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A Review on Herbal Plants with Hepatoprotective Effects

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Abstract

The development of liver illnesses has emerged as a serious concern in world health. These diseases may be caused by several harmful compounds, such as chemotherapeutic drugs, thioacetamide, carbon tetrachloride, certain antibiotics, heavy alcohol use, and harmful bacteria. Therefore, excellent health and well-being depend on maintaining a functioning liver. Synthetic drug drawbacks have surpassed their benefits, despite pharmacological advancements. Contemporary medical approaches to liver disease treatment are not only inefficient, but also linked to harmful side effects and very high prices, making them unaffordable for underdeveloped nations. Therefore, there seems to have been a global upsurge in interest in investigating medicinal plants as potential alternative treatment agents for illnesses. These plants are readily accessible, inexpensive, and do not need labor-intensive pharmaceutical manufacturing methods. The focus has so been on traditional herbs that are very effective, have minimal toxicity, and are cost-efficient. This research presents the results of a literature search that used many databases, including PubMed, ISI Web of Knowledge, and Google Scholar. We reviewed all available material on medicinal plants from throughout the globe that have the potential to protect the liver. Additionally, we covered phytochemical substances that have hepatoprotective properties, and we concluded by highlighting upcoming research in the topic.

Key words: Bioactive compounds, hepatotoxicity, liver diseases, medicinal plant, pharmacology.

Introduction

The liver, with its many roles in the body, is the most important and vital organ. In addition to excreting waste metabolites, it plays a role in the metabolism of nutrients including lipids, proteins, and carbs. The liver has a role in the breakdown and removal of toxins, including medicines and other foreign chemical compounds, because it is the first organ in the body to receive toxins from the intestines. The liver's precise roles in the body are as follows.

There are a lot of chemicals that may be stored in it, including glycogen, minerals, vitamins, and iron. When energy needs arise and blood sugar drops too low, the liver converts glycogen stores into glucose, which the body may use.Toxin by-products, pathogenic organisms, medications, alcohol, chemicals, heavy metals, and more are all removed from the bloodstream by this process.In addition, chemicals, medications, viruses, bacteria, parasites, fungus, herbicides and pesticides, lipids, dietary additives, alcohol, and dead cells are among the waste products and pollutants of blood that the liver eliminates. Furthermore, the liver is sometimes referred to as the body's biochemical unit due to the fact that it performs all duties via various organs including the lungs, skin, and mouth. Prior to their distribution to various areas of the body, it metabolises chemicals in the circulation.Digesting and emulsifying lipids, oils, and other substances (including vitamins A, D, E, and K) requires the production of bile,

which the liver produces as part of its digestive function [4]. Blood proteins, enzymes, hormones, immunological factors, and clotting factors are among the proteins that it may produce. At last, during times of low blood sugar, the liver may manufacture cholesterol, a transporter for the energy-supplying lipids required for adenosine triphosphate production in the body.

HEPATOTOXICITY AND LIVER DISEASES

The incidence of liver illnesses in developing nations ranks high among the world's most pressing health concerns. Different types of liver illness include noninflammatory hepatosis, inflammatory acute or chronic hepatitis, and degenerative cirrhosis or fibrosis. They are usually caused by heavy metals, poisons, starvation, and the use of OTC drugs without a doctor's prescription. Alcoholic liver disease, hepatitis, jaundice, and liver fibrosis are the end outcomes of the aforementioned causes' destruction and impairment of hepatocytes. One sign of liver damage or illness is an increase in blood cholesterol levels. Cardiovascular disorders are more likely to occur in individuals with high levels of low-density lipoprotein cholesterol (LDL-C) and triacylglycerols (TAGs).[5]

Further factors that have been extensively studied and found to cause damage to hepatic cells include hepatic cell overconsumption, toxic substances like thioacetamide (TAA), drug abuse (e.g., paracetamol), chemotherapeutic agents like carbon tetrachloride (CC14), aflatoxin, microbes, and viral infections (e.g., hepatitis A, B, C, and D).From 6 to 8, A chain reaction occurs and potentially initiates lipid peroxidation when the endoplasmic reticulum and mitochondrial cytochrome P-450 metabolise CC14, leading to the generation of reactive oxygen species (ROS, CCl_3O^-).

PCM is often used as an analgesic or an antipyretic to reduce or eliminate fever. Overdosing on this medication causes harm to the liver cells, which in turn causes illness or injury to the liver.[9] Moreover, considerable excessive hepatic damage may result from the death of the majority of liver cells (necrosis), which is marked by nuclear pyknosis and eosinophilic cytoplasm, when PCM is administered in excess. An oxidative byproduct, N-acetyl-P-benzoquinoneimine, is formed during PCM metabolism in the liver. This compound makes a covalent connection with the sulfhydryl groups of proteins, namely with cytochrome P-450 enzymes. Hepatocyte necrosis results from this process's ultimate cause: the peroxidative breakdown of glutathione (GSH) lipids.

One other chemical that causes membrane damage is trimethylammonium (TAA), which blocks the free passage of RNA between the nucleus and cytoplasm. This damage to the liver is caused by the TAA metabolite.[9] In addition to lowering the frequency of oxygen consumption, TAA may decrease the number of hepatocytes. Furthermore, it decreases both the amount of bile and the concentration of bile salts and deoxycholic acid within it. An rise in blood levels of toxins is a symptom of hepatotoxin-associated liver damage, which causes abnormal bile excretion.[10] The health of humans depends on this liver's ability to function normally at all times.From 11 to 13, Despite its remarkable regenerating capabilities, the liver is constantly exposed to harmful environmental contaminants such xenobiotics and chemotherapeutic drugs, which may inhibit its natural defensive mechanisms and cause liver dysfunction and damage.[14]

Conversely, most hepatotoxic substances cause damage to hepatocytes, which in turn hinders kidney function, often via oxidative processes such lipid peroxidation. The body's antioxidant mechanisms fall short when the liver is injured. Radon oscillations (ROS) may be produced by several external factors, including X-rays, contaminants, UV radiation, or metabolic reactions inside the mitochondria.[15] The rate of ROS generation and clearance by various endogenous antioxidants, including enzymatic and nonenzymatic mechanisms, is the only factor that determines the intracellular concentration of ROS.[15]

According to many studies, free radicals cause oxidative stress, which in turn causes hepatocyte degeneration, swelling, necrosis, and apoptosis. Lipid peroxidation and covalent binding are the typical pathways by which free radicals cause liver damage or damage, leading to subsequent tissue destruction. The lipids, proteins, and nucleic acid in cell membranes are destroyed by reactive oxygen species (ROS),

which have been associated with various age-related problems such as atherosclerosis, diabetes, kidney and lung damage, liver disorders, cancer, inflammatory diseases, and cardiovascular diseases.On pages 16 and 17, Cell membranes are vulnerable to lipid peroxidation, which compromises their structural integrity and functioning. This, in turn, reduces the cell's ability to sustain consistent ion gradients and transport.[18] in Conversely, chemical exposure and excessive drug usage may also harm the liver.[14] The effects of many medicines on the liver have been documented, as shown in Table 1 and Figure 1.

FREE RADICALS AND LIPID PEROXIDATION

To prevent free radical-induced lipid peroxidation, the free radical scavenging process is crucial.The metabolic pathway that begins with ethanol exposure enhances lipid peroxidation, which in turn causes hepatitis and, ultimately, cirrhosis [19].

In recent decades, hepatoprotective medicines derived from less toxic plant compounds have been used. Therefore, there has been significant study in this sector focused on continuously exploring plant diversities for new hepatoprotective potential.In [20], It is important to maintain a balance between reactive oxygen species (ROS) and antioxidant enzymes like glutathione peroxidase (GSH-Px), superoxide dismutase (SOD), and catalase (CAT) in order to prevent damage caused by oxidative stress, as earlier research has shown that an excess of ROS intensifies oxidative stress, leading to health problems like diabetes, kidney and liver injury, cancer, and heart disease.Natural lipid peroxidation defenders, the enzymatic antioxidant defence systems [22] include Cu-Zn, Mn-SOD, CAT, and GSH reductase; they work by directly or sequentially removing ROS, therefore halting or decreasing this process.[23] Glutathione (GSH) is a crucial cytosolic antioxidant that plays a role in the detoxification and excretion of xenobiotics; keeping its level high is vital for avoiding lipid peroxidation.CCl4 is one of the xenobiotics that may cause acute damage to liver cells by generating free radicals, namely trichloromethyl radicals [24].[25] The Typically, the liver has an increasingly protective mechanism for compounds that enhance the activity of glutathione S-transferase, an enzyme that may transform harmful molecules into innocuous ones. Because they have less of an impact on the body's processes, natural goods, such as medicinal plants and their constituents, have the potential to cure and prevent a wide range of disorders.references 26 and 27 Research has shown that some herbal extracts may have a protective effect on an overloaded liver.8,13, and 28

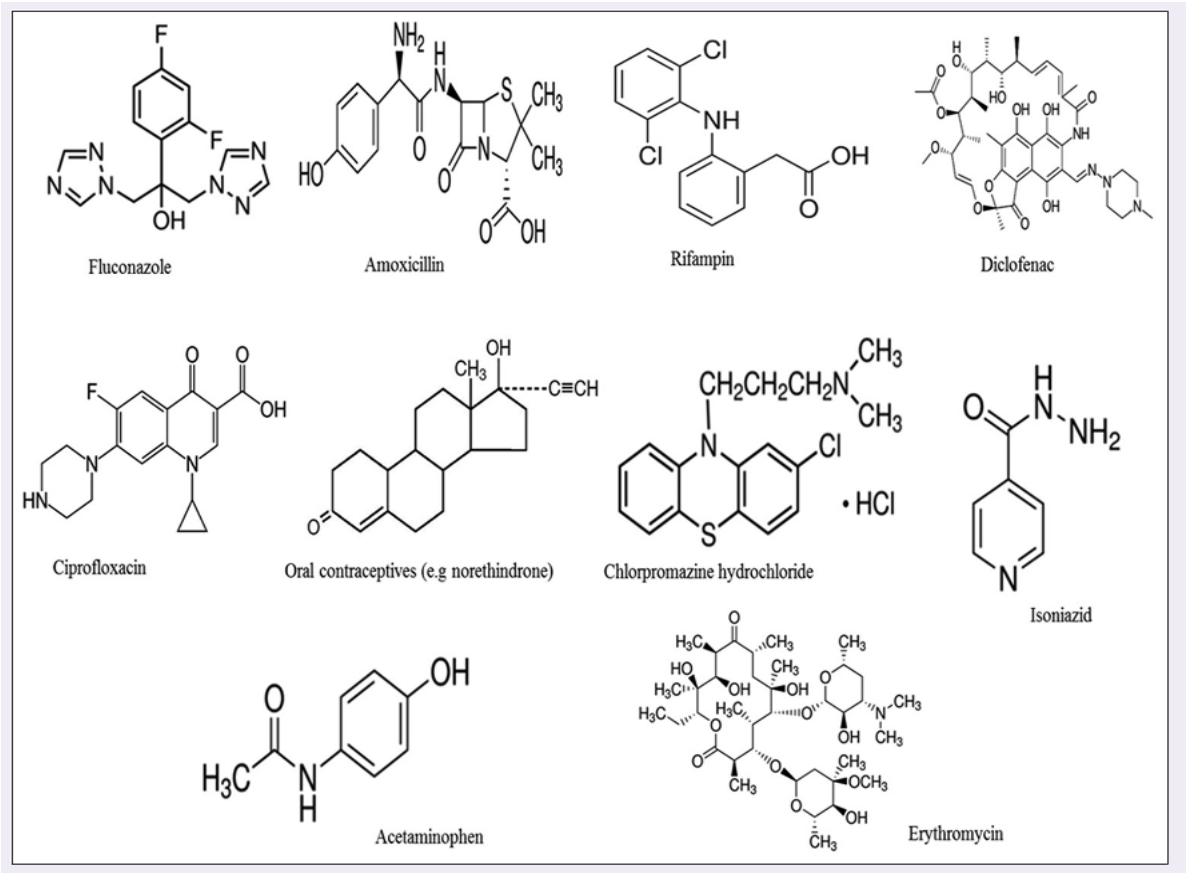
Table 1: Example of some drugs with hepatotoxicity effects

Drugs	Implication
Fluconazole	It leads to hepatitis; it increases the transaminase level, fulminant hepatic failure, and cholestasis
Amoxicillin	It moderates or brings about an increase in SGPT and SGOT levels, hepatic failure such as jaundice, acute cytolytic hepatitis, and hepatic cholestasis
Diclofenac	It elevates AST and ALT levels, jaundice, fulminant hepatitis, and liver necrosis
Rifampin	It leads to hepatitis, hyperbilirubinemia, and cholestasis Ciprofloxacin Elevation of SGOT alkaline phosphatase and SGPT levels occurs from cholestatic jaundice
Oral	Benign neoplasm, hepatic vein occlusion, and jaundice, contraceptives but rarely neoplasm of the liver
Chlorpromazine	It leads to infectious hepatitis with obstructive jaundice as a biomarker
Isoniazid	It elevates the serum transaminase level, severe and fatal hepatitis
Acetaminophen	It makes the cytochrome P-450-2E1 produce a toxic metabolite NAPQI that causes hepatic necrosis Erythromycin. It increases SGPT and SGOT concentration, and it also brings about hepatocellular hepatitis that are sometimes associated with it.

SGOT=Serum glutamic oxaloacetic transaminase, ALT=Serum alanine aminotransferase, AST=Aspartate aminotransferase, SGPT=Serum glutamic pyruvic transaminase, NAPQI=N-acetyl-P-benzoquinoneimine

Diseases of the Liver and Alcohol

In today's world, a major contributor to liver issues is drinking too much alcohol.[14] The liver is involved in alcohol metabolism, which impacts lipoprotein and lipid metabolism, which in turn links ethanol use to alcoholic liver disease. Additionally, cytochrome P4502E1 is activated during the alcohol dehydrogenase-to-acetate conversion of ethanol to ROS.The numbers [29,30] The liver goes through a series of events that culminate in oxidative stress [Figure 2], which in turn causes damage to the liver and alters the structural stiffness of the cell membrane, allowing cytosolic enzymes to seep into the circulation. As a result, elevated levels of cytosolic enzymes in the blood are the most prevalent biochemical indicator of liver injury.[31] in Both the cytoplasm and mitochondrial concentrations of aspartate transaminase (AST) and alanine transaminase (ALT) rise in injured liver cells. A change in the structure of the liver cell membrane, brought about by membrane leakage, leads to an elevation in serum hepatospecific enzymes. Furthermore, elevated blood bilirubin levels indicate a quickening of the erythrocyte degradation rate. Therefore, maintaining a healthy liver is critical to human wellbeing.[32] The process of alcohol-induced liver damage is shown in



MEDICINAL PLANTS AS AN ALTERNATIVE TREATMENT

Metabolic diseases, including liver impairment, account for the vast majority of deaths and illnesses worldwide. The harmful effects of numerous allopathic medications on the liver have recently brought liver injury therapies into the spotlight on a worldwide scale. Therefore, researchers have paid a lot of attention to folkloric herbs that have hepatoprotective properties for treating liver damage or illness. This is mostly because these herbs are therapeutic and have minimal toxicity. Animal studies have recently looked at the hepatoprotective effects of many traditional medicines. The positive effects of herbal medicine on human health have long been recognised and used in traditional medicine. Scientists have isolated several molecule types and investigated their pharmacological and

physicochemical characteristics. It is important to synthesise compounds and extracts correctly so that they may achieve their physiological aim and exert their pharmacological effects. The absorption and delivery of bioactive compounds may be impacted by factors including poor solubility and permeability.[32] However, to ensure their stability during the duration of usage, it is

important to assess the shelf life of herbal medications. Environmental factors such as heat, moisture, acidity, oxygen, and light speed up the degradation process. Herbal remedies include a wide variety of chemical components, including primary and secondary metabolites, carbohydrates, proteins, and lipids.[33]

Numerous efforts have been undertaken to discover new sources of hepatoprotective agents due to the adverse effects associated with synthetic medicines.on page 34 These days, the majority of hepatoprotective medications used to treat various liver illnesses are derived from plants, either in the form of individual plants or complex mixes of herbs. Rural residents, particularly in underdeveloped nations without appropriate modern healthcare facilities, rely heavily on folkloric herbs to enhance their quality of life.[1] The medicinal value of plants exceeds 70,000 species. While plants have gained popularity as natural treatment options, the science behind their preparation and dosage is often unclear. Despite their effectiveness and cost-effectiveness, it is imperative to prioritise plants with low toxicity. There are many herbal drugs on the market, but only a few bioactive ingredients have been proven to have antiviral, antioxidant, anticarcinogenic, antifibrotic, and anti-inflammatory effects.35 and 36

IN VITRO AND *IN VIVO* HEPATOTOXICITY ASSAYS

The choice of appropriate treatment for the liver disease relies solely on the suitability of the model the system preferred for hepatic damage. Although a number of prototypes exist to assess the hepatoprotective prospect of any chemical or plant extract, most of these models have limitations. Hence, it will be appropriate to combine these models for better results.[37] In a study carried out by Cerný *et al*.[38] *In vitro* assays such as hepatocyte cultures, perfused hepatocytes study with pathophysiological damage caused by various chemical substance (e.g., hypoxia hepatotoxins, or anoxia assays in perfused immobilized hepatocytes were documented. Some of the reported *in vivo* models are presented in Table 2. The majority of these studies on the hepatoprotective role of some medicinal plants are still based on the laboratory experiments.

Most organisms have their own antioxidant-based defense mechanisms which combat the activity of free radical species. The protective role of the endogenous antioxidant system in humans is not always adequate when the free radical species are much greater than the available antioxidant, and hence, additional antioxidants from different sources become important. Various antioxidant agents of plant origin appear to be effective in scavenging free radicals that lead to liver injuries.[39] Phytochemicals such as phenolics, thiols, and caretonoids present in herbal plants protect the human body against oxidative damage by ROS.[17] Therefore, attention is being diverted to promising medicinal plants that have the hepatoprotective potential to treat different kinds of liver disease. The folkloric herbs for treating all kinds of diseases have been in existence since ancient times due to their therapeutic efficacy and safety, and several herbs have been investigated for their hepatoprotective potential for the treatment of different types of liver disorders.[14] Numerous herbal formulations have proved to be effective therapeutic agents against various kinds of liver disorders [Table 2], and this review mainly focused on available literature on those that have been confirmed around the globe to have hepatoprotective properties.

SOME MEDICINAL PLANTS WITH HEPATOPROTECTIVE ACTIVITY

Dodonaea viscosa *(*Sapindaceae*)*

The flowering plant Dodonaea viscosa is a member of the soapberry family. Sapindaceae may be found all throughout the Southern Hemisphere, from the subtropics to the warm and tropical temperate zones of Africa, the Americas, and Australia.[47] Traditional healers in this area have used this plant, which

they name "Sanatha," for decades to control their patients' diabetes.[132] The antihyperlipidemic and hepatoprotective effects of an aqueous: methanolic (70:30) D. viscosa leaf extract were recorded in a study by Ahmed et al., [47]. The rabbits were induced with diabetes by alloxan. The results showed that as compared to the control group, the experimental group had lower blood levels of TAG, total cholesterol, LDL-C, HDL-CHL, ALT, and AST. In addition, levels of HDL-CHL, AST, and ALT were significantly raised by the extract. These results demonstrate that D. viscosa leaf extract has hepatoprotective properties.

Phyllanthus muellarianus (Euphorbiaceae)

The straggling, monoecious, glabrous, climbing shrub or small tree known as Phyllanthus muellarianus is widely distributed in many African countries, including Senegal, Uganda, Mali, Congo, Togo, South Africa, and Ivory Coast.[40] A wide range of medical conditions, including paralysis, fever, and bacterial infections, have been treated using extracts from this plant.On pages 133 and 134, A phytochemical analysis of an extract from P. muellarianus leaf showed the presence of phytochemical components that may be responsible for the therapeutic action, including furosin, isoquercetin, phaselic acid, corilagin, nitidine, geraniin, and gallic acid.13, 35, 136 The hepatoprotective ability of an aqueous extract of P. muellarianus leaf was studied in 2017 by Ajiboye et al. in relation to hepatocellular indices, proinflammatory factors, oxidative stress, and lipid peroxidation in Swiss albino mice that had been injured in the liver by b-acetaminophen.[40] The results demonstrated that the acetaminophen-induced changes in the ALT, ALP, AST, ALB, and TB were significantly reduced by the aqueous leaf extract ($P < 0.05$), according to this research. The potential antioxidant properties of the water-based leaf extract may be due to its capacity to counteract the increase in these liver enzymes caused by acetaminophen, suggesting a protective benefit against acetaminophen-induced liver damage. It has been shown that gallic acid, a phytochemical component of this plant extract and a well-known antioxidant, may reverse AST, ALT, and ALP, as well as acetaminophen-induced liver damage.[137]

Similarly, the rat liver showed a substantial reduction in the activities of SOD, GSH, CAT, G6PH, and GSH-Px when acetaminophen was used. Aqueous leaf extract from the plant under study considerably reduced the increase in levels of several compounds, including malondialdehyde, lipid hydroperoxides, fragmented DNA, protein carbonyl, and tumour necrosis factor-alpha. Because of its preventative properties, the plant was also determined to have promising future use as a dietary supplement.[40]

Aquilaria agallocha (Thymelaeaceae)

This massive tree may reach heights of 60–80 feet and has a trunk that is three to four feet in diameter. Its original habitat is in South-east Asia. Similar to Betula's usage of tree bark for writing, the bark is papery thin and was sometimes used for that purpose. The thin, leathery leaves may grow to be three inches in length. White blossoms accompany smooth, slender fruit that is one to two inches in length. Aquilaria agallocha is a plant with a wide range of pharmacological effects, including but not limited to: protecting against cancer, inflammation, diabetes, anxiety, ulcers, and seizures; alleviating pain; reducing fever; and antidiabetic, antihistaminic, antipyretic, laxative, antidiarrheal, antidiabetic, antihistaminic, sedative, antibacterial, and antimicrobial properties.[138] A study conducted by Alam et al. [72] shown that a 400 mg/ml ethanolic extract of A. agallocha (AAE) leaves protected the livers of Sprague-Dawley (SD) rats against PCM-induced hepatotoxicity. The findings demonstrated that AAE leaves have a hepatoprotective effect, as they prevented PCM-induced histopathological changes in the liver, increased ALB and total protein concentration, and significantly reduced AST, ALP, ALT, LDH, CHL, and TB in SD rats.[72]

Table 2: Medicinal plants with hepatoprotective potentials

Family	Name of the plant	Plant parts used	Extract used	Oral dose (mg/kg)	Hepatotoxicity inducing agents	Biochemical and histopathological parameter studied	Reference
Euphorbiaceae	*Phyllanthus muellarianus*	Leaves	Aqueous	400 mg/kg	Acetaminophen	ALP, ALT, AST, ALB, TB, CAT, SOD, GSH-Px, GSH	[40]
Scrophulariaceae	*Picrorhiza kurroa*	Roots rhizomes	Ethanol Alcohol	2.60 ml/kg	CCl_4 CCl_4	SGOT, SGPT, ALP, CHL, TB, and TP	[41]
Fabaceae	*Bauhinia variegata*	Stem barks	Alcohol	100 and	CCl_4 CCl_4 CCl_4 PCM	AST, ALP, GGT, ALT, TBARS, and	[42]
Rubiaceae			Methanol	200 mg/kg	Alloxan	liver protein	
Cannaceae	*Galium aparine*		Methanol/ethyl		CCl_4 PCM CCl_4		
Moraceae	*Canna indica Ficus*	Whole plant	acetate	2 ml/kg	Country-made liquor	ALT, AST, and ALP	[43]
Zingiberaceae	*cordata*	Aerial parts	Ethanol Methanol				
Sapindaceae	*Curcuma longa*			100 and	PCM	SGPT, SGOT, TB,	[44]
	Dodonaea viscosa	Roots	Methanol	200 mg/kg		CAT, GSH, LPO LDH	
Asteraceae			Methanol	400 mg/kg			[45]
Cyatheaceae	*Eclipta prostrata*	Rhizome	Ethanol and			ALT, ALP, and AST	
Araceae	*Cyathea gigantea*	Leaves	aqueous Ethanol	600 mg/kg		AST, LDLC, ALT,	[46]
Nyctaginaceae	*Alocasia*			500 mg/kg		HDL STG, and TC	[47]
Apocynaceae	*macrorrhizos*	Fresh leaves	Methanol,			ALT, AST, and	
	Boerhavia diffusa	Leaves	petroleum ether,	10 80 mg/kg	CCl_4 TAA	serum bilirubin SGPT,	[48]
		Leave and	chloroform,		d-GalN/LPS	SGOT, ALP, TB, TP	
	Leptadenia pyrotechnica	tuber Roots	acetone, and	100 and	CCl_4 CCl_4	Serum ALT and AST	[49]
			aqueous	200 mg/kg		SGPT, SAP, TGs,	
Asclepiadoideae		Whole plant	Methanol	200 mg/kg		and total lipid levels	[17]
Arecaceae						SGPT, TB, ALP, and	
Asteraceae			Methanol Ethanol	200 and		SGOT	[50]
				400 mg/kg			
Cactaceae	*Tylophora*		Aqueous	150 ml/kg	CCl_4 CPF		[7]
		Leaves Fruit			Ethanol CCl_4		
	Phoenix dactylifera	Aerial parts			CCl_4/ethanol		
Rutaceae	*Tridax procumbens*		Methanol			SGPT, ALP, SGOT, and bilirubin content	
					PCM	TBAST, ALT, and	
	Opuntia ficus-indica	Leaves		200 and		ALP	[51]
	Clausena lansium			300 mg/kg	INH and RIF	AST, LDH, ALT,	
		Stem bark		300 mg/kg		ALP, GGT, TB, and	[52]
Apiaceae			Methanol			TBARS	
Cactaceae			Aqueous	300 mg/kg		AST, ALT,	[53]
						creatinine, urea, and	
Rosaceae			Aqueous			uric acid	
	Apium graveolens			2, mL/kg		Reduction in	[54]
Vitaceae		Seeds Stem	Alcohol N/A			phenobarbitone,	
Polygonaceae	*Opuntia ficus-indica*					sleeping time and	
		Aerial part	Ethanol Alcohol	100 and		serum liver protein,	[55]
Pandanaceae	*Agrimonia*			200 mg/Kg		serum AST, ALT, and	
Rhamnaceae	*eupatoria Vitis vinifera*	Leaves Aerial part				ATP.	
	Rheum palmatum					SGOT, SGPT, SALP, TP, TA, and GSH	
		Roots Roots				ALAT, ASAT, ALP,	
	Pandanus odorifer			250 mg/Kg		LDH, CHL, and	[56]
	Ziziphus oenoplia					albumin	
				1500 mg/kg		AST and ALT	[57]
						AST and ALT N/A	
				100 and			[58]
				300 mg/kg		SGOT, SALP, SGPT,	
				125 mg/kg		TB, and TGA SGOT,	[59]
				25 and		SGPT, SALP, SB, SOD,	[60]
				100 mg/kg		CAT, GST,	
				200 and		and GPx	[61]
				400 mg/kg			
				150 and			[62]
				300 mg/kg			

Family	Name of the plant	Plant parts used	Extract used	Oral dose (mg/kg)	Hepatotoxicity inducing agents	Biochemical and histopathological parameter studied	Reference
Asteraceae	*Cichorium intybus*	Leaves	Ethanol	50, and	CCl_4	ALT, AST, and ALP	[63]
Betulaceae	*Corylus avellana*	Leaves Bark	Aqueous	100 mg/kg	CCl_4 and acetaminophen		
Lauraceae	*Cinnamomum cassia*	Seeds Gums	Ethanol NA NA	NA 40 mg/kg	Dimethylnitrosamine	GPT and GOT TP, albumin, TB, direct bilirubin, GOT, GPT, and ALP	[64] [65]
Apiaceae							
Anacardiaceae	*Anethum graveolens Pistacia lentiscus*	Edible portion (seed coats and juice) Flower	Acetone	500 and 1000 l/kg NA	CCl_4 CCl_4	SGPT, SGOT, and ALP	[66]
Lythraceae			Aqueous		INH and RIF	AST, ALT and MDA, GSH, GPx, GST, GR, SOD, and CAT	[67]
Rosaceae	*Punica granatum*	Aerial parts Fruits	Methanol	400mg/kg	Acetaminophen	AST, ALT, and LDH	[68]
Cucurbitaceae	*Rosa damascena* mill	Leaves	Methanol	250,			
Muntingiaceae			Ethanol	500 and 1000 mg/kg	CCl_4	AST, ALT, ALP, LDH, ALBTB, urea and creatinine, TBARS, and GSH	[69]
Thymelaeaceae		NA Root	NA Hydroalcohol	250 and	Acetaminophen PCM		
Berberidaceae	*Cucurbita maxima*		Methanol	500 mg/kg	CCl_4 CCl_4	SGPT, SGOT, ALP, TP, and TB	[70]
Apiaceae	*Muntingia calabura*	Whole plant Roots	Hydroalcoholic acid	50, 250, and 500 mg/kg	Acetaminophen/CCl_4 Ethanol	AST, ALT, and ALP	[71]
Asteraceae	*Aquilaria malaccensis*			400 mg/kg			
Asteraceae	*Coptidis rhizoma*	Edible root and shoot	Methanol		CCl_4	AST, ALT, LDH, ALP, bilirubin, CHL, TP, and ALB	[72]
Asteraceae	*Cynara scolymus L.*			120 mg/kg			
Euphorbiaceae	*Calendula officinalis*	Root	Methanol	900 mg/kg	TAA	ALT, AST, and SOD	[73]
Fabaceae	*Taraxacum officinale*	Aerial parts	Ethanol	500 mg/kg 250 mg/kg	TAA	ALT, ALP, AST, GSH, and CAT ALT, AST, and LDH	[74] [75]
Euphorbiaceae	*Tragopogon porrifolius*	leaves	Methanol		CCl_4	TBARS, GST, GSH, SOD, CAT, GR, and GPx	[76]
Fabaceae	*Baliospermum montanum*	Leaves	Ethanol	250 mg/kg 2000 mg/kg	H_2O_2; CCl_4 CCl_4	CAT, SOD and GSTAST, ALT, and LDH	[77]
Rutaceae	*Tephrosia purpurea*	Leaves, bark	Methanol		CCl_4 CCl_4	GOT, GPT, ALP, TB, TC, TB, and albumin	[78]
Acanthaceae	*Alchornea cordifolia*	Leaves		500 mg/kg	PCM	AST, GSH, ALT, ALP, TB, GGT, and MDA	[79]
Asteraceae	*Trigonella foenum-graecum* L.	Leaves	Methanol	300 mg/kg		SGOT/AST,	[80]
Fabaceae	*Glycosmis pentaphylla* Corr.	Seeds	Ethanol			SGPT/ALT, ALP, and TB	
	Andrographis lineata Nees *Wedelia chinensis* L.		Methanol	100 mg/kg		ALT, AST, ALP, and GGT	[81]
	Cassia fistula			500 mg/kg		ALT/SGPT, AST/SGOT, CHL, bilirubin, and glucose	[82]
				845 mg/kg		SGOT, SGPT, and ALP	[83]
				200 mg/kg		AST, ALT, ALP, protein, and bilirubin	[84]
				200 and 400 mg/kg		SGOT, SGPT, ALP, and bilirubin	[85]

Fabaceae	*Bauhinia racemosa*	Bark Stem bark	Methanol	NA	CCl4 and PCM CCl4 PCM	SGPT, SGOT, SOD, GSH, and TBARS	[86]
Fabaceae	*Lam. Bauhinia variegata L.*	Aerial parts	Methanol Ethanol Methanol	100 and 200 mg/kg	Acetaminophen CCl4 Ethanol	AST, ALT, ALP, and GGT ALT, GGT, AST, and ALP	[87] [88]
Scrophulariaceae Phyllanthaceae	*Scrophularia hypericifolia*	Whole plant	NA	250 and 500 mg/kg		Cytochrome P450	
Phyllanthaceae	*Phyllanthus urinaria*	Fruits				CYP2E1 protein GSH	[89]
Liliaceae	*Phyllanthus emblica*	Fresh bulbs	Aqueous	200 mg/kg	Rifampicin	ALT, ALP, AST, and TB NA	[90]
Moraceae	*Allium cepa*	Leaves, fruit, and roots	Petroleum ether extract, aqueous extract, and methanolic	100 mg/kg 100, 300 and 600 mg/kg	Dimethoate		[91]
Rhamnaceae	*Ziziphus mucronata*	Leaves	extract Methanol	NA	CCl4	SGOT, TBARS, SGPT, GSH, SOD, tocopherol, HDL, LDL, CHOL, TL, TGA Induce apoptosis of hepatic stellate cells (HSCs) AST, ALT, ALP	[92]
Lamiaceae	*Salvia miltiorrhiza*	Dried pulverized roots Flower	Ethanol Aqueous	200 mg/kg	Mixture of cholesterol and cholic acid with coconut oil CCl4 CCl4 CCl4		[93]
Malvaceae	*Hibiscus rosasinensis*	Leaves	Aqueous and ethanol Ethanol	50 mg/kg		AST, TP ALP, and ALT, TB AST, ALT, and LDH	[94]
Loranthaceae	*Dendrophthoe falcata*	Dried aerial parts Fruiting bodies and mycelia	Aqueous extract and ethanol	80, 160 and 240 mg/kg	CCl4 CCl4 CCl4 PCM STZ D-galactosamine and CCl4 TAA	induced elevation of expression of hepatic mRNAs, i.e., MMP-9, TNF-α, KLF-6, and TGF-β1 levels	[95] [15] [96]
Asteraceae	*Bidens pilosa*						
Fomitopsis Deae	*Antrodia cinnamomea*			100 mg/kg			
Cyperaceae	*Cyperus rotundus*	Leaves Aqueous extract Dried root	Methanol Aqueous Ethanol Aqueous	15 mg/kg 1250 mg/kg	CCl4 PCM PCM PCM	SGOT, SGPT, ALP ALT, AST, and ALP ALT, AST, HA, and laminin (LN) sGPT, serum glutamic ALP, TBARS, and GSH SGPT	[97]
Malvaceae	*Hibiscus sabdariffa*						
Polygonaceae	*Rheum palmatum*	Tubers Leaves Leaves Dried seeds Root	Aqueous and methanol Ethanol Ethanol Ethanol				
Araceae	*Amorphophallus paeoniifolius*	Whole plants	Ethanol	200 mg/kg			[98]
Apiaceae	*Petroselinum crispum*	Leaves	Methanol Aqueous methanol	NA 400 mg/kg		ALP and GGT Induce apoptosis of hepatic stellate	[99] [100]
Loranthaceae	*Loranthus parasiticus*	Aerial parts		300 mg/kg		cells (HSCs) SGOT, SGPT, and ALP	[101]
Fabaceae	*Trigonella foenum-graecum*			200 mg/kg		TBARS, SOD, CAT, and GSH	[102]
Fabaceae	*Tephrosia purpurea*			100 mg/kg 20-100 mg/kg 50-200 mg/kg 100 mg/kg		TB, DB, ALP, and AST	[103] [104]
Oxalidaceae	*Oxalis corniculata*			75, 150, 300 mg/kg			[94]
Fabaceae	*Indigofera tinctoria*			200 mg/kg			[105]
Malvaceae	*Alcea rosea*						[106] [107]

Fabaceae	*Cajanus cajan*	Whole plant Leaves	Methanol	NA	CCl4 PCM PCM CCl4 CCl4	SGOT, CHL, and SGPT	[108]
Solanaceae	*Cestrum nocturnum*		Aqueous ethanol	250 and	PCM	SGOT, SGPT, ALP,	[109]
Convolvulaceae	*Convolvulus*	Whole plant	Ethanol	500 mg/kg	Galactosamine/	AST, ALT, and LDH	
Fabaceae	*arvensis Glycyrrhiza*	Roots		200 and	lipopolysaccharide	ALP, ALP, AST,	[110]
Convolvulaceae	*glabra*		Aqueous	500 mg/kg	CCl4	and TB	
Malvaceae	*Ipomoea*	Leaves	Hydroalcohol	2 mg/kg	PCM PCM	SOD, GST, CAT,	[111]
Ranunculaceae	*staphylina Malva*		Methanol			GSH, and GSH-Px	
Oleaceae	*parviflora*	Whole plant	Alcohol Ethanol	200 mg/kg	PCM and CCl4 CCl4	ALP, SGOT, AST,	[28]
Polygonaceae		Seeds	Aqueous/		CCl4 CCl4	CHL, ALT, SGPT	
Amaranthaceae	*Nigella sativa*		methanol	250 and	CCl4 PCM PCM CCl4	ALT, TP, AST, and	[112]
		Whole plant	Aqueous/	500 mg/kg		ALP	
Lamiaceae	*Fraxinus*	Whole	methanol	NA		ALP, ALT, TB, AST,	[113]
Boraginaceae	*rhynchophylla*	plant Leaves	Aqueous/ether		PCM	and TP	
	Rumex dentatus		Ethanol	100 and		GOT, GPT, CAT,	[114]
Vitaceae				500 mg/kg		SOD, and GPx ALP,	
Acanthaceae	*Suaeda fruticosa*	Leaves Leaves	Ethanol Aqueous	250 and		ALT, TB, and AST	[115]
				500 mg/kg	PCM CCl4	SGPT, ALP, ALT,	
Lamiaceae		Roots Roots	Methanol	500 and	CCl4	SGOT, AST, TP,	[116]
Fabaceae	*Thymus linearis*		Ethanol	750 mg/kg		and TB	
Plumbaginaceae		Fresh leaves	Methanol		PCM CCl4	SGOT, ALT, SGPT,	
Salicaceae	*Trichodesma*	Leaves Aerial	Ethanol	250 and	PCM	TB, ALP, and AST	[117]
	sedgwickianum	parts Flowers		500 mg/kg		GSH, ALP, SOD,	
	Vitis vinifera			400 mg/kg	PCM and azithromycin	AST, CAT, TB, ALT,	[118]
Bignoniaceae			Aqueous/ ethanol		CCl4	and TP	
	Hygrophila	Aerial parts				SGPT, SGOT, ALP,	
	auriculata			200 mg/kg		and TB	[119]
	Ocimum		Ethyl acetate			MDA, GSH, protein,	
Anacardiaceae	*gratissimum*		Ethanol	100 mg/kg		bilirubin, SGOT,	[120]
Scrophulariacea	*Bauhinia*	Bark Leaves				ALP, and SGPT ALT,	
e	*purpurea Plumbago*		Ethanol			AST, and ALP	
	zeylanica	Whole plant		40 mg/kg		ALT, ALP, and AST	[121]
Verbenaceae	*Salix caprea*	Leaves Leaves				TB, SGPT, SGOT,	
			Alcohol	50 and		and ALP	[122]
		Leaves Fruits	Methanol	250 mg/kg		ALT, AST, ALP,	
Lamiaceae		Stem barks		300 mg/kg		albumin, TB, TG, urea,	[123]
Mimosaceae	*Tecomella undulata*		Aqueous Ethanol			creatinine, TB,	
			Ethyl alcohol	150 mg/kg		TBARS, and GSH AST,	[29]
Rubiaceae	*Pistacia integerrima*					GSH, SGOT, SOD,	
Cupressaceae	*Scoparia dulcis*					SPGT, CAT,	
Oleaceae						GSH-Px, GST, ALP,	
				100 and		and ALT,	[108]
	Stachytarpheta			200 mg/kg		ALP, ALT, and AST	
	jamaicensis						
	Ocimum tenuiflorum					SGPT, TB, ALT, ALP,	
	Mimosa pudica			NA		SGOT, and AST	[124]
						SGPT, TB, ALP,	
				500 and		SGOT, AST, TP, CHL,	[125]
	Kohautia grandiflora			1000 mg/kg		and ALT ALP, ALT,	
	Juniperus					SGOT,	
	communis Fraxinus			200 mg/kg		AST, and SGPT AST,	[126]
	rhynchophylla					SGOT, ALT, SGPT, TP	
						ALP,	
				200 mg/kg		and TB	[127]
						TP ALP, TB, ALT,	
				200 mg/kg		and AST	[128]
						SGOT, TB, SGPT,	
						and ALP	
				300 mg/kg		ALT, AST, MDA,	[129]
						SOD, GSH, and	
				200 mg/kg		GSH-Px	[130]
				400 mg/kg			[13]
Family	*Name of the plant*	Plant parts used	Extract used	Oral dose (mg/kg)	Hepatotoxicity inducing agents	Biochemical and histopathological parameter studied	Reference
Saururaceae	*Saururus chinensis*	Whole plant	Ethanol	70 mg/kg	CCl4	AST, ALT, ALP, CHL, SOD, CAT, MDA, and GSH	[131]

SGOT=Serum glutamic oxaloacetic transaminase, GPT=Glutamic pyruvic transaminase, SB=Serum bilirubin, ALT=Serum alanine aminotransferase, SOD=Superoxide dismutase, GST=Glutathione S-transferase, AST=Aspartate aminotransferase, ALP=Alkaline phosphatase, SALP=Serum alkaline phosphatase,

MDA=Malondialdehyde content, GSH=Glutathione, GSH-Px=Glutathione peroxidase, TG=Triglycerides, GPT=Glutamic pyruvic transaminase, TB=Total bilirubin, TBARS=Lipid peroxidation (thiobarbituric acid reactive substance), GSH=Reduced glutathione, ALB=Albumin, GR=Glutathione reductase, SALP=Serum alkaline phosphatase, GGT=Gamma glutamyl transferase, SALT=Serum aspartate amino transaminase, GPx=Glutathione peroxidase, GR=Glutathione reductase, CHL=Cholesterol, LDH=Lactate dehydrogenase, SGPT=Serum glutamate pyruvate transaminase, TP=Total protein, GOT=Glutamic oxaloacetic transaminase, CAT – catalase, TB=Total bilirubin, NA=Not applicable, CPF=Organophosphorous insecticide chlorpyrifos, TAA=Thioacetamide, d-GalN/LPS=d-galactosamine/lipopolysaccharide, INH=Isoniazid, RIF=Rifampicin, N/A=Not available

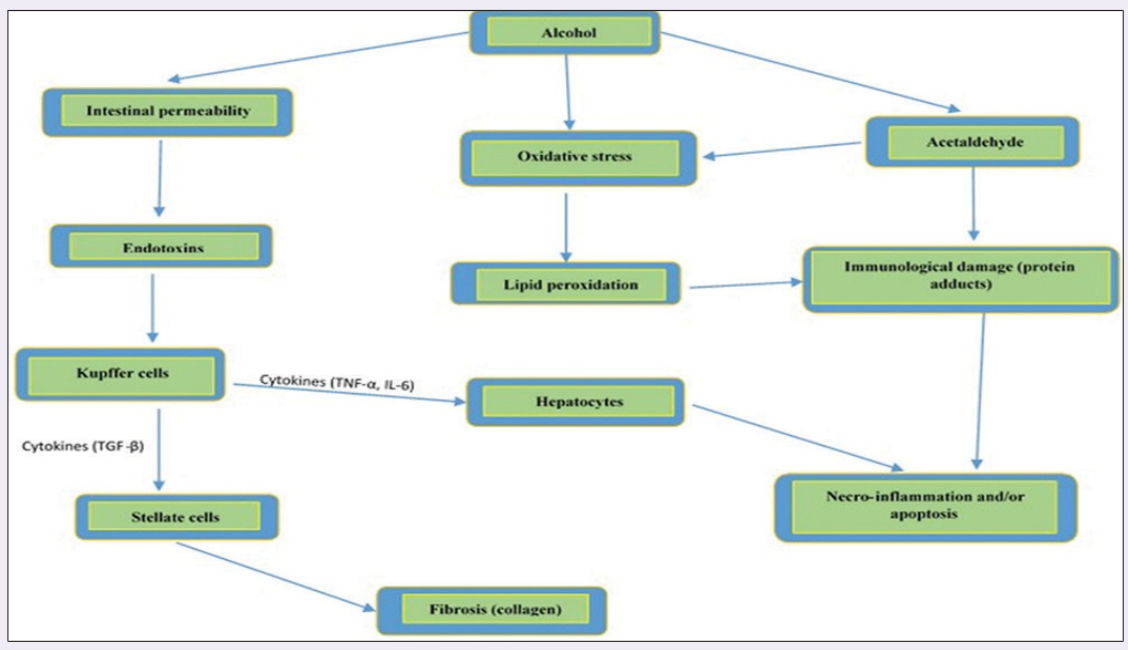


Figure 2: Mechanism of alcohol-induced hepatotoxicity[2]

Salix caprea *(*Salicaceae*)*

One of Salix caprea's family names is Salicaceae.[29] One of the most common types of willow in Europe, Western and Central Asia, this tree is also known as great sallow, pussy willow, or goat willow. Past research has shown that the plant has several biological potentials, including antioxidant, anti-inflammatory, and anti-inflammatories properties.at the number 47,139 Traditional healers have used S. caprea to cure a wide range of illnesses in both humans and animals. It is used most often to alleviate symptoms such as fever, headaches, stomachaches, and constipation.[29] The plant extract was shown to containbioactive components, namely flavonoids and phenolic acids, according to qualitative analysis. Salignin and catechins were among the phenolic chemicals found, while quercetin, rutin, and luteolin-7-glucoside were flavonoids.the number 140

In CCl4-induced liver damage, Wahid et al. evaluated the hepatoprotective efficacy of an ethanolic extract of Salix subserrata Willd flower.[29] The ethanolic extract of this plant significantly reduced serum enzyme levels, suggesting that it may repair CCl4-induced damage to liver tissue or restore plasma membrane integrity. This plant extract may have shown antioxidant activity because of its hepatoprotective function, which prevented CCl4 free radical metabolites from damaging liver cells by preventing lipid peroxidation, membrane destabilisation, and subsequent cell death.

Caesalpinia crista *(*Fabaceae*)*

A wide shrubby perennial climber widespread all throughout India in the plains, deserts, coastal regions, and hills up to a height of 1000 m, Caesalpinia crista is a member of the Fabaceae family, a genus of flowering plants in the legume family. It is often known as Karanja in Hindi.[141] The bioactive substances found in C. crista include glycosides, alkaloids, saponins, and flavonoids. The medical properties of this plant include actions against inflammation, malaria, jaundice, worms, diabetes, periodontal disease, and fever.In references [61,142], Mishra et al. evaluated the hepatoprotective efficacy of ethanolic extracts of C. crista leaves in rats subjected to PCM-induced hepatotoxicity. The positive control group showed no change in levels of TB and serum marker enzymes or TGA when treated with ethanolic extract at doses of 200 or 400 mg/kg. In contrast, the treated group showed a significant drop in these levels. The ethanolic extracts of C. crista leaves showed promising hepatoprotective effects against PCM-induced liver damage in rats, according to these results.[61]

Alocasia indica *(*Araceae*)*

Southern India, West Bengal, Assam, and Maharashtra are among the tropical and subtropical zones where Alocasia indica is widely grown. This herbaceous perennial reaches a height of about 5 metres.[17] Because it is both inexpensive and widely accessible, the edible tuber portion of the A. indica plant is often eaten as a common vegetable. Traditional medicine traditionally employs A. indica for the treatment of conditions involving the spleen and the abdomen. Although their study is focused on the nonedible leaf section of the plant, the edible tuber component is extensively used as a vegetable by the Indian people. The hepatoprotective effect of A. indica tuber extracts, both ethanolic and aqueous, was testedagainst CCl4-induced liver damage in male Albino Wistar rats by Pal et al. [14]. Their results showed that biochemical examination in both water and ethanolic extracts identified many pharmacological components including tannins, flavonoids, alkaloids, glycosides, and saponins. The antioxidant capacity and flavonoid and phenolic content were both found to be higher in the ethanolic extract compared to the water-based one. In an in vivo experiment, both the water and alcohol extracts showed strong hepatoprotective effects. This study's findings suggest that this plant extract may be useful as an antioxidant in the development of medications for liver illnesses..

Opuntia ficus-indica *(*Cactaceae*)*

As a house-trained crop plant crucial to agricultural economies spread across the arid and semiarid regions of the globe, Opuntia ficus-indica is a species of cactus that is often employed for fruit production and belongs to the Cactaceae family. The most likely place of origin is Mexico. When herbaceous plants and water are scarce, it is common practice to utilise it as a vegetable fodder resource for cattle.[143] Instead than studying the fruit, most scientific medical research focuses on the leaves (cladodes). The ability of an aqueous extract (2 mL/kg) from cactus cladodes to protect the liver from CCl4-induced toxicity in male Wistar rats was investigated.[54] The The results showed that compared to the group treated with CCl4, which caused hepatotoxicity, the group treated with aqueous extract of O. ficus-indica had significantly lower levels of AST and ALT..

Cyathea gigantea *(*Cyatheaceae*)*

The tree fern Cyathea gigantea (Wall. ex. Hook.) is native to damp, open habitats in Nepal, Western Java, Northeastern to Southern India, and Sri Lanka. The maximum height that this plant may reach is 20 metres.144 in all The hepatoprotective efficacy of a methanolic extract of C. gigantean leaves on PCM-induced toxicity in Wistar Albino rats was shown by Kiran et al. [49]. Hepatic histological and biochemical damage was seen in the experimental rats after PCM intoxication. However, the liver damage was reversed by restoring the structural integrity of the plasma membrane, and the elevated levels of ALP, serum glutamic oxaloacetic transaminase, TB, and serum glutamate-pyruvate transaminase were decreased as a result of treatment with methanolic C. gigantean leaf extract. According to the results of the phytochemical screening, C. gigantean leaf extract contains phenols, triterpenes, saponins, sterols, and flavonoids. Its hepatoprotective activity may be due to these bioactive components. The rat PCM-induced

hepatotoxicity model was used to determine C. gigantean's hepatoprotective capabilities.

Phoenix dactylifera *(*Arecaceae*)*

In the northern regions of Nigeria, Middle Eastern nations, and Arabian countries, the date palm, or Phoenix dactylifera, is frequently used to cure liver diseases and their symptoms, including jaundice.[52] The fruit extract shields the liver from harmful substances including alcohol, according to earlier research.[145] In a study on male rats, Okwuosa et al.[52] examined the possible hepatoprotective effects of date palm (P. dactylifera) fruit extracts in TAA-induced toxicity. Because the levels of hepatocellular enzymes were lower in the test groups compared to the TAA-induced group, the researchers concluded that the plant's methanolic fruit extract had strong hepatoprotective capabilities. The extract may have reversal potential for plasma membrane damage since it may counteract the increase in serum bilirubin and ALP caused by TAA.[52] Plant extracts were found to include tannins, flavonoids, saponins, terpenoids, carbs, steroids, proteins, and glycosides, according to qualitative screening. There have been reports that flavonoids may stabilise the cell membrane.[146] It is reasonable to assume that the flavonoid content of P. dactylifera extract is responsible for its membrane stabilising activity. Unfortunately, this research did not examine the biochemical mechanism by which P. dactylifera exerts its hepatoprotective effects. It was thought that the bioactive ingredient □-sitosterol in the fruit extract was the one responsible for its activity.[147] It was also thought that flavonoids' hepatoprotective effects were due to their ability to inhibit cytochrome P450 aromatase.[148] Likewise, Al-Qarawi et al. [149] confirmed that extracts from the flesh and pits of dates (P. dactylifera L.) had a hepatoprotective effect against CCl4-induced toxicity in rats.

Convolvulus arvensis *(*Convolvulaceae*)*

The creeping weed Convolvulus arvensis is native to Asia.The number 150 This kind of plant is a member of the family Convolvulaceae. When not climbing, the plant may spread out into thick carpets 5 cm thick; it is also often used as a laxative. Skin conditions, coughs, jaundice, and the flu may all benefit from the plant extract. Furthermore, it has the potential to alleviate inflammation, edoema, and aching joints. The hepatoprotective efficacy of an ethanolic extract of C. arvensis at doses of 200 and 500 mg/kg in rats subjected to PCM-induced toxicity was recently shown by Ali et al. [110]. The elevated levels of TB and hepatic enzymes were significantly reduced ($P < 0.05$) in rats treated with PCM-induced ethanolic extract of C. arvensis. Quercetin and kaempferol were the primary phytochemical components of C. arvensis. One flavonoid with proven hepatoprotective properties is quercetin.The number 151

Bioactive Molecules With Hepatoprotective Potentials

Past research has led to the isolation of several plant biomolecules with intriguing hepatoprotective properties. Humans have not yet been the subjects of comprehensive clinical studies with these pure substances. The presence of biomolecules such as resveratrol, curcumin, silymarin, glycyrrhizin, and quercetin gives some of the bioactive compounds their various biological properties, which include antiviral, antioxidant, anticancer, antiaging, antifibrotic, antidiabetic, and anti-inflammatory potentials (Table 3).

Table 3: Examples of reported phytochemical compounds with hepatoprotective potential

Phytochemical compounds	Plants
Glycyrrhizin	*Glycyrrhiza glabra*
Resveratrol	*Hygrophila auriculata*
Curcumin	*Curcuma spp.*
Colchicine	*Colchicum autumnale*
Silymarin (silybin)	*Silybum marianum*
Quercetin	*Hibiscus vitifolius*
Fumaric acid	*Sida cordifolia*

Coumarins	*Artemisia abrotanum*
Schizantherin A	*Schisandra chinensis*
Kutkoside	*Picrorhiza kurroa*
Catechin	*Anacardium occidentalis*
Papyriogenin	*Tetrapanax papyrifer*
Cronin	*Gardenia jasminoides*
Syringopicroside	*Syringa oblata*
Piceid	*Polygonum cuspidatum*
Gomishins	*Schisandra chinensis*
Saikosaponin	*Bupleurum falcatum*
Cosmosiin	*Cupressus sempervirens L.*
Patuletin	*Ficus ingens*

CONCLUSIONS AND FUTURE PROSPECTS

Even though everyone is very concerned about their health, health problems have become a major issue in our society. Liver disorders and injuries are among the most prevalent medical problems worldwide, despite the liver's vital role in the body. Liver damage may be caused by a variety of things, the most common of which include poor dietary habits, excessive alcohol intake, herbal supplements, microbial infections, autoimmune illnesses, malignancies, metabolic diseases, and drug addiction. Therefore, it is crucial to safeguard the liver against the dangers listed above.

However, given that current therapy for treating various liver illnesses is either insufficient or linked with negative effects on renal function, the need for the discovery of new therapies that effectively cure liver damage has become urgent. Consequently, the development of novel hepatoprotective medicines derived from plants is imperative. Their antioxidant-related characteristics and hepatoprotective actions are the basis of most plant-based medications used to treat liver disorders. In order to treat liver illnesses with innovative medications that have minimal adverse effects on the kidney, these are the key scientific principles that are founded on. Hence, more research is required to assess the chances of developing more powerful hepatoprotective medications from novel candidate phytochemicals.

Due to the fact that half of the population in poor nations relies on herbal treatments to cure liver diseases, these therapies have become famous across the world. The majority of commercially available herbal extracts have shown encouraging results in alleviating the signs and symptoms of liver damage or illness. Even yet, there has been no proof of the herbal extracts' scientific validity; consequently, further study is required, particularly in this field, to define protocols for the safe and effective manufacture and administration of herbal extracts. Also, it's crucial to put these herbal remedies through preclinical testing before putting them through clinical trials. The therapeutic efficacy of these all-natural herbal remedies may then be assessed, and the established dose regimen from clinical trials can inform future medication development and delivery. In addition, many important medications for treating various disorders may be made accessible using the conventional medical method to drug discovery and design.

It takes a lot of effort and money to isolate active principles and turn them into medications. The availability of plant-based medications, namely those derived from individual or mixed plant extracts, should be prioritised in the treatment of liver illnesses, particularly those that aim to restore the hepatic cell membrane's structural integrity. In most cases, a single plant extract will not be able to cure every kind of liver illness. Because of this, it may be required to create a herbal combination using extracts from two or more plants in order to increase the treatment's effectiveness. Furthermore, further study, particularly toxicity tests, should be conducted to guarantee the plant combination is safe to use. This is because it is quite probable that one of the plant extracts may be poisonous, which would undermine the effectiveness of the other extracts in the mixture. Also, traditional healers

in developing nations need to be educated on proper hygiene practices when preparing plants for use, as the majority of plant extracts are used by impoverished rural residents. Contamination must be prevented or eliminated when herbal extracts are prepared.

In conclusion, more research into the structural alterations of the active principles produced from herbal extracts using computational chemistry methods is required in order to develop plant-based hepatoprotective medicines that are more successful.

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