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Comparative Pharmacognostic Evaluation and Standardization of Root Extracts of Selected Ayurvedic Plants

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Abstract:

This review gives a detailed comparative pharmacognostical and phytochemical appraisal of the roots extracts of three Ayurvedic plants, which are of great significance viz. *Withania somnifera, Plumbago zeylanica, and Asparagus racemosus* with a view of their possible applications in veterinary sciences. By examining morphological, microscopic and chemical outlines in exceptional details, the study provides diagnostic points that are to be used to authenticate botanicals and avoid adulteration. The existence of therapeutically significant constituents withanolides, plumbagin, and shatavarins was confirmed with phytochemical screenings with ability to confer diverse biological effects including antistress (adaptogenic), immunomodulatory, digestive, and reproductive properties to animals. Several species of animals (cattle, goats, and poultry) are investigated in preclinical studies, proving the effectiveness of these roots as enhancing stress-resistance, digestion, reproductive health, and immunity. State-of-the-art level of standardisation procedures like TLC, HPTLC and physicochemical test guarantees consistency in formulations, safety and quality of formulations. Based on the review, there is a high concern in the need to incorporate these standardized herbal medicines into animal practice medicine, especially in peripheral regions where prescription medicines cannot be located or are unavailable. Nevertheless, there is also a need to emphasize the consideration of optimization of doses, toxicity and regulations to achieve safe and effective usages. The results open up to viable, effective, and natural solutions in the health of animals.

Keywords: Veterinary Pharmacognosy, Ayurvedic Root Extracts, *Withania Somnifera, Plumbago Zeylanica*, Standardization, Herbal Veterinary Medicine.

1. INTRODUCTION

Medicinal plants as a constituent of veterinary healthcare have a long tradition of use in such traditional veterinary systems as Ayurveda, which are centuries old in India. Roots are some of the many plant components that have therapeutic properties given their high content of bioactive elements that include alkaloids, flavonoids, glycosides, tannins, and saponins[1]. The phytochemicals frequently have appealing pharmacological effects such as anti-inflammatory, antimicrobial, immunomodulatory, adaptogenous, etc., consequently being of special interest in treating varieties of animal diseases. Although the roots-based formulas have been widely used in the ethnoveterinary practices, yet the pharmacognostic standardization and scientific validation of the corresponding botanical resources is underrepresented. In addition, substitution, misidentification and non-standardized methods of extraction represent enormous challenges in providing safety as well as efficacy of herbal veterinary treatment modalities[2].

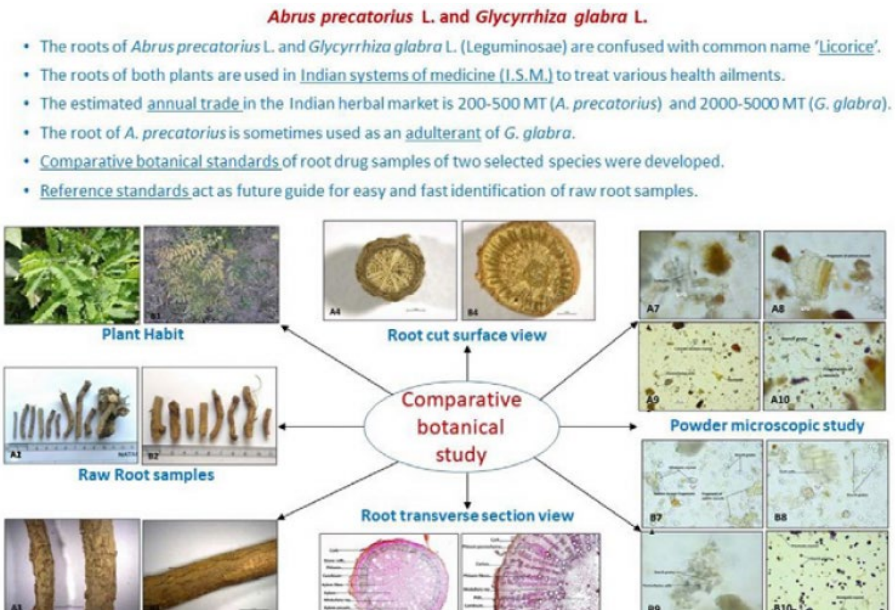

Figure 1: Comparative Botanical Analysis of Ayurvedic Roots[3]

To curb these issues, the present review is based on a comparative phytochemical analysis of some selected root plants in Ayurveda that people have been using in the management of animal health like Withania somnifera, Plumbago zeylanica, and Asparagus racemosus. Through comparative approach, the assessment of morphological, anatomical, physicochemical and phytochemical properties of these root extracts could be done in detail. It also focuses on the current processes of standardization that may assure reproducibility and quality assurance of veterinary herbal medicine. This review will use the folk veterinary knowledge, as well as the contemporary scientific methods, to fill the knowledge gap between folk veterinary practices and evidence-based animal pharmacotherapy[4].

1.1.Background Information and Context

Ayurvedic also contributes to the ancient animal healthcare procedure, especially in the countryside and agricultural regions where no availability of modern veterinary formulations is available. The roots of medicine plants are common in the treatment of livestock which include digestive issues and imbalance of reproductive organs. Nonetheless, due to the growing demand of the plant-based animal remedies sources, there is also the urge of the precise identification of the base materials as well as its standardization. The low roots are particularly prone to misidentification since they have no external shapes that may be easily identified. Hence, pharmacognostic assessment, which includes macroscopic, microscopic and chemical assessment is needed to fulfill validation and therapeutic consistency of authenticity criteria of drug substances or products[5].

1.2.Objectives of the Review

This review seeks to systematically compare the pharmacognostic characteristics of root extracts from selected Ayurvedic plants with recognized veterinary applications. It aims to:

- To compare pharmacognostic features of selected Ayurvedic roots.
- To analyze physicochemical and phytochemical properties.
- To evaluate therapeutic effects in veterinary applications.
- To assess standardization methods like TLC and HPTLC.
- To explore suitable veterinary formulations and delivery systems.

1.3.Importance of the Topic

Ayurvedic therapies based on plants and integrated into treating pets offer a viable, cost effective solution to the current systems where traditional medicine normally comes into play, mainly due to the increasing antimicrobial resistance levels and skyrocketing market demand of organic animal products. The safety of herbal veterinary medicine is not only ensured by standardization and pharmacognostic analysis, but also through the affordability and popularity of herbal veterinary medicine in the mainstream practice. Moreover, pharmacognostic baseline strengthens regulatory systems, as this approach allows controlling quality of commercial herbal veterinary products. With the further field development, these comparative assessments are important in supporting the integration of traditional knowledge and evidence in the modern animals health system[6].

2. PHARMACOGNOSTIC APPROACHES AND PRECLINICAL EVIDENCE FOR ROOT EXTRACT EFFICACY IN VETERINARY APPLICATIONS

This paper brings to fore the pharmacological abilities of Ayurvedic root extracts-Withania somnifera, Plumbago zeylanica and Asparagus racemosus in enhancing stressing response, immunological status, digestive, reproductive, and infectious resistance in livestock and poultry[7]. They were analyzed using methodologies that entailed macro os sharp and microscopic identification, physicochemical and phytochemical profile, and TLC and HPTLC-based standardization. Although low toxicity, cost-effectiveness and multi-target therapeutic outcomes with traditional use prevail these extracts, there is still a problem with standardized dosing, phytochemical variability, long term safety data and regulatory pathways on veterinary use.

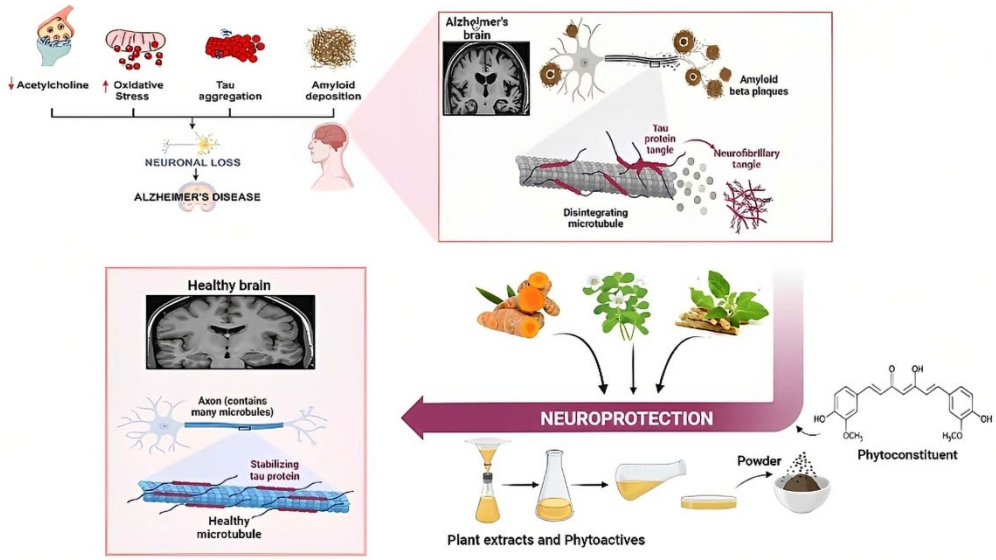

Figure 2: Neuroprotective Role of Plant Extracts Against Alzheimer's Pathology[8]

2.1.Summary of Key Research Studies

Multiple preclinical and veterinary studies highlight the pharmacological potential of Ayurvedic root extracts in animal health management:

A. Withania somnifera (Ashwagandha)

1. Modulus of Stress and Inflammation: The adaptogenic capacity of the Withania somnifera (Ashwagandha) in animals has been outlined to attenuate stress and inflammations in livestock. Interestingly, the Ashwagandha root extracts had a profound effect of inducing a reduction in serum cortisol levels in a situation of environmental and transport stress-related conditions, and this was indicative of diminished stress responses. The extract was also found to have anti-inflammatory activities by suppressing the pro-captive cytokines namely interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- a), especially in poultry and cattle. All these effects lead to an enhanced resilience and even health status in stressful situations[9].
2. Immunomodulatory Action: Ashwagandha has also been referred to as having strong immunomodulatory functions in a variety of animal models. When the extracts of the roots were administered orally in goats and poultry, there was a significant elevation of lymphocyte proliferation because of the adaptive immunity. In addition, there was also an increase in the macrophage phagocytic activity which implied innate immune reactions. This is in support of the possible benefit of Ashwagandha to augment immune system and resistance to diseases in veterinary use.

B. Plumbago zeylanica (Chitrak)

1. **Digestive health among ruminants:** Ethnoveterinary practices have been applying Plumbago zeylanica (Chitrak) as a traditional digestive health supplement in ruminants. According to feeding trials and observational studies, feeding Chitrak root extract helps in stimulating biliary secretion and increases the action of digestive enzymes like amylase and protease and it thus promotes better breakdown and absorption of nutrients. It also works on the smooth muscles in the body which enhances gut motility thus it is very useful in the treatment of diseases such as indigestion and slow rumen movement in cattle[10].
2. **Anthelmintic Properties:** In addition to its intestinal value Chitrak has proved to have good anthelmintic properties in livestock. In sheep and goats, controlled studies have revealed that use of Chitrak root extract reduces gastro intestinal parasitic load considerably especially in helminths. The phytoconstituents in the root have an anti parasite effect but a very broad margin of safety in adequate doses. This underscores the opportunity of Chitrak as an effective, naturally occurring and low-toxic alternative of synthetic dewormers in sustainable veterinary care.

C. Asparagus racemosus (Shatavari)

1. **Reproductive benefits:** Over the ages Asparagus racemosus (Shatavari) has been touted to act as an enhancer of reproductive performance in dairy cattle. And it used traditionally to increase the consistency of estrus, increase the rate of conception and improve the general reproductive health. Research indicates that Shatavari induces prolactin hormone, which is required to make milk thus enhancing lactation and enhanced milk supply in postnatal animals. Its phytoestrogenic contents also play a role in hormonal balancing, which helps in the management of dairy hormonal fertility[11].
2. **Enhancement of Immunity:** Shatavari root extract supplementation in poultry improved immune system of poultry especially the humoral immune system. Fowls fed with Shatavari had a better resistance to infection like the Newcastle disease which is a common viral infection in birds and their titers were also increased. Such immunomodulatory activities are because of the steroidal saponins and flavonoids contained in the extract which stimulate the production and efficiency of immune cells. This puts Shatavari as an appreciable natural additive in the dietary regime of poultry as a sensual disease preventer and fitness promoter[12].

2.2.Methodologies and Core Findings

- **Pharmacognostic Evaluation Techniques**

The drug products comprising Ayurvedic root extracts were gotten using pharmacognostic assessment of the roots containing macroscopic and microscopic examination to check the quality and the correct identification of the roots studied. The main macroscopic descriptors as root length, external color (e.g., brownish in the case of Withania somnifera, reddish in the case of Plumbago zeylanica), texture, strength of smell, and breakage type were registered. Microscopy under an optical microscope, through histological sections performed, portrayed peculiar anatomical characteristics of each species. Withania somnifera had starch-filled

cortex, well organized medullary rays, and travel mirrored xylem vessels. Plumbago zeylanica was typified by lignified fibers, cork cells and the well-developed secretory canal whereas Asparagus racemosus has mucilage cells, a broad cortical region and also radial vascular bundles. These Authentication and Quality Control Diagnostic characteristics factors play important roles as it pertains to veterinary herbal medicine formulation[13].

- **Physicochemical Characterization**

The procedure of physicochemical analysis of the root sample was carried out in accordance with WHO and Ayurvedic Pharmacopoeia procedures to guarantee quality and homogeneity. The most important parameters were total ash that indicates the content of all minerals and acid insoluble ash that allows determining the presence of siliceous impurities like sand or soil; moisture content which is important in the determination of the shelf life and prevention of microbial contamination. Also, alcohol and water-soluble extractive values were determined so as to identify how well active phytoconstituents could be extracted according to their polarity in order to seek proper extraction solvents during subsequent pharmacological studies[14].

- **Phytochemical Screening (Qualitative)**

The extracts of the roots were preliminarily screened phytochemically and several bioactive compounds detected through standard qualitative tests. Alkaloids were identified using Dragendorffs and Wagner whilst flavonoid identified using Shinoda test. The presence of saponins was shown by the foam test, though the presence of steroidal components was ascertained by the Salkowski test. Tannins and glycosides too were detected in some extracts indicating a wide spectrum of phytochemicals in these extracts which justify the therapeutic potential of these medicinal plants in veterinary use[15].

- **Analytical Standardization Tools**

The standardization and quality analysis of the root extracts were done within chromatographic parameters of Thin Layer Chromatography (TLC) and High-Performance thin-Layer Chromatography (HPTLC). TLC was done to optimize the mobile phase on each plant once it was done the Rf values of certain bioactive markers were identified hence preliminary identification. HPTLC was also used to determine important phytoconstituent such as withanolides in Withania somnifera, plumbagin in Plumbago zeylanica and shatavarin in Asparagus racemosus. Not only will this be able to do batch-to-batch consistency and detection of adulterants, it can allow interspecies standardization of dose in veterinary uses[16].

2.3.Strengths and Weaknesses of Current Studies

Strengths

- **Ethnoveterinary Support:** The safety and field use are supported by centuries of general use.
- **Low Toxicity:** In all studies it has demonstrated to have little side effects when used in recommended doses.
- **Multi-targeted Action:** These extracts have their impact on the modulation of various pathways (immune, digestive, endocrine) and improve the whole health of animals.
- **Economic:** Root powders and crude extracts are cost effective substitutes of synthetic veterinary medications[17].

Weaknesses

- **Nonstandardized dosing:** Since there is no standardized data on pharmacokinetics (ADME profiles) in any species, it is difficult to find the exact dose.
- **Phytochemical Content Variability:** It is inconsistent due to environmental, harvest time and post harvest-management.
- **Poor Long-term Toxicological Information:** Its chronic toxicity, genotoxicity and reproductive animal safety, are not well investigated.
- **Regulatory Gaps:** No common veterinary herbal pharmacopeia or monographs with regard to livestock uses[18].

3. PHARMACOGNOSTIC, PHYTOCHEMICAL, AND ETHNOVETERINARY INSIGHTS INTO SELECTED AYURVEDIC ROOT EXTRACTS

This chapter indicates the pharmacognostic and ethnoveterinary value of the roots of Withania somnifera, Plumbago zeylanica and Asparagus racemosus. Every species has unique morphology textural and microscopic features which are important in authentication. Their activity is attributed to their important phytoconstituents- e.g. withanolides, plumbagin, and shatavarins which make them useful in veterinary medicine as stress decreasing, digestive and reproductive stimulants[19]. The physicochemical parameters standardisation offer safety and quality. The concept of animal health Traditional applications in animals such as immune enhancement, deworming, fertility, and others are currently being validated by scientific research confirming that they comprise the basis of sustainable and effective veterinary practice.

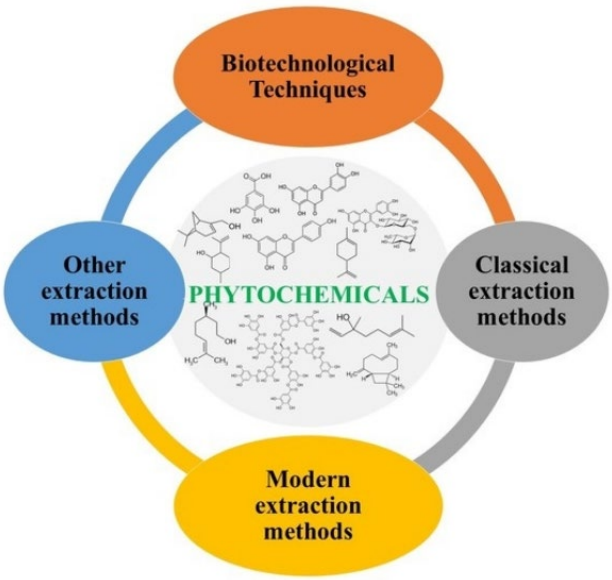

Figure 3: Phytochemical Extraction Techniques: Classical, Modern, Biotechnological, and Other Methods[20]

3.1.Morphological and Microscopic Features

Accurate morphological and anatomical identification is fundamental for the standardization and quality control of herbal formulations. The roots of each selected species show distinctive features:

- **Withania somnifera (Ashwagandha):** These roots are stout, cylindrical, brownish in color with the rough surface. They have a typical earthy smell with a bitter taste macroscopically. By microscopic study a plentiful starch-filled cortex, clear medullary rays, and pitted xylem vessels are seen. Starch granules are common in the presence of parenchymatous cells, which helps in storage of energy.
- **Plumbago zeylanica (Chitrak):** Its roots are thin, reddish brown, and are fibrous. They are multilayered and have large lignified fibers and are but numerous secretory cells filled with plumbagin under the microscope. Such structures play an essential role in the distinction between authentic Chitrak roots and the possible adulterants[21].
- **Asparagus racemosus (Shatavari):** The roots are shallow, tuberous and are generally gathered in fascicles and are pale to yellow in color. The cross-section is found to be rich in the mucilage cells which contributes towards the demulcent nature. There is also a broad cortex showing radially oriented vascular bundles and calcium oxalate crystals when observed under microscopy.

These are morphological and microscopic features that are crucial to the authentication of plants before any kind of pharmacological or veterinary use[22].

3.2.Phytochemical Profiles

This table contains the overview of the most important phytoconstituents in three well known Ayurvedic root extracts and their recognized veterinary uses. Withania somnifera has withanolides and flavonoids, which facilitate the decrease of stress and inflammation among livestock. Plumbago zeylanica is very rich in plumbagin and naphthoquinones which give it ability to promote digestive health and deworming in ruminants. Asparagus racemosus offers steroidal saponins and mucilage which have reproductive functions and also have an increase in immunity of cattle and poultry. These are the phytochemicals that lie on their ethnoveterinary application and scientific emergence of interest[23].

Table 1: Key Phytoconstituents and Veterinary Applications of Selected Ayurvedic Plants[24]

Plant Name	Key Phytoconstituents	Veterinary Application
Withania somnifera	Withanolides, alkaloids, flavonoids	Stress relief, immunomodulation, anti-inflammatory in cattle and poultry
Plumbago zeylanica	Plumbagin, naphthoquinones, tannins	Digestive stimulant, carminative, and anthelmintic in ruminants
Asparagus racemosus	Steroidal saponins (shatavarins), flavonoids, mucilage	Reproductive enhancer, lactogenic agent, and immune booster in livestock and poultry

The phytoconstituents have a role to play in the recorded pharmacological action and are used as chemical indicators of quality control. Withanolides are adaptogenic and anti-inflammatory, plumbagin is a potent digestive and antiparasitic, the saponins in Shatavari are reproductive and immune promoting.

3.3.Standardization Parameters

Standardization of herbal materials ensures reproducibility, safety, and efficacy in veterinary formulations. The following parameters are routinely assessed:

- **The Loss on Drying (LOD):** Depicts how much water is in. The lower numbers on the scale (most LOD <8%) desired to cost microbial growth and improve shelf life.
- **Total Ash:** It accounts as the quantity of inorganic substances, viz., minerals and extraneous matter. It can go to acceptable levels that are species-specific but are normally 4-10 percent.
- **Acid-Insoluble Ash:** Assists in the analysis of siliceous impurities such as sand and dirt; the low values (<1.5%) indicate high purity.
- **Water and alcohol Soluble extractive values:** The values indicate the quantity of active non-polar, polar content extracted by solvents. The larger the extractive value, the more phytochemicals are rich and have healing power.

These physicochemical standards are correlated to Ayurvedic Pharmacopoeia and WHO to maintain uniformity of every batch[25].

3.4.Ethnoveterinary Use and Scientific Evidence

The common practice of these roots in the animal health care has been highly recorded among rural and tribal people in India:

- Withania somnifera: Tribal medicine commonly used to treat antibiotics and stress-related weakness at various respiratory infections in bovines and goats. Decoctions or root powders are used in transportation or in period of stress that come by seasons to keep the immune strength.
- Plumbago zeylanica: Widely 3107-6386 as the stimulant of the digestion system in the ruminant. Chewed roots are used to make paste that is then taking orally to combat bloating, indigestion, and helminths. It is also used to mix other herbs in deworming in sheep and goats.
- Asparagus racemosus: Widespread fertility enhancer and galactagogues in beef and milk cattle. Conventional preparations are used to treat anestrus as well as to promote recovery after giving birth. Shatavari powder is added to the feed of poultry to strengthen the immunity and increase the output of the eggs.

These conventional arguments are starting to have scientific backing in the form of experimental research. An example of this could be the increased titers of antibodies in randomized trials in the poultry with Shatavari supplementation and the efficacy of plumbagin as anthelmintic in controlled studies in goats. This kind of incorporation of ethnoveterinary information with scientific evaluations can be of assistance in creating sustainable veterinary practices with a limited toxicity[26].

4. VETERINARY FORMULATION DEVELOPMENT AND DELIVERY SYSTEMS

The vet formulation development is an approach oriented towards production of safe, effective, stable veterinary dose form specific to animal, its behaviour and physiology. Veterinary products unlike the human products will have to factor in such aspects as size of the animal, digestive system, feeding patterns and stress in response to administration. Phytomedicine especially when 3107-6386 to veterinary medicine needs greater caution in terms of standardizing botanical extracts so that active phytochemicals and response is consistent. A general process of development can include the selection of proven plant materials, extraction with appropriate solvents (e.g. hydroalcoholic extraction or water extraction) that will best release active constituents and is truly the process that will give optimal yield of active constituents. The quality control tests such as a phytochemical profiling, microbial load determination and stability are performed on these extracts. The formulations are targeted to treat under the

interpretation of deworming, immunity augmentation, fertility promotion, or stress circumvention of livestock or poultry and pet animals[27].

The delivery systems adapted in the veterinary herbal preparations should be focused on the feasibilities in administering the preparations and willingness of the animals to accept the modes of delivery. Boluses, powders, syrups and feed additives all belong to oral dosage forms widely utilized because they not only are easy to administer, but adapt to feeding behavior of the animals. Mass administration in poultry or cattle are especially common with the powders mixed in feed, and with the young or weak animals with syrups. The ruminants are given a concentrated dose as boluses and in most cases, anthelmintics or minerals are added. In case of the skin problems, the ointment and creams containing herbal extract have a specific effect and minimize exposure to the system. Newer delivery methods, including controlled-release pellets, nanoparticles, and encapsulation promises to boost bioavailability and minimise dosing frequencies and enhance therapeutic precision in veterinary phytomedicine[28].

Besides formulation and delivery, shelf-life and stability is a very important aspect. Moisture, heat and microbial contamination are likely to cause degradation of herbal veterinary products and would require use of preservatives, desiccants and suitable packs. There is a need to comply with the national and international regulations on quality, safety, efficacy, and ethical utilization mandates that include the AYUSH ministry and WHO. Pharmacokinetic and field trials are more and more being included in the development chain to know the dosing pattern, absorption and therapeutic effects across the species. Finally, blending of ethnoveterinary practice with commercial pharmaceutical technology enables the creation of credible and convenient herbal veterinary formulae in sustaining livestock and poultry health management.

Table 2: Summary of Pharmacognostic and Phytochemical Studies of Selected Medicinal Plants[29]

Author(s)	Study Title	Focus Area	Methodology	Key Findings
Prakash et al. (2019)[30]	Development and standardization of quality control parameters of different parts of Trianthema portulacastrum L.	Pharmacognostic standardization	Macroscopic, microscopic, physicochemical, and phytochemical evaluation	Established standard pharmacognostic and quality control parameters for various plant parts.
Pratap et al. (2021)[31]	Pharmacognostical and phytochemical studies of Mollugo nudicaulis Lam.	Identification of controversial Ayurvedic drug	Morphological, microscopic, and preliminary	Confirmed diagnostic characters and presence of key

			phytochemical screening	phytoconstituents supporting its identity and medicinal value.
Ray & Rahaman (2018)[32]	Pharmacognostic standardization and phytochemical investigation of Cajanus scarabaeoides	Standardization and compound profiling	Microscopy, physicochemical analysis, TLC for phytochemicals	Identified pharmacognostic features and presence of alkaloids, flavonoids, and saponins.
Sampath et al. (2023)[33]	Variations in the pharmacognostic properties of Aegle marmelos from five regions of Sri Lanka	Geo-botanical pharmacognostic variation	Collection from different sites, comparative anatomical and physicochemical evaluation	Significant inter-regional variation in diagnostic and physicochemical properties noted.
Shaheen et al. (2018)[34]	Comparative pharmacognostic evaluation and standardization of Capsicum annuum L.	Quality control of herbal spice	Morphological and microscopic study, ash value, extractive values, fluorescence analysis	Provided comprehensive quality standards for C. annuum as a medicinal and spice pl

5. DISCUSSION

Withania somnifera, Plumbago zeylanica, and Asparagus racemosus have been recommended as battlefield drugs with great promise as marginally field-tested veterinary medications by pharmacognostic, phytochemical, and preclinical evidence which is noted in this review[35]. The roots present cheap natural alternatives to synthetic medicines especially in organic and rural livestock systems. Nonetheless, there exist loopholes of undefined doses, lack of records on its long-term safety, diversity in phytochemicals, ineffective regulations among others as well as the necessity to be innovative in formulations. These issues, that is, by conducting pharmacokinetic research, standardized propagation, clinical studies and policy formulation, will be important when aiming to integrate Ayurvedic plant-based medicine into modern veterinary practice.

5.1 Interpretation and Analysis of the Findings

The comparative pharmacognostic and phytochemical analysis of Withania somnifera, Plumbago zeylanica and Asparagus racemosus puts forward the importance of the field in veterinary care. The roots also have clear morphological and microscopic characteristics that can help in an authentication of the botanical basis which helps in avoiding adulteration and

improve how the formulation is made. Phytochemical studies established the absence of major bioactive compounds-including withanolides, plumbagin and shatavarins-related bioeffects of adaptogenic, digestive, reproductive and immuno-modulatory effects in animals[36]. These advantages were supported by preclinical trials in animal species such as the cattle, goats, and poultry, showing enhanced stress resistant, immune competence, digestive, and reproductive efficiency. The identity and concentration of the active constituents and quality control through physicochemical parameters such as ash content and extractive values were done by standardization techniques, i. e. TLC and HPTLC. Also the development of species specific dosage forms which includes animal powders, boluses and syrups has improved effectiveness and therapeutic compliance of practical veterinary practice[37].

5.2 Implications and Significance

Special implications are attached to the findings of this review in regard to the development of herbal veterinary medicine. Incorporation of standard Ayurvedic root extracts into the veterinary practice as a natural, cost effective alternative to synthetic drugs would be quite relevant especially in the context where there is increasing antimicrobial resistance and the demand is on the rise of organic, residue free animal products[38]. These are the natural remedies 3107-6386 in livestock management, which are favorable and useful in the rural areas where there might be a scarcity of modern medications. Also, the review suggests that there should be a harmonization between ethnoveterinary knowledge and advanced pharmacognostic and pharmacological validation. The scientific assessment of indigenous formulations may result in a formalization of the same through formal commercialization in controlled contexts, a move that will not only safeguard animal health, but that to the growth of economies in rural areas without endangering biodiversity conservation efforts.

5.3 Gaps and Future Research Directions

Although the results are encouraging, there is a number of gaps, which should be filled in to facilitate the implementation of standardized Ayurvedic root extracts in veterinary medicine:

- **Absence of Standardization of Doses:** In most experiments, the effect of time and variable amounts on the doses cannot be determined because there is no standard dosage between animals under different species, age, and physiological status. These pharmacokinetic investigations (involving absorption, distribution, metabolism, and excretion) are necessary to scale efficacy and decrease the risks[39].
- **Other One possibility is the Limited Long-Term Toxicity Data:** there are limited available data in long-term benefits. Increased chronic safety, enhanced toxicity studies such as studies of genotoxicity, reproductive toxicity and chronic exposure are needed urgently.
- **Phytochemical Composition variability:** Phytoconstituent levels largely depend on environmental and geographical factors. The creation of chemo ctaxonomic and

genomic tools should ensure quality stabilization and the appearance of new elite cultivars that are more medicinally valuable.

- **Regulatory and Legal Voids:** A special veterinary herbal pharmacopeia or a set of veterinary herbal monographs to be 3107-6386 as livestock pharmacopeia is in giant void. This hinders the systematical advancement and marketing of the products. Common rules to approve, label, and advise on the usage of herbal drugs among veterinary drug usage should be conducted.
- **Formulation Innovation:** New delivery approaches like nanoformulations, bio encapsulation and slow release pellets and the likes needs to be further exploited to improve bioavailability and targeted delivery in animal systems.

Human studies in different livestock population with large scale trials, the interaction effects of combinations of polyherbs (synergies) and regulatory regimes need to be developed in future. Research ventures between ethnobotanists, pharmacologists, veterinarians as well as industry players will be crucial toward rendering these findings into the routine veterinary practice[40].

6. CONCLUSION

The given review highlights a significant potential of Ayurvedic root-derived medicines, such as Withania somnifera, Plumbago zeylanica and Asparagus racemosus, as alternative solutions to usual veterinary medicines that are safe and sustainable. Careful pharmacognostic and phytochemical analysis indicates their distinct morphological characteristics and rich content in important bioactive substances, especially withanolides, plumbagin, and shatavarins, which makes them help treat animals with adaptogenic, immune-modulating, gastrointestinal, and reproductive effects in different animal models, including cows, goats, and chicken. The identity, purity and consistency of these herbal preparations is also achieved by application of standardization techniques e.g. TLC and HPTLC and physicochemical profiling. A rising interest in herbal veterinary medicine is also highlighted by the review in terms of increasing antimicrobial resistance and consumer interest in residue-free animal products, along with difficulty of veterinary access in rural areas. However, there are a few gaps: dose-related studies, extended surveillance activities, novel products, and standard jurisprudence specially formed to fit animal health are needed to realize the potential. Collaborative/interdisciplinary research should be conducted in the future to establish validated, safe, and efficacious herbal veterinary medicines that can be suited to combine the ancient wisdom of traditional medicine with the sciences of modern veterinary medicine, eventually leading to better animal health and sustainable livestock activities.

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