Ind. J. Pharm. Edu. Res., 2025; 59(1):377-383.
https://www.ijper.org

Original Article

Evaluation of Hepatoprotective Potential of *Bougainvillea spectabilis* Extracts against CCl_4-Induced Hepatotoxicity

Prabhat Kumar Das[1,*], Jai Singh Vaghela[2]

[1]Department of Pharmacology, GRY Institute of Pharmacy, Borawan, Khargone, Madhya Pradesh, INDIA.
[2]Department of Pharmacology, Bhupal Nobles' University, Udaipur, Rajasthan, INDIA.

ABSTRACT

Background: Injuries and fatalities caused by liver disease are among the highest in the globe. Every year, more than one million people lose their lives due to chronic hepatitis, which affects an estimated 500 million people worldwide. In order to create liver disease treatments that can successfully cure or slow the illness's progression without side effects, new approaches are needed. **Objectives:** The present study's aim is to examine and confirm the buffering properties of *Bougainvillea spectabilis* extracts of ethanolic and aqueous against rat hepatic damage caused by CCl_4. **Materials and Methods:** The mice were grouped into several groups. To induce acute and massive hepatopathy, CCl_4 was injected intraperitoneally in a 1:1 ratio with olive oil at a dosage of 2 mL/kg. The toxic control group showed significant weight loss after the intoxication, as revealed by evaluation of biochemical parameters. The hepatoprotective effect was investigated by measuring body weight, serum liver enzymes such as AST, ALT, ALP, SGPT, SGOT, Total protein and albumin. Liver histopathology was then used to evaluate the hepatic architecture, every alignment and inflammatory cells. **Results:** All of the rats treated with carbon tetrachloride had significantly elevated protective markers and the rats given *B. spectabilis* extracts i.e. ethanolic and aqueous made a full recovery, returning to nearly normal levels. Histological examination corroborated these results, which indicate that *B. spectabilis* protected the cellular architecture of Carbon Tetrachloride-damaged liver cells and the hepatic membrane's structural integrity. During comparison to the aqueous group, the rats administered with the ethanolic extract showed promising outcomes that were on par with those of a conventional polyherbal medicine. **Conclusion:** Thus, ethanolic extract of the plant *B. spectabilis* may have a protective role against CCl_4-induced hepatopathy, according to the statistically significant results of our investigation.

Keywords: *Bougainvillea spectabilis*, Carbon Tetrachloride, Hepatopathy, SGPT, SGOT.

Correspondence:
Dr. Prabhat Kumar Das
Professor, Pharmacology Department, GRY Inst. of Pharmacy, Khargone, Madhya Pradesh, INDIA.
Email: kumar.prabhat3027@gmail.com

Received: 08-07-2024;
Revised: 30-08-2024;
Accepted: 18-11-2024.

INTRODUCTION

In mammals, the liver serves as a key location for cellular detoxification and is essential for general health and metabolic function. Multiple organ failure and death can result from any liver disorder, known as hepatopathy. Hepatotoxicity and liver damage can also be caused by a variety of metabolic and physiological abnormalities that makes hepatopathy a top killer on a global scale.[1-3] The lack of an effective treatment, the increasing number of cirrhosis cases and the need for liver transplantation all contribute to the enormous public health and economic burden that is chronic liver illnesses. There must be cost-effective and efficient treatment methods to reduce mortality and morbidity associated with chronic liver disease. Herbal remedies are more accessible, safer, less expensive and less harmful to the environment, and can be utilized to treat liver issues.[4] Medicinal herbs have become increasingly important in healthcare systems around the globe. There is encouraging evidence that herbal treatments containing phytochemicals can treat or prevent a variety of diseases and ailments. The exact origins of many liver diseases are still a mystery, but the most prevalent ones include things like excessive alcohol consumption, being overweight, having a genetic predisposition, an autoimmune issue, certain medications or environmental pollutants, cancer, or viral hepatitis.[5-8]

When creating models of liver and kidney damage, CCl_4 is the most well-known chemical molecule to use.[5,6] It follows that CCl_4-induced liver injury is a common and effective technique to screen hepatoprotective or liver therapeutic medications, as well as an excellent way to produce damage by xenobiotics. Free radicals trichloromethyl and proxy chloromethyl are produced during the first step of CCl_4 metabolism by the endoplasmic reticulum-based cytochrome P450 oxygenase system. Several crucial biological components, including lipids, nucleic acids, fatty acids, proteins and amino acids, are reactive

DOI: 10.5530/ijper.20250293

with the trichloromethyl radical.[7,8] Thus, to avoid CCl_4-induced hepatopathies, it is crucial to decrease free radical formation and increase the body's antioxidant activity. Drugs used to treat liver damage have several negative effects and make the disease worse, despite the great advances in medicine and modern pharmacology. Finding new medications that do not have as many adverse effects is, hence, essential. Finding a chemical with hepatoprotective and antihyperlipidemic properties while avoiding other adverse effects appears to be an urgent need.[9]

The paper flower, or *B. spectabilis*, is a member of the Nyctaginaceae family that originates in tropical South America but is now found all over the globe. It was in the early 17th century that the native South American plant Bougainvillea was introduced to Brazil. The genus quickly spread to tropical and warm areas after being introduced to the rest of the world by French Navy officer Louis Antoine de Bougainville (1729-1811). It goes by three names in different Indian languages: Booganbel, Booganvel and Kagithala puvvu.[10]

The papery bracts are narrow and delicate. This vine can reach a height of 2-4 m and has woody perennial stems that branch out in multiple trunks and form large clumps. The most popular color for Bougainvilleas is magenta or purple. A light, corky bark covers the tree. The ovate to rounded shape of the leaf is complemented by its 2-6 cm width and 5-10 cm length. The plant leaves are dark green in color and have a leathery, hairy texture on the underside. The axils of the leaves sprout a trio of blossoms. Small and slender, they have hairy tubes and are encircled with showy. They are cream-colored. The fruit is an achene with five lobes that is less than one to two cm long. Its dry, crunchy fruit layer makes it fairly unassuming.

The Brazilian native plant *B. spectabilis* is often used. This species of plant is a member of the Nyctaginaceae family, more specifically the Nyctaginaceae genus. The herb is highly valued in horticulture, pharmaceuticals, agricultural and environmental sectors in dry landscapes due to its exceptional ability to survive in a wide range of agroclimatic situations globally. It is thought that there are about eighteen different species. This Bougainvillea plant has darker-colored leaves than most of its counterparts and is coated in dense, hairy tufts.[11]

B. spectabilis contains flavonoids, alkaloids, phlobotannins, quinones, saponins, tannins, steroids, furanoids, glycosides, phenols and terpenoids in its stem, blossom and leaf extracts. Bougainvinones, α-(E)ionone, peltogynoids, pinitol, essential oils (including methyl salicylate, quercetin and terpinolene), β-sitosterol and quercetin-3-O-rutinoside are the other active ingredients.[12]

Historically, *B. spectabilis* has had multiple medicinal functions and research has shown that it has antibacterial,[13-15] anti-cancer,[16] anti-diabetic,[17-19] fertility,[20-22] analgesic,[23] anti-inflammatory,[24] antihyperlipidemic,[25,26] anti-fungal, antioxidant,[27-29] antiulcer,[30] antiviral,[31] hepatoprotective,[32] and thrombolytic effects.[33]

Despite this, there are a plethora of modern and traditional herbal remedies for liver diseases, including tricholine citrate, essential phospholipids, pancreatin with l-ornithine l-aspartate, silymarin and ursodesoxycholic acid. Unfortunately, the majority of these remedies are ineffective and come with harmful side effects. New herbal treatments have an opportunity to gain traction in industrialized countries due to the growing popularity of complementary and alternative medicine.

No research into *B. spectabilis* ability to alleviate hapatotoxicity in the leaf portion has been conducted as far as we are aware. The stem area of the herb is where its hepatoprotective properties have been found.[34] Flavonoids, tannins, phenols, steroids and a plethora of other phytochemicals were identified by phytochemical screening, as were their antioxidant properties and their potential for use in many biomedical contexts.[12] This study investigates the potential hepatoprotective effects of *B. spectabilis* leaves extract against CCl_4-induced hepatic toxicity in experimental animals. Rats given *B. spectabilis* extract had their liver enzyme levels measured, including total protein, albumin, AST, ALT and ALP and subjected to carbon tetrachloride-induced hepatotoxicity. In addition to standard drug Liv 52, we compared the outcomes to those of lipid peroxidation and Glutathione (GSH) levels.

MATERIALS AND METHODS

The process of collecting and authenticating plant samples

Taxonomists helped identify *B. spectabilis* leaves collected in and around Narmada River Valley, during the flowering stage based on their morphological traits. The plant specimen, with the accession number SKM/PGC/2018/X-10 and the Professor Dr. S.K. Mahajan, a retired Botany professor from PG Government College Khargone, authenticated as *B. spectabilis* Willd. (Family: Nyctaginaceae) and sent to BN Pharmacy College in Udaipur, Rajasthan. Following authentication, the blooms and stems were delicately removed, and leaves were collected for further screening.

Chemicals and Reagents

The investigation utilised analytical grade chemicals supplied from Merck Specialties Private Limited in Mumbai, India.

Method of extract preparation

The collected leaves were air-dried in a shady spot, split and ground into a coarse to fine powder with a mechanical grinder. The powder was subsequently passed through sieves 40 and 10. The dried powdered leaves of *B. spectabilis* (250 g) were initially defatted with pet ether (60-80°C). Subsequently, they were extracted with chloroform, ethyl acetate and ethanol based on their polarity index using the continuous hot extraction method

in a Soxhlet apparatus. Finally, water extraction was performed using the maceration with heat and agitation method. The resultant extracts were standardized and used to assess the *in vivo* hepatoprotective efficacy.

Animal Husbandry

The care and use of animals in this study was conducted in accordance with the criteria established by the CCSEA. Animal house conditions at BNCP, Udaipur, Rajasthan, were approved by the CCSEA members. The proposal number for accepted protocol is 13/BNCP/IAEC/2024 and the study has been approved by the IAEC of the institute. The study included male Wistar rats between the ages of 8 and 10 weeks. The animals will be monitored daily for clinical signs and they will be socialized with the laboratory environment for at least 14 days. The animals were housed in a typical scientific lab setting with 12 hr of light and dark cycles, fresh air circulation, temperatures between 22 and 28°C and relative humidity between 39 and 50%. A stainless-steel mesh top grill served as a food storage area for pellets and a water source for each animal housed in a cage. The animals were provided with an abundance of reverse osmosis water and were fed standard laboratory rodents.

Acute Oral Toxicity Study[35]

Using adult Swiss albino mice (weighing 20-25 gm), we conducted this experiment in accordance with the guidelines provided in OECD No. 423. Ten mice per group were given one of five dosages of the ethanolic and water-based extract, with doses ranging from 500 to 2500 mg/kg, for the purpose of the acute toxicity test. Throughout the investigation, researchers utilised tools like the Rota rod and actophotometer to closely analyze the mice's behaviour. Excretion, dilated pupils, sedation, hypothermia, convulsions, hyperactivity, skin or fur alterations, decreased spontaneous activity and any other abnormalities or toxic symptoms were examined. Afterwards, the animals were checked on every day for seven days at regular intervals.

In vivo hepatoprotective activity

In order to conduct pre-clinical investigations, a cohort of thirty Wistar rats were arbitrarily distributed in five groups, every group contained six animals. Gr-I, designated as the usual control, administered orally a dose of 0.5% Sodium CMC, with every member receiving 1 mL each day for a period of seven days. Gr-II, the toxic control group, was administered only dose of CCl_4 (CCl_4 mixed with olive oil in same ratio, 2 mL/kg, intraperitoneally) on the first and seventh day of the protocol.[36] Group III designated as standard was administered a standard drug Liv-52 with a dose of 5 mL/kg oral. They also received an only intraperitoneal dosage of CCl_4 on the first and seventh day. Gr-IV and V was given an ethanolic and aqueous fraction of *B. spectabilis* at the dosage of 200 mg/kg. Both Gr-IV and V administered the respective extracts once in everyday for all seven days, with an only intraperitoneally dosage of CCl_4 on the first and seventh day.[37]

Parameters to be analyzed

After the treatment period ended, on day 8 all of the rats were anaesthetized with Phenobarbital at the dose of 40 to 50 mg/kg. Some of the animals had their blood samples taken by directly puncturing the heart at the ventricular location prior to sacrifice. Serum and plasma samples were kept at -20°C for biochemical examination. Subsequently, according to predetermined procedures, the serum markers of hepatic function, including albumin, total protein, SGPT, SGOT, AST and ALP, were determined.[38-40] The biochemical measurements were conducted using Biochemical semi auto analyzer following normal methods with the use of commercial kits.

In a subsequent phase, the same animals were put to death by administering a phenobarbital dosage of 80 to 90 mg/kg. Prior to sacrifice, the livers of the test animals were extracted, and the tissue samples were preserved using a formalin solution (a mixture of formaldehyde and normal saline, with a concentration of 10% v/v). Before histological investigation, the tissue samples were fixed in paraffin wax and micro sliced into thin sections.[41,42]

Statistical Analysis

Mean values±SEM (standard error of mean) were used to tabulate the results of hepatoprotective experiments conducted. To find the statistical difference and significance of the data, we conducted analysis of variance and evaluated the groups using the "Tukey-Kramer" multiple comparison test. We used a significance level of $p<0.05$. All other treatment groups were evaluated in relation to the toxic control group by *in vivo* procedures, whereas the normal control group was evaluated in relation to the toxic control group.

RESULTS

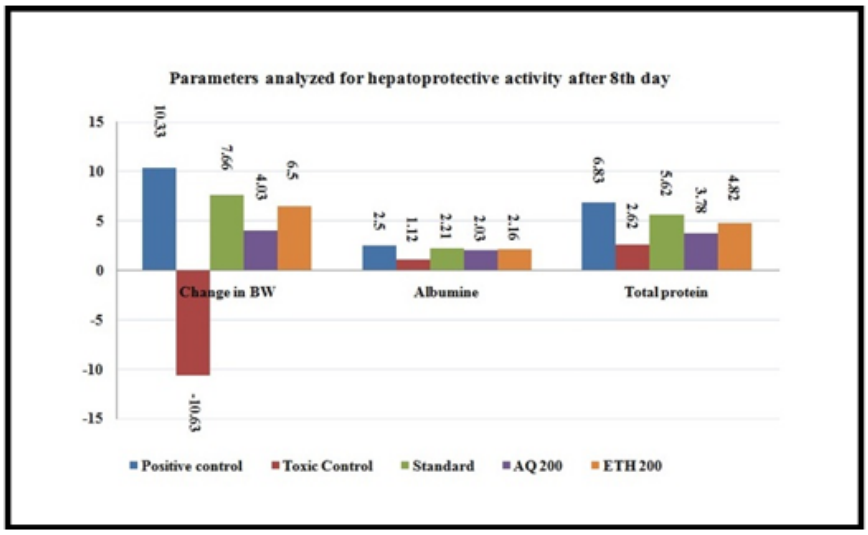
For $n=6$. Gr-I, III, IV, V were compared to the toxic control group and the toxic control group was compared to the normal control group. $^{*}p<0.05$, $^{**}p<0.01$, $^{**}p<0.001$ statistically significance.

In our toxicological studies despite receiving dosages ranging from 500 to 1500 mg/kg, none of the experimental drug groups experienced major or deadly adverse effects. A dosage of 2000 mg/kg was found to influence the behavior of selected mice when exposed to ethanolic and water-based extracts. Hence, we used a dosage of 200 mg/kg of ethanolic and aqueous extract to perform additional tests. Tables 1, 2 and Figure 1 summarize the findings of our *In vivo* hepatoprotective investigations. We discovered that *B. spectabilis* extract had a beneficial hepatoprotective effect in mice based on the parameters. On the eighth day of the experiment, we looked at the subjects' weight changes along with serum liver function markers such as AST, ALT, ALP, SGPT, SGOT, albumin and total protein. A notable increase in marker

Table 1: Biochemical analysis and Enhancement of rat liver recovery by extracts of *B. spectabilis* (200 mg/kg/day) and a poly herbal formulation Liv. 52 (5 mL/kg/day) given daily for 07 days to CCl_4 induced rats. (*n*=6).

Groups	Difference in body weight (g)	Albumin (g/dl)	Total protein (g/dl)	AST (IU/l)	ALT (IU/l)
Gr- I (Normal control)	10.33±0.88	2.5±0.42	6.83±1.65	86.23±8.16	62.38±3.52
Gr-II (Toxic control)	-10.63±1.72	1.12±0.29	2.62±0.85	538.21±42.12	351.75±25.63
Gr-III (Standard)	7.66±0.71**	2.21±0.31***	5.62±0.37**	189.34±12.45***	153.26±12.36***
Gr-IV (Aq 200 mg/kg)	4.03±0.57*	2.03±0.27*	3.78±0.83	412.63±24.16*	289.57±17.92
Gr-V (Eth 200 mg/kg)	6.5±0.76***	2.16±0.43**	4.82±0.65**	238.45±16.52**	195.37±5.23*

Values are given in mean ±SEM.



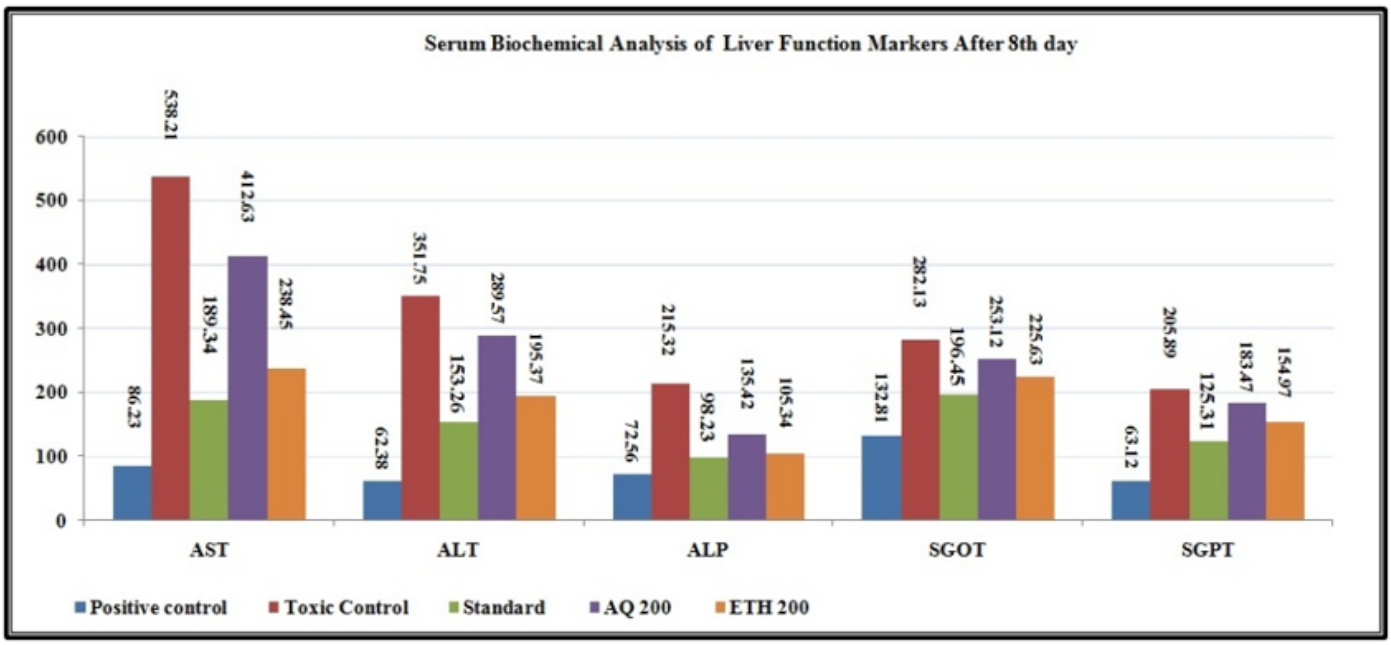


Figure 1: Histogram of analyzed parameters in hepatoprotective model.

enzyme levels (538.21±42.12 IU/l for AST, 351.75±25.63 IU/l for ALT, 215.32±6.24 IU/l for ALP, 282.13±27.13 IU/l for SGOT and 205.89±16.36 IU/l for SGPT) indicated that the animals given CCl_4 (Toxic control) had severe hepatotoxicity comparable to normal controls (86.23±8.16 IU/l for AST, 62.38±3.52 IU/l for ALT, 72.56±7.29 IU/l for ALP, 132.81±2.13 IU/l for SGOT and 63.12±6.53 IU/l for SGPT) . In comparison to the normal control, toxic control also indicated a notable drop in serum total protein (2.62±0.85), albumin (1.12±0.29) and ultimate altered body weight (-10.63±1.72). The rat group that was administered the standard polyherbal drug (Liv-52) had significantly lower serum levels of AST (189.34±12.45 IU/l), ALT (153.26±12.36 IU/l), ALP (98.23±5.71 IU/l), SGPT (125.31±18.93 IU/l) and SGOT (196.45±12.53 IU/l) as well as significantly higher serum albumin (2.21±0.31), total protein (5.62±0.37) and altered body weight (7.66±0.71) in comparison to toxic control. The rats of Group IV, who were given an aqueous extract at dosage of 200 mg/kg, showed increase in body weight of 4.03±0.57 g. There was a considerable decline in the levels of AST (412.63±24.16 IU/l), ALT (289.57±17.92 IU/l), ALP (135.42±5.65 IU/l), SGPT (183.47±27.51 IU/l) and SGOT (253.12±17.83 IU/l). The serum albumin level (2.03±0.27) and total protein level (3.78±0.83) were considerably higher than that of toxic control. In comparison to toxic control, Group V treated with 400 mg/kg ethanol extract had significantly higher body weight (6.5±0.76g) and significantly lower levels of AST (238.45±16.52 IU/l), ALT (195.37±5.23 IU/l), SGPT (154.97±17.43IU/l) and SGOT (225.63±11.29 IU/l). When comparison to the toxic group, the levels of serum total protein (4.82±0.65 g/dl) and albumin (2.16±0.43 g/dl) were higher, but the level of ALP (105.34±7.21 IU/l) was significantly lower.

In addition, we looked at the potential protective impact of *B. spectabilis* extract on liver tissue by histological studies. Figure 2a-e shows a transverse segment of liver tissue from each experimental group. The TS of a control rat with normal hepatocellular structure is shown in Figure 2a. On the other hand, inflammatory cells, necrotic patches and disrupted hepatocellular organisation were seen in the TS of toxic control rats (Figure 2b), indicating drastic hepatic injury with the presence of necrotic cells around central vein. In compared to the toxic control, the TS of the standard group and the group treated with *B. spectabilis* ethanolic extract (200 mg/kg) demonstrated better hepatocellular architecture and almost no necrotic lesions and regeneration of hepatocytes around central vein (Figure 2c and 2e, respectively), while in aqueous extract treated group indicated less inflammatory cells around central vein, with the presence of necrosis cells (Figure 2d).

DISCUSSION

Based on the results show that the rats treated with *B. spectabilis* extract (*in vivo*) were far less likely to suffer liver damage from CCl_4 exposure. The ethanolic extract of *B. spectabilis* had a far

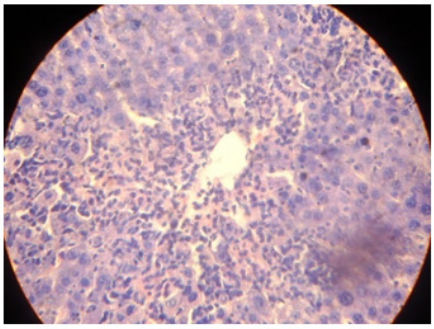


Figure 2a: Liver histopathology of control group

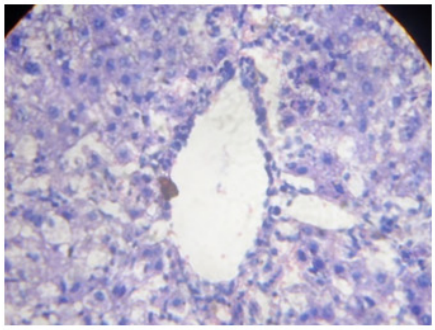


Figure 2b: Liver histopathology of Toxic control

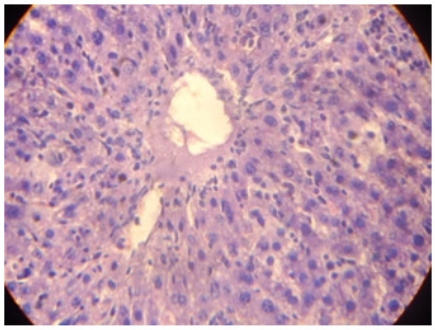


Figure 2c: Liver histopathology of Standard group

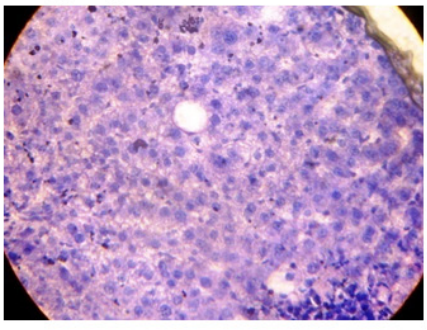


Figure 2d: Liver histopathology of aqueous group

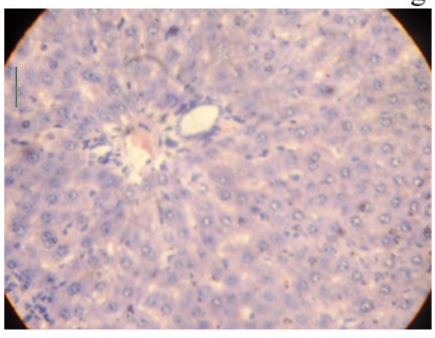


Figure 2e: Liver histopathology of ethanolic group

Figure 2: Histopathological section of liver tissue in hepatoprotective model.

Table 2: Biochemical analysis and Enhancement of rat liver recovery by extracts of *B. spectabilis* (200 mg/kg/day) and a poly herbal formulation Liv. 52 (5 mL/kg/day) given daily for 07 days to CCl_4 induced rats. (*n*=6).

Groups	SGOT (U/l)	SGPT (U/l)	ALP (IU/l)
Gr- I (Normal control)	132.81±2.13	63.12±6.53	72.56±7.29
Gr-II (Toxic control)	282.13±27.13	205.89±16.36	215.32±6.24
Gr-III (Standard)	196.45±12.53*	125.31±18.93***	98.23±5.71**
Gr-IV (Aq 200 mg/kg)	253.12±17.83	183.47±27.51*	135.42±5.65*
Gr-V (Eth 200 mg/kg)	225.63±11.29**	154.97±17.43**	105.34±7.21**

Values are given in mean ±SEM.

stronger hepatoprotective effect *in vivo* than the water-based extract, which is quite intriguing. By enhancing metabolic processes (as measured by biochemical marker enzymes) and hepatocellular architecture (as measured by tissue histology), the *B. spectabilis* extract treatments made it such that the hepatic cells could withstand CCl_4. This was in contrast to the toxic group.

Many active phytoconstituents, including alkaloids, phenols, quinones, saponins, steroids, tannins, flavonoids, furanoids, glycosides, phlobotannins, and terpenoids, are found in ethanolic fraction of plant, as has been extensively described. We conclude that the active phytochemicals in the ethanolic extract of the plant are responsible for its strong hepatoprotective potential, as opposed to the insignificant effect of the water-based extract, which lacks these compounds. As previously stated, CCl_4 is a powerful hepatotoxin that promotes hepatopathy *in vivo* by inducing lipid peroxidation. Multiple studies have shown that certain phytochemicals, including flavonols, flavonoids, triterpenoids, sterols and alkaloids, can prevent CCl_4-induced lipid peroxidation.[43,44] Therefore, we infer that the hepatoprotective action displayed by *B. spectabilis* in our experimental setting is due to the active phytochemicals found in the plant's ethanolic extract, which could be composed of single molecules or a complex combination of them. In order to progress in this area of study, we need to determine which phytochemicals in *B. spectabilis* are hepatoprotective.

CONCLUSION

In this pharmacological evaluation against substance (CCl_4) caused hepatopathy, the hepatoprotective effect of ethanolic and aqueous *B. spectabilis* plant leaf extracts was investigated in detail. Based on our findings, the ethanolic extract of *B. spectabilis* has more hepatoprotective effects than the water-based fraction. At a dosage of 200 mg/kg, the plant's ethanolic extract showed competent, potent and comparable effects, while the water-based extract showed moderate efficacy. These findings support the idea that *B. spectabilis* is a potentially useful hepatoprotective plant species and they call for extensive, multi-faceted, molecular-level research into the plant in the future to fill in the gaps in our understanding of it and its protective mechanism. Possible future research directions include investigating antioxidant and free radical scavenging capabilities, toxicological investigations, hepatoprotective studies in different chronic hepatopathies models.

ACKNOWLEDGEMENT

Dr. Y. S. Sarangdevot, Dean of the BNCP, BN University in Udaipur, Rajasthan and Dr. J.S. Vaghela, Associate Professor at the same institution, were invaluable in providing the writers with the guidance and support they needed to complete this project on schedule and the writers are eternally grateful to them.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

FUNDING SOURCE

No source of fundings have been disclosed by the authors.

ETHICAL APPROVAL

All the animal experimentation were conducted in CCSEA approved facility in BN University, Udaipur and Proposal number for accepted protocol is 13/BNCP/IAEC/2024 and the study has been approved by the IAEC of the concerned institute.

ABBREVIATIONS

B. spectabilis: *Bougainvillea spectabilis*; **AST:** Asparate transaminase; **ALT:** Alanine aminotransferase; **ALP:** Alkaline phosphatase; **SGPT:** Serum glutamate oxaloacetate transaminase; **SGOT:** Serum glutamate pyruvate transaminase; **CCl_4:** Carbon Tetrachloride; **CMC:** Carboxy methyl cellulose; **CCSEA:** Committee for the control and supervision on experimental animals; **IAEC:** Institutional Animal Ethical Committee.

SUMMARY

- The pharmacological efficacy of *B. spectabilis* against CCl_4-induced hepatotoxicity in rats is detailed in this work.
- In contrast to the effects of CCl_4-induced hapatotoxicity, which reduced levels of AST, ALP, ALT, SGPT and SGOT, the ethanolic extract of *B. spectabilis* increased levels of albumin and total protein.

- Rats subjected to CCl_4-induced hapatotoxicity had their levels of histopathological parameters markedly reduced by an ethanolic extract of *B. spectabilis*.
- An substantial hepatoprotective effect was eventually elicited by an extract of *B. spectabilis*.

REFERENCES

1. Ram VJ, Goel A. Past and present scenario of hepatoprotectants. Current Medicinal Chemistry. 1999;6(3):217-54.
2. Weber LW, Boll M, Stampfl A. Hepatotoxicity and mechanism of action of haloalkanes: Carbon tetrachloride as a toxicological model. Critical Reviews in Toxicology. 2003;33(2):105-36.
3. Maddrey WC. Drug-induced hepatotoxicity. Journal of Clinical Gastro enterology. 2005;39:83-9. DOI:10.1080/713611034
4. Izzo AA, Hoon-Kim S, Radhakrishnan R, Williamson EM. A critical approach to evaluating clinical efficacy, adverse events and drug interactions of herbal remedies. Phytotherapy research. 2016;30(5):691-700. Available from: doi.org/ 10.1002/ptr.5591.
5. Koul B, Kumar A, Yadav D, Jin JO. Bergenia genus: Traditional uses. phytochemistry and pharmacology. Molecules. 2020;25(23):5555. Available from: doi.org/ 10.3390/molecules25235555.
6. Petta S, Muratore C, Craxi A. Non-alcoholic fatty liver disease pathogenesis: the present and the future. Dig Liver Dis. 2009;41(9):615-25. Available from: doi.org/10.1016/j.dld.2009.01.004.
7. Mirzaagha F, Azali SH, Islami F, Zamani F, Khalilipour E, Khatibian M, Malekzadeh R. Coeliac disease in autoimmune liver disease: a cross-sectional study and a systematic review. Digestive and Liver Disease. 2010;42(9):620-23. Available from: doi.org/10.1016/j.dld.2010.02.006.
8. Fong CY, Gauthaman K, Bongso A. Teratomas from pluripotent stem cells: a clinical hurdle. Journal of cellular biochemistry. 2010;111(4):769-81. Available from: doi.org/10.1002/jcb.22775.
9. Negi VS, Elluru S, Siberil S, Graff Dubois S. Intravenous immunoglobulin: an update on the clinical use and mechanisms of action. Journal of clinical immunology. 2007;27:233-45. Available from: doi.org/ 10.1007/s10875-007-9088-9.
10. Mahajan MM, Dudhgaonkar S, Deshmukh SN. Anti-diabetic and hypolipidemic effects of the aqueous leaf extract of Bougainvillea species. Int J Basic Clin Pharmacol. 2015;4:596-7. Available from: https://doi.org/10.18203/2319-2003.ijbcp20150007.
11. Aruna Kumari T. A phytopharmacological review on *Bougainvillea spectabilis*, International Journal of Pharmacology Research, 2017;7(1):36-9.
12. Das P, Vaghela J, Badore N. Pharmacognostical, Phytochemical and Fluorescence analysis of the plant *Bougainvillea spectabilis* (Willd.). Research J. Pharm. and Tech.2021;14(7): 3733-8. Available from: https://doi.org/10.52711/0974-360x.2021.00646.
13. Alamelu V, Ananthi T. Phyto-chemical Screening and *In vitro* Anti-bacterial Studies on *Bougainvillea spectabilis* Willd. Research Journal of Pharmacognosy and Phytochemistry. 2013;5(3):130-2.
14. Swamy KM, Sudipta KM, Lokesh P, Neeki MA, Rashmi W, Bhaumik SH. Phytochemical screening and *in vitro* antimicrobial activity of *Bougainvillea spectabilis* flower extracts. Int J Phytomed. 2012;4(3):375-9.
15. Hajare CN, Inamdar FR, Patil RV, Shete CS, Wadkar SS, Patil KS. Antibacterial activity of the leaves of *Bougainvillea spectabilis* against E. coli NCIM 2832 and M. aureus NCIM 5021. Int J Pharm Sci Rev Res. 2015;34(1):194-6.
16. Kumar DJ, Sonia K, Madhan R, Selvakumar K. Anti yeast, antioxidant and anticancer activity of Tribulus terrestris Linn and *Bougainvillea spectabilis* Linn. Res J Pharm Technol. 2011;4(9):1483-9.
17. Devi MC, Ramesh B. Hypoglycemic activity of Leaves of *Bougainvillea spectabilis* extract in Streptozotocin-Induced Diabetic Rats. Asian Journal of Pharmaceutical Research. 2018;8(2):99-105. Available from: https://doi.org/10.5958/2231-5691.2018.00017.5
18. Saikia H, Das S. Anti diabetic action of *Bougainvillea spectabilis* (leaves) in normal and alloxan induced diabetic albino rats. Indian Drugs. 2009;46(5):391-7.
19. Jawla S, Kumar Y, Khan MS. Hypoglycemia activity of *Bougainvillea spectabilis* stem bark in normal and alloxan-induced diabetic rats. Asian Pac J Trop Biomed. 2012;2(2):919-923. Available from: https://doi.org/10.1016/s2221-1691(12): 60337-2.
20. Mishra N, Joshi S, Tandon VL, Munjal A. Evaluation of anti-fertility potential of aqueous extract of *Bougainvillea spectabilis* leaves in swiss albino mice. Int J Pharm Sci Drug Res. 2009;1(1):19-23.
21. Available from: https://doi.org/10.25004/ijpsdr.2009.010105.
22. Singh VN, Hembrom AR, Pragya S. Selective and directional influence of *Bougainvillea spectabilis* on anodic electrophoretic proteins and M-Isozymes of LDH in semen of mice in relation to fertility control. International research journal of pharmacy. 2014;5(7):576-7. Available from: https://doi.org/10.7897/2230-8407.0507116.
23. Ali MS, Ibrahim SA, Ahmed F, Pervez MK. Colour versus bioactivity in the flowers of *Bougainvillea spectabilis* (Nyctaginaceae). Nat Prod Res. 2005;19(1):1-5. Available from: https://doi.org/10.1080/14786410310001630609.
24. Chatterjee, C, Mandal G, Mukhopadhyay K, Das S, Mukherjee S, Chatterjee M. Evaluation of Analgesic Activity of Methanolic Extract of *Bougainvillea spectabilis* Leaves in Experimental Animal Models. Annals of International Medical and Dental Research. 2016;2(5):145-50.
25. Available from: https://doi.org/10.21276/aimdr.2016.2.5.pc1.
26. Mandal G, Chatterjee C, Chatterjee M. Evaluation of anti-inflammatory activity of methanolic extract of leaves of *Bougainvillea spectabilis* in experimental animal models. Pharmacogn Res. 2015;7(1):18-22.
27. Available from: https://doi.org/10.4103/0974-8490.147194.
28. Adebayo JO, Adesokan AA, Olatunji LA, Buoro DO, Aoladoye AO. Effect of ethanolic extract of *Bougainvillea spectabilis* leaves on hematological and serum lipid variables in rats. Biokemistri. 2005;17(1):45-50.
29. Available from: https://doi.org/10.4314/biokem.v17i1.32588.
30. Saikia H, Lama A. Effect of *Bougainvillea spectabilis* leaves on serum lipids in albino rats fed with high fat diet. Int J Pharm Sci Drug Res. 2011;3(2):141-5. Available from: https://www.ijpsdr.com/index.php/ijpsdr/article/view/266
31. Martinez CL, Reyes ME, Bringas BA, Avalos HA, Jimenez SG. Determination of radical scavenging activity of hydroalcoholic and aqueous extracts from Bauhinia divaricata and *Bougainvillea spectabilis* using the DPPH assay. Pharmacognosy Res. 2009;1(5):238-44. Available from: https://www.phcogres.com/article/2009/1/5/nil.
32. Venkatachalam RN, Singh K, Marar T. *Bougainvillea spectabilis*, a good source of antioxidant phytochemicals. Res J Pharm Biol Chem Sci. 2012;3(3):605-13. Available from: https://api.semanticscholar.org/CorpusID:98039524.
33. Dhankhar S, Sharma M, Ruhil S, Balhara M, Kumar M, Chhillar AK. Evaluation of antimicrobial and antioxidant activities of *Bougainvillea spectabilis*. Int J Pharmacy and Pharmaceutical Sciences. 2013;5(3):178-82.
34. Malairajan P, Gopalakrishnan G, Narasimhan S, Jessi KV. Antiulcer activity of crude alcoholic extracts of *Bougainvillea spectabilis* Willd. Jundishapur J Nat Pharm Prod. 2007;2(1):1-6. Available from: https://brieflands.com/articles/jjnpp-75748.
35. Bolognesi A, Polito L, Olivieri F, Valbonesi P, Barbieri L, Battelli MG. New ribosome-inactivating proteins with polynucleotide:adenosine glycosidase and antiviral activities from Basella rubra L. and *Bougainvillea spectabilis* Willd. Planta. 1997;203(4):422-9. Available from: https://doi.org/10.1007/s004250050209.
36. ADEBAYO, Joseph O, Ayoade A, ADESOKAN, Lawrence A. OLATUNJI, Daniel O. BUORO, Ayodele O. SOLADOYE. Effect of ethanolic extract of *Bougainvillea spectabilis* leaves on haematological and serum lipid variables in rats. BIOKEMISTRI. 2005;17(1):45-50.
37. Suresh A, Sultana DM. Evaluation of *in vitro* thrombolytic activity using *Bougainvillea spectabilis* aqueous leaf extract under different concentrations. International Research Journal of Pharmacy. 2019;10(7):65-69. https://doi.org/10.7897/2230-8407.1007220.
38. Sarje S. K, Kadam V. M, Hede A. B, Ware S. V, Patil V. D. Phytochemical Investigation And Pharmacological Evaluation of *Bougainvillea spectabilis* For Hepatoprotective Activity. World Journal of Pharmaceutical Research. 2020;9(3):1128-44. Doi: 10.20959/Wjpr20203-16885.
39. Smith QE. Pharmacological screening tests progress in medicinal chemistry, Butterworths. London, 1960;16:1-5.
40. Ray D, Sharatchandra Kh, Thokchom IS, Antipyretic, antidiarrhoeal, hypoglycemic and hepatoprotective activities of ethyl acetate extract of Acacia catechu Wild. in albino rats. Indian Journal of Pharmacology. 2006;38(6):408-13.
41. Sandhir R, Gill KD. Hepatoprotective effects of Liv.52 on ethanol-induced liver damage in rats. Indian Journal of Experimental Biology. 1999;37(8):762-6.
42. Doumas BT, Watson WA, Biggs HG. Albumin standards and the measurement of serum albumin with bromocresol green. Clinica et Chimica Acta. 1971;31:87-96.
43. Tietz NW, Burtis CA, Ashwood ER. Tietz Text Book of Clinical Chemistry (3rd Edn), W.B Saunders Co., Philadelphia, USA, 1999;617-721.
44. Cheesbrough M, District Laboratory Practice in Tropical Countries, Cambridge University Press, United Kingdom, 2003;1:310-95.

Cite this article: Das PK, Vaghela JS. Evaluation of Hepatoprotective Potential of Bougainvillea spectabilis Extracts against CCl4-Induced Hepatotoxicity. Indian J of Pharmaceutical Education and Research. 2025;59(1):377-83.