

An Overview of Various Properties and Medicinal Uses of *Acorus Calamus* L

Deepak Devilal Pardhe

Associate Professor and Head, Department of Botany, Sant Dnyaneshwar Mahavidyalaya, Tal. Soegaon,
Dist. Chhatrapati Sambhaji Nagar, M.S., India

Abstract

Acorus calamus L. is an aromatic perennial rhizomatous plant that has occupied an important place in traditional medicine for centuries. The species, commonly called sweet flag or Vacha, is especially valued for its underground rhizome, from which volatile oil and several classes of secondary metabolites can be obtained. This review presents an independently written synthesis of the available literature on the plant, with emphasis on its botanical identity, traditional applications, chemical composition, experimentally reported pharmacological properties, medicinal significance, and safety limitations. *Acorus calamus* L. preparations with antioxidant, anti-inflammatory, antimicrobial, antispasmodic, anticonvulsant, neuroprotective, antidepressant-like, cardiovascular, metabolic, immune-modulatory and cytotoxic activities. The evidence, however, is predominantly preclinical and varies according to plant material, extraction method, geographic origin, chemotype, and experimental model. Asarone compounds, particularly α -asarone and β -asarone, are prominent constituents and have been investigated for both pharmacological effects and toxicological properties. The toxicological profile is a critical consideration. Experimental evidence has raised concerns regarding hepatotoxicity, genotoxicity, reproductive toxicity, mutagenicity, and carcinogenicity associated with propenyl isomers. Consequently, traditional use should not be equated with demonstrated clinical safety, and concentrated essential oils or extracts should not be regarded as automatically safe. Future development of *Acorus calamus* L. as a medicinal resource should prioritize authenticated plant material, chemical standardization, exposure assessment, pharmacokinetic studies, rigorous toxicity testing, and controlled clinical research.

Keywords: *Acorus calamus* L., Rhizome, Essential oil, Asarone, Phytochemistry etc.

Introduction

Plants have provided medicines, food additives, fragrances, dyes, and biological materials throughout human history. Modern pharmacognosy continues to investigate traditional medicinal plants because their chemical diversity can reveal molecules with useful biological activity. *Acorus calamus* L. is one such plant. Its rhizome is strongly aromatic and has been incorporated into several traditional medical systems, particularly in South Asia and East Asia. The botanical and pharmacological literature presents *Acorus calamus* L. as a chemically diverse species rather than a single chemically uniform drug. The numerous constituents of *Acorus calamus* L. belonging to phenyl propanoids, terpenoids, lignans and related groups, while asarones receive particular attention because they occur in the volatile oil and have both pharmacological and toxicological relevance [1–5].

The traditional reputation of Vacha includes uses connected with digestion, respiration, cognition, neurological complaints, inflammation, and general well-being. Modern laboratory studies have expanded this list considerably. Extracts and isolated compounds have been evaluated in models of epilepsy, neurodegeneration, oxidative stress, microbial infection, metabolic dysfunction, and cancer-related cellular processes [2, 3, 6]. The objective of the present review is not to promote unverified therapeutic claims. Instead, it is to organize the evidence in a way that separates traditional knowledge, laboratory observations, animal research and clinically meaningful evidence. This distinction is especially important for *Acorus calamus* L. because pharmacological promise coexists with recognized safety concerns.

The major aims were to describe the plant, summarize traditional uses, explain its major phytochemical groups, review experimentally reported biological properties, discuss possible mechanisms, and assess limitations related to toxicity and standardization. The recent and established peer-reviewed literature was consulted through PubMed-indexed sources and scientific reviews. The particular attention was given to comprehensive reviews of *Acorus calamus* L., reviews of Vacha in neurological and metabolic disorders, studies of asarone pharmacology and toxicology, and reports dealing with intoxication and safety [1–8].

Botanical Identity and Classification

Acorus calamus L. is a perennial monocotyledonous herb belonging to the family Acoraceae. The genus *Acorus* is taxonomically distinct from the Araceae in modern classifications, although older botanical literature sometimes grouped the plant with aroids. The plant is commonly referred to as sweet flag, calamus, flagroot, or Vacha.

Taxonomic level	Classification
Kingdom	Plantae
Order	Acorales
Family	Acoraceae
Genus	<i>Acorus</i>
Species	<i>Acorus calamus</i> L.

The correct identification is important because different *Acorus* taxa and populations can possess different chemical profiles. The literature on the genus includes several species and varieties and conclusions obtained from one chemotype should not automatically be transferred to all *Acorus* material [4,9]. The plant is characterized by an aromatic underground rhizome, narrow linear leaves, and a cylindrical spadix. The rhizome is the principal medicinal material used in most pharmacognostic descriptions.

Morphology and Morphological Identification

The rhizome is thick, creeping and branched with a characteristic fragrance caused by volatile constituents. The leaves arise from the rhizome and are elongated, narrow and sword-like. The inflorescence is a compact cylindrical spadix that emerges from the leaf region. The fine roots arise from the rhizome and anchor the plant in moist soil. The dried rhizomes used for medicinal purposes should be authenticated before processing. The macroscopic appearance alone may be insufficient when powdered drugs are involved. The microscopic characteristics, chromatographic fingerprints and

chemical marker analysis can improve confidence in identity. The importance of authentication extends beyond quality assurance. Since the proportion of asarones and other volatile constituents may vary substantially among samples, two materials both labelled *Acorus calamus* L. may not produce equivalent pharmacological or toxicological exposures.

Distribution, Ecology and Cultivation

Acorus calamus L. is associated with wet or moist environments such as marshes, pond margins, streams and other water-rich habitats. The Botanical databases and reviews describe its distribution across temperate and subtropical regions, with both native and introduced populations recorded in different parts of the world [1,4]. The plant can be propagated vegetatively through rhizome segments. The moisture availability is an important cultivation factor, while soil characteristics, temperature, harvesting stage and post-harvest drying can influence the quality of the resulting material. For medicinal production, controlled cultivation has several advantages. It permits selection of authenticated planting material, reduces uncertainty associated with wild collection and can improve consistency between batches. It may also reduce pressure on natural wetland populations. A major challenge is chemical variability. The volatile-oil composition of *Acorus calamus* L. can change with geographic origin and genetic background. This makes it essential for researchers to document the source and analytical profile of plant material used in experiments.

Traditional Medicinal Uses

Vacha has a long history in traditional Indian medicine. Historical descriptions associate the rhizome with digestive, respiratory and neurological applications, while traditional systems have also used it for conditions involving fever, inflammation, pain and general weakness. Reviews document its presence in Ayurveda, Unani, Siddha and Chinese medical traditions [2,3,5]. The traditional neurological applications are particularly notable. The plant has been associated with memory, speech and cognitive functions in Ayurvedic practice. The other traditional applications involve epilepsy-like conditions, anxiety-related complaints and symptoms described in traditional medical frameworks as disorders of the nervous system [3]. The digestive uses include preparations intended for indigestion, abdominal discomfort, flatulence and related complaints. The aromatic rhizomes have historically been valued for their carminative and antispasmodic qualities. Traditional use is valuable as a source of research hypotheses, but it cannot establish modern clinical efficacy. Traditional formulations may differ from laboratory extracts in dose, processing, composition and route of administration. The safety of a historical preparation therefore cannot be assumed for concentrated essential oil or purified compounds.

Phytochemical Profile

The chemical composition of *Acorus calamus* L. is complex. The scientific reviews have catalogued a substantial number of constituents, including phenylpropanoids, sesquiterpenoids, monoterpenes, lignans, phenolic substances and other secondary metabolites [3,4,9].

Chemical class	Examples or description	Scientific significance
Phenylpropanoids	α -asarone, β -asarone and related compounds	Important pharmacological and toxicological markers

Terpenoids	Mono- and sesquiterpenoid constituents	Contribute to volatile oil composition
Lignans	Various lignan derivatives	Potential antioxidant and other biological effects
Phenolic compounds	Different phenolic constituents	May contribute to redox and inflammatory effects
Volatile oil	Complex mixture of aromatic compounds	Important fraction for pharmacognostic and pharmacological studies

The concentration of individual compounds is not fixed. The extraction solvent, distillation procedure, storage, plant age, environment and genetic background can all influence the measured profile.

Asarone and related constituents

Asarones are among the characteristic constituents associated with *Acorus*. The α -Asarone and β -asarone are phenylpropene compounds, while γ -asarone belongs to a related structural category. Their presence has attracted substantial interest because studies report effects on the central nervous system, inflammatory pathways, oxidative processes and other biological targets [7,8]. The pharmacological literature on α - and β -asarone includes experimental work involving anti-depressant-like, anxiolytic-like, anticonvulsant, neuroprotective, anti-inflammatory, metabolic and anticancer effects. A review of preclinical evidence also noted that their oral bioavailability in rodents is relatively poor and that metabolism involves cytochrome-P450 pathways [7]. The same compounds create an important safety problem. The toxicological reviews have described evidence of hepatotoxicity, reproductive toxicity, mutagenicity and carcinogenicity with the reliability and relevance of evidence differing by compound and experimental endpoint [8]. Thus, asarone concentration is not simply a marker of potency. It can also be a marker of risk. Any future medicinal product based on *Acorus calamus* L. requires careful control of these compounds.

Pharmacological Applications

The published pharmacological literature describes *Acorus calamus* L. as a multi-activity medicinal plant. The reported properties include antioxidant, anti-inflammatory, antimicrobial, antispasmodic, anticonvulsant, sedative, neuroprotective, cardiovascular, hypolipidemic, metabolic, immunomodulatory and cytotoxic effects [2,3,5]. The breadth of reported effects is partly explained by the chemical diversity of the plant and by the use of different extracts and isolated molecules. It also means that findings from one preparation cannot automatically be applied to another. The following sections discuss the principal properties separately, emphasizing the distinction between experimental evidence and proven human therapeutic benefit.

Antioxidant Property

The oxidative stress is produced when reactive molecular species overwhelm protective cellular systems. Because oxidative imbalance participates in inflammation, neurodegeneration, metabolic disease and tissue injury, antioxidant activity is frequently investigated in medicinal plants. *Acorus calamus* L. extracts have shown radical-scavenging and reducing activity in laboratory assays. Such observations

indicate that compounds in the plant can interact with oxidizing molecules under experimental conditions [5,10]. The potential antioxidant effects may involve both direct chemical scavenging and modulation of endogenous defense systems. The contribution of each constituent is likely to depend on extract composition and biological availability. It is important, however, to distinguish an antioxidant assay from a clinical antioxidant effect. A high activity in a chemical test does not demonstrate that a preparation reaches the relevant tissues at effective concentrations after administration to humans.

Anti-Inflammatory and Analgesic potential

Inflammation is a normal protective response but persistent inflammatory signaling can contribute to chronic disease. Traditional use of *Acorus calamus* L. for inflammatory and rheumatic complaints has encouraged experimental investigation of its anti-inflammatory potential. The extracts and isolated constituents have been evaluated using biochemical and cellular models. The reported effects include inhibition of processes associated with protein denaturation, membrane damage and inflammatory signaling. The reviews also describe anti-inflammatory activity for rhizome preparations and asarone-related compounds [2,3,5]. The possible mechanisms include interactions with oxidative pathways and inflammatory mediators. Because different extracts contain different chemical mixtures, a single mechanism cannot be assigned to the plant as a whole. The analgesic observations should be interpreted similarly. Experimental pain models can suggest biological activity, but they do not establish that *A. calamus* is a safe substitute for clinically validated analgesic medicines.

Antimicrobial Activity

The antimicrobial research has examined both essential oil and solvent extracts of *Acorus calamus* L., the laboratory investigations indicate activity against selected bacterial and fungal organisms, suggesting that volatile and non-volatile constituents may interfere with microbial survival. The studies of *Acorus* rhizome oil have reported bactericidal and antifungal effects, while more recent work has investigated membrane integrity, biofilm formation and changes in bacterial physiology as possible mechanisms [11,12]. The antimicrobial property is scientifically interesting because plant-derived molecules can provide structural leads for new anti-infective agents. Nevertheless, in vitro activity should not be equated with treatment of human infection. The effective concentrations, tissue penetration, toxicity and resistance development all need to be evaluated. The future research could focus on identifying non-toxic fractions, determining synergistic combinations with established antibiotics, and studying activity against resistant organisms.

Neuro-Pharmacological Effects

The nervous system is one of the most intensively investigated targets of *Acorus calamus* L., the experimental research has explored sedative, anticonvulsant, antidepressant-like, anxiolytic-like and neuroprotective effects [3,7,9]. Several mechanisms have been proposed which include regulation of neurotransmission, reduction of oxidative stress, modulation of inflammatory pathways, influence on ion channels and protection of neuronal cells against experimentally induced injury. The results provide a plausible scientific explanation for some aspects of the plant's traditional reputation. However, most evidence remains preclinical. The behavioral improvements in animals or protective effects in cultured neurons cannot establish efficacy in people with neurological disease. The research should therefore

move from broad screening toward well-characterized active fractions, dose-response studies, pharmacokinetic analysis and carefully designed clinical investigations where safety permits.

Anti-Convulsant Potential

Anticonvulsant activity has been reported for Acorus preparations in experimental seizure models. The reviews discuss possible effects on neurotransmitter systems, ion channels, oxidative pathways and inflammatory processes [3,7]. This area has attracted interest because epilepsy involves several interacting biological mechanisms and because plant-derived compounds may act at multiple targets. However, a broad mechanism is not necessarily an advantage if it is accompanied by toxicity or unpredictable pharmacokinetics. Acorus calamus L. should not be substituted for prescribed antiepileptic treatment on the basis of experimental findings. The future research needs to establish whether a chemically standardized and safer fraction can retain anticonvulsant activity while avoiding the risks associated with asarones.

Neuro-Protective and Cognitive Potential

Neurodegenerative disorders involve oxidative injury, neuroinflammation, mitochondrial dysfunction, abnormal protein accumulation and loss of neuronal connections. Acorus calamus L. constituents have been investigated against several of these processes. The reviews describe experimental evidence for effects relevant to Alzheimer's disease, Parkinsonian models, epilepsy and other neurological conditions. The proposed mechanisms include reduction of oxidative damage, modulation of inflammatory signaling and support of neuronal survival [3,9]. The findings are useful for identifying drug-development leads, but they do not prove that consuming Acorus calamus L. prevents dementia or improves memory in healthy individuals. Such claims would require randomized clinical trials using standardized products and validated cognitive outcomes.

Anti-Diabetic and Metabolic Effects

Acorus calamus L. has been investigated in experimental models related to glucose and lipid metabolism. The reviews describe anti-hyperglycemic, hypolipidemic and anti-obesity effects among the reported activities of Acorus preparations [2,3]. The possible mechanisms include effects on oxidative stress, inflammatory signaling and pathways regulating glucose or lipid handling. However, the evidence is heterogeneous and often based on animals or biochemical assays. The clinical diabetes management depends on disease type, severity, comorbidities and medication use. Therefore, experimental evidence from Acorus calamus L. cannot be used to recommend replacing established glucose-lowering therapy.

Cardiovascular Effects

The experimental literature reports several cardiovascular effects of Acorus calamus L., including observations related to lipid metabolism, cardiac protection, vascular function and blood pressure [2,3]. These findings may arise from antioxidant, anti-inflammatory and other actions of its chemical constituents. Some asarone studies have also investigated antithrombotic and related mechanisms [7]. The current evidence is insufficient to establish Acorus calamus L. as a treatment for hypertension, dyslipidemia, thrombosis or cardiovascular disease. The potential interactions with cardiovascular medicines should also be considered in future studies.

Gastrointestinal and Antispasmodic Effects

The digestive complaints represent one of the longest-standing traditional applications of *Acorus calamus* L., aromatic rhizome preparations have been used for symptoms such as indigestion, abdominal discomfort and excessive intestinal gas [2,5]. The experimental antispasmodic activity offers a possible pharmacological explanation for some of these traditional applications. The volatile constituents may influence smooth-muscle function, while other components could affect inflammatory or oxidative pathways. Nevertheless, abdominal symptoms can arise from serious disease. Traditional use should therefore not delay appropriate medical assessment, particularly when pain is severe, persistent or associated with bleeding, fever or vomiting.

Anti Cancer and Cytotoxic Activity

The laboratory investigations have explored the ability of *Acorus calamus* L. extracts and individual compounds to affect cancer-cell growth and survival. Some studies report cytotoxic effects and changes consistent with apoptosis in cultured tumor cells [5,9]. These findings are relevant to early-stage drug discovery because they may identify molecular structures worth further investigation. They do not demonstrate that the whole plant or its essential oil is an anticancer treatment. A successful anticancer drug requires selectivity toward malignant cells, favorable pharmacokinetics, acceptable toxicity, reproducible manufacturing and evidence of benefit in animal and human studies. The toxicological liabilities associated with asarones make this distinction particularly important.

Immuno-Modulatory and Other Reported Properties

The reviews describe immune-modulatory activity among the experimental effects attributed to *Acorus calamus* L., modulation of immune signaling may be relevant to inflammatory disorders, but immune activity is context dependent and can have both desirable and undesirable consequences. The other reported properties include antidiarrheal effects, insect-related activity, antioxidant effects and possible anti-obesity actions. The large number of reported activities reflects the complexity of plant chemistry and the variety of models used by investigators [2,4,5]. The drug development generally requires a specific indication, a defined active substance or standardized fraction, a measurable therapeutic window and reproducible clinical benefit.

Possible Mechanisms of Action

Acorus calamus L. does not appear to act through one universal molecular pathway. Instead, different constituents may influence different biological systems. The proposed mechanisms include modulation of oxidative stress, inflammatory signaling, neurotransmitter systems, membrane integrity, apoptosis, ion-channel activity and cellular metabolic pathways [3,7,9,11].

Reported property	Mechanistic interpretation from experimental studies
Antioxidant	Radical-scavenging activity and possible modulation of cellular antioxidant defenses
Anti-inflammatory	Influence on inflammatory mediators and oxidative signaling
Antimicrobial	Disruption of microbial membranes and interference with biofilms

Neuroprotection	Reduction of oxidative/inflammatory injury and modulation of neuronal survival pathways
Anticonvulsant	Potential influence on neurotransmitters, ion channels and neuronal excitability
Cytotoxic	Activation of cell-death pathways and impairment of cancer-cell survival
Metabolic	Possible effects on glucose/lipid regulation and inflammatory-oxidative pathways

Pharmacokinetic Considerations

Pharmacokinetics determines how much of a compound enters the body, where it travels, how it is transformed and how it is eliminated. This information is particularly important for *Acorus calamus* L. because the plant contains volatile constituents with potentially active and toxic metabolites. The preclinical reviews report relatively low oral bioavailability and short plasma half-life for α - and β -asarone in rodents, with metabolism involving cytochrome-P450 enzymes [7].

Toxicological Profile and Safety

The Safety is a central issue in evaluating *Acorus calamus* L.. The literature on α -, β - and γ -asarone indicates that the propenyl asarones have been associated with several toxicological endpoints. A detailed review reports evidence concerning hepatotoxicity, reproductive toxicity, mutagenicity and carcinogenicity, although the strength of evidence varies among endpoints [8]. The clinical toxicology data also demonstrate that concentrated calamus-oil products can result in systemic asarone exposure. A report investigating intoxication cases detected α - and β -asarone in biological samples; prolonged vomiting was among the reported clinical symptoms [6]. These observations mean that the phrase 'natural product' should not be interpreted as synonymous with 'risk free'. The chemical composition and concentration of a preparation are crucial determinants of exposure. The safety assessment should address acute toxicity, repeated-dose toxicity, liver injury, reproductive effects, genotoxicity, carcinogenicity, drug interactions and vulnerable populations. Concentrated essential oils and unstandardized extracts require particular caution.

Quality Control and Standardization

A medicinal plant can only be studied reliably when the test material is adequately characterized. For *Acorus calamus* L., quality control should begin with botanical authentication and extend to chemical analysis. The useful quality-control measures include macroscopic and microscopic identification, moisture and contaminant testing, chromatographic fingerprinting, volatile-oil analysis and quantitative measurement of relevant marker compounds. The gas chromatography coupled with mass spectrometry is especially suitable for volatile constituents. The standardization is also a safety strategy. The controlling the concentration of potentially hazardous asarones can reduce variability in exposure and make toxicological assessment more meaningful.

Traditional Use and Modern Evidence

Traditional or proposed use	Modern evidence	Interpretation
Digestive complaints	Experimental antispasmodic and related observations	Plausible traditional application; clinical evidence limited
Neurological complaints	Animal and cellular neuropharmacology studies	Promising research area, not established therapy
Epilepsy	Experimental anticonvulsant activity	Requires rigorous clinical validation
Microbial conditions	In vitro antibacterial and antifungal activity	Potential source of antimicrobial leads
Inflammatory conditions	Biochemical and preclinical studies	Evidence remains experimental
Metabolic disorders	Animal and biochemical studies	Insufficient for therapeutic recommendation
Cancer	Cellular cytotoxicity and mechanistic studies	Early-stage research only
Cognitive disorders	Neuroprotective studies in experimental models	No established human disease-modifying benefit

Advantages and Limitations as a Medicinal Resource

A major advantage of *Acorus calamus* L. is its rich chemical diversity and extensive history of traditional use. The plant offers multiple classes of molecules that can be investigated for new pharmacological targets. Its long ethnomedical history also provides useful hypotheses for research. The major limitations are chemical variability, incomplete clinical evidence and the toxicological concerns surrounding asarones. Another limitation is methodological heterogeneity: studies often use different extracts, doses, animal models and analytical methods. A positive laboratory result may depend on concentrations that cannot be achieved safely in humans. Future studies must therefore connect pharmacological activity with realistic exposure and safety margins.

Future Research Directions

The future research should begin with rigorous botanical and chemical characterization. The geographic variation and chemotype should be documented and low-risk preparations should be identified where possible. The next priority is pharmacokinetic and toxicological investigation. Researchers should establish dose-response relationships, identify active and toxic metabolites, investigate chronic exposure and evaluate interactions with clinically important medicines. The mechanistic research should move beyond nonspecific antioxidant assays toward validated cellular targets and disease-relevant models. The Omics technologies, molecular biology, metabolomics and advanced cell models may help clarify how individual constituents act.

The clinical trials should be considered only after appropriate preclinical safety evidence is available. Such studies should use standardized products, transparent chemical specifications, adequate sample sizes and systematic adverse-event reporting.

Summary and Major Properties

Property	Evidence level	Overall scientific assessment
Antioxidant	In vitro/preclinical	Promising experimental activity
Anti-inflammatory	In vitro/preclinical	Potential; human evidence limited
Antimicrobial	In vitro/preclinical	Strong natural-product research interest
Antispasmodic	Traditional/preclinical	Plausible, requires clinical validation
Anticonvulsant	Preclinical	Important research lead; not replacement therapy
Neuroprotective	Cell/animal/review evidence	Promising but clinically unconfirmed
Metabolic	Preclinical	Insufficient for clinical recommendation
Cardiovascular	Preclinical	Requires stronger translational evidence
Anticancer	Cell/preclinical	Early-stage drug-discovery evidence
Safety	Toxicological/preclinical/clinical exposure reports	Major limitation; standardization essential

Conclusion

Acorus calamus L. is a pharmacologically interesting medicinal plant with a long history of traditional use. Its rhizome contains a chemically diverse mixture that includes volatile compounds and phenylpropanoids such as α -asarone and β -asarone. The experimental studies have reported a wide range of biological activities, including antioxidant, anti-inflammatory, antimicrobial, antispasmodic, anticonvulsant, neuroprotective, metabolic and cytotoxic effects. The evidence supports continued investigation of *Acorus calamus* L. as a source of natural-product research leads. It does not, however, justify treating the plant as a universally proven medicine. Most modern evidence remains preclinical, and different preparations may differ substantially in composition and biological behavior. The most important conclusion is that therapeutic potential and toxicological risk must be evaluated together. The Asarone-associated safety concerns mean that chemical standardization is not optional but central to responsible research. The future medicinal value of *Acorus calamus* L. will depend on identifying reproducible preparations or individual molecules with a favorable balance between activity and safety.

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