymol, Carvacrol	Antibacterial, Antioxidant, Anti-inflammatory	Poultry, Ruminants
Allium sativum	Garlic	Allicin, Ajoene	Antibacterial, Antiparasitic, Immunomodulatory	Cattle, Poultry, Fish
Melaleuca alternifolia	Tea tree	Terpinen-4-ol	Antibacterial, Antifungal, Acaricidal	Companion animals
Syzygium aromaticum	Clove	Eugenol	Antibacterial, Antifungal, Analgesic	Cattle, Dogs, Cats
Cinnamomum verum	Cinnamon	Cinnamaldehyde	Antibacterial, Antifungal, Anti-inflammatory	Poultry, Ruminants
Echinacea purpurea	Purple coneflower	Alkylamides, Polysaccharides	Immunomodulatory, Antiviral	Horses, Dogs, Cats
Calendula officinalis	Marigold	Triterpenoids, Flavonoids	Wound healing, Anti-inflammatory	Companion animals

Plant Species	Common Name	Major Active Compounds	Therapeutic Applications	Target Species
Matricaria chamomilla	Chamomile	α-Bisabolol, Chamazulene	Anti-inflammatory, Spasmolytic	Companion animals, Horses
Moringa oleifera	Moringa	Isothiocyanates, Flavonoids	Antibacterial, Anti-inflammatory	Cattle, Poultry, Fish

Table 2: Medicinal Plants Used Against Bacterial, Viral, Fungal and Parasitic Diseases in Veterinary Medicine

Plant Species	Active Compound(s)	Target Pathogen(s)	Disease/Condition	Activity Type
Origanum vulgare	Carvacrol, Thymol	Staphylococcus aureus, E. coli	Mastitis, Enteritis	Antibacterial
Allium sativum	Allicin	Salmonella enterica, C. jejuni	Salmonellosis, Campylobacteriosis	Antibacterial
Thymus vulgaris	Thymol	Pseudomonas aeruginosa, MRSA	Respiratory infections, Wound infections	Antibacterial
Calpurnia aurea	Flavonoids, Alkaloids	S. aureus, S. agalactiae	Bovine mastitis	Antibacterial
Syzygium aromaticum	Eugenol	Candida albicans, Aspergillus spp.	Dermatophytosis, Candidiasis	Antifungal
Melaleuca alternifolia	Terpinen-4-ol	Malassezia pachydermatis	Otitis externa, Dermatitis	Antifungal
Artemisia annua	Artemisinin	Babesia spp., Theileria spp.	Babesiosis, Theileriosis	Antiparasitic
Azadirachta indica	Azadirachtin	Haemonchus contortus, Ticks	Helminthiasis, Ectoparasitosis	Antiparasitic
Cinchona spp.	Quinine	Babesia spp.	Babesiosis (cattle)	Antiparasitic
Echinacea purpurea	Alkylamides, Polysaccharides	Influenza viruses, Herpesviruses	Respiratory infections	Antiviral

Table 3: Applications of Medicinal Plants in Livestock Species and Reported Outcomes

Livestock Species	Medicinal Plant/Extract	Application	Reported Outcome	Reference
Cattle (dairy)	Essential oils (oregano, thyme)	Mastitis prevention	Reduced SCC, decreased bacterial load	Cui *et al.,* (2024)
Cattle (beef)	Oregano essential oil	Growth promotion	↑ ADG by 5-8%, improved FCR	(Torres *et al.*, 2021)
Cattle	Condensed tannins	Anthelmintic	↓ Fecal egg counts by 30-60%	(Matte & Luciano 2023)
Poultry (broiler)	Thyme/oregano EO	Growth promotion	↑ Weight gain 5-12%, ↓ mortality	(Zhai *et al*., 2018)
Poultry	Tea tree oil	Ectoparasite control	Acaricidal efficacy against mites	(Puvaca *et al*., 2019)
Pigs	Garlic extract	Antibacterial feed additive	↓ E. coli counts, improved gut health	(Li *et al*., 2021)
Sheep/Goats	Condensed tannins (Lotus)	Anthelmintic	↓ H. contortus burden	(Tedeschi *et al*., 2021)
Fish (tilapia)	Garlic, Neem extracts	Immunostimulant	↑ Lysozyme, complement activity	(Elumalai *et al*., 2020)
Shrimp	Herbal immunomodulators	Disease resistance	↑ Survival against Vibrio infection	(Jeyavani *et al*., 2022)
Dogs/Cats	Milk thistle (silymarin)	Hepatoprotection	Improved liver enzyme profiles	(Tedesco & Guerrini 2023)

Table 4: Medicinal Plants Used in Wildlife Health Management and Conservation Programs

Plant Species	Active Compound(s)	Wildlife Application	Target Species	Conservation Context
Triticum aestivum	Flavonoids	Gastrointestinal treatment	African elephants	Captive management
Theobroma cacao	Cocoa flavonoids	Antidiarrheal	Crab-eating macaques	Zoo medicine
Melaleuca alternifolia	Terpinen-4-ol	Dermatological conditions	Koalas	Rehabilitation
Aloe vera	Aloin, Emodin	Wound healing	Various mammals, birds	Rehabilitation centers
Calendula officinalis	Triterpenoids	Wound treatment	Raptors, mammals	Wildlife rescue
Chamomile (Matricaria)	α-Bisabolol	Anti-inflammatory, calming	Zoo animals	Captive management
Neem (Azadirachta indica)	Azadirachtin	Ectoparasite control	Elephants, ungulates	Free-ranging populations
Artemisia annua	Artemisinin	Antiprotozoal	Equids, bovids	Disease control programs
Echinacea purpurea	Alkylamides	Immune support	Various species	Captive breeding programs
Turmeric (Curcuma longa)	Curcumin	Anti-inflammatory	Large felids, elephants	Geriatric care in zoos

Table 5: Advantages and Limitations of Plant-Based Therapies Compared with Conventional Veterinary Treatments

Parameter	Plant-Based Therapies	Conventional Treatments
Resistance development	Low (multi-target mechanisms)	High (single-target mechanisms)
Environmental impact	Generally low, biodegradable	Variable, some persistent residues
Safety profile	Generally favorable, some toxicity concerns	Well-documented, adverse effects known
Standardization	Difficult (complex mixtures)	High (pure compounds)
Clinical evidence	Limited, growing rapidly	Extensive, well-established
Cost-effectiveness	Variable, often lower cost	Higher, especially for newer drugs
Regulatory approval	Limited frameworks, variable	Well-established pathways
Shelf stability	Variable, susceptible to degradation	Generally high stability
Synergistic potential	High (multiple active compounds)	Limited
Immunomodulatory effects	Significant documented benefits	Limited
Palatability in feed	Variable, some palatability issues	Generally acceptable
Spectrum of activity	Broad-spectrum	Often narrow-spectrum

Table 6: Major Research Gaps and Future Research Priorities in Veterinary Phytomedicine

Research Domain	Current Status	Priority Research Needs
Clinical trials	Limited RCTs; mostly in vitro/small-scale studies	Large-scale, multi-center RCTs with standardized preparations
Wildlife pharmacology	Virtually absent	Species-specific PK/PD studies for non-domestic species
Safety assessment	Acute toxicity data available	Long-term chronic toxicity, reproductive safety studies
Standardization	Variable methods; limited reference standards	Validated analytical protocols; certified reference materials
AMR mechanisms	In vitro data promising	Clinical efficacy against resistant infections in vivo
Delivery systems	Conventional formulations dominate	Nanoencapsulation; targeted delivery for veterinary species
Conservation	Limited integration	Sustainable harvesting; cultivation optimization; climate adaptation
Regulatory science	Fragmented frameworks	Harmonized international guidelines for botanical veterinary products
AI integration	Emerging applications	Predictive modeling; formulation optimization; quality control
One Health linkages	Underexplored	Zoonotic disease reduction; ecosystem health integration

Figures

Figure 1: Classification of Major Medicinal Plant Bioactive Compounds and Their Mechanisms of Action.

This figure illustrates the major classes of bioactive phytochemicals (alkaloids, flavonoids, terpenoids/essential oils, tannins, phenolic compounds, and saponins) and their respective pharmacological mechanisms including membrane disruption, efflux pump inhibition, biofilm interference, quorum sensing modulation, immune modulation and protein/enzyme inhibition.

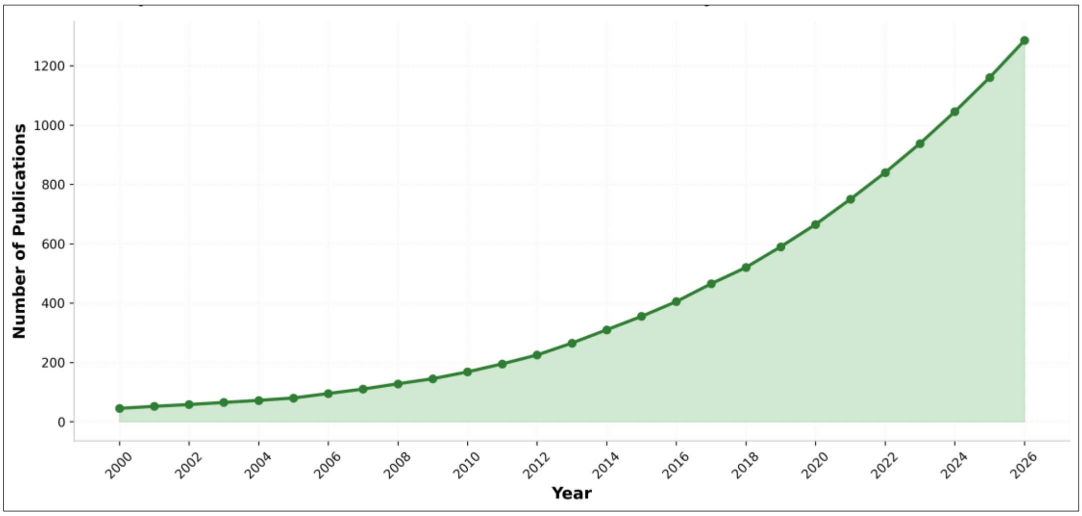
Figure 2: Role of Medicinal Plants in Veterinary and Wildlife Disease Management. This schematic illustrates the therapeutic applications of medicinal plants across livestock (cattle, poultry, swine, small ruminants), companion animals (dogs, cats) aquaculture species (fish, shrimp) and wildlife, encompassing antibacterial, antiviral, antifungal, antiparasitic, anti-inflammatory, wound healing, and immunomodulatory functions.

Figure 3: One Health Model Connecting Uses of Medicinal Plants, Animal Health, Human Health and Ecosystem Protection. The model represents the connections between phytomedicine utilization, food safety, zoonoses control, biodiversity protection, sustainable farming practices, and human well-being in the One Health concept.

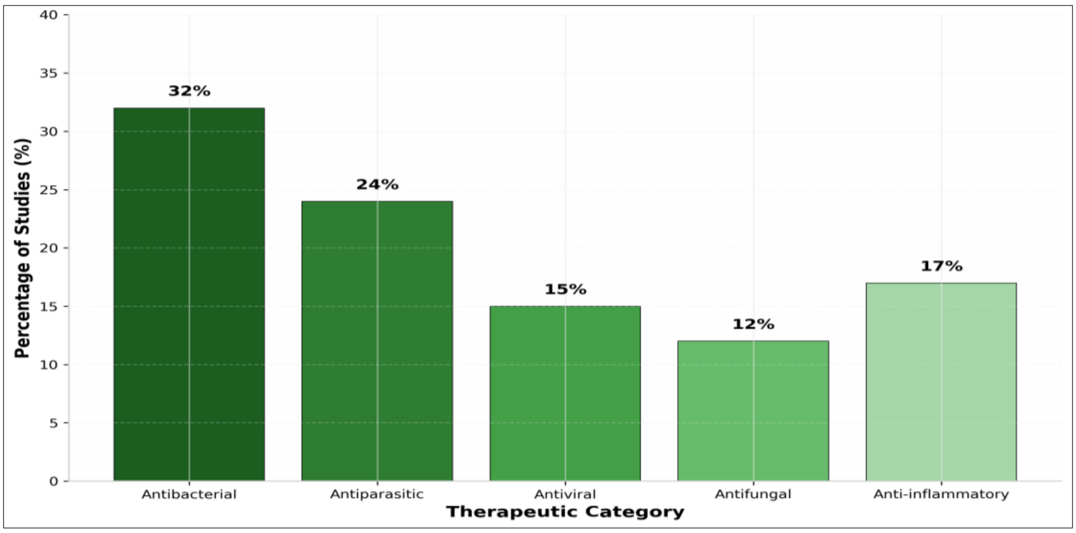
Figure 4: Model of Integrated Conservation and Sustainable Utilization for Medicinal Plants. This diagram shows the cyclic relationship between in-situ conservation, ex-situ conservation, sustainable collection, farming, stakeholder involvement, research, and legislation to ensure the sustainability of the medicinal plants resources for veterinary uses.

Graphs

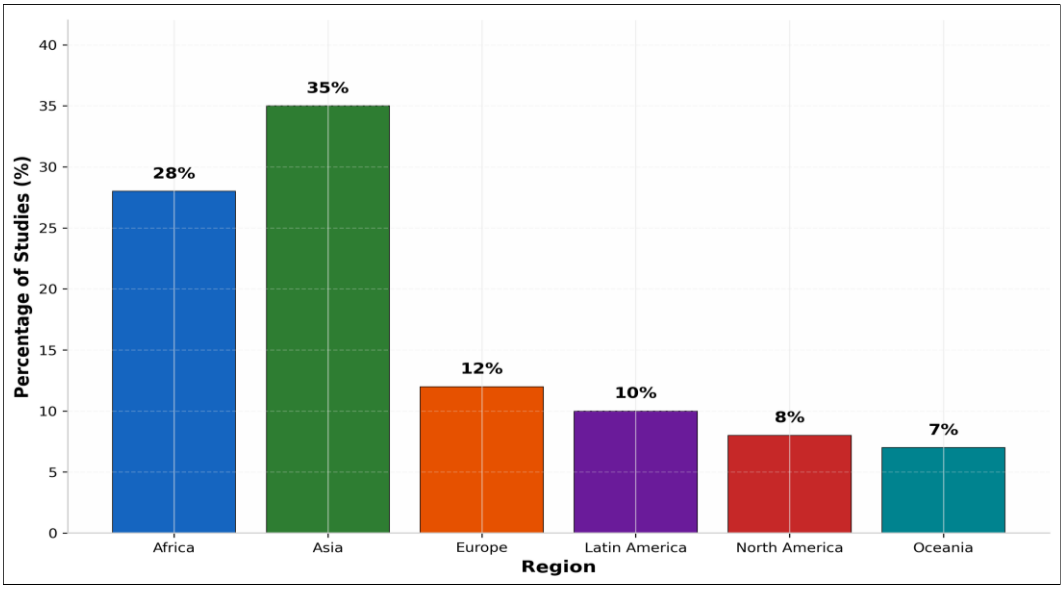
Graph 1: Publication Trends on Medicinal Plants in Veterinary and Wildlife Health (2000–2026). The graph shows exponential growth in publications, increasing from approximately 45 publications in 2000 to an estimated 1,285 in 2026, reflecting intensified research interest in veterinary phytomedicine.



Graph 2: Distribution of Therapeutic Applications of Medicinal Plants in Veterinary Medicine. Antibacterial applications dominate (32%), followed by antiparasitic (24%), anti-inflammatory (17%), antiviral (15%) and antifungal (12%) applications, based on analysis of published studies.



Graph 3: Regional Distribution of Ethnoveterinary Medicinal Plant Studies Worldwide. Asia leads with 35% of studies, followed by Africa (28%), Europe (12%), Latin America (10%), North America (8%), and Oceania (7%), reflecting the geographic concentration of ethnoveterinary research activities.



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