

A Review of the Pharmacological and Toxicological Profiles of Selected Botanical Extracts in Experimental Animal Models

Anamika¹ and Dr. Nikhil Dadarao Amnerkar²

¹Research Scholar, Department of Pharmacy

²Professor, Department of Pharmacy

Sunrise University, Alwar, Raj., India

Abstract: Botanical extracts have gained considerable scientific attention as potential sources of therapeutic agents because they contain diverse bioactive compounds with antioxidant, anti-inflammatory, antimicrobial, analgesic, hepatoprotective, nephroprotective, and other pharmacological properties. Experimental animal models play an important role in investigating these effects and evaluating the safety of plant derived preparations before their potential translation into human clinical research. However, the biological activity and toxicity of botanical extracts can vary considerably depending on plant species, geographical origin, extraction methods, phytochemical composition, dose, route of administration, and duration of exposure.

Keywords: Botanical Extracts, Pharmacological Activity, Toxicological Evaluation, Experimental Animal Models, Phytochemicals

I. INTRODUCTION

Medicinal plants have been used in traditional healthcare systems for centuries and continue to serve as important sources of compounds for pharmaceutical research. Their therapeutic potential is associated with a wide range of naturally occurring constituents, including alkaloids, flavonoids, phenolic acids, terpenoids, tannins, glycosides, and essential oils. These compounds may influence multiple biological pathways, including oxidative stress, inflammatory responses, cellular signaling, microbial growth, and metabolic regulation. The increasing interest in plant-derived medicines has encouraged systematic investigation of their pharmacological properties and toxicological limitations using experimental models.

Experimental animal studies provide a means of examining biological responses in an integrated organism, including interactions among the liver, kidneys, cardiovascular system, immune system, and other physiological processes. Such studies can help researchers investigate preliminary therapeutic activity, characterize dose-related adverse effects, identify potential target organs, and establish exposure ranges for subsequent research. Nevertheless, findings from animal models cannot automatically be generalized to humans because species differences in metabolism, absorption, distribution, and excretion may substantially influence both efficacy and toxicity.

The selection of botanical extracts for pharmacological investigation requires careful attention to botanical authentication, plant parts, extraction solvents, preparation procedures, and chemical standardization. For example, aqueous and alcoholic extracts obtained from the same plant may contain different proportions of active constituents and may consequently produce different biological effects. Similarly, variations in cultivation, harvesting, storage, and processing can influence phytochemical concentrations. Without adequate characterization, it becomes difficult to compare findings across studies or determine whether observed effects are attributable to specific compounds, interactions among constituents, or nonspecific biological responses.

Toxicological assessment is equally important because some plant-derived substances can produce adverse effects at particular doses or under prolonged exposure. Potential concerns include gastrointestinal disturbances, liver and kidney injury, reproductive or developmental effects, neurological changes, and interactions with conventional medicines. Contamination, adulteration, and variability in product composition may introduce additional risks. Therefore, pharmacological benefits should be interpreted alongside systematic safety findings rather than considered independently.

This review discusses selected botanical extracts that have received attention in experimental pharmacology, focusing on their reported therapeutic activities, major phytochemical constituents, potential toxicological concerns, and the methodological requirements for evaluating their safety. It also identifies research gaps and proposes priorities for improving the reliability and translational relevance of preclinical botanical research.

PHARMACOLOGICAL PROFILES OF SELECTED BOTANICAL EXTRACTS

1. *Curcuma longa* (Turmeric)

Curcuma longa, commonly known as turmeric, contains curcuminoids, particularly curcumin, which have been investigated for antioxidant, anti-inflammatory, antimicrobial, and organ-protective activities. Experimental studies suggest that turmeric-derived preparations may influence inflammatory mediators and oxidative stress pathways. Animal models of inflammation, arthritis, metabolic disturbances, and organ injury have been used to investigate these effects. However, the results depend on the extract composition, dose, route of administration, and bioavailability. A review published in 2023 describes its diverse pharmacological potential while emphasizing the need for better quality control and further evaluation of therapeutic applications.

Toxicological evaluation is essential because different turmeric formulations cannot be assumed to have identical safety profiles. A 90-day repeated-dose study of a standardized turmeric extract, NR-INF-02, in Wistar rats reported no major treatment-related clinical, biochemical, or histopathological abnormalities at the tested doses of 250, 500, and 1,000 mg/kg/day. The investigators established a no-observed-adverse-effect level (NOAEL) of 1,000 mg/kg/day for that particular preparation under the study conditions. This result should not be applied automatically to all turmeric extracts or human doses.

2. *Azadirachta indica* (Neem)

Azadirachta indica is widely investigated for its antimicrobial, anti-inflammatory, antioxidant, and metabolic effects. Neem leaves, bark, seeds, and oils contain chemically diverse constituents, including limonoids and other bioactive compounds. Experimental models have been used to investigate possible effects on microbial infections, inflammatory responses, glucose regulation, and tissue injury. The biological activity of a neem preparation depends strongly on the plant part and extraction procedure.

Safety evaluation requires particular care because neem leaf extracts, seed preparations, and neem oil are chemically different materials. Toxicological outcomes may vary with concentration, route, and duration of exposure. Studies should examine clinical signs, food consumption, body weight, blood chemistry, organ weights, and histopathology. Reproductive and developmental toxicity also warrant consideration where relevant. Evidence from one preparation should not be used to establish the safety of every neem-based product.

3. *Ocimum tenuiflorum* (Holy Basil)

Ocimum tenuiflorum, also known as *Ocimum sanctum* or holy basil, contains phenolic compounds, flavonoids, and volatile constituents. Its extracts have been investigated for antioxidant, anti-inflammatory, antimicrobial, and stress-related effects. Experimental animal models may help researchers explore changes in oxidative stress markers, inflammatory cytokines, metabolic parameters, and behavioral outcomes.

The safety profile depends on the plant material, extract composition, dosage, and duration of administration. Short-term tolerability does not establish long-term safety, particularly for concentrated preparations. Studies should include appropriate vehicle controls and systematic monitoring of liver and kidney function, hematological parameters, and

tissue morphology. Reproductive and developmental endpoints should be considered when the intended use or exposure pattern makes them relevant.

4. Aloe vera

Aloe vera is investigated for wound healing, anti-inflammatory, antioxidant, and gastrointestinal effects. Its inner-leaf gel differs substantially from the latex and whole-leaf preparations. Inner-leaf gel contains polysaccharides, including acemannan, whereas latex contains anthraquinone-related compounds such as aloin. These differences are important when interpreting both therapeutic activity and toxicological outcomes.

Experimental studies should clearly identify whether the test material is purified inner gel, decolorized whole-leaf extract, non-decolorized whole-leaf extract, or latex. Some preparations, especially those containing particular anthraquinone constituents, raise concerns regarding gastrointestinal effects and potential systemic toxicity. Consequently, safety conclusions based on inner-leaf gel should not be generalized to all Aloe vera products.

5. Withania somnifera (Ashwagandha)

Withania somnifera is an important medicinal plant traditionally used in preparations intended to support stress management and general well-being. Its principal studied constituents include withanolides and related steroidal lactones. Experimental investigations have examined potential antioxidant, anti-inflammatory, neuroprotective, and stress-modulating effects.

Animal models can help characterize behavioral changes, biochemical responses, endocrine effects, and possible organ protection. Nevertheless, differences in root and leaf composition, withanolide concentration, and extraction techniques can influence the results. Toxicological studies should assess repeated exposure, liver and kidney parameters, and potential interactions with other substances. Reproductive, developmental, and endocrine endpoints may also be necessary depending on the intended application.

CAMELLIA SINENSIS (GREEN TEA)

Camellia sinensis leaves contain catechins, including epigallocatechin gallate (EGCG), alongside other polyphenols and methylxanthines. Green tea extracts have been studied for antioxidant, anti-inflammatory, metabolic, and cardiometabolic effects. In experimental models, researchers have examined their influence on oxidative damage, lipid metabolism, inflammatory responses, and tissue protection.

The toxicological profile depends on catechin concentration, formulation, exposure, and dosing conditions. Concentrated extracts should not be considered equivalent to traditionally prepared tea. High exposures to certain concentrated green tea preparations have raised concerns about liver injury, making hepatic biochemical testing and histopathological examination particularly important. A thorough assessment should distinguish the effects of purified EGCG from those of whole extracts.

COMPARATIVE TABLE OF SELECTED BOTANICAL EXTRACTS

The following table summarizes major areas of investigation and important safety considerations. It is a qualitative overview rather than a quantitative ranking of efficacy or toxicity.

Botanical extract	Important constituents	Pharmacological activities investigated	Experimental models or endpoints	Key toxicological considerations
Curcuma longa	Curcuminoids, including curcumin	Anti-inflammatory, antioxidant, antimicrobial, organ-protective	Inflammation, arthritis, oxidative stress, liver and kidney injury	Dose-dependent effects, formulation-specific safety, possible hepatic changes at excessive exposures
Azadirachta indica	Limonoids and other phytochemicals	Antimicrobial, anti-inflammatory, metabolic	Infection, inflammation, metabolic and organ-	Plant-part differences, extract variability, reproductive and systemic

			function models	toxicity
Ocimum tenuiflorum	Phenolics, flavonoids, volatile compounds	Antioxidant, anti-inflammatory, stress-related	Oxidative stress, inflammatory markers, behavioral and metabolic outcomes	Long-term exposure, organ function, preparation-specific effects
Aloe vera	Polysaccharides, anthraquinone-related compounds	Wound healing, anti-inflammatory, gastrointestinal effects	Wound models, inflammation, gastrointestinal and organ-function endpoints	Distinguish gel, latex, and whole-leaf products; gastrointestinal and systemic risks
Withania somnifera	Withanolides and related compounds	Stress-modulating, antioxidant, anti-inflammatory, neuroprotective	Behavioral, stress, endocrine, and biochemical models	Extract standardization, liver function, endocrine and reproductive endpoints
Camellia sinensis	Catechins, including EGCG	Antioxidant, metabolic, anti-inflammatory	Oxidative stress, lipid metabolism, inflammatory and hepatic models	Concentrated-extract exposure, dose dependence, possible liver injury

TOXICOLOGICAL EVALUATION IN EXPERIMENTAL ANIMAL MODELS

Toxicological evaluation is necessary to determine whether a botanical extract produces adverse biological effects at specific exposure levels. A well-designed investigation should characterize the test material, select an appropriate animal model, establish dose groups, and use validated endpoints. Acute toxicity studies examine effects following a single dose or short exposure period, whereas repeated-dose studies investigate possible cumulative or delayed effects. The duration of exposure should reflect the scientific objective and relevant regulatory guidance.

ACUTE AND REPEATED-DOSE TOXICITY

Acute toxicity investigations generally monitor mortality, behavioral changes, clinical signs, body weight, and gross pathological findings following administration. These observations help identify immediate hazards and inform the selection of doses for further research. However, the absence of mortality does not establish that an extract is harmless. Sublethal effects may occur even when animals survive high exposures.

Repeated-dose toxicity studies provide additional information about changes in hematological and biochemical parameters, organ weights, and tissue morphology. Depending on the botanical and its intended use, investigations may include liver enzymes, renal function indicators, blood glucose, lipid profiles, and markers of oxidative stress. The standardized turmeric extract study discussed earlier illustrates how repeated-dose evaluation can combine clinical observations, laboratory measurements, and histopathological examination to characterize a particular preparation's safety.

HEPATOTOXICITY AND NEPHROTOXICITY

The liver plays a central role in the metabolism of botanical constituents, making it an important organ in preclinical safety evaluation. Measurements of alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, and bilirubin can help identify possible hepatic injury. Histopathological examination can provide additional evidence of cellular degeneration, inflammation, necrosis, or other structural abnormalities.

The kidneys are also important targets because they participate in the elimination of metabolites and other substances. Serum creatinine, urea, electrolyte concentrations, urinalysis, and renal histopathology may be used to evaluate possible

nephrotoxicity. These findings should be interpreted together because an isolated biochemical change does not necessarily establish clinically meaningful organ damage.

HEMATOLOGICAL, REPRODUCTIVE, AND DEVELOPMENTAL TOXICITY

Hematological investigations can identify changes in red blood cells, white blood cells, hemoglobin, platelets, and related indices. Such alterations may reflect systemic toxicity, inflammation, or other physiological responses. Their interpretation requires baseline information, suitable control groups, and consideration of normal variation between animal species.

Reproductive and developmental toxicity assessments may be necessary when botanical extracts are intended for prolonged use, use during pregnancy, or administration to populations for whom reproductive safety is important. Potential outcomes include fertility changes, embryonic development, fetal growth, and postnatal development. These endpoints should be investigated using suitable, ethically justified study designs rather than inferred from general acute toxicity findings.

HISTOPATHOLOGICAL AND MECHANISTIC ASSESSMENT

Histopathological examination complements biochemical measurements by identifying structural changes in major organs. Examination of the liver, kidneys, heart, lungs, spleen, and other relevant tissues may reveal adverse effects that are not apparent from external clinical observations. Where justified, mechanistic investigations may examine oxidative stress, inflammatory signaling, mitochondrial function, apoptosis, or other pathways relevant to the observed effects. Reliable interpretation requires consistency between biochemical findings, tissue morphology, clinical observations, and exposure levels. Histopathological assessment should ideally use blinded evaluation and clearly defined criteria to reduce observer bias.

RESEARCH METHODOLOGY FOR A REVIEW OF BOTANICAL EXTRACTS

The present article is structured as a narrative review of selected botanical extracts and their pharmacological and toxicological profiles. The objective is to synthesize existing scientific knowledge, compare major research themes, and identify methodological issues relevant to experimental animal studies. It is not a report of a new animal experiment, and no original experimental sample size or animal data are claimed.

A systematic version of this review could search databases such as PubMed, Scopus, Web of Science, and Google Scholar using combinations of botanical names, pharmacological activities, animal models, acute toxicity, repeated-dose toxicity, organ toxicity, and safety evaluation. Eligible studies would include original *in vivo* investigations that clearly identify the plant material, preparation method, experimental species, administered dose, exposure duration, and relevant efficacy or toxicity outcomes.

Studies could be excluded if the botanical preparation is inadequately identified, the experimental design is insufficiently described, or the findings do not address the review question. Data extraction should cover botanical authentication, plant part, extraction solvent, phytochemical standardization, animal species, group size, dose, administration route, control groups, study duration, pharmacological endpoints, adverse findings, and statistical methods.

For a formal systematic review, the selection process should be documented using a recognized reporting framework such as PRISMA. Risk of bias should be assessed with an appropriate tool for animal studies, and findings should be grouped according to the type of extract, experimental model, and outcome. A meta-analysis should be conducted only when studies are sufficiently comparable in their preparations, experimental designs, and reported outcomes.

DISCUSSION

The literature on botanical extracts demonstrates that medicinal plants can contain compounds with promising pharmacological properties, but their therapeutic potential must be assessed alongside their toxicological limitations.

Antioxidant and anti-inflammatory effects are frequent areas of investigation because oxidative stress and inflammation are involved in numerous experimental disease models. However, improvements in biochemical markers or tissue morphology do not necessarily demonstrate clinically meaningful therapeutic benefit.

A major challenge is the variability of botanical preparations. Two extracts bearing the same plant name may differ substantially in their chemical composition because of variations in species, plant part, harvesting conditions, solvents, and processing. Standardization is therefore necessary to establish reproducibility and improve comparisons between studies. Chemical fingerprinting and quantitative measurement of selected marker compounds can help researchers characterize the administered material.

Dose selection is another critical issue. A pharmacological response observed at one dose may not occur at a lower dose, while higher exposures may introduce adverse effects. The relationship between dose and response should be examined systematically, and the highest administered dose should not be interpreted as a safe dose without adequate evidence. Similarly, findings from purified constituents should be distinguished from those obtained with crude extracts, which may contain numerous interacting compounds.

Methodological limitations can also weaken conclusions. Small sample sizes, inadequate randomization, lack of blinded outcome assessment, incomplete reporting, and selective publication of positive findings can create uncertainty about the reliability of results. Future studies should use scientifically justified sample sizes, clearly defined primary outcomes, appropriate statistical methods, and transparent reporting of both positive and negative findings.

Animal welfare is an additional consideration. Investigators should apply the principles of replacement, reduction, and refinement, use the least harmful scientifically appropriate design, and obtain relevant ethical approval. Results from animal experiments should be interpreted cautiously and supplemented, where appropriate, by validated non-animal methods and human-relevant evidence.

II. CONCLUSION

Selected botanical extracts, including *Curcuma longa*, *Azadirachta indica*, *Ocimum tenuiflorum*, *Aloe vera*, *Withania somnifera*, and *Camellia sinensis*, represent important subjects for pharmacological and toxicological investigation. Their bioactive constituents have been studied for antioxidant, anti-inflammatory, antimicrobial, metabolic, and organ-protective properties. Experimental animal models contribute to the assessment of these effects and help identify potential adverse responses, including hepatic, renal, hematological, and reproductive effects.

Nevertheless, botanical origin alone does not guarantee safety. The biological effects of an extract depend on its composition, dose, administration route, exposure duration, and the characteristics of the experimental model. Standardized preparations, rigorous experimental design, comprehensive safety endpoints, and transparent reporting are essential for reliable conclusions. Further research should establish reproducible dose–response relationships, investigate mechanisms of toxicity, and integrate preclinical findings with human-relevant evidence. Ultimately, a balanced evaluation of therapeutic activity and potential harm is necessary to support the responsible development of plant-derived medicines.

REFERENCES

1. *Curcuma longa* (Turmeric): Ethnomedicinal uses, phytochemistry, pharmacological activities and toxicity profiles—A review. (2023). *Pharmacological Research – Modern Chinese Medicine*, 6, 100222.
2. Murugan, S. B., et al. (2021). Safety evaluation of standardized extract of *Curcuma longa* (NR-INF-02): A 90-day subchronic oral toxicity study in rats. *BioMed Research International*, 2021, 6671853.
3. *Curcuma longa* (Turmeric) and its major constituent (curcumin) as nontoxic and safe substances: Review. (2018). PubMed-indexed review.
4. Antidotal or protective effects of *Curcuma longa* (turmeric) and its active ingredient, curcumin, against natural and chemical toxicities: A review. (2018). *Biomedicine & Pharmacotherapy*, 99, 411–421.