International Journal of Pharmacognosy and Herbal Drug Technology (IJPHDT)
ISSN: 3049-1630, Vol.02, Issue No. 08, 2025 (pp.120-133)
AKT PUBLICATION
ORIGINAL ARTICLE
https://www.aktpublication.com/index.php/ijphdt

Exploring Traditional Chinese Medicinal Plants Through Modern Pharmacognostic Approaches: An Animal-Based Perspective

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ABSTRACT

Traditional Chinese Medicine (TCM) plants have been known to confer beneficial therapeutic effects in the traditional systemic Chinese Medicinal, but a science-based verification is important to offer evidence-based utilization. This review will cover or discuss the pharmacological prospect of TCM plants, including Andrographis paniculata, Glycyrrhiza glabra, Scutellaria baicalensis, astragalus membranaceus, ginkgo biloba and panax ginseng using the preclinical study in animals. These investigations indicate a high level of antiviral, anti-inflammatory, immuno-modulator, anti-oxidant, heendoguinative proteomin and neuro-protection, which have been explained through recent pharmacognostic strategies such as phytochemical screening, chromatographic studies, in-vitro tests, as well as molecular analyses. Although translation into humans is impeded by species-specific effects, complex, formulations and reproducibility, the incorporation of standardized extracts, high- fidelity disease models, and increasing ethical options all improve the translational significance. The results indicate the possible potential in TCM plants as evidence-based human and veterinary medicines and point to possible areas of future intensive preclinical and clinical studies.

Key Words:

Traditional Chinese Medicine, Animal Models, Pharmacognostic Approaches, Antiviral, Anti-inflammatory, Antioxidant, Hepatoprotective, Neuroprotective.

Article History:

Received April 13, 2025

Revised June 18, 2025

Accepted July 19, 2025

Published Aug. 21, 2025

DOI: https://doi.org/10.64063/30491630.vol.2.issue8.10

1. INTRODUCTION

Animals models have been considered as a critical contributor to biomedical research with ability to provide a controlled platform on which the efficacy, safety, and the functions of therapeutic agents are conducted. Regarding the Traditional Chinese Medicinal (TCM) plants, animal studies provide an opportunity to understand hard-to-understand pharmacological activities, i.e., antiviral, anti-inflammatory, antioxidant, and immunomodulatory properties in reproducible conditions of experiments[1]. Among these preclinical models, those offered by rodents, poultry, and aquatics, give the opportunity to investigate dosage, bioavailability, and possible toxicity before being

transferred to a human or veterinary setting, bridging this gap between the empirical knowledge and scientific validation[2].

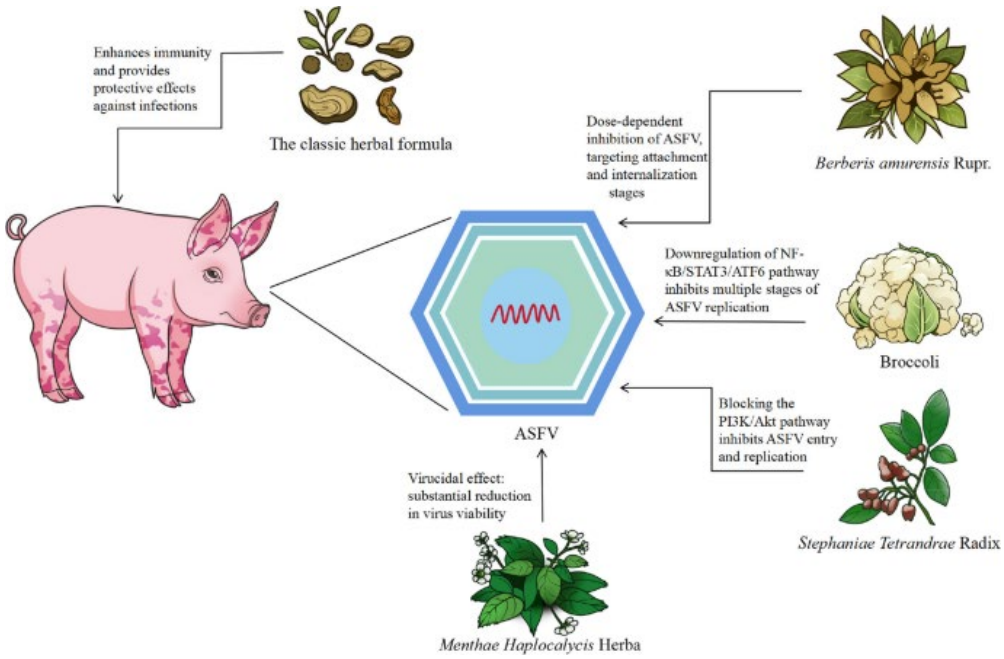

Figure 1: Traditional Chinese Medicinal Plants[3]

Also, the animal-based research approach provides the possibility of elaborated mechanistic research which is impossible to undertake in human cases, namely, tissue-specific studies, enzyme activity determination, cytokine characterization, and histopathologic assessment. With the choice of animal models and a methodical process of studying TCM plants, it is possible to define the active compound and the mechanism of its action, and evaluate the efficiency of its implementation in disease-specific conditions. Such research does not just enhance the scientific validity of traditional medicine but gives important preclinical data to drive the future of new, evidence-based treatment of humans and veterinary medicine[4].

1.1 Background and Context

TCM plants have been exploited in the human and veterinary medicines over the centuries because of their broad based pharmacological effects, such as antiviral, anti-inflammatory, antioxidant, hepatoprotective, and immunomodulatory effects. They are used under the support of the empirical knowledge, however, are necessary scientific verification to provide safety, efficacy, and reproducibility[5]. Animal models provide a pre-eminent linkage between conventional knowledge and the newer scientific research, provide controlled examination of pharmacologic effects, dose-response relationships and mechanistic pathways that are otherwise hard to examine in humans. These are preclinical models comprising rodents, poultry, and fish where the effect of short-term and long-term exposure of TCM extracts receives a valuable clue[6].

1.2 Objectives of the Review

The primary objectives of this review are:

- To summarize animal-based studies on TCM plants' pharmacological activities.

- To evaluate antiviral, anti-inflammatory, immunomodulatory, antioxidant, and hepatoprotective effects.
- To analyze modern pharmacognostic methodologies used in TCM research.
- To identify research gaps and translational limitations.
- To suggest future directions for standardized, evidence-based TCM therapeutics.

1.3 Importance of the Topic

The use of systematic animal models to study TCM could further than only confirming traditional medicinal statements since it helps in finding new therapeutic ideas in this plant. Results of these preclinical studies can be used in veterinary medicine as well as human medicine to steer the process of creating evidence-based solutions and the decision to implement the traditional remedies in contemporary medicine[7].

2. PRECLINICAL EVALUATION OF TRADITIONAL CHINESE MEDICINAL PLANTS: ANIMAL MODELS AND PHARMACOGNOSTIC APPROACHES

TCM have shown anti-SARS effects in vitro and in vivo but not in humans by modifying the effects of antiviral, immunomodulation, flexible, and hepatoprotective capabilities in Andrographis paniculata, Glycyrrhiza glabra, Scutellaria baicalensis, and Astragalus membranaceus[8]. The techniques of contemporary pharmacognostic like phytochemical screening, chromatographic analyses, in vivo studies as well as molecular studies have assisted in determining their mechanisms of action. Although species differences, dose restriction, and ethical issues are limiting factors, controlled animal studies are valuable with regards to preclinical data that helps underline the therapeutic promise of such plants.

2.1 Key Research Studies on TCM Plants in Animal Models

Animal model studies have been done famously on the Traditional Chinese Medicinal (TCM) plants to determine their pharmacological potential mostly in antiviral, immunomodulatory and hepatoprotective aspects[9].

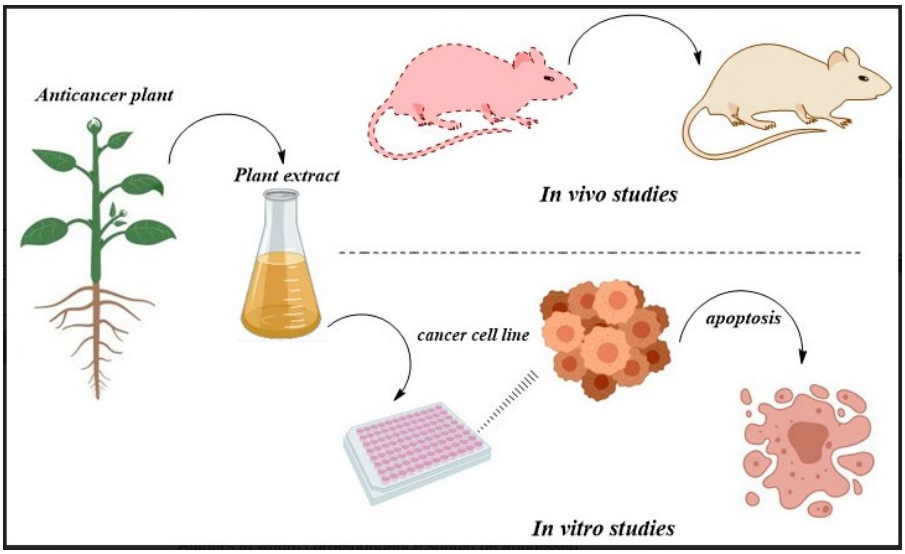

Figure 2: Anticancer Plants[10]

- **Andrographis paniculata:** In poultry, literature has shown that extracts of Andrographis have boosted innate and adaptive immune responses. Namely, in a Newcastle Disease Virus (NDV) infection models, Andrographis supplementation resulted in a higher antibody titre and survival rate. Mechanistic research indicates that such effects occur through the stimulation of macrophage and the regulation of cytokine production enabling the bird to increase its antiviral protection ability[11].
- **Oscarum Oscimum (Licorice):** Licorice root extracts are associated with considerable anti inflammatory and antiviral activity in murine models. Experimental infections with virus like influenza and herpes simplex found that glycyrrhizin which is one of the key bioactive compounds have the potential to inhibit the replications of virus and cause the viral load to decrease. It also dampens the immune response of the host tissue, keeping levels of pro-inflammatory cytokines low and increasing the balance of regulatory cytokines, thus preventing detrimental tissue damage resulting through over-inflammatory responses.
- **Scutellaria baicalensis:** Branded as the flavonoid component plant that contains higher amounts of flavonoid compounds such as baicalin and wogonin shows hepatoprotective and an antioxidant effect in rodents. In in vivo liver injury models caused by toxins (carbon tetrachloride), administration of Scutellaria extracts resulted in a considerable decrease in markers of oxidative injury, lipid peroxidation, and pro-inflammatory cytokines whereas liver histology was improved. Such results have indicated possible therapeutic applications in liver related to oxidative stress[12].
- **Astragalus membranaceus:** Astragalus extracts have been shown to induce the humoral and cellular immune responses in experimental models of bacterial and viral infection and are very widely used in TCM as an enhancer of immune function. The literature indicates the proliferation of lymphocytes, production of high antibody response and regulation of inflammatory mediators, indicating that there is twofold quality of enhancing host defense and dampening inflammation.

2.2 Pharmacognostic Methodologies

Contemporary phytochemical applications embody the ancient wisdom of plants with the emerging high tech laboratories to further test the bioactivity of natural products in animal models:

- **Phytochemical Screening:** Both qualitative and quantitative methods are used to detect bioactive secondary metabolites which are flavonoids, saponins, alkaloids, terpenoids and polysaccharides. Colorimetric assays, thin-layer chromatography (TLC), and spectrophotometry are methods to enable a rapid profiling and standardization of plant extracts[13].
- **Chromatographic techniques:** Ultra-Performance Liquid Chromatography (UPLC), - High-Performance Liquid Chromatography (HPLC) and - Gas Chromatography-Mass Spectrometry (GC-MS) are standardized techniques to use in determining phytochemicals with precision and accuracy. These tools enable scientists to link individuals compounds to observed biological results making the results repeatable and ensuring quality control between the studies.

- **In Vivo Pharmacological Assays:** Viral diseases, rodent disease, poultry and fish disease models are conducted to determine antiviral, anti-inflammatory, antioxidant and immunomodulatory activity. These models enable dose-response, time-course and local organ-specific outcome testing which are important preclinical demonstrations of efficacy[14].
- **Biochemical and Molecular Analyses:** Among the mechanistic studies, the measurements of the activities of enzymes, markers of oxidative stress (MTD, superoxide dismutase), cytokine profile, and gene expression are common. Molecular pathways of the action of TCM extracts are explained using the methods of ELISA, RT-PCR, Western blotting, and immunohistochemistry[15].

2.3 Critical Evaluation of Methodologies

The pharmacognostic investigations on animals, being of great mechanistic interest, are not without shortcomings:

- **Species-Specific Responses:** The physiology of animals is generally not similar to those of the human and may change in an aspect of absorption, metabolism and response to the immune system. The extrapolation of efficacious doses and safety anticipations in humans should be done prudently[16].
- **Dosage/Duration issues:** Most studies use high doses on time-limited interventions, which are not all relevant to chronic exposures or clinical relevance. There is a tendency to under investigate long-term toxicity and pharmacokinetics.
- **Ethical Considerations:** Ethical concerns are posed by the invasiveness of the procedures, large doses administered, and generation of a disease, which requires following a strict set of rules of animal welfare.

Notwithstanding these constraints, animal models have several significant strengths: they can be tested under controlled experimental conditions; analysis can be invasive without being possible in human models; and have value in providing foundation evidence on which subsequent investigations can build. Combination of animal data, current pharmacognostic methods guarantees strong materials, scientifically justified, with reference to the therapeutic potential of the TCM plants[17].

3. THERAPEUTIC AND PROTECTIVE EFFECTS OF TCM PLANTS IN PRECLINICAL ANIMAL MODELS

Andrographis paniculata, Glycyrrhiza glabra, Scutellaria baicalensis, Astragalus membranaceus, Ginkgo biloba, and Panax ginseng are traditional Chinese Medicinal (TCM) plants with a wide therapeutic potential in animal models. They exhibit antiviral, anti-inflammatory, immunomodulatory, antioxidant, hepatoprotective, and neuroprotective properties through immune moderation, the alleviation of oxidative stress, liver and neural tissue protection, and disease survival and cognitive improvement, making them potentially valuable during the management of disease and neurodegenerative processes[18].

3.1 Antiviral Potential of TCM Plants in Animals

Various plants of TCM have exhibited good antiviral effects in experimental research on different animal models. Extracts high in flavonoids (Andrographis paniculata, Scutellaria baicalensis) have shown viral replication inhibitory, viral load reduction, and improved survival in models of pathogenlike Newcastle Disease Virus, influenza virus, and herpes simplex virus. The Glycyrrhiza glabra saponins also showed direct antiviral action interrupting the entry process as well as the viral cycle[19]. Mechanically these plants upregulate host immunity by increasing macrophage and natural killer cell activation, inducing antiviral cytokines like the interferons as well as influence responses to inflammatory mediators to offer a two pronged effect of inhibition of the virus as well as a boost of immunity at host level.

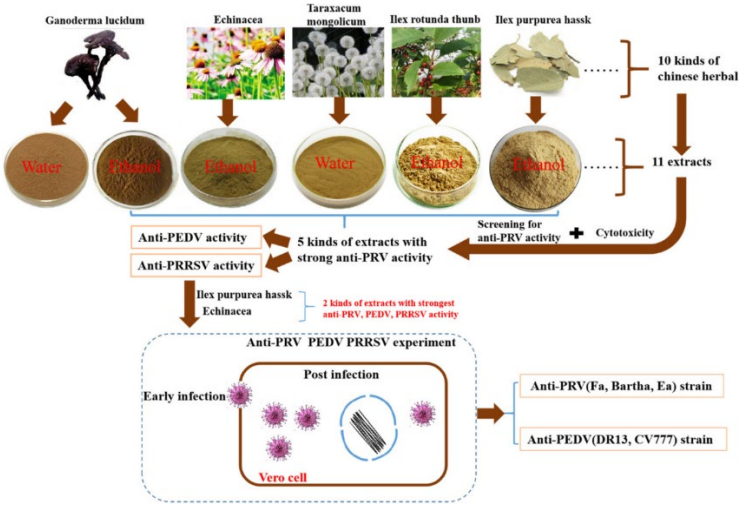

Figure 3: Chinese Herbal Extracts with Antiviral Activity[20]

3.2 Anti-Inflammatory and Immunomodulatory Effects

TCM plants are well known to have immune regulating qualities and to inhibit inflammation. Extracts of Astragalus membranaceus and Licorice (Glycyrrhiza glabra) are found to reduce pro-inflammatory cytokines levels (TNF-alfa, IL-6, and IL-1 epsilon), in a rodent and avian model. Adaptive immunity is also enhanced in these plants (proliferation of lymphocytes, etc.). These immunomodulating effects can improve resistance to viral and inflammatory agents and tissue damage and make them favorable supportive therapies in the care of diseases[21].

3.3 Antioxidant and Hepatoprotective Activities

Oxidative stress is an otherwise widespread mechanism of tissue damage and chronic illness. Flavonoid-enriched Scutellaria baicalensis, with baicalin and wogonin as main components of flavonoid, exhibits strong antioxidant properties in liver injury models of chemical toxins or viral infections. The Scutellaria extracts used as a therapy are effective in relieving a mark of oxidative damage malondialdehyde (MDA) and improving activity of endogenous antioxidant enzymes such as superoxide dismutase (SOD) and catalase. As indicated in histopathological examinations, there is better liver architecture and less inflammation, thus indicating a hepatoprotective property that may reduce tissue damage due to oxidative stress[22].

3.4 Neuroprotective and Cognitive Effects in Animal Models

Recent research shows that some TCM plants can have neuroprotective effects on decreased neuroinflammation and oxidative stress of the central nervous system. Plant extracts of species like Ginkgo biloba, Panax ginseng, and Scutellaria baicalensis have also been demonstrated to increase learning, memory and cognitive performances through rodent models. The effects have been attributed to the inhibition of markers of neuroinflammation, depletion of reactive oxygen forms in the neurological system, and the increase of neurotrophic factors. These results give reason to believe that TCM plants may be used as adjunct governments to the management of neurodegenerative diseases or cognitive decline, but additional investigations are required to determine clinical importance[23].

4. CHALLENGES AND FUTURE PERSPECTIVES IN ANIMAL-BASED TCM RESEARCH

TCM studies of lab animals have played an important role in learning the pharmacological properties of medicinal plants, though their use has been complicated by constraints including variation in species, the complexity of herbal concoctions, the standardization of doses, ethical and safety issues, absence of disease models and replicatability concerns, thus hampering translation to humans[24]. Future prospects are incorporation of novel technologies, refinement of models of disease, harmonization of extracts, across-preclinical-clinical translation, implementation of ethical approaches, and investigation of synergistic actions all of which can increase the validity, translational feasibility and evidence-based use of TCM therapeutics[25].

4.1 Challenges in Animal-Based TCM Research

Animal models have played a key role in unraveling the pharmacological actions of Traditional Chinese Medicinal (TCM) plants, though many pitfalls have restricted such findings and translational properties:

- **Species-Specific Differences:** Physiologically, metabolically and immunologically, animals are different than humans, and this can cause interspecific variability in absorption, distribution, metabolism and excretion of drugs. This also complicates extrapolation of its good doses, toxicity, and treatment related therapies between animals to humans[26].
- **Complexity of Herbal Preparations:** TCM preparations usually include a variety of bioactive compounds that have a synergistic impact. It is still a major challenge in animals' studies not to replicate the exact composition, standardize the extracts, and determine which compounds bring about seen effects[27].
- **Dosage and Administration Problems:** A consequence of studying a limited number of doses and a short time period in many preclinical experiments is the question of whether the dose that results in a measurable outcome is clinically meaningful and whether the corresponding dose and schedule in humans is relevant. Chronic toxicity, cumulative effects, long-term pharmacokinetics are not often studied.
- **Regulatory and Ethical concerns:** The practice of more invasive procedures, contracting diseases or high dosages brings ethical concerns into the picture and the animal welfare

rules and regulations must be strictly followed. These can restrict the experimentation and sample sizes[28].

- **Restricted Disease Models:** A number of specific human diseases, especially the complex chronic diseases, cannot be recreated properly in an animal model. This may limit insight into long-term therapeutic effects or into multifactorial diseases.
- **Reproducibility and Standardization:** Animal strain, environmental effects, and extraction approach may all influence the outcomes of an experiment raising questions relating to reproducibility of the results between laboratories.

Table 1: Key Literature on Traditional Plants, Foods, and Ancient Remedies[29]

Author(s)	Study	Focus Area	Methodology	Key Finding
Penerbit, U. M. T. (2021)[30]	Antidiabetic Property of Medicinal Plants in Malaysia	Traditional medicinal plants for diabetes management	Experimental studies on bioactive plant compounds	Bioactive compounds in plants demonstrated hypoglycemic effects, supporting their use as natural antidiabetic agents
Prathapachandran, N., & Devadas, V. (2023)[31]	Sustainable and traditional agricultural practices to reinforce income dynamics among tribal communities in Wayanad, Kerala, India	Integration of traditional and sustainable agricultural practices	Field study and literature review of tribal farming practices	Traditional practices improved income, crop productivity, and environmental sustainability
Rajendram, R., Preedy, V., & Patel, V. (2023)[32]	Ancient and Traditional Foods, Plants, Herbs and Spices Used in the Middle East	Historical, nutritional, and medicinal significance of traditional foods and plants	Comprehensive literature review	Traditional knowledge maintained health and well-being and highlighted nutritional and medicinal value of natural resources
Redman, W. K., & Rumbaugh, K. P. (2019)[33]	Are Ancient Remedies the New Answer to Fighting Infections?	Ancient remedies and alternative approaches to combat infections	Literature review and preclinical studies on natural compounds and nanotechnology	Ancient remedies showed antimicrobial efficacy and potential as complementary or alternative therapies, especially against MDR pathogens

4.2 Future Perspectives

Nonetheless, there is massive potential in the area of animal-based TCM research, and multiple measures that can be taken to boost its scientific validity and its changes in translational value:

- **Intervention with Advanced Technologies:** Blending animal studies with the use of modern pharmacognostic methods, including, high-throughput screening, metabolomics, proteomics and gene expression profiling, is likely to facilitate the discovery of active compounds and mechanism of action in a better definition[34].
- **Better Disease Models:** The enhancement of genetically engineered or humanized bi-modal animal models can allow more realistic representation of human disease to evaluate efficacy and safety more accurately.
- **Standardization of Extracts:** Standardization and rigorous quality control procedures in herbal extracts make the extracts structurally standardized according to their composition as well as biodoactivity, making them replicable within studies.
- **Bridging Preclinical and Clinical Research:** Systematic translation of preclinical data to in vitro, and in vivo, drug testing data Either a systematic integration with preclinical data, structuring and translation to in vitro, or in vivo, drug testing data will help to validate results, streamline dosing regimens and expedite the process of translating TCM therapy to human application.
- **Ethical Innovations:** Ethical innovations leading to the organ-on-a-chip model, 3D cell cultures, genetic simulations, and computational simulations all have the potential of decreasing the number of animal experiments needed to obtain mechanistic understanding.
- **Understanding the Synergistic Interactions:** Future research can be aimed at elucidating synergistic interactions between bioactive compounds within multi-herb formulations which are a key component of TCM theory but have not been explored well to date in pre-clinical studies.

Although animal-based research is vital in the confirmation of the pharmacological potentials of the TCM plants, issues to do with species variations, dosage consistency, ethical concerns and reproducibility must be considered vital. Combination of modern technologies, better disease models, and validation of protocols will make the future of TCM research more reliable and translational, an avenue to evidence-based therapeutic application[35].

5. DISCUSSION

The preclinical studies reviewed show that TCM plants, such as Andrographis, Glycyrrhiza, Scutellaria, Astragalus, Ginkgo, and Panax, are antiviral, anti-inflammatory, immunomodulatory, possess antioxidant, hepatoprotective, and neuroprotective effects in experimental animals. Those results confirm classic statements, identify processes like cytokine modulation and antioxidant improvement and justify the presence of possible veterinary uses and human use. There are however challenges such as those that deal with species differences, complex formulations, lack of chronic safety data, and challenges of reproducibility. Future directions must be based on better disease models, standardised extracts, enhanced mechanistic studies, ethical parallels, and clinical translation to support fully on the therapeutic benefits of TCM plants[36].

5.1 Interpretation and Analysis of Findings

The preclinical literature reported in this paper illustrates the fact that TCM plants such as Andrographis paniculata, Glycyrrhiza glabra, Scutellaria baicalensis, Astragalus membranaceus,

Ginkgo biloba, Panax ginseng have exhibited high pharmacological activities in animal models. These are antiviral, anti-inflammatory, and immunomodulating, antioxidant, hepatoprotective and neuroprotective. These documented antiviral activities, especially in poultry and rodent models, outlined that flavonoids and saponins have the potential to directly interfere with viral replication and help boost immune defenses of the host at the same time. In the same way, the important potentials of these plants in the context of immunomodulators and anti-inflammatory indicate the capacity of these plants to modulate, inhibit cytokine secretion, activate adaptive immunity, and decrease tissue destruction. Liver injury caused consistent antioxidant and hepatoprotective effects in animal models of liver injury, as assessed by histopathological, and labelled reductions of oxidative stress markers. TCM plants have neuroprotective effects as observed in rodent models that can make it possible to reduce neuroinflammation and enhance cognitive ability, hence its possible expanded therapeutic use[37].

5.2 Implications and Significance

These results justify the role of animal studies in confirming traditional herbs and clearing the mode of action of TCM herbs. The therapeutic use of these has a scientific basis in that mechanistic animal studies have identified cytokine modulation, antioxidant enzyme expression, and neurotrophic factors upregulation as possible mechanisms of action. This in vitro data holds the promise of clinical use in veterinary and human fields, especially in treatment of viral and inflammatory diseases, liver diseases, and neurodegenerative diseases. Moreover, it is noted in these studies that modern methods of pharmacognosy need to be employed to get standardized evaluation of plant products e.g. phytochemical screening, chromatographic analyses and molecular assays[38].

5.3 Research Gaps

Irrespective of these positive results, a number of gaps are still present. Direct extrapolation of dose, pharmacokinetics and efficacy between animal models and human is restricted due to species-specific differences. The active constituents of multi-compound TCM formulation are difficult to identify, and there is a problem of synergistic effects. Ethical and regulatory limitations census diverse experimental designs, and variable mockeries of long-term safety, chronic toxicity and pharmacokinetic profiles are under-investigated. Further, animal models of disease might not be completely suitable to model complex human pathologies and hence limits the evaluation of long-term or multifactor effects[39].

5.4 Future Research Directions

Future research must be aimed towards a better representation of clinical situations in the disease model, such as with humanized or genetic engineering of animals. Extract standardization and high-quality control are essential factors in reproducibility and translational relevance. Mechanistic knowledge can be advanced by combining new technologies like metabolomics, proteomics and gene expression profiling, in the identification of bioactive compounds. Ethically alternative tools, such as organ-on-a-chip systems, 3D cell cultures, and modeling with computer can be used as tools that will help to reduce animal tests and offer their complementary information. Also, the study on synergistic effects between the combination of compounds in

multi-herb formulas is mandatory to be able to comprehend the healing capacity of TCM plants. Standardized translation of preclinical results using animal models to both in vitro and early-stage clinical trials will result in more evidence-based TCM drug development[40].

6. CONCLUSION

Traditional Chinese Medicinal (TCM) plants such as Andrographis paniculata, Glycyrrhiza glabra, Scutellaria baicalensis, Astragalus membranaceus, Ginkgo biloba, Panax ginseng have a substantial antivirus, anti-inflammatory, immunomodulatory, antioxidant, hepatoprotective, and neuroprotective effects based on the findings of animal preclinical studies. These experiments confirm conventional medicinal effects and clarify their underlying mechanisms, including cytokine-balancing, antioxidant enzyme induction, and up-regulation of neurotrophic factors, their therapeutic significance in viral infections, inflammatory disorders, liver diseases, and neurodegenerative diseases. Although issues such as species-specific effects, highly complex multi-compound formulations, less chronic safety data, and reproducibility can be associated with AMTs, incorporation of contemporary pharmacognostic tools and techniques, including phytochemical profiling, chromatographic analysis, in vivo pharmacology and molecular evaluation, strengthens the validity and clinical application of studies. Future avenues that aim to standardize the extracts, enhance the disease models, further mechanistic analysis, ethical substitutes, and methodical bridge with clinical research are needed in order to maximize the potential of TCM plants as evidence-based therapeutics in human and veterinary medicine.

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