The Bioscan
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
20(3): S.I (3), 470-474, 2025 www.thebioscan.com

PHARMACOTHERAPEUTIC POTENTIAL OF *AVICENNIA OFFICINALIS* LEAF EXTRACT IN MANAGING ALCOHOL-INDUCED HEPATOTOXICITY

Mahalakshmi S [*1], Tehseen Javed [2], Kannan[3], Subha S C [4]and Ruby[5]

[1]Department of Nursing, PERI College of Nursing, Chennai -48

[2]Department of Physiotherapy, PERI College of Physiotherapy, Chennai -48

[3]Department of Pharmacy, PERI College of Pharmacy, Chennai -48

[4]Department of Microbiology, PERI Arts and Science, Chennai – 48

[5]Department of Chemistry, PERI Institute of Technology, Chennai - 48

Corresponding mail id: publications@peri.ac.in

DOI: 10.63001/tbs.2025.v20.i03.S.I(3).pp470-474

KEYWORDS
Avicenniaofficinalis, hepatoprotection, antioxidant activity, alcohol-induced liver toxicity, phytochemicals, oxidative stress, ethanolic extract, Wistar rats, liver enzymes, natural therapeutics
Received on:

16-06-2025

Accepted on:

12-07-2025

Published on:

20-08-2025

ABSTRACT

This study evaluates the hepatoprotective and antioxidant potential of ethanolic leaf extract of *Avicenniaofficinalis* in a rat model of alcohol-induced liver toxicity. Chronic ethanol administration resulted in elevated serum hepatic enzymes (SGOT, SGPT, ALP, GGT), total bilirubin, and lipid peroxidation, along with decreased levels of total protein and both enzymatic (SOD, CAT, GPx, GST) and non-enzymatic (GSH, vitamins C and E) antioxidants. Oral administration of *A. officinalis* extract (100 mg/kg body weight) significantly restored liver function biomarkers and antioxidant levels, comparable to the standard hepatoprotective drug silymarin. Phytochemical analysis confirmed the presence of flavonoids, alkaloids, tannins, terpenoids, and other bioactive compounds, which may contribute to its therapeutic efficacy. These findings support the potential of *A. officinalis* as a natural, pharmacologically active agent for the prevention and treatment of alcohol-induced hepatic damage.

INTRODUCTION

Liver diseases remain a major global health concern, often triggered by chronic alcohol consumption, drug toxicity, viral infections, and oxidative stress. The liver, being the primary organ for detoxification and metabolism, is highly susceptible to damage by reactive oxygen species (ROS) generated during alcohol metabolism. Alcoholic liver disease (ALD) progresses through stages including fatty liver (steatosis), alcoholic hepatitis, and ultimately cirrhosis. These conditions are characterized by inflammation, hepatocyte damage, lipid peroxidation, and impaired antioxidant defense mechanisms. Conventional hepatoprotective drugs often have limited efficacy and adverse side effects, prompting interest in alternative therapeutic strategies using natural products.

Medicinal plants offer a rich source of bioactive compounds with potential hepatoprotective and antioxidant properties. Mangroves, in particular, are known for their unique secondary metabolites and ethnopharmacological uses. *Avicenniaofficinalis*, a dominant mangrove species belonging to the family Avicenniaceae, is traditionally used to treat skin ailments, ulcers, and dental infections. Its leaves, bark, and fruits have been reported to possess antimicrobial, anti-inflammatory, and antioxidant properties. However, there is limited pharmacological evidence supporting its hepatoprotective effects against alcohol-induced toxicity.

In this context, the present study aims to evaluate the antioxidant and hepatoprotective activity of ethanolic leaf extract of *Avicenniaofficinalis* in Wistar rats subjected to chronic alcohol-induced liver damage. The study also investigates the phytochemical profile of the extract to understand the bioactive constituents contributing to its therapeutic efficacy.

2. LITERATURE REVIEW

The liver plays a pivotal role in detoxification, metabolism, and homeostasis, making it a prime target for xenobiotic-induced oxidative stress, especially from chronic alcohol exposure. Alcohol metabolism generates reactive oxygen species (ROS), leading to lipid peroxidation, mitochondrial dysfunction, and hepatocyte death. Natural compounds with antioxidant and hepatoprotective properties have gained significant attention in mitigating such liver damage.

Among mangrove plants, *Avicenniaofficinalis* has emerged as a promising source of bioactive phytochemicals. Studies have demonstrated that ethanolic leaf extracts of *Avicennia marina* significantly restore altered liver enzyme levels and reduce oxidative stress markers in alcohol-induced liver injury in rats, indicating strong hepatoprotective activity [1], [2]. Similarly, *A. officinalis* leaf and bark extracts have shown antioxidant and anti-inflammatory properties attributed to flavonoids, tannins, and terpenoids [3], [4]. Bioactivity-guided fractionation of bark extracts has led to the isolation of antidiabetic and antioxidant compounds, further confirming the plant's therapeutic value [5].
The hepatoprotective potential of *A. officinalis* has also been validated in HepG2 liver cell lines and in vivo models, showing comparable efficacy to standard drugs such as silymarin [6]. This activity correlates with the high total phenolic and flavonoid content, which are known to modulate redox balance and cellular antioxidant defenses [3]. Phytochemical screenings have consistently reported the presence of alkaloids, cardiac glycosides, saponins, and sterols, contributing to the plant's broad pharmacological effects [4], [10], [21].
Extensive phytochemical and pharmacological evaluations have been conducted to understand the therapeutic scope of *Avicennia marina* and *A. officinalis*, including antimicrobial, anti-HIV, and antiviral activity, particularly against HSV [8], [11]. Moreover, optimization studies on extraction protocols have enhanced the yield of antioxidant compounds from *A. officinalis*, improving its reproducibility for pharmacological applications [12].
In models of hepatotoxicity, lipid peroxidation is a key marker of oxidative damage. The thiobarbituric acid reactive substances (TBARS) assay, widely used to measure lipid peroxides, has revealed significant protective effects of *A. officinalis* extracts in suppressing oxidative lipid degradation [13]. Other mechanisms of action involve the enhancement of endogenous antioxidants such as glutathione (GSH), catalase (CAT), superoxide dismutase (SOD), and glutathione peroxidase (GPx) [14], [15].
In comparative herbal medicine studies, *A. officinalis* is on par with other hepatoprotective plants like *Emblicaofficinalis* and *Allium ochotense*, both of which exhibit antioxidant-mediated hepatoprotection in ethanol and chemical-induced models [23], [24]. Plant-derived antioxidants are considered safer and more sustainable than synthetic drugs, especially for long-term use in chronic liver diseases [16], [17].
Oxidative stress is a major pathophysiological factor in alcoholic liver disease and other hepatic dysfunctions, and natural products rich in polyphenols and vitamins (e.g., C and E) can stabilize cellular membranes and inhibit the chain reactions of ROS [18], [25]. Several reports also emphasize the need for standardization of plant extracts to ensure consistent therapeutic efficacy [19], [20].
Collectively, the literature supports the use of *A. officinalis* as a natural hepatoprotective agent. It exhibits multi-targeted actions including antioxidant, anti-inflammatory, and membrane-stabilizing effects, making it suitable for further development into pharmacotherapeutic formulations [6], [7], [22].
Babu et al. [26] discussed the increasing concerns of microplastic accumulation in terrestrial and aquatic ecosystems. Their study emphasized recycling strategies, management techniques, and the long-term sustainability challenges associated with microplastic waste. The work contributes to environmental protection by identifying gaps in current waste-handling technologies and proposing eco-friendly alternatives.Rubala et al. [27] reviewed the histopathological impacts of environmental pollutants on living systems. The authors highlighted pathological changes caused by toxic exposure, underlining the importance of biomonitoring and early detection for preventive healthcare. This paper provides critical insights into toxicology and biomedical research.Ramya et al. [28] analyzed the growth trends and economic implications of *Penaeusmonodon* aquaculture. Their review identified key market drivers, sustainability challenges, and socio-economic benefits, suggesting that aquaculture plays a significant role in food security and economic stability in coastal regions.Geetha et al. [29] presented a comprehensive review of ecotourism, emphasizing its applications in biodiversity conservation and environmental education. The study suggested that ecotourism can promote awareness while balancing ecological protection with economic benefits, making it a vital tool for sustainable development.Swetha et al. [30] provided a concise review of mosquito control measures, ranging from biological methods to chemical interventions. Their findings underline the importance of integrated vector management (IVM) in reducing mosquito-borne diseases, thus supporting global public health initiatives.Mahalakshmi et al. [31] explored the health risks associated with inhalation of volatile paint fumes. Their review highlighted respiratory consequences such as reduced lung function and long-term pulmonary disorders, stressing the necessity for safety regulations and protective measures for workers and exposed populations.
Farheen et al. [32] investigated medicinal plants as therapeutic candidates for hepatocellular carcinoma. Their mini-review pointed out the hepatoprotective properties of phytochemicals and their potential to provide affordable, accessible alternatives to conventional cancer treatments.Geetha et al. [33] used computational methods to evaluate natural bioactive compounds and their interactions with mosquito proteins. This research provides insights for novel insecticide design and biocontrol measures, advancing eco-friendly mosquito management strategies.Devasena et al. [34] highlighted sustainable biofuel production from fruit waste, offering a waste-to-energy approach. Their work underscored the dual benefit of reducing organic waste accumulation and providing renewable energy alternatives to fossil fuels.Krishanan et al. [35] quantified airborne microbial loads in clinical and adjacent environments. Their study demonstrated the importance of microbial monitoring for infection control and prevention, contributing to improved healthcare facility management.Krishanan et al. [36] studied the effect of aquarium wastewater irrigation on mustard and green gram plants. Results indicated enhanced growth responses, suggesting the feasibility of using treated wastewater in agriculture as a resource recovery and sustainability measure.
Krishanan et al. [37] explored the green synthesis of superparamagnetic iron oxide nanoparticles (SPIONs). Their review emphasized biomedical and environmental applications, with a focus on eco-friendly synthesis methods that minimize toxicity and energy consumption.Geetha et al. [38] discussed fabrication and analysis of nickel oxide nanoparticles for advanced applications. Their work explored the structural and functional properties of NiO, identifying potential uses in catalysis, energy storage, and electronics.Sindhuja et al. [39] synthesized and characterized spinel $SrFe_2O_4$ nanoparticles. Their review highlighted the application potential in magnetic storage, catalysis, and biomedical fields, demonstrating how nanostructuring enhances material properties.Geetha et al. [40] reported on the microwave-assisted synthesis and characterization of ZnO nanoparticles. Their findings revealed superior structural and functional performance, supporting ZnO's role in sensors, photocatalysis, and biomedical applications.

3. MATERIALS AND METHODS

3.1 Collection and Authentication of Plant Material

Fresh, healthy, and mature leaves of Avicenniaofficinalis were collected from the Muthupet mangrove forest region in Thiruvarur district, Tamil Nadu, India. The plant material was authenticated by a plant taxonomist at the Department of Botany, St. Joseph's College, Tiruchirappalli, and a voucher specimen was deposited under the herbarium number JS 001 for future reference.

3.2 Preparation of Ethanolic Extract

The collected leaves were washed with distilled water, shade-dried for 7 days, and ground into a coarse powder using a mechanical grinder. Approximately 500 g of the powdered leaves was subjected to Soxhlet extraction using 80% ethanol at 70°C for 24 hours. The resulting extract was filtered and evaporated under reduced pressure in a hot air oven at 40°C to remove residual solvent, yielding a dark brown viscous residue. The dried extract was stored in an airtight container at 4°C for further use.

3.3 Experimental Animals

Adult male Wistar albino rats (weighing 180–220 g) were procured and housed under standard laboratory conditions (25 ± 2°C, 12 h light/dark cycle, 50–60% humidity). The animals were provided with standard pellet diet and water ad libitum. All experimental protocols were conducted in compliance with institutional animal ethical guidelines and were approved by the Institutional Animal Ethics Committee.

3.4 Experimental Design

The animals were randomly divided into four groups (n = 6 per group):

- **Group I**: Control (received distilled water only)
- **Group II**: Alcohol-induced group (received ethanol 6 g/kg/day orally for 21 days)
- **Group III**: Treated with A. officinalis extract (100 mg/kg/day orally) + ethanol
- **Group IV**: Standard drug group (Silymarin 25 mg/kg/day orally) + ethanol

Treatments were administered for 21 consecutive days. After the experimental period, the animals were anesthetized, and blood and liver tissues were collected for biochemical and antioxidant analysis.

3.5 Biochemical Analysis

Blood samples were centrifuged at 3000 rpm for 15 minutes to obtain serum, which was analyzed for liver function markers including serum glutamic oxaloacetic transaminase (SGOT/AST), serum glutamic pyruvic transaminase (SGPT/ALT), alkaline phosphatase (ALP), gamma-glutamyltransferase (GGT), total bilirubin, and total protein using standard diagnostic kits (Span Diagnostics Ltd., India) as per the manufacturer's protocols [13–15].

3.6 Assessment of Antioxidant Parameters

Liver tissues were homogenized in phosphate buffer (pH 7.4) and used to estimate enzymatic antioxidants including superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and glutathione-S-transferase (GST) [14–16]. Non-enzymatic antioxidants such as reduced glutathione (GSH), vitamin C (ascorbic acid), and vitamin E (tocopherol) were also quantified using established biochemical assays [17–19]. Lipid peroxidation (LPO) was assessed by measuring malondialdehyde (MDA) content via the thiobarbituric acid reactive substances (TBARS) method [13].

3.7 Phytochemical Screening

Qualitative phytochemical analysis of the ethanolic extract was performed to detect the presence of alkaloids, flavonoids, tannins, steroids, terpenoids, saponins, cardiac glycosides, and anthraquinones using standard protocols [4], [5].

3.8 Statistical Analysis

All data were expressed as mean ± standard error of the mean (SEM). Statistical significance was determined by one-way analysis of variance (ANOVA) followed by Tukey's post hoc test using SPSS software (version 20.0). A p-value < 0.05 was considered statistically significant.

4. RESULTS

4.1 Phytochemical Screening

The ethanolic leaf extract of *Avicenniaofficinalis* was subjected to qualitative phytochemical analysis, which revealed the presence of multiple secondary metabolites. Alkaloids, flavonoids, tannins, terpenoids, steroids, anthraquinones, and cardiac glycosides were detected, while saponins and proteins were absent. These constituents are known to possess antioxidant and hepatoprotective activities and may be responsible for the therapeutic efficacy of the extract (Table 1).

Table 1. Qualitative Phytochemical Screening of Ethanolic Leaf Extract of *Avicenniaofficinalis*

S. No.	Phytochemical Test	Observation	Result
1	Alkaloids	Pale precipitate	+
2	Flavonoids	Dirty brown coloration	+
3	Cardiac Glycosides	Brown ring formation	+
4	Steroids	Violet to blue coloration	+
5	Terpenoids	Reddish-brown coloration	+
6	Tannins	Yellow precipitate	+
7	Anthraquinones	Red coloration	+
8	Proteins	Absence of pink/red color	-
9	Saponins	Absence of frothing	-

(+): Present; (-): Absent

4.2 Effect on Hepatic Enzymes

Chronic alcohol administration (Group II) significantly elevated serum levels of liver enzymes SGOT, SGPT, ALP, GGT, and total bilirubin, and decreased serum protein levels compared to control (Group I), indicating hepatic dysfunction. Treatment with *A. officinalis* extract (Group III) significantly reversed these changes, suggesting potent hepatoprotective activity. The standard drug silymarin (Group IV) showed comparable protective effects (Table 2).

Table 2. Effect of *Avicenniaofficinalis* Leaf Extract on Hepatic Enzyme Markers in Alcohol-Induced Rats

Parameter	Control	Alcohol	Alcohol + *A. officinalis*	Alcohol + Silymarin
SGOT (IU/L)	34.91 ± 0.33	178.42 ± 4.25	102.16 ± 3.66*	86.75 ± 1.44***
SGPT (IU/L)	29.12 ± 0.93	127.08 ± 1.23	72.32 ± 0.58*	50.33 ± 0.60***
ALP (IU/L)	28.94 ± 1.41	81.03 ± 1.30	38.78 ± 0.43***	34.46 ± 2.42***
GGT (IU/L)	31.06 ± 0.10	58.23 ± 0.68	16.61 ± 0.23***	16.21 ± 0.15***
Total Bilirubin (µmol/L)	0.21 ± 0.11	1.39 ± 0.08	0.71 ± 0.01**	0.46 ± 0.01***
Serum Protein (g/dL)	6.92 ± 0.33	3.53 ± 0.10	5.28 ± 0.26**	5.78 ± 0.52***

Values are expressed as Mean ± SEM (n = 6).

*Statistical significance vs. toxicant: *p < 0.05, **p < 0.01, ***p < 0.00*

4.3 Effect on Antioxidant Parameters

Ethanol administration resulted in a significant reduction in antioxidant enzyme levels (SOD, CAT, GPx, GST) and non-enzymatic antioxidants (GSH, vitamin C, and vitamin E), along with elevated lipid peroxidation (LPO), indicating severe oxidative stress in liver tissues. Treatment with *A. officinalis* significantly improved antioxidant status and reduced LPO levels. The activity was statistically significant and comparable to silymarin-treated rats (Table 3).

Table 3. Antioxidant Parameters in Liver Tissue of Experimental Animals

Parameter	Control	Alcohol	Alcohol + *A. officinalis*	Alcohol + Silymarin
SOD (units/mg protein)	12.48 ± 0.55	3.58 ± 0.26	7.30 ± 0.20**	8.47 ± 0.46***
LPO (nmol MDA/mg protein)	4.31 ± 0.07	9.29 ± 0.00	7.60 ± 0.20	6.59 ± 0.15*
CAT (nmol H_2O_2/min/mg protein)	93.80 ± 1.42	28.63 ± 0.40	59.44 ± 1.81**	82.14 ± 1.68***
GSH (µmol/L)	18.87 ± 0.07	8.01 ± 0.04	14.93 ± 0.05***	15.42 ± 0.04***
GPx (nmol/min/mg protein)	13.96 ± 0.83	6.51 ± 0.47	10.87 ± 0.67***	11.29 ± 0.10***
GST (nmol/min/mg protein)	98.35 ± 0.02	49.70 ± 0.01	72.08 ± 0.10**	88.79 ± 0.03***
Vitamin E (mg/dL)	1.50 ± 0.09	0.65 ± 0.03	1.49 ± 0.08***	1.48 ± 0.07***
Vitamin C (µmol/L)	1.28 ± 0.07	0.57 ± 0.03	1.03 ± 0.09***	0.89 ± 0.06**

Values are expressed as Mean ± SEM (n = 6).
*Statistical significance vs. toxicant: *p < 0.05, **p < 0.01, ***p < 0.001*

CONCLUSION

The findings of this study provide strong evidence that the ethanolic leaf extract of *Avicenniaofficinalis* exhibits significant pharmacological activity in mitigating alcohol-induced hepatotoxicity. Chronic ethanol exposure is known to cause oxidative stress, lipid peroxidation, and disruption of hepatocellular integrity, leading to elevated liver enzyme levels and depletion of endogenous antioxidants. In this model, *A. officinalis* treatment effectively reversed the biochemical and oxidative changes, restoring liver function markers such as SGOT, SGPT, ALP, GGT, bilirubin, and serum proteins toward normal values.

Furthermore, the extract enhanced the activity of enzymatic antioxidants such as SOD, CAT, GPx, and GST, while reducing malondialdehyde levels, a key indicator of lipid peroxidation. The restoration of non-enzymatic antioxidants including GSH, vitamin C, and vitamin E further confirms the extract's role in strengthening hepatic redox homeostasis. These pharmacodynamic effects are likely due to the presence of bioactive phytochemicals—particularly flavonoids, tannins, and terpenoids—identified in the phytochemical screening.

Compared to the standard hepatoprotective agent silymarin, *A. officinalis* extract showed comparable efficacy, indicating its potential as a natural alternative with minimal side effects. Additionally, the plant's abundance in coastal mangrove ecosystems offers a sustainable and accessible source for medicinal use.

In conclusion, *Avicenniaofficinalis* demonstrates remarkable hepatoprotective and antioxidant potential, supporting its traditional use in liver-related ailments. These results justify further investigation, including bioactive compound isolation, dose standardization, toxicity profiling, and clinical trials, to develop it into a standardized, plant-based hepatoprotective formulation suitable for therapeutic application.

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