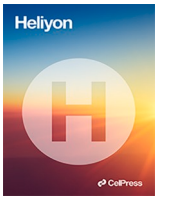
Heliyon 10 (2024) e25340

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Review article

Medicinal herbs and their metabolites with biological potential to protect and combat liver toxicity and its disorders: A review

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ARTICLE INFO

Keywords:
Liver
Hepatotoxicity
Medicinal plants
Phytoconstituent
Serum transaminases

ABSTRACT

The liver is an essential organ that helps the body with immunity, metabolism, and detoxification, among other functions. Worldwide, liver illnesses are a leading cause of mortality and disability. There are few effective treatment choices, but they frequently have unfavorable side effects. Investigating the potential of medicinal plants and their bioactive phytoconstituents in the prevention and treatment of liver disorders has gained more attention in recent years. An assessment of the hepatoprotective potential of medicinal plants and their bioactive secondary metabolites is the goal of this thorough review paper. To determine their hepatoprotective activity, these plants were tested against liver toxicity artificially induced in rats, mice and rabbits by chemical agents such as carbon tetrachloride (CCl_4), paracetamol (PCM), thioacetamide (TAA), N-nitrosodiethylamine, D-galactosamine/lipopolysaccharide, antitubercular medicines (rifampin, isoniazid) and alcohol. To find pertinent research publications published between 1989 and 2022, a comprehensive search of electronic bibliographic databases (including Web of Science, SpringerLink, ScienceDirect, Google Scholar, PubMed, Scopus, and others) was carried out. The investigation comprised 203 plant species from 81 families in total. A thorough discussion was mentioned regarding the hepatoprotective qualities of plants belonging to several families, such as Fabaceae, Asteraceae, Lamiaceae, and Euphorbiaceae. The plant groups Asteraceae and Fabaceae were the most frequently shown to have hepatoprotective properties. The phytochemical constituents namely flavonoids, phenolic compounds, and alkaloids exhibited the highest frequency of hepatoprotective action. Also, some possible mechanism of action of some active constituents from medicinal plants was discussed in brief which were found in some studies. In summary, the information on medicinal plants and their potentially hepatoprotective bioactive phytoconstituents has been consolidated in this review which emphasizes the importance of further research to explore the efficacy and safety of these natural remedies for various liver ailments.

1. Introduction

One of the most vital organs in our body is the liver. The liver is the site of numerous metabolic processes required for immunity, storage, and energy production. The liver is also involved in the metabolism of glucose, amino acids, and fatty acids, which are end-products of the digestion of carbohydrates, proteins, and fats [1]. The liver retains an accumulation of vital components such as iron,

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https://doi.org/10.1016/j.heliyon.2024.e25340
Received 8 September 2023; Received in revised form 22 January 2024; Accepted 24 January 2024
Available online 1 February 2024

minerals, vitamins, hormones, glycogen, and more [2]. Toxins and other foreign chemicals that are ingested from the GI tract also travel to the liver, where they undergo detoxification and are removed via bile and urine [3]. Aside from these, the liver is where medicines are primarily metabolized. There, with the aid of cytochrome P-450-containing enzymes, they are changed into active or inactive metabolites [3,4].

Liver diseases cause the deaths of millions of people each year and throughout the world. Every year, liver diseases cause death to over 20 lakh persons (10 lacs from liver cirrhosis, 10 lacs from viral hepatitis, and 10 lacs from liver cancer) [5]. Despite significant advancements in modern medicine, there are still no reliable medications that may increase liver function, provide complete liver protection, or multiply liver cells [6]. Immunization and certain medications, such as steroids and antivirals, are available to prevent and manage liver illnesses; nevertheless, they are not only expensive but also have undesirable side effects [7–9]. Certain data clearly show that liver illnesses may be treated and controlled with the help of medicinal plants and their phytoconstituents [7,10–12]. Consequently, a great deal of work has gone into identifying medicinal plants that have the ability to both prevent and treat liver diseases. Research on medicinal plants with the ability to protect the liver due to their bioactive phytoconstituents is covered in this review article.

Liver illnesses include a variety of pathological conditions like hepatosis, liver adenoma, or liver cancer, as well as acute or chronic inflammation of the liver [13]. Liver toxicity can be caused by allopathic medications, such as oral contraceptives, ciprofloxacin, paracetamol, diclofenac, fluconazole, amoxicillin, and chlorpromazine. These medications have the potential to cause benign neoplasms, hepatic vein blockage, liver cell death, and fulminant inflammation of the liver. Aflatoxin, alcohol, and carbon tetrachloride are among the harmful substances that can also cause liver damage [3,14,15]. Each year, hepatic cirrhosis, hepatocellular carcinoma, and viral hepatitis cause death to almost 20 million people. Globally, liver cancer ranks as the 16th most common cause of death from tumors [5,16,17]. Liver disease has been shown to progress and evolve as a result of medicines, obesity, viral infections, and excessive alcohol intake. Out of the 2 billion people who consume alcohol globally, about 75 million are known to have problems related to alcohol consumption, such as alcohol-associated hepatic dysfunction [18]. The conditions of obesity and diabetes, which affect about 2 million individuals and 400 million people worldwide, respectively, are linked to an elevated risk of hepatic damage, including hepatocellular carcinoma and nonalcoholic fatty liver disease [19]. Acute hepatitis and other hepatitis B and C virus infections raise the risk of hepatic diseases even more [19,20]. Oxidative stress is brought on by the aforementioned substances as well as hepatotoxic chemicals, which produce reactive oxygen species (ROS). Overproduction of ROS can lead to hepatocellular cancer, cirrhosis, chronic hepatitis, and hepatic steatosis by increasing lipid peroxidation and oxidative damage to liver cells.

All these events have attracted phytochemists/medicinal chemists to find suitable drugs for the remedy of liver toxicity and its diseases. Plants can be one of the most valuable sources for finding such drugs.

2. Methodology

Various electronic bibliographic databases, for example, MEDLINE, Web of Science, SpringerLink, ScienceDirect, Google Scholar, PubMed, Scopus, and Wiley Online Library, were elaborately consulted for getting scientific information about hepatoprotective plants by applying specific keywords. These keywords included “plants against hepatotoxicity”, “hepatoprotective effect of plants”, “hepatoprotective plants”, “plants used in liver disorders”, “plants and hepatoprotective effects,” and “hepatoprotective effect of phytoconstituents”. The research articles were downloaded from various scientific journals and examined thoroughly for their relevance, authenticity, data quality, and validity. Subsequently, a total of around 247 research and review articles covering 203 plant species, which have been published from 1989 to 2022, were included in this review. The structures of hepatoprotective phytoconstituents were drawn using ChemDraw Ultra 12.0 according to standard ACS guidelines.

3. Hepatoprotective potentials of medicinal plants and their bioactive secondary metabolites

Since the beginning of human history on earth, human lives have been dependent on plants for their survival from various diseases. Despite significant developments in modern medicine, human beings still use thousands of plants for medicinal purposes. These plants provide phytochemicals, which show various biological activities such as antiulcerogenic, antioxidant, anticancer, antimicrobial, anti-inflammatory, and hepatoprotective properties [21–26]. Almost 25 % of modern medicines have been derived from medicinal plants [27]. Nearly 65 % of patients in the United States and Europe depend on folk remedies of plant origin for their liver diseases [28]. In the following table, 201 hepatoprotective plant species from 81 families have been described. In addition, 40 phytoconstituents isolated from these plants have been illustrated in Table 1 and Fig. 1.

4. Discussions

The review analyzed 201 plant species belonging to 81 families that have been reported to have hepatoprotective effects against various liver diseases. The study provided a detailed overview of the plant parts used, types of extracts, animal models, hepatotoxicity-inducing agents, maximum extract doses, biochemical parameters, and active components of these plants.

4.1. Plant parts used

Among the plant parts employed for ethnopharmacological use, leaves were highly utilized, followed by whole plants, roots, fruits, seeds, bark, rhizomes, and flowers. Based on the table, we can make some general observations:

Table 1
Plants and plant extracts having hepatoprotective activity.

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Acampe praemorsa (Orchidace-ae)	Hydroalco-holic extract of Whole plant	Wistar albino rats	Ethanol	100, 200, and 400 mg/kg	AST↓, ALT↓, ALP↓ and total bilirubin↓		Used in bone fractures, reducing headache and fatigue. Also an anti-typhoid agent.	[29]
Adansonia digitata (Malvaceae)	Aqueous extract of Fruits	Wistar male albino rats	Carbon tetrachloride	1 mg/kg p.o.	AST↓, ALT↓, and ALP↓	β-sitosterol, β-amyrin palmitate (**1**), or/and α-amyrin(**2**) and ursolic acid(**3**)	Immunostimulant, anti-inflammatory, analgesic, pesticide, antipyretic, febrifuge, and astringent in the treatment of diarrhea & dysentery	[30]
Aegle marmelos (Rutaceae)	Petroleum ether and ethanol extract of Leaves	Wistar albino rats	Paracetamol	25,50 and 100 mg/kg	ALT↓, AST↓, ALP↓, LDH↓, SOD↑, CAT↑,		Used in fever, cardiac dysfunction, hepatitis, asthma, diabetes, dyspepsia, seminal weakness, inflammation and febrifuge	[31]
Aerva lanata (Amarantha-ceae)	Petroleum ether extract of Whole plant	Sprague Dawley rats	Carbon tetrachloride	50 and 100 mg/ kg	SGOT↓, SGPT↓, and ALP↓,		Used in acute renal failure and DM, antimicrobial	[32]
Alhagi mauronum (Fabaceae)	Aqueous ethanol (30:70 %) extract of whole plant	Rabbits	Paracetamol	250 mg/kg and 500 mg/kg	ALP↓, SGOT↓, SGPT↓ and TB↓		Used in stomatitis, kidney stones, urinary retention, flatulence and piles	[33]
Allium cepa (Amaryllida-ceae)	Methanolic extract of Fresh bulb	White wistar male albino rats	Paracetamol	200,300 and 450 mg/kg	AST↓, ALT↓, and ALP↓, LDH↓ total bilirubin↓		Antimicrobial, antihypertensive, antithrombotic, antioxidant and hypoglycemic	[34]
Allium sativum (Amaryllida-ceae)	Raw garlic bulb	ALD patients	Ethanol	2.4 g orally for 45 days	AST↓, ALT↓, ALP↓, LDH↓	S-allyl-cysteine(**4**), alliin**(5),** S-allylmer-Capto-cysteine**(6),** and allicin**(7)**	Anti-oxidant, anti-inflammatory, and anti-cancer. Used in lipid regulation, reducing blood pressure, and improving blood glucose control	[35]
Alocasia indica (Araceae)	Hydro-alcoholic extract of Roots	Male albino wistar rats	Carbon tetrachloride	400 mg/kg p.o.	AST↓, ALT↓, and ALP↓		Antioxidant, analgesic and antiarthritic. Used in disease of abdomen and spleen inflammation	[36]
Aloe barbadensis (Liliaceae)	Petroleum ether, chlo-roform, methanol and aqueous extract of Aerial parts	Male Wistar rats or Swiss albino mice	Carbon tetrachloride	125, 250 and 500 mg/kg	AST↓, ALT↓, and ALP↓		Anti-fertility, oxytocic and antibacterial. Used in X-ray burns, Dermatitis and cutaneous leishmaniasis	[37]
Alstonia scholaris (Apocynac-eae)	Aqueous extract of Bark	Male wistar rats	β-D-galacto-samine	300 mg/kg p.o.	SGOT↓, SGPT↓		Used in dryness of mouth, dizziness, deafness and vertigo	[38]
Amaranthus caudatus (Amaranth-aceae)	Methanolic extract of Whole plant	Wister rats	Paracetamol	200 and 400 mg/ kg	ALT↓, Total Bilirubin↓, AST↓, CAT↑, GSH↑, Albumin↑		Used in amoebiasis and kidney disease. Blood purifier, diuretic, abortifacient and astringent	[39]
Amaranthus spinosus (Amaranth-aceae)	Ethanolic extract of Whole plant	Sprague–Dawley rats	Carbon tetrachloride	100, 200, and 400 mg/kg p.o.	AST↓, ALT↓, ALP↓, TB↓		Anti-inflammatory, antimalarial, antibacterial, antidiuretic, antiviral and	[40]

(*continued on next page*)

Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
							prevent swelling around stomach.	
Amaranthus hypochond-riacus (Amaranth-aceae)	Ethanolic extract of Seeds	Male Wistar rats	Sodium arsenite	200 and 300 mg/ kg	ALT↓, AST↓, ALP↓, GGT↓, MDA↓, H2O2↓, SOD↑, CAT↑, GPx↑		Used in cold sores, reduce infection and boost the body's immune system.	[41]
Amburana cearensis (Fabaceae)	Ethanolic extract of Bark	Male wistar rats	Carbon tetrachloride	25 and 50 mg/kg i.p.	AST↓, ALT↓	Amburoside-A (**8**)	Used in respiratory disease including asthma, and anti-inflammatory.	[42,43]
Amorphoph-allus campanulat-us (Araceae)	Methanolic and aqueous extract of Tubers	Wistar rats	Paracetamol	300 mg/kg p.o.	SGOT↓, SGPT↓, ALP↓, Bilirubin↓, SOD↑, CAT↑, GPx↑		Digestive, anthelmintic, aphrodisiac and anti-inflammatory.	[44]
Anacardium occidentale (Anacardia-ceae)	Methanolic extract of Leaves	Wister rats	Carbon tetrachloride	500 and 1000 mg/kg	AST↓, ALT↓, ALP↓		DM, anti-inflammatory. Used in eczema, psoriasis, dyspepsia, bronchitis and cough.	[45]
Anastatica hierochunt-ica (Brassicac-eae)	Methanolic extract of Whole plant	Mice	D-galactosa-mine	845 mg/kg/day	SGOT↓, SGPT↓, ALP↓, Bilirubin↓	Anastatin A **(9),** Anastatin B (**10**)	Used in parasitic disease.	[46]
Andrograp-his paniculata (Acanthac-eae)	Ethanolic extract of Aerial parts,	Swiss albino mice	Paracetamol	100–200 mg/kg	SGOT↓, SGPT↓, ALP↓, Bilirubin↓	Andrograph-olide (**11**)	Anti-inflammatory, Anti-carcinogenic, antidiarrheal, antiviral and antimalarial.	[47,48]
Anisochilus carnosus (Lamiaceae)	Ethanolic extract of Stem	Rats	Carbon tetrachloride	200 and 400 mg/ kg	SGOT↓, SGPT↓, ALP↓, Bilirubin↓		Used in gastrointestinal disorders, cough, cold, fever and ulcer.	[49]
Annona crassiflora (Annonace-ae)	Ethanolic extract of Fruits	Rats	Diabetes induced oxidative and nitrosative stress	25,50 and 100 mg/kg	AST↓, ALT↓, ALP↓	Procyanidin B2 (**12**), epi-catechin (**13**), catechin (**14**), chlorogenic acid (**15**), caffeoyl-glucoside (**16**)	Used in rheumatism, wounds, snakebites and antimicrobial.	[50]
Annona squamosa (Annonace-ae)	Alcoholic and aqueous extract of Seeds	Rats	Isoniazid and Rifampicin, Alcohol	200 and 400 mg/ kg	AST↓, ALT↓, ALP↓, TB↓, GGT↓		Antioxidant, wound healer, antiarthritic, anti-inflammatory, analgesic, antimicrobial, antidiabetic and antinociceptive.	[51]
Anoectochil-us formosanus (Orchidace-ae)	Methanolic and aqueous extract of Whole plant	Wistar albino rats	Paracetamol	100,300 and 500 mg/kg	AST↓, ALT↓, hepatic hydroxyprol-ine↓, hypoalbumi-nemia↓ and splenomega-ly↓	Kinsenoside (**17**)	Used in hypertension, tuberculosis, impotence, under-developed children, liver and spleen disorders.	[52,53]
Antennaria dioica (Asteraceae)	Ethanolic extract of Herb	Rats	Carbon tetrachloride	50 mg/kg	ALT↓, AST↓		Has hemostatic and astringent properties, used in respiratory and biliary ailments.	[54]
Apanamixis polystachya (Meliaceae)	Ethanolic extract of Leaves	Long-Evans female rats	Carbon tetrachloride	50,100 & 200 mg/kg p.o.	AST↓, ALT↓, ALP↓		Used in rheumatism, ulcers, and tumors.	[55]
Apium graveolens (Apiaceae)	Petroleum ether and methanolic extract of Seeds	Rats	Paracetamol and thioacet -amde	200 mg/kg	SGOT↓, SGPT↓, ALP↓, Bilirubin↓		Used in bronchitis, asthma, liver and spleen diseases.	[56]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Arachniodes exilis (Dryopterid-acea)	Ethanolic extract of Rhizome	Kunmi-ng albino mice	Carbon tetrachloride	360, 720 mg/kg	Lipid peroxide↑, SOD↑, and SGOT↓, SGPT↓		Used in Inflammation, dysentery and burn scald.	[57]
Asparagus racemosus (Liliaceae)	Ethanolic extract of Root	Male albino rats	INZ	50 mg/kg	AST↓, ALT↓, and ALP↓, GGT↓		Galactagogue, aphrodisiac, anodyne, diuretic, antispasmodic and nervine tonic.	[58]
Averrhoa carambola (Oxalidace-ae)	Methanolic extract of Fruits	Rats	Carbon tetrachloride	900 mg/kg p.o.	AST↓, ALT↓, and ALP↓,	5-hydroxy-methyl furfural	Diaphoretic, diuretic, expectorant, antidiarrhoeal, antiemetic and used in acute dyspepsia.	[59]
Azadirachta indica (Meliaceae)	Ethanolic extract of Leaf	Albino rats of Wistar strain	Paracetamol	500 mg/kg, p.o.	SGOT↓, SGPT↓, ALP↓		Antihyperglycem-ic, antiserotonin, anti-inflammatory, hypotensive, hypolipidemic and antifertility activity.	[6]
Baliosperm-um montanum (Euphorbia-ceae)	Methanolic extract of Root	Wistar albino rats	Carbon tetrachloride	300 mg/kg	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Purgative, anthelmintic, and diuretic, and also used in pains, enlarged spleen, inflammations, and leucoderma, abdominal tumors and cancer	[60]
Bauhinia purpurea (Fabaceae)	Methanolic extract of Leaves	Rats	Paracetamol	500 mg/kg b.w.	AST↓, ALT↓		Used in stomach tumors, ulcers, wounds, glandular swellings, diarrhea, and fever	[61]
Bauhinia variegate (Fabaceae)	Alcoholic extract of Stem barks	Sprag-ue-Dawle-y rats	Carbon tetrachloride	100 and 200 mg/ kg	AST↓, ALT↓, ALP↓ and gamma-GT↓		Hypoglycemic agent and has hemagglutinating effect. Antibacterial and antifungal, astringent to bowel	[62]
Berberis lyceum (Berberidac-eae)	Methanolic crude extract of Root	Rats	Carbon tetrachloride	500 mg/kg	SGOT↓, SGPT↓ and ALP↓		Used in UTI, swelling of spleen, stomach and intestinal ulcer and liver diseases	[63]
Bidens Pilosa (Asteraceae)	Methanolic and aqueous extract of Aerial parts	Male albino mice	Carbon tetrachloride and D-galactosam-ine	700 mg/kg	AST↓, ALT↓, and ALP↓, and serum total protein↑, albumin↑, and liver glutathione↑		Used in stomach disorders, diabetes, malaria and inflammation.	[64]
Bixa Orellana (Bixaceae)	Methanolic extract of Leaves	Rats	Carbon tetrachloride	500 mg/kg	AST↓, ALT↓, ALP↓ and bilirubin↓		Antioxidant and anti-inflammatory.	[65]
Boerhaavia diffusa (Nyctagina-ceae)	Ethanolic extract of Whole plants	Rats	Carbon tetrachloride	500 mg/kg	Total bilirubin↓, SGPT↓, SGOT↓		Used in dyspepsia, jaundice, enlargement of the spleen and abdominal pain.	[66]
Bupleurum kaoi (Apiaceae)	Ethanolic extract of Roots	Sprague-Dawley rats	Carbon tetrachloride	100 and 500 mg/ kg	ALT↓, AST↓	Saiko-saponins	Anti-inflammatory and antipyretic	[67]
Byrsocarpus coccineus (Connarace-ae)	Aqueous extract of Leaf	Rats	Carbon tetrachloride	200,400 and 1000 mg/kg	AST↓, ALT↓, and ALP↓ and serum total protein		Used in mouth and skin sores, swellings, tumors, muscular and rheumatic pains, venereal diseases, pile and dysentery	[68]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Caesalpinia bonducella Linn. (Caesalpiniaceae)	Aqueous extract of Leaves	Rats	Carbon tetrachloride	500 mg/kg p.o.	AST↓, ALT↓, ALP↓		Antipyretic, antidiuretic, anthelmintic, antibacterial and anti-tumor	[69]
Caesalpinia crista (Caesalpin-iaceae)	Ethanolic extract of Leaves	Rats	PCM and Iron-Overload	50, 100, and 200 mg/kg p.o.	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓, TGs↓		Adaptogenic, anthelmintic, anti-inflammatory, antipyretic and analgesic, antimalarial, antibacterial, antitumor, anticonvulsant, immune-modulatory, anxiolytic and antidiabetic.	[70]
Cajanus cajan Linn. (Papilionac-eae)	Ethanolic extract of Leaves	Male albino rats	N-Nitrosodiethylamine	200,400 & 800 mg/kg p.o.	ALT↓, AST↓ albumin↑		Antioxidant and anticancer	[71]
Capparis decidua (Capparac-eae)	Methanolic and aqueous extract of Stems	Rats	Carbon tetrachloride	200,400 mg/kg	SGOT↓, SGPT↓, ALP↓, Bilirubin↓		Anthelmintic, analgesic, aphrodisiac, carminative. Also used in cough, asthma, inflammation and fever.	[72]
Capparis spinosa (Capparac-eae)	Ethanolic extract of Root bark	Male mice	Carbon tetrachloride	100, 200 and 400 mg/kg	ALT↓, AST↓		Used in flatulence, rheumatism, anemia, dropsy, and gout. Also used as expectorant, tonic and vasoconstrictive, analgesic, anthelmintic, antihaemorrhoidal, diuretic and emmenagogue.	[73]
Careya arborea (Myrtaceae)	Methanolic extract of Bark	Mice	Carbon tetrachloride	50,100 and 200 mg/kg	SGOT↓, SGPT↓, ALP↓, Bilirubin↓		Analgesic, anti-inflammatory, antioxidant, anticancer and antiulcer. Used in diarrhea, dysentery with bloody stools and ear pain.	[74,75]
Carica papaya Linn. (Carieaceae)	Aqueous extract of Fruits	Sprague-Dawley rats	Carbon tetrachloride	100 mg/kg	AST↓, ALT↓, ALP↓		Antisickling, anthelmintic, anti-diabetic, and anti-cancer	[76]
Carthamus tinctorius Linn. (Composit-ae)	Ethanolic extract of Flower	Male Kunming mice	Carbon tetrachloride	200 & 400 mg/ kg p.o.	AST↓, ALP↓,total proteins↑	kaempferol 3-O-rutinoside (**18**) and kaempferol 3-O-glucoside (**19**)	Soothe the liver and relieve jaundice and used in liver disorders.	[77]
Cassia fistula (Fabaceae)	Methanolic extract of Leaves	Male albino rats	Paracetamol	400 mg/kg p.o.	SGOT↓, SGPT↓, ALP↓, Bilirubin↓		Used in hematemesis, pruritus, leucoderma, diabetes and skin disease	[78]
Cassia tora (Caesalpini-acea)	Methanolic extract of Leaves	Albino rats	Carbon tetrachloride	100–600 mg/kg p.o.	SGOT↓, SGPT↓	Ononitol mono-hydrate (**20**)	Anthelmintic and purgative. Also used in ulcers.	[79,80]
Casuarina equisetifolia (Casuarina-ceae)	Methanolic extract of Inflorescе-nce and Pollen	Swiss albino rats	Carbon tetrachloride	500 mg/kg	ALT↓, AST↓, and cholesterol↓		Astringent and antioxidant. Used in stomachache, diarrhea, dysentery and nervous disorders,	[81]
Cecropia pachystac-hya (Urticaceae)	Ethyl acetate extract of Leaves	Mice	Hypercaloric diet(non-alcoholic)	20 mg/kg	SOD↑	Chlorogenic acid, iso-orientin, orientin (**21**)	Diuretic and used in cough, asthma, hypertension, and diabetes.	[82]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Centella asiatica (Apiaceae)	Ethanolic extract of Leaves	Mice	Lipopolysac-charide/D-galacto-samine	100 & 200 mg/ kg	ALT↓, AST↓		Used in gastrointestinal disorders, cutaneous troubles and revitalization of brain cells. Also antiulcer, antidiabetic, cardioprotective, radioprotective, antimutagenic and skin protective.	[83]
Chenopodi-um album Linn. (Chenopodi-aceae)	Methanolic extract of Aerial parts	Wister rats	Carbon tetrachloride	100,200 and 300 mg/kg p.o.	AST↓, ALT↓, ALP↓		Antiscorbutic, laxative, sedative, blood purifier, diuretic and anthelmintic.	[84]
Cichorium intybus (Asteraceae)	Ethanolic extract of Whole plants	Wistar albino rats	Carbon tetrachloride	6, 18, and 54 g/ kg	ALT↓, AST↓		Antimicrobial, antidiabetic, immune-enhancementer, antihepatotoxic, anti-hyperuricemia, anti-hypertriglyceride-mia, diuretic, laxative and mild sedative.	[85]
Cinnamom-um cassia (Lauraceae)	Ethanolic extract of Bark	Male Wister rats	Diabetes (strepto-zotocin)	100, 200, 400 mg/kg	SOD↑, CAT↑, MDA↑		Used in DM and kidney disease.	[86]
Citrullus colocynthis Linn. (Cucurbitac-eae)	Ethanolic extract of Fruits	Han-Wist rat	Carbon tetrachloride	25, 50 and 100 μg/ml	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Anti-inflammatory and laxative. Soften bowel contents.	[87]
Citrullus lanatus (Cucurbitac-eae)	Aqueous extract of Seeds	Wister rats	Ethanol	200 and 400 mg/ kg	AST↓, ALT↓, ALP↓		Antioxidant	[88]
Clausena lansium (Rutaceae)	Methanolic extract of Stem bark	Wistar rats	Carbon tetrachloride	100 and 200 mg/ kg	ALP↓, ALT↓, AST↓		Used in coughs, asthma, gastro-intestinal diseases, ulcers, and vermifuge.	[89]
Cleome viscosa (Capparida-ceae)	Ethanolic extract of Leaves	Male albino rats	Carbon tetrachloride	100 and 200 mg/ kg b.w	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Used in diarrhea, fever, inflammation, bronchitis, skin diseases, and malarial fever.	[90]
Clidemia hirta (Melastoma-taceae)	Aqueous extract of Leaves	Mice	Carbon tetrachloride	150,300 and 600 mg/kg b.w.	ALT↓, AST↓, GSH↑		Antioxidant	[12]
Clitoria ternatea (Fabaceae)	Methanolic extract of Leaves	Wister albino mice	Carbon tetrachloride and paracetamol	200 mg/kg	AST↓, ALT↓,total bilirubin (TB)↓		Used in body aches, infections, urogenital disorders, and as an anthelmintic and antidote to animal stings.	[91]
Clutia abyssinica (Euphorbia-ceae)	Methanolic extract of Leaves	Swiss albino mice	Carbon tetrachloride	100,200 and 400 mg/kg b.w	ALP↓,ALT↓, AST↓		Used in ectoparasite infestation, dysentery, gastritis, hypertension, herpes zoster, superficial fungal infections, internal parasite infections and anthrax.	[92]
Coccinia grandis (Cucurbitac-eae)	Ethanolic extract of Fruits	Wister rats	Carbon tetrachloride	250 mg/kg p.o.	ALP↓,ALT↓, AST↓		Used in leprosy, fever, asthma, infective hepatitis, jaundice, and sore throats.	[93]
Cochlosper-mum planchonii	Aqueous extract of Rhizome	Sprague Dawley (SD) rats	Carbon tetrachloride	10 mg/day	ALP↓, SGPT↓, SGOT↓		Jaundice.	[94]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
(Coclosper-maceae)								
Colocasia esculenta (Araceae)	Methanolic extract of Leaf	Mice	Paracetamol	1000 and 2000 mg/kg/day	AST↓, ALT↓, ALP↓, Albumin↓		Anti-inflammatory, anti-microbial, anti-oxidant and anti-cancer	[95]
Commiph-ora opobalsa-mum (Burserac-eae)	Ethanolic extract of Aerial parts	Wistar albino rats	Carbon tetrachloride: liquid paraffin (1:1)	250 and 500 mg/ kg	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Treatment of chest, stomach and kidney complaints; to promote digestion and to relieve rheumatism, scurvy and jaundice.	[96]
Commelina nudiflora (Commelin-aceae)	Methanolic extract of Leaves	Sprague Dawley rats	Carbon tetrachloride	150, 300, 450 mg/kg b.w.	ALT↓, AST↓, GSH↑, MDA↑		Used in intestinal obstruction, hemorrhoids, abnormal uterine and vaginal discharge.	[10]
Cordia macleodii (Boraginac-eae)	Ethanolic extract of Leaves	Rats	Carbon tetrachloride	100 mg/kg p o	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Antioxidant	[97]
Croton macrostac-hys (Euphorbia-ceae)	Crude extract, aqueous fraction and chloroform fraction of Root bark	Swiss albino mice	Paracetamol	200 mg/kg and 400 mg/kg	ALP↓,ALT↓,AST↓		Used in jaundice and hepatitis.	[98]
Curcuma longa (Zingiberac-eae)	Ethanolic extract of Rhizome	Mice	Bleomycin	40 mg/kg body weight (0.7 ml/ kg body weight)	AST↓, ALT↓, ALP↓, gamma-GT↓, total proteins↑, albumin↑, and globulin↑	Curcumin (**22**)	Antioxidant, anti-inflammatory and anticarcinogenic activity in various chemical-induced tumors, including digestive organs and skin cancers.	[99]
Cuscuta chinensis (Convolvula-ceae)	Ethanolic and aqueous extract of Seeds	Rats	Paracetamol	125 and 250 mg/ kg p.o.	GPx↑, SOD↑, CAT↑, and MDA↑		Used in vision improvement. Also immune-stimulatory and Anti-aging.	[100]
Cyperus rotundus (Cyperace-ae)	Ethanolic extract of Rhizomes	Wister albino rats	Carbon tetrachloride	100 and 200 mg/ kg/day b.w.	ALP↓, SGPT↓, SGOT↓		Stomachic astringent, sedative, stimulant, vermifuge, diaphoretic, diuretic, analgesic, antispasmodic and carminative.	[101]
Daucas carota Linn. (Umbellifer-ae)	Aqueous extract of Tuber roots	Male Swiss albino mice	Carbon tetrachloride	10,25,50 ml/kg	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Used in Kidney dysfunction, asthma, dropsy, inflammation, leprosy and worm troubles	[102]
Dillenia suffruticosa (Dilleniace-ae)	Methanolic extract of Leaves	Sprague Dawley rats	Carbon tetrachloride	200,300 and 400 mg/kg b.w.	ALT↓, AST↓, GSH↑		Antioxidant	[103]
Dodonaea viscosa (Sapindace-ae)	Methanolic extract of Whole plant	Male wistar rats	Carbon tetrachloride	500 mg/kg	ALT↓, AST↓, ALP↓	Hautriwaic acid (**23**)	Used in skin diseases. Also antidiabetic, antimalarial, antibacterial and gastroprotective.	[104]
Ecbolium viride Forsk. (Acanthace-ae)	Methanolic extract of Root	Wister albino rats	Paracetamol	400 mg/kg p.o.	Total bilirubin↓, ALP↓, ALT↓, AST↓		Used in gout, dysuria and rheumatism.	[105]
Echinophora platybola (Apiaceae)	Aqueous-ethanolic extract of Aerial part	Rats	Paracetamol	200, 500, and 1000 mg/kg b.w	ALT↓, AST↓, ALP↓, CAT↑		Antiseptic, antispasmodic, antimicrobial and antifungal agents.	[106]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Eclipta alba (Asteraceae)	Ethanolic extract of Whole plant	Charles Foster rats	Carbon tetrachloride	62.5–500.0 mg/ kg p.o.	ALT↓, AST↓	Wedelo-lactone and demethyl wedelo-lactone (**24**)	Tonic and deobstruent in hepatic and splenic enlargements, and in various chronic skin diseases.	[107,108]
Eclipta prostrata (Asteraceae)	Ethanolic extract of Leaves	Wister albino rats	Carbon tetrachloride	250 mg/kg p.o.	Total bilirubin↓, ALP↓, ALT↓, AST↓, SOD↑, CAT↑, and GSH↑		Antioxidant	[109]
Elaeis guineensis (Arecaceae)	Methanolic extract of Leaves	Mice	Paracetamol	200 mg/kg b.w.	ALT↓, AST↓, Bilirubin↓		Used in wound healing, cancer, headache and rheumatism and as an aphrodisiac and diuretic.	[110,111]
Elephantop-us scaber Linn. (Composit-ae)	Ethanolic extract of Leaves	Male ICR mice	Ethanol	3,15,30 mg/kg p.o.	Total bilirubin↓, ALP↓, ALT↓, AST↓		Used in nephritis, edema, dampness, chest pain, pneumonia andscabies.	[112]
Eleusine indica Linn. (Gramineae)	Aqueous extract of Aerial part	SpragueDawley male rats	Carbon tetrachloride	150 and 300 mg/ kg	ALT↓, AST↓		Diuretic, anti-helminthic, diaphoretic and febrifuge and for treating cough.	[113]
Equisetum arvense (Equisetac-eae)	Methanolic extract (ethyl acetate fraction) of Aerial part	human liver-derived Hep G2 cells	Tacrine	400 mcg/ml	ALP↓,ALT↓, AST↓, normalized histopathological changes	Onitin (**25**) luteolin (**26**)	Used in hemorrhage, urethritis, jaundice, and hepatitis.	[114]
Erythrina senegalen-sis (Fabaceae)	Aqueous extract of Stem	Rat	Paracetamol	200 mg/kg & 400 mg/kg	ALP↓,ALT↓, AST↓		Used in malaria, gastrointestinal disorders, fever, dizziness, secondary sterility, diarrhea, jaundice, and nose bleeding and relieve pain.	[115]
Euphorbia paralias (Euphorbia-ceae)	Methanolic extract of Aerial part	Male sprague dawley rats	Thio-acetamide	200 mg/kg	ALT↓, AST↓, Bilirubin↓, cholesterol↓,TG↓, LDL↓, HDL↑, GSH↑, CAT↑, SOD↑		Antioxidant and cytotoxic. Used in kidney disease.	[116,117]
Euphorbia geniculata (Euphorbia-ceae)	Methanolic extract of Aerial part	Male sprague dawley rats	TAA	200 mg/kg	ALT↓, AST↓, Bilirubin↓, cholesterol↓,TG↓, LDL↓, HDL↑, GSH↑, CAT↑, SOD↑		Antioxidant and antifibrotic.	[116]
Feronia limonia (Rutaceae)	Methanolic extract of Roots	Rats	Carbon tetrachloride	200 mg/kg & 400 mg/kg	ALT↓, AST↓		Relieving body pain and in treating snake bite.	[118]
Ficus carica (Moraceae)	Petroleum ether extract of Shade dried leaves	Rats	Rifampicin	500 mg/kg	SGOT↓, SGPT↓, Bilirubin↓		Jaundice.	[119]
Ficus hispidia (Moraceae)	Methanolic extract of Leaves	Rats	Paracetamol	400 mg/kg p.o.	Bilirubin↓, ALP↓, SGPT↓, SGOT↓		Antidiarrheal, hepatoprotective, antitussive, antipyretic, astringent, anti-inflammatory, vulnerary, hemostatic and anti-ulcer	[120]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Flacourtia indica (Salicaceae)	Petroleum ether, ethyl-acetate and methanolic extract of Aerial part	Long Evans rats	Paracetamol	1.5 g/kg	ALP↓, SGPT↓, SGOT↓		Appetizing, digestive and diuretic. Used in jaundice and enlarged spleen.	[121]
Foeniculum vulgare (Umbellifer-ae)	Ethanolic extract of Seed	Rat	Carbon tetrachloride and paracetamol	250 and 500 mg/ kg b.w.	Bilirubin↓, ALP↓, SGPT↓, SGOT↓		Used in spleen disorders and suppressing appetite, improving colic and irritable bowel.	[122]
Fumaria indica (Fumariace-ae)	Ethanolic and aqueous extract of Whole plants	Albino (Wistar) rats	D-galactosa mine	100 & 400 mg/ kg p.o.	Bilirubin↓, ALP↓, SGPT↓, SGOT↓, MDA↑,GSH↑	Protopine (**27**)	Hepatitis.	[31])
Gentiana olivieri (Gentianac-eae)	Ethanolic extract of Aerial part	Male Sprague-Dawley rats	Carbon tetrachloride	125, 250, 62.5 mg/kg bw.	AST↓, ALT↓	Isoorientin (**28**)	Used in hyperglycemia and anemia.	[123]
Ginkgo biloba (Gilkgoa-ceae)	Ethanolic extract of dried leaf extract	Wistar albino rats	Carbon tetrachloride	25 mg/kg and 50 mg/kg, i.p.	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Cardioprotective, antiasthmatic, antidiabetic and potent central nervous system activator.	[124]
Gloriosa superba (Liliaceae)	Alcoholic extract of Leaves	Rats	Carbon tetrachloride	200 mg/kg	Bilirubin↓, ALP↓, SGPT↓, SGOT↓		Used in sprains, chronic ulcers, hemorrhoids, cancer, leprosy and labor pain	[125]
Glycosmis pentaphyllaCorr. (Rutaceae)	Methanolic extract of Leaves	Swiss albino mice	Paracetamol	200 and 400 mg/ kg	AST↓, ALT↓, ALP↓, TP↓		Used in anemia, jaundice, rheumatism, cough, eczema, homeopathy, diarrhea, and dysentery. Also anthelmintic, febrifuge, vermifuge spasmolytic and diuretic.	[126]
Glycyrrhiza glabra (Fabaceae)	Dimethyl sulfoxide extract of Root	Albino (Wistar) rats	Carbon tetrachloride	50 mg/kg	AST↓ALT↓, ALP↓, and TBARS↓; GSH↑, SOD↑, and CAT↑	Glycyrrhizin (**29**)	Used in cirrhosis and hepatitis	[127]
Gmelina asiatica Linn. (Verbenac-eae)	Chloroform and ethanol extracts of Aerial parts	Rats	Carbon tetrachloride	400 mg/kg	AST↓, ALT↓, ALP↓, total bilirubin↓		Used in gonorrhea and rheumatism and as a blood purifier.	[128]
Grewia mollis (Malvaceae)	Methanolic extract of Leaves	Albino (Wistar) rats	Carbon tetrachloride	5 mg/kg	AST↓, ALT↓, ALP↓, Bilirubin↓, MDA↑		Abortifacient and antidote	[129]
Gundelia tourenfortii (Asteraceae)	Aqueous-ethanolic extract of Fresh edible stalk	Male Sprague–Dawley rat	Carbon tetrachloride	200 and 300 mg/ kg	AST↓, ALT↓, ALP↓, bilirubin↓		Blood purifier	[130]
Halenia elliptica (Gentianac-eae)	Methanolic extract of Whole plant	Sprague–Dawley rats	Carbon tetrachloride	100 mg/kg and 200 mg/kg	AST↓, ALT↓, ALP↓, bilirubin↓ and normalizes histo-pathological changes		Vasodilator, antioxidant, antibacterial and antitumor.	[131]
Hancornia specicosa (Apocyana-ceae)	Freeze dried extract of Fruit juice	Rats	Paracetamol	200 mg/kg	AST↓, ALT↓, GGT↓	Chlorogenic acid (**30**), rutin	Used in tuberculosis, gastric ulcer, diarrhea and inflammatory disorders.	[132]
Hedyotis corymbosa (Rubiaceae)	Methanolic extract of Whole plants	Albino (Wistar) rats	Paracetamol	100 and 200 mg/ kg	SGPT↓, SGOT↓,and serum bilirubin↓		Used in viral infections, cancer, syndromes involving "toxic heat", acne, boils, skin ailments,	[133]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
							appendicitis, hepatitis, eye diseases and bleeding.	
Hibiscus sabdariffa (Malvaceae)	Aqueous extract of Flowers	Male Wistar rats	Azathioprine	10 ml (10 gm/ 100 ml)	ALT↓,AST↓		Hypertension	[134]
Hoslundia opposite (Lamiaceae)	Methanolic and ethyl acetate extract of Stem	Mice	Carbon tetrachloride	400 mg/kg bw	AST↓, ALT↓, Bilirubin↓		Antipyretic, diuretic, and antimalarial.	[135]
Hygrophilia auriculata (Acanthace-ae)	Aqueous extract of Roots	Albino (Wistar) rats	Carbon tetrachloride	50,100 & 150 mg/kg	AST↓, ALT↓, ALP↓,TB↓ and TP↑		Used in rheumatism, inflammation, pain, urinary infections, edema and gout.	[136]
Hyptis crenata (Lamiaceae)	Ethanolic extract of Aerial parts	Rats	Cecal ligation and puncture (CLP)	300 mg/kg	AST↓, ALT↓, ALP↓		Gastroprotection.	[137]
Hypericum japonicum (Hypericac-eae)	Aqueous extract of Whole plant	Mice	Carbon tetrachloride	0.5–4.5 gm/kg p. o.	AST↓, ALT↓,TB↓		Used in bacterial diseases, infectious hepatitis, acute and chronic hepatitis, and gastrointestinal disorder, internal hemorrhage and tumor.	[138]
Hypericum perforatum (Hypericac-eae)	Alcoholic extract of Aerial part	Mice	Carbon tetrachloride	250 and 500 mg/ kg	AST↓, ALT↓, LDH↓		Used in ulcer, diabetes, common cold, gastrointest inal disorders, jaundice, hepatic and biliary disorders and healing wounds.	[139]
Indigofera tinctoria (Fabaceae)	Petroleum ether extract of Aerial parts	Rats and mice	Carbon tetrachloride for rat and zoxazolami-ne for mice	6.25–50 mg/kg p.o	Transamin-ases↓, bilirubin↓, TG↓, LPO↓ and restored the depleted GSH	Indigtone (bioactive fraction)	Used in epilepsy, nervous disorders, and bronchitis.	[140]
Ixora coccinea (Rubiaceae)	Ethanolic extract of Roots	Wistar rats	Aflatoxin	300 mg/kg	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓ and total protein↑		Used in diarrhea, dysentery, leucorrhoea, dysmenorrhea, hemoptysis, catarrhal bronchitis.	[141]
Justice schimperia-na (Acanthace-ae)	Methanolic extract of Leaves	Mice	Carbon tetrachloride	200 mg/kg	ALT↓,AST↓		Used in excessive pellagra, laxative, stomach complaints, hepatitis, venereal diseases, malaria, jaundice, epilepsy, mental illness and leprosy	[142]
Kalanchoe pinnata (Crassulaceae)	Ethanolic extract of Leave	Albino (Wistar) rats	Carbon tetrachloride	200 mg/kg bw	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Astringent to the bowels, analgesic, carminative, antiulcer, antiinflammatory and antimicrobial. Used in diarrhea and vomiting	[143]
Laggera pterodonta (Asteraceae)	Ethanolic and aqueous extract of Whole herb	Rats	Carbon tetrachloride and D-galactosamine	1–100 mcg/ml	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓ and total protein↑		Used in inflammation and hepatitis.	[144]
Lawsonia inermis Linn. (Lythraceae)	Methanolic extract of Leaves	Wister rats	2-acetyl aminofluorene (2-AAF)	100, 200 and 400 mg/kg bw p. o.	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓		Used in renal lithiases, jaundice, healing wounds and skin inflammation.	[145]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Lepidium sativum (Brassicac-eae)	Methanolic extract of Seeds	Rats	Carbon tetrachloride	200 and 400 mg/ kg	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓ and total protein↑		Used in diabetes, arthritis, traumatic injuries. Also antioxidant, anti-inflammatory, antidiarrheal, antimicrobial and antispasmodic	[146]
Leptadenia pyrotechn-ica (Apocynac-eae)	Methanolic extract of Whole plant	Wister rats	Paracetamol	150 ml/kg/day	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Antihistamine and expectorant. Used in eczema and other skin diseases, diabetes and wound healing.	[147]
Leucas aspera (Lamiaceae)	Aqueous extract of Whole plant	Female wistar albino rats	D-galacto-samine	100,200 and 400 mg/kg p.o.	ALP↓, ALT↓, AST↓, CAT↑, GSH↑, and SOD↑		Used in coughs, cold, painful swelling and chronic skin eruptions.	[148]
Litchi chinensis (Sapinda-ceae)	Methanolic extract of Fruit pulp	Male ICR mice	Carbon tetrachloride	100 and 200 mg/ kg p.o.	Total protein↑, ALP↓, SGPT↓, SGOT↓		Anti Inflammatory and anti-carcinogenic	[149]
Lobelia alsinoides Lam. (Campanul-aceae)	kalka paste of Whole plant	Wister rats	Carbon tetrachloride	0.54 g/kg, 1.08 g/kg and 2.16 g/ kg	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓ and total protein↑		Jaundice	[150]
Luehea divaricata (Malvaceae)	Aqueous extract of Leaves	Rats	3-Nitropropio-nic Acid	500 mg/kg	ALT↓,AST↓,CAT↑, GSH↑		Used in dysentery, leucorrhea, rheumatism, blennorrhea, tumors, bronchitis and skin lesions.	[151]
Luffa echinata (Cucurbita-ceae)	Methanolic, petroleum ether and Acetone extract of Fruits	Albino rats	Carbon tetrachloride	250 mg/kg	Total protein↑, ALP↓, SGPT↓, SGOT↓		Used in jaundice, rhinitis, skin diseases and cough.	[152]
Lygodium microphyl-lum (Lygodiac-eae)	Aqueous extract of Aerial part	Rats	Carbon tetrachloride	200,400 and 600 mg/kg b.w.	AST↓, ALT↓		Used in dysentery and skin ailments.	[153]
Mangifera indica (Anacardia-ceae)	Ethanolic and aqueous extract of Leaves	Swiss albino mice	Mercuric chloride	25 & 50 mg/kg p.o.	ALT↓, AST↓, CAT↑, GSH↑		Antidiabetic, hepatoprotecitve, radioprotective, antidiarrheal, anticancer and antimicrobial.	[154]
Mentha arvensis Linn. (Labiatae)	Aqueous-ethanolic extract of Leaves	Wister albino rats	Carbon tetrachloride	375 mg/kg p.o.	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Carminative, antispasmodic and anti-peptic ulcer agent.	[155]
Mikania glomerata (Asteraceae)	Ethanolic extract of Aerial part	Female Swiss mice	SMG(water soluble)	10 mg/kg	ALP↓, ALT↓, AST↓, CAT↑, GSH↑		Depurative, antipyretic, anti influenza, appetite stimulant, anti-inflammatory, analgesic, anti-allergic, bronchialdilator, antitussive and expectorant.	[156]
Mimosa pudica (Fabaceae)	Ethanolic extract of Leaves	Albino rats	Carbon tetrachloride	400 mg/kg	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Anti-diabetic, antitoxin, antioxidant and wound healer.	[157]
Momordica charantia Linn. (Cucurbitac-eae)	Hydro-alcoholic extract of Leaves	Rats	Carbon tetrachloride	100 & 200 mg/ kg	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Antimicrobial	[158]
Momordica dioica (Cucurbita-ceae)	Ethanolic and aqueous extract of Leaves	Rats	Carbon tetrachloride	200 mg/kg	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓		Used in head trouble, urinary calculi, tridosha, fever, asthma, bronchitis, high cough and piles. Aphrodisiac and anthelmintic.	[159]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Morinda citrofolia (Rubiaceae)	Ethanolic extract of Leaves	Sprague Dawley (SD) rats	Carbon tetrachloride	10,15, 20 % noni juice (500 mg/ kg)	ALP↓,ALT↓, AST↓		Used in hypertension, skin diseases and respiratory disorders.	[160]
Nigella sativa (Ranuncula-ceae)	Methanolic and aqueous extract of Seed	Human liver cancer cell line (HepG2), Sprague-Dawley rats	Paracetamol	100,300 and 900 mg/kg	Alanine aminotrans-ferase↓, aspartate aminotrans-ferase↓, and alkaline phospha-tase↓	Thymoquin-one (**31**)	Anti-viral, anti-inflammatory, anti-diabetic, immune-modulatory, anti-cancer, and hepatoprotective.	[161,162]
Ocimum basilicum Linn. (Labiatae)	Ethanolic extract of Leaves	Wister rats	Paracetamol	200 mg/kg	AST↓, ALT↓, bilirubin↓		Antioxidant, chemopreventive, anti-inflammatory, antimicrobial and immune-modulatory.	[163]
Olea europaea (Oleaceae)	Ethanolic extract of Leaves	Rats	Diazinon, Carbon tetrachloride	400 mg/kg	AST↓, ALT↓, ALP↓, gamma-GT↓,		Antioxidant.	[164]
Orthosiphon stamineus (Lamiaceae)	Ethanolic extract of Leaves	Rats	Thio-acetamide	100 & 200 mg/ kg	AST↓, ALT↓, ALP↓ and MDA↑		Used in kidney problems, fever, hypertension, gout, diabetes, hepatitis and jaundice.	[165]
Oxalis corniculata (Oxalidace-ae)	Ethanolic extract of Whole plant	Wister rats	Paracetamol and thio-acetamide	200 and 400 mg/ kg/day	ALP↓, SGPT↓, SGOT↓		Used in worms, dizziness, diarrhea and dysentery, cough, cold, fever and as anthelmintic, stomachache. Stop bleeding from wounds and as anthelmintic.	[166]
Paederia foetida Linn. (Rubiaceae)	Methanolic extract of Leaves	Male Wistar rats	Carbon tetrachloride	100,200 & 400 mg/kg	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Used in enteromegaly, enterosis, flatulence, gastromegaly, rheumatism, toothache, stomach ache and sore	[167]
Parkinsonia aculeata (Fabaceae)	Ethanolic extract of Leave	Albino rats	Carbon tetrachloride	100, 200 and 300 mg/kg	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓ and peroxide↓		Used in typhoid fever, bacterial disease, DM and trypanosomiasis	[168]
Paullinia cupana (Sapindace-ae)	Aqueous extract of Seeds	Rats	Carbon tetrachloride	100, 300 and 600 mg/kg	AST↓, ALT↓		Antioxidant activity, antimicrobial, anticarcinogenic, improvement in cognitive performance, antidepressive, weight loss.	[169]
Pavetta indica (Rubiaceae)	Ethanolic extract of Leaves	Albino rats	Paracetamol	100 mg/kg and 200 mg/kg b.w	Total bilirubin↓, ALP↓, SGPT↓, SGOT↓		Used in pain of piles, urinary diseases and fever.	[170]
Peganum harmala (Nitrariace-ae)	Hexane extract of Seeds	Wistar rats	Ethanol	10 mg/kg bw i.p.	CAT↑, GPx↑, and SOD↑		Pain killer, antiseptic, anti-bacterial, anti-fungal, anti-viral, anti-oxidant, anti-diabetic, anti-tumor, anti-leishmanial, insecticidal and cytotoxic.	[171]
Phyllanthus acidus Linn. (Euphorbia-ceae)	Ethanolic and aqueous extract of Leaves	Rats	Paracetamol and thio-acetamide	200 and 400 mg/ kg p.o.	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓ and oxidative stress↓		Analgesic, antipyretic, antirheumatic. Cures jaundice, smallpox, itching and gum infection. Blood purifier.	[172]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Phyllanthus amarus (Euphorbia-ceae)	Ethanolic extract of Dried leaves	Swiss albino mice	Aflatoxin B1	300 mg/kg	CAT↑, GSH↑, and SOD↑	Phyllanthin (**32**) and hypophylla-nthin, Vitamin C	Used in jaundice, gonorrhea, frequent menstruation and diabetes, skin ulcer, sores, swelling and itchiness	[173]
Phyllanthus emblica (Euphorbia-ceae)	Aqueous extract of Dried and pitted fruit	Male Wistar rats	Carbon tetrachloride	0.9, 1.8 and 3.6 g/kg	AST↓, ALT↓	Phyllanthin and hypophyllan-thin	Antimicrobial, antioxidant, anti-inflammatory, analgesic, antipyretic and antitumor.	[174]
Phyllanthusmuellarian-us (Euphorbiac-eae)	Aqueous extract of Leaves	Mice	Paracetamol	100, 200 and 400 mg/kg b.w	ALP↓,ALT↓, AST↓, CAT↑, GSH↑, and SOD↑		Antimicrobial, antiplasmodial, analgesic, anti-inflammatory and sedative	[175]
Phyllanthus niruri (Euphorbiac-eae)	Methanolic and aqueous extract of Leaves and fruits	Rats	Carbon tetrachloride	200 mg/kg b.w.	SGPT↓, SGOT↓	Phyllanthin, hypophyllan-thin	Hypolipidemic and antiviral.	[176]
Phyllanthus polyphyllus (Euphorbiac-eae)	Methanolic extract of Dried leaves	Male Wistar rats	N-nitrosodiethylamine	200 and 400 mg/ kg, p.o.	UDP-GT↑, QR↑ and GST↑		Anti-inflammatory and antitumor activity.	[177]
Phyllanthus urinaria (Euphorbiac-eae)	Methanolic extract of Whole plant	Rat	Carbon tetrachloride	250 and 500 mg/ kg	GSH-Px↑, SGOT↓,	Gallic acid	Diuretic, and antidiarrheal. Clear away toxins, subdue swelling, improve the acuity of vision and alleviate urinary tract infection.	[178]
Picrorhiza kurroa (Scrophulari-aceae)	Methanolic extract of Rhizome	Guinea pig	Lantadenes	200 mg/kg bw	SGPT↓, SGOT↓, ALP↓, lipoprotein-X (LP-X)↓	Picroside-1 (**33**), Kutkoside	Used in upper respiratory tract and liver disorders, fever, dyspepsia and chronic diarrhea. Also nephroprotective, antiasthmatic and anticancerous.	[179]
Piper chaba (Piperaceae)	Aqueous-acetone extract of Fruit	Rat	Paracetamol and D-galacto-samine	200 mg/kg b.w.	SGPT↓, SGOT↓, ALP↓, Total protein↑		Used in dyspepsia, colic and gastralgia, asthma, bronchitis, fever, inflammation, piles, pain in abdomen and anus. Carminative.	[180]
Piper longum (Piperaceae)	Ethanolic extract of Seeds	Charles foster rats	Carbon tetrachloride	100, 200, and 400 mg/kg p.o	SGPT↓, SGOT↓, ALP↓, bilirubin↓		Used in bronchitis, asthma, constipation, chronic malaria, viral hepatitis, respiratory infections and stomach ache.	[181]
Piper nigrum (Piperaceae)	Ethanolic extract of Root	Sprague- Dawley rats	Carbon tetrachloride	500 mg/kg BW	ALT↑, AST↑, and MDA↑, as well as liver enzyme GSH↑		Antituberculosis	[182]
Pistacia vera (Anacardiac-eae)	Ethanolic extract of Gum	Rat	Carbon tetrachloride	500 & 1000 mg/ kg BW	SGPT↓		Antidiabetic	[183]
Polygala arvensis (Polygalace-ae)	Chlorofor-m extract of Leaves	Wistar albino rats	D-galactosam-ine	200 mg/kg and 400 mg/kg	SGPT↓, SGOT↓, ALP↓		Used in dizziness, asthma, snake-bite poisoning. Also antidiabetic and febrifuge.	[184]
Prosthechea michoacana (Orchidace-ae)	Methanolic extract of Aerial parts and pseudobulbs	Albino rats	Carbon tetrachloride and paracetamol	400 mg/kg i.p.	SGPT↓, SGOT↓, ALP↓, bilirubin↓		Antidiabetic, relaxant, antispasmodic, anti-inflammatory and wound healer.	[185]

(*continued on next page*)

Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Protium heptaphyll-um (Burserace-ae)	Methanol/ dichlorom-ethane (4:1) extract of trunk wood resin	Mice	Paracetamol	50 and 100 mg/ kg	ALT↓,AST↓	β-amyrin, α-amyrin	Used in gangrenous ulcers, inflammatory and painful conditions, diarrhea and wound healing.	[186]
Pterocarpus santalinus (Fabaceae)	Ethanolic and aqueous extract of Stem bark	Wistar albino rats	Carbon tetrachloride	45 mg/kg and 30 mg/kg p.o.	SGPT↓, SGOT↓, ALP↓, Total protein↑↓		Used in wounds, cuts and inflammations, headache, skin diseases, fever, boils, scorpion sting and to improve sight, tonic and astringent.	[187]
Punica granatum (Punicace-ae)	90 % ethanol extract of Outer rind	Rats	INH and RIF	300 mg/kg	ALT↓,AST↓		Anti-inflammatory, anticipatory and antioxidant. Used in DM and cardiovascular disease.	[188]
Rhinacanth-us nasuta (Acanthace-ae)	Methanolic extract of Leaves	Male Wistar rats	Streptozoto-cin (STZ)	200 mg/kg/day p.o.	ALT↓,AST↓		Used in eczema, herpes, pulmonary tuberculosis, hepatitis, diabetes, hypertension and skin Diseases.	[189]
Rosmarinus officialis (Lamiaceae)	Aqueous extract of Leaves	Male Wistar rats	Azathioprine	10 ml(10 gm/ 100 ml)	ALT↓, AST↓		Used in asthma, eczema and rheumatism.	[134]
Rubia cardifolia (Rubiaceae)	50 % aqueous-ethanolic extract of Roots	Sprague Dawley rats	Carbon tetrachloride	50, 100 and 200 mg/kg	SGOT↓, SGPT↓, ALP↓, GGT↓, glutathione S-transferase↑ and glutathione reductase↑	Rubiadin (**34**)	Antioxidant, anti-inflammatory, immune-modulatory,anti-convulsant, anti-tumor and anxiolytic.	[190]
Rumex vesicarius Linn. (Polygona-ceae)	Methanolic extract of Whole plant	Rats	Carbon tetrachloride	100 and 200 mg/ kg p.o.	SGOT↓, SGPT↓, ALP↓, Total protein↑, CAT↑, GSH↑, and SOD↑		Used in toothache, nausea, constipation and indigestion. Cooling agent, asperients, diuretic, and promotes appetite	[191]
Salvia officinalis (Labiatae)	Aqueous extract of Leaves	Male Wistar rats	Azathioprine	10 ml(10 gm/ 100 ml)	ALT↓, AST↓		Used in cold and abdominal pain.	[134]
Sargassum fluitans (Sargassa-ceae)	Ethanolic extract of Seaweed	Sprague-Dawley rats	Carbon tetrachloride	50 mg/kg/day	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓	Fucoidan (**35**)	Anticoagulant, antitumor, antiviral, antiinflammatory, antibacterial, immune-modulatory,anti-oxidant and antifibrotic.	[192]
Saururus chinensis (Saururac-eae)	Ethanolic extract of Whole plant	Male Wistar rats	Carbon tetrachloride	70 mg/kg	AST↓, ALT↓, ALP↓, TC↓, TGL↓		Used in Edema, jaundice and gonorrhea. Also Antipyretic, diuretic and anti inflammatory.	[193]
Schisandra chinensis (Schisandra-ceae)	Pollen extract	Mice	Carbon tetrachloride	10,20 and 40 mg/kg	ALT↓,AST↓, GSH↑, and SOD↑		Anti-lipid peroxidative, anticancer, anti-HIV and antioxidant	[194]
Schouwia thebica (Arecaceae)	Alcohol extract (ethyl acetate or butanol fraction) of Aerial part	Sprag-ue-Dawley rats	Carbon tetrachloride	400 mg/kg b.w	AST↓, ALT↓, GGT↓	chrysoeriol-7-O-xyloside- (1,2)-arabino-furanoside	Hepatitis	[195]
Scutellaria rivularis (Labiatae)	Ethanolic extract of Whole plant	Male Wistar rats	Paracetamol, Carbon tetrachloride and D-GalN	50 and 100 mg/ kg	SGOT↓, SGPT↓	Baicalein (**36**), Baicalin and Wogonin	Hematemesis and epistaxis. Used in dysentery, jaundice,	[196]

(*continued on next page*)

Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
							Sore-throat, carbuncle, scrofula, malignant tumors.	
Sedum sarmentos-um (Crassulace-ae)	Ethanolic extract of Whole plant	Sprague-Dawley rats	D-galactosamine & alpha-naphthyl isothio-cyanate (ANIT)	100, 200 and 400 mg/kg	AST↓, ALT↓, ALP↓, GGT↓	Sarmentosi-ns (**37**) and δ-amyrin	Chronic viral hepatitis.	[197,198]
Senna alata (Fabaceae)	Ethanolic extract of Leaves	Male albino Wistar rats	Streptozoto-cin (STZ)	400 mg/kg bw	TP↑, albumin↑, CAT↑, GSH↑, SOD↑		Antioxidant	[199]
Silybum marianum (Asteraceae)	Poly-phenolic extract of Fruits	Male Wistar rats	Paracetamol	200 mg/kg	AST↓, ALT↓, ALP↓, GGT↓	Silymarin (**38**)	Immuno-modulator, antiinflammatory, antioxidant, and antifibrotic.	[200]
Solanum fastigiatum (Solanaceae)	Aqueous extract of Leaves	Male Wistar rats	Paracetamol	100 and 200 mg/kg	SGOT↓, SGPT↓		Used in fevers, anemia, erysipelas, liver diseases, hepatitis, spleen disorders, uterine tumors, irritable bowel syndrome and chronic gastritis.	[201]
Solanum nigrum (Solanaceae)	Aqueous extract of Fruits	Kunming mice	Ethanol	100,150 and 200 mg/kg	AST↓, ALT↓, and MDA↑, GSH↑, SOD↑		Antioxidant, antiulcerogenic, antitumorigenic and anti-inflammatory.	[202]
Solanum paniculatum (Solanaceae)	Aqueous extract of Leaves	Mice	Paracetamol	300, 600 mg/kg	ALT↓		Tonics, carminatives, diuretics, antipyretic, analgesic and anti-inflammatory.	[203]
Solanum pseudocap-sicum (Solanaceae)	Methanolic extract of Leaves	Rat, HepG2 cells	Carbon tetrachloride	20 mg/kg	AST↓, ALT↓, GSH↑		Antibacterial, hyper-tensive, antispasmodic and anti-viral.	[204]
Solanum torvum Sw. (Solanaceae)	Aqueous extract of Leaves	Rats	Paracetamol	600, 1200 mg/kg p.o.	↓ the elevated ALT and AST and ↑ liver enzyme SOD and CAT		Used in Pain, fever, wounds, liver, spleen enlargement, hypertension and poison antidote. Antimicrobial, antiviral, antidiabetic and nephroprotective.	[205]
Spilanthes ciliata (Asteraceae)	Ethanolic extract of Whole plants	Male Wistar rats	Paracetamol	50, 100 and 200 mg/kg	SGOT↓, SGPT↓, ALP↓, Bilirubin↓		Anti-inflammatory, diuretic, and aphrodisiac effects.	[206]
Spinacia oleracea Linn. (Chenopodi-aceae)	Ethanolic extract of Leaves	Male Wistar albino rats	Carbon tetrachloride	250 and 500 mg/kg	SGOT↓, SGPT↓, ALP↓, Bilirubin↓, GGT↓		Carminative and laxative. Used in anemia, jaundice and cirrhosis.	[207]
Stachys pilifera (Lamiaceae)	Ethanolic extract of Aerial parts	Male Wistar rats	Carbon tetrachloride	100, 200 and 400 mg/kg/day p.o.	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓, MDA↑		Used in infectious diseases, respiratory and rheumatoid disorders.	[208]
Sternbergia fischeriana (Amaryllida-ceae)	Ethanolic extract of Bulbs	Sprague Dawley rats and Swiss albino mice	Carbon tetrachloride	1 mg/kg	AST↓, ALT↓	Lycorine (**39**)	Antitumor, antiviral, antifungal, antimalarial, antiinflammatory, antioxidant, antiparasitic and antifeedant.	[209]
Swertia chirayita (Gentianac-eae)	Ethanolic extract of Shade dried aerial parts	Female Swiss albino mice	Paracetamol	100–200 mg/kg	SGOT↓, SGPT,↓ ALP↓, Bilirubin↓		Anti-inflammatory, anticarcinogenic, antidiarrheal, antiviral and antimalarial	[47]
Syzygium jambos Linn. (Myrtaceae)	Methanolic extract of Leaves	Adult Wistar Albino Rats	Paracetamol	100, 200 mg/kg p.o.	SGOT↓, SGPT↓, ALP↓, TB↓, TP↓		Used in gout, hemorrhages, syphilis, leprosy, colic,	[210]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
							helminthiasis, wounds, and ulcer.	
Tamarindus indica (Caesalpini-aceae)	Aqueous extract of Fruits, leaves and unroasted seeds	Sprague Dawley rats	Isoniazid and rifampicin	200mg/kg p.o.	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓		Antibacterial, antidiabetic, antifungal, antiinflammatory, antimalarial, and antioxidant.	[211]
Tephrosia purpurea (Fabaceae)	Hydroalcoholic extract of Leaves	Wistar Albino Rats	Sodium arsenite	500 mg/kg p.o.	AST↓, ALT↓, ALP↓		Used in dyspepsia, diarrhea, rheumatism, asthma and urinary disorders.	[212]
Terminalia arjuna Roxb. (Combretac-eae)	Aqueous extract of Bark	Rats	Carbon tetrachloride	50 mg/kg p.o.	SGPT↓, ALP↓, MDA↑, GSH↑, SOD↑		Used in coronary artery diseases, heart failure, hyperchol-esterolemia and renal disease	[213]
Terminalia bellirica (Combretac-eae)	Ethanolic and aqueous extract of Fruits	Wistar Albino Rats	Carbon tetrachloride	200 mg/kg p.o.	↑ liver drug metabolizing enzyme and ↓the elevated transaminas, bilirubin, and LPO		Used in leucorrhoea, common cold, constipation, headache, pharyngitis, liver diseases, gastrointestinal complaints and hair fall.	[214]
Terminalia catappa (Combretac-eae)	Chloroform extract of Leaves	Rats	Carbon tetrachloride and D-galactosam-ine	50, 100 mg/kg	ALT↓, AST↓	Ursolic acid and asiatic acid	Used in dermatitis, and for antipyretic and homeostatic effect.	[215]
Thunbergia laurifolia Linn. (Acanthace-ae)	Aqueous extract of Leaves	Rats	Ethanol	25 mg/kg p.o.	ALT↓, AST↓		Antipyretic and antidote.	[216]
Tinospora crispa (Menispermaceae)	Methanolic extract of Whole plant	Swiss albino mice	Carbon tetrachloride	500 mg/kg p.o.	AST↓, ALT↓, ALP↓, MDA↑, and SOD↑		Used in abdominal pain and DM.	[217]
Trianthema portulacast-rum Linn. (Aizoaceae)	Ethanolic extract of Leaves	Wister albino Rats	Paracetamol and thio-acetamide	100 and 200 mg/ kg p.o.	SGOT↓, SGPT↓, ALP↓, TP↑		Used in bronchitis, heart disease, blood anemia, inflammation, Piles, ascites, ulcers, itching, dimness of sight and night blindness and rheumatism.	[218]
Tridax procumbens (Asteraceae)	Ethanolic extract of Leaves	Wister albino Rats	Carbon tetrachloride	300 mg/kg	AST↓, ALT↓, ALP↓, GGT↓, bilirubin↓		Anticoagulant, antifungal and insect repellent. Used in bronchial catarrh, diarrhea and dysentery.	[219]
Trianthema decandra (Aizoaceae)	Ethanolic extract of Roots	Wister albino Rats	Carbon tetrachloride	200 & 400 mg/ kg p.o.	AST↓, ALT↓, ALP↓,TP↑		Used in asthma and in orchitis.	[220]
Trigonella foenumgrae-cum (Fabaceae)	Ethanolic extract of Seed	Wister albino Rats	TAA	500 mg/kg p.o.	GGT↓, ALP↓, MDA↑, SOD↑, GSH↑, and GPx↑		Tonify kidneys, disperse cold and alleviate pain, remedy for hernia and pain in the groin.	[221]
Tylophora indica (Apocyna-ceae)	Aqueous and alcoholic extract ofLeaves	Albino rats	Ethanol	200,300 and 500 mg/kg	SGOT↓, SGPT↓, total protein↓, Bilirubin↓		Used in jaundice. Also antitumor, immune-modulator, antioxidant, anti-asthmatic, smooth muscle relaxant, antihistaminic, hypotensive, antiinflammatory, analgesic, anticonvulsant, antirheumatic.	[222]

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Table 1 (*continued*)

Plant name (Family)	Plant part used with type of extracts	Animal model	Hepato-toxicity inducing agents	Maximum extract dose/ route of administration	Biochemical and histo-pathological parameters studied	Isolated hepato-protective constituent	Other Pharmacological uses	References
Verbascum sinaiticum (Scrophular-iaceae)	Methanolic extract of Leaves	Mice	Carbon tetrachloride	200 mg/kg	ALT↓, AST↓		Used in syphilis, tumor, liver diseases, stomach troubles, diabetes, scabies, amoebiasis, diarrhea, epilepsy, and cough	[142]
Verbena monteviden-sis (Verben-aceae)	Methanolic extract of Aerial part	Human hepato-blastoma HepG2 cells	Ethanol	0.1, 1, 10, and 100 μg/ml	Normalizes histo-pathological changes	Brasoside (**40**)	Antiprotozoal and antinociceptive.	[223]
Vitex trifolia (Lamiaceae)	Aqueous and Ethanolic extract of Leaves	Wister albino Rats	Carbon tetrachloride	20 & 30 mg/kg p.o.	AST↓, ALT↓, ALP↓, total bilirubin↓, total protein↑		Used in rheumatic pains, inflammations, sprains, fever, febrifuge, cough, fever and amenorrhoea.	[224]
Vitis vinifera (Vitaceae)	Alcoholic extract of Leaves	Rats	Carbon tetrachloride	125 mg/kg	ALT↓, AST↓, MDA↑, GSH↑		Used in diarrhea, wounds healing, stomachache, lance abscess. Also diuretics and hemostatic.	[225]
Wedelia calendulac-ea (Asteraceae)	Ethanolic extract of Leaves	Rats	Carbon tetrachloride	500 mg/kg p.o.	AST↓, ALT↓, ALP↓, total bilirubin (TB)↓		Used in hemorrhage and menorrhagia.	[226]
Woodfordia fruticosa (Lythraceae)	Methanolic extract of Flowers	Wistar albino rats	Diclofenac sodium	400 mg/kg and 600 mg/kg bw p. o.	AST↓, ALT↓, ALP↓, total protein↑		Anti-inflammatory, anti-tumor, hepatoprotective and free radical scavenger.	[227]
Zanthoxylum armatum (Rutaceae)	Ethanolic extract of Bark	Rats	Paracetamol	125, 250 and 500 mg/kg	AST↓, ALT↓, ALP↓, total bilirubin↓, total protein↑		Fever, dyspepsia, toothache and rheumatism and as a lotion for scabies.	[228]
Ziziphus mucronata (Rhamnace-ae)	Methanolic extract of Leaves	Sprague Dawley (SD) albino rats	Dimethoate	100,200 & 300 mg/kg p.o.	SGOT↓, SGPT↓, ALP↓		Used in arthritis, chest pain and boils.	[229]
Ziziphus oenoplia (Rhamnac-eae)	Alcoholic extract of Roots	Wistar albino rats	Isoniazid and rifampicin	150 and 300 mg/ kg	SGOT↓, SGPT↓, ALP↓, Bilirubin↓, MDA↑, SOD↑, CAT↑and GPx ↑		Wound healing and stomachache. Anti-tuberculosis and antiplasmodial.	[230]

A. Leaves: The majority of studies used leaves as their plant part of choice, which might indicate that hepatoprotective properties are more likely to be found in leaves.
B. Whole plant: Whole plants were also frequently studied, indicating that hepatoprotective properties may be present in multiple parts of the plant.
C. Other parts of plants, such as roots, fruits, seeds, flowers, rhizomes, etc., were also commonly studied, suggesting that these parts of plants may also contain hepatoprotective chemicals.

4.2. Extraction

The most commonly used form of extraction was alcoholic (ethanolic and methanolic), followed by aqueous, petroleum ether, ethyl acetate and chloroform.

4.3. Family details

A total of 81 plant families have been identified in this article for their hepatoprotective activity. The Fabaceae family, also known as the legume family, has been recognized as a valuable source of hepatoprotective agents. This family comprises a diverse group of plants that are widely distributed across different regions. Within the Fabaceae family, 15 identified plants possess hepatoprotective properties: *Alhagi mauronum, Amburana cearensis, Bauhinia variegata, Bauhinia purpurea, Cassia fistula, Clitoria ternatea, Erythrina senegalensis, Glycyrrhiza glabra, Indigofera tinctori a, Mimosa pudica, Parkinsonia aculeata, Pterocarpus santalinus, Senna alata, Tephrosia purpurea and Trigonella foenumgraecum*. These plants offer a range of phytochemical constituents, including flavonoids, phenolic compounds, alkaloids, and other bioactive compounds, which contribute to their hepatoprotective effects against paracetamol and carbon tetrachloride-induced hepatotoxicity. The hepatoprotective activity of these plants from the Fabaceae family has been attributed to their antioxidant, anti-inflammatory, and detoxifying properties, which help to alleviate liver damage and promote liver health [33,42]. *Glycyrrhiza glabra* (licorice) root contains compounds such as glycyrrhizin and flavonoids, which possess hepatoprotective properties. These compounds help protect the liver from oxidative stress, reduce inflammation, and promote liver cell regeneration [127].

Another notable family is Asteraceae, which includes 12 plants with hepatoprotective activity. *Antennaria dioica, Bidens pilosa, Cichorium intybus, Eclipta alba, Eclipta prostrata, Gundelia tourenfortii, Laggera pterodonta, Mikania glomerata, Silybum marianum, Spilanthes ciliata, Tridax procumbens, and Wedelia calendulacea* are plant species with hepatoprotective activity from the Asteraceae family. Chicory (*Cichorium intybus*) has a long history of traditional medicinal use for treating various inflammatory conditions and liver disorders. It has been employed as a remedy for ailments such as gallstones, gout, rheumatism, and loss of appetite [231].

The Euphorbiaceae family, another plant family, includes 12 plants with hepatoprotective properties. *Baliospermum montanum, Clutia abyssinica, and Croton macrostachys* are hepatoprotective plants from the Euphorbiaceae family. Other notable plants from this family include *Euphorbia paralias, Euphorbia geniculata, Phyllanthus acidus Linn. Phyllanthus amarus, Phyllanthus emblica, Phyllanthus muellarianus, Phyllanthus niruri, Phyllanthus polyphyllus, and Phyllanthus urinaria.* These plants have been investigated for their potential to protect and promote liver health.

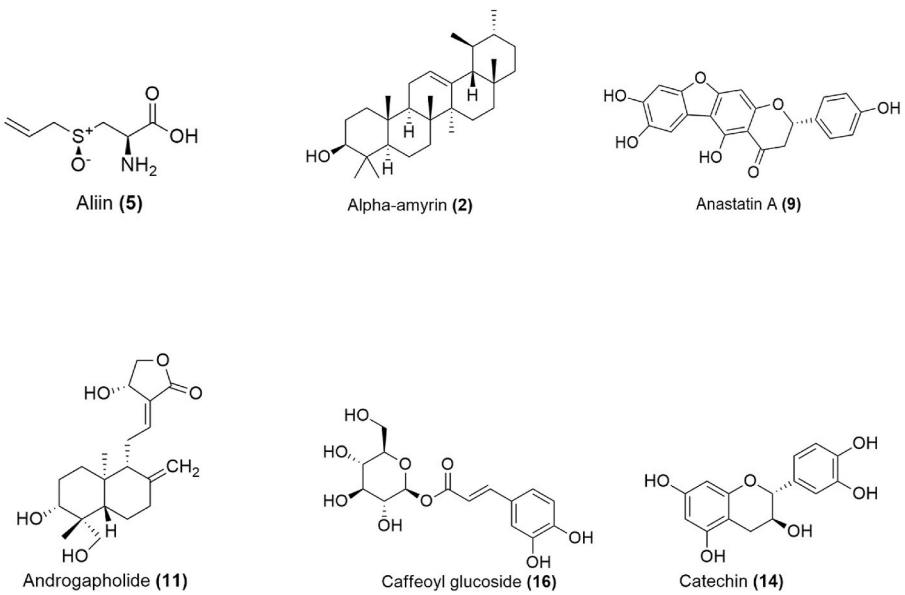

Fig. 1. Selected hepatoprotective constituents from hepatoprotective plants.

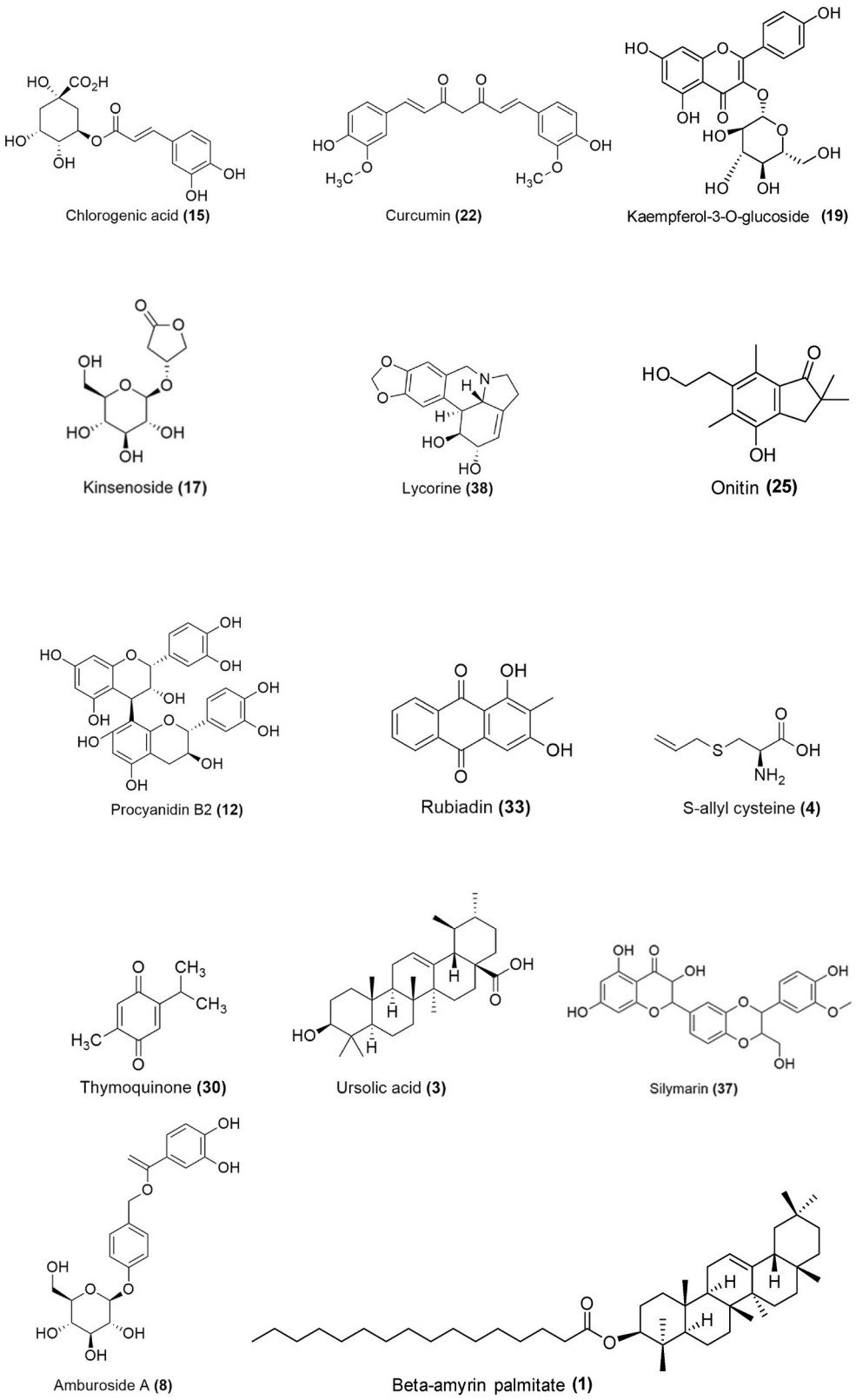

Fig. 1. (*continued*).

The Lamiaceae family, commonly known as the mint or sage family, encompasses several plants that have been investigated for their hepatoprotective properties. Among them are *Anisochilus carnosus, Hoslundia opposita, Hyptis crenata, Leucas aspera, Orthosiphon stamineus, Rosmarinus officinalis, Stachys pilifera, and Vitex trifolia*. While specific mechanisms and effects may vary, these plants exhibit properties such as antioxidant, anti-inflammatory, and liver-protective activities, making them promising candidates as hepatoprotective agents. *Orthosiphon stamineus*, also known as Java tea or cat's whiskers, is widely recognized for its hepatoprotective properties and is commonly utilized in traditional medicine for liver-related ailments. It has been studied extensively for its antioxidant and anti-inflammatory effects, which contribute to its hepatoprotective benefits [165].

The Acanthaceae, Cucurbitaceae, Rubiaceae, Rutaceae, and Solanaceae families contribute six plants each known for their hepatoprotective effects. Additionally, Amaranthaceae, Apocynaceae, Caesalpiniaceae, Labiatae, Malvaceae, Amaryllidaceae, Apiaceae, Araceae, Combretaceae, Gentianaceae, Liliaceae, Piperaceae, Sapindaceae, and Orchidaceae families have shown hepatoprotective properties, with 3–4 plants identified within each family. There are also other families with 1–2 plants within each family.

These plant families provide a diverse range of natural sources for potential hepatoprotective agents. Further research is needed to explore their efficacy and safety in various liver conditions.

4.4. Animal model

Animal models such as rats, mice, rabbits, and in vitro cell lines like HepG2 cells are commonly used in hepatotoxicity and hepatoprotective studies. Rodents, particularly rats and mice, are widely used in toxicology and pharmacology studies due to their availability, relatively low cost, and physiological similarities to humans (in terms of liver structure, function, and drug metabolism). Mice exhibit a high degree of genomic similarity to humans, with approximately 99 % similarity between their genomes and the human genome [232]. Rats were shown to have higher expression of liver steatosis genes than mice in the steatosis GSEA (Gene Set Enrichment Analysis). As a result, rats appear to be a better choice for studying steatosis in humans than mice [233].

4.5. Toxicity-inducing agents

Various xenobiotics, including chemicals, medications, household objects, plants, and environmental variables, are known to induce liver damage, a condition known as hepatotoxicity. The liver injury caused by xenobiotics is especially severe because it affects centrilobular (zone-3) hepatocytes, which have high levels of hemoprotein P450 enzyme activity and are hence prone to injury. Laboratory investigations have demonstrated that chemicals such as carbon tetrachloride (CCl4), paracetamol (PCM), thioacetamide (TAA), N-nitrosodiethylamine, D-galactosamine/lipopolysaccharide, antitubercular medicines (rifampin, isoniazid), alcohol and others can cause hepatotoxicity [234,235]. Drug-induced liver damage is still an important and unresolved clinical issue. Necrotic death can occur as a result of antioxidant consumption and oxidation of intracellular proteins, which causes increased permeability of mitochondrial membranes, potential loss, decreased ATP synthesis, inhibition of Ca2+-dependent ATPase, decreased ability to sequester Ca2+ within mitochondria, and membrane bleb formation. On the other hand, nuclease activation and the energetic involvement of mitochondria might lead to apoptosis [236].

4.6. Biochemical parameters studied

Liver function tests (LFTs) are a set of diagnostic procedures used to assess the health of the liver. These tests include measuring biochemical parameters such as AST, ALT, GGT, and alkaline phosphatase, as well as bilirubin and albumin levels and prothrombin activity for coagulation assessment. They are commonly performed as part of routine screening for both symptomatic and asymptomatic patients. It is crucial to interpret the results accurately. Elevated serum aminotransferases indicate cytolytic damage, which can be caused by various factors including pharmacological toxicity, viral hepatitis, fatty liver disease, and hemochromatosis. Cholestatic elevation of serum enzymes, particularly alkaline phosphatase, requires further evaluation to determine if it is of hepatic origin, which can be confirmed by GGT levels [237]. Additionally, a complete blood count, international normalized ratio (INR), and albumin levels are also analyzed to evaluate the overall functionality of the liver [238].

4.6.1. ALT, AST, and ALP

The hepatocytes, which are liver cells, play a role in synthesizing various amino acids with the help of transaminases (ALT, AST). When hepatocytes are harmed or affected by factors such as alcohol, viruses, or non-alcoholic fatty liver disease, they release the enzymes ALT and AST. While AST is not exclusive to the liver and can also be found in the heart, skeletal muscle, pancreas, lung, kidney, and red blood cells, ALT is primarily produced in the liver in significantly higher quantities, making it a liver-specific enzyme [239]. Hepatic ALP is produced by the cells forming the biliary epithelium, and its levels increase in cases of biliary tract damage, which can be caused by obstruction or cholestasis, as seen in conditions like primary biliary cholangitis [239].

4.6.2. Bilirubin

A total bilirubin test measures both conjugated and unconjugated bilirubin levels. This information can help with diagnosis. If the level of conjugated bilirubin is high, it may indicate a condition called obstructive jaundice. On the other hand, a high level of unconjugated bilirubin can suggest conditions like sickle cell disease, where red blood cells are destroyed faster than the liver can process bilirubin, or congenital hyperbilirubinemia, such as Gilbert's syndrome [239].

4.6.3. GGT

Glutamyltransferase (GGT) is primarily found in the liver, but it is also present in the kidney, intestine, prostate, and pancreas. Its absence in the bones makes it helpful in determining whether elevated levels of alkaline phosphatase (ALP) originate from the liver or the bones. While an elevated GGT level is not specific to liver disease, it is considered one of the best indicators of liver-related mortality [238].

4.6.4. ROS

Maintaining the balance between ROS and antioxidant enzymes such as glutathione peroxidase (GSH-Px), superoxide dismutase (SOD), and catalase (CAT) is crucial in preventing oxidative stress damage [100], as previous studies have shown that the over-production of ROS reinforces oxidative stress and results in an injury mechanism associated with common clinical diseases such as diabetes, kidney and liver injury, cancer, and heart disease [240].

4.7. Active compounds

Recently, there has been increasing interest in utilizing natural product small molecules (NPSMs) or active fractions containing these molecules for the treatment of liver diseases, mainly due to their antioxidant and anti-inflammatory properties [241]. Various plants and fruits have been explored for their potential to protect liver function, as they contain diverse phytoconstituents such as phenolics, flavonoids, coumarins, alkaloids, essential oils, glycosides, xanthenes, carotenoids, organic acids, lignins, and monoterpenes [9]. Numerous hepatoprotective phytoconstituents from different chemical classes have been isolated and reported from plants.

4.7.1. Flavonoids

In this article, flavonoids with hepatoprotective activities are anastatin A, anastatin B, procyanidin B2, orientin, isoorientin, luteolin, rutin, baicalein, baicalin, wogonin, silymarin, catechin and epicatechin. Catechin is present in the leaves and specific fruits of *Annona crassiflora* and *Anacardium occidentale* [45,50]. Silymarin (*Silybum marianum*) possesses hepatoprotective and regenerative properties, acting through a dual mechanism. It works by decreasing the formation of free radicals (FR) generated by toxins that cause damage to cell membranes, specifically lipid peroxidation (LPO) [200,242].

4.7.2. Phenolics (phenols)

The hepatoprotective plants possess phenolics as a major constituent, and a number of reports showed the hepatoprotective activity of these plants due to their active phenolics, such as chlorogenic acid, phyllanthin, hypophyllanthin, gallic acid and caffeic acid. Phyllanthin, a protective compound derived from the plants *Phyllanthus amarus, Phyllanthus emblica, Phyllanthus niruri, and Phyllanthus polyphyllus*, demonstrates its ability to combat liver fibrosis. It was discovered that phyllanthin suppresses the TGF signaling pathway by inhibiting ALK5 and Smad2 and 3 [243].

4.7.3. Terpenoids (terpenes)

Terpenoids include alpha-amyrin, beta-amyrin, delta-amyrin, ursolic acid, andrographolide, hautriwaic acid, onitin, glycyrrhizin and asiatic acid. Andrographolide, present in *Andrographis paniculata* (Nagalekshmi et al., 2011), exerts its effects through multiple mechanisms. It has been shown to possess antioxidant, anti-inflammatory, and immunomodulatory properties, which contribute to its hepatoprotective activity [244]. Ursolic acid is present in many plants, such as *Adansonia digitata*, which belongs to the family Malvaceae. It is used for its beneficial effects, which include anti-inflammatory, anti-oxidant, anti-apoptotic, and anticarcinogenic properties [30].

4.7.4. Glycosides

They are often found in plants and can have medicinal properties. Some plants that possess hepatoprotective activity due to their active glycosides, such as amburoside A, caffeoyl-glucoside, kinsenoside, saikosaponins, kaempferol-3-O-rutinoside,ononitol monohydrate, picroside, kutkoside and brasoside. Picroside II, present in *Picrorhiza kurroa* (Scrophulariaceae), protects against cholestasis possibly via activating the FXR, which controls the transporters and enzymes involved in maintaining the balance of bile acids [179,245].

4.7.5. Alkaloids

There are plants that possess hepatoprotective activity due to their active alkaloids, such as protopine, sarmentosin and lycorine.

4.7.6. Sulfur-containing compounds

Plants with the active compounds S-allyl-cysteine (SAC), S-allylmercaptocysteine, and allicin exhibit hepatoprotective activity. The presence of allicin (Allium sativum) led to a notable suppression of NLRP3 inflammasome activation, leading to reduced levels of caspase-1 and IL-1. Allicin exhibits hepatoprotective properties against liver injury induced by APAP, achieved through the reduction of oxidative stress, inhibition of the inflammasome pathway, and apoptosis [35,246].

4.7.7. Curcuminoid

Curcumin, a curcuminoid present in Curcuma longa protects and treats oxidative liver disease by decreasing proinflammatory

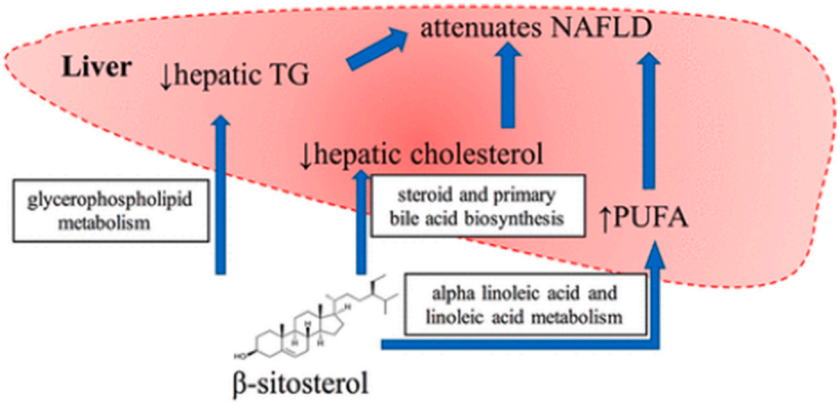

Fig. 2. Mechanism of action of ß-sitosterol on liver [249].

cytokines, lipid peroxidation products, hepatic stellate cells, and Akt activation. Curcumin reduces the expression of Nrf2, SOD, CAT, and GSH in response to oxidative stress. Curcumin, through its active phenolic pharmacophore, -diketone, and methoxy group, serves as a free-radical scavenger, inhibiting the activity of several types of ROS [99,247].

4.7.8. Others

Steroid (beta-sitosterol), Carbohydrate (fucoidan), p-Benzoquinone (thymoquinone), Anthraquinone (rubiadin), Furan (5-hydroxymethylfurfural), Coumestans (wedelolactone and demethylwedelolactone).

4.8. Possible mechanism of action of some selected active constituents found in abovementioned medicinal plants

4.8.1. ß-sitosterol

ß-sitosterol containing diets have the ability to alter the ultra-structure of the liver in both young and adult mice. ß-sitosterol, although only in large dosages, can also lower serum and liver cholesterol and prevent gallstone formation. There is insufficient data on the impact of ß-sitosterol on various liver enzymes [248] (see Fig. 2).

4.8.2. Silymarin

Silymarin is used to treat a range of liver diseases, including alcoholic liver disease, liver cirrhosis, and both acute and chronic viral or drug- or toxin-induced hepatitis. By lowering the quantity of the cytochrome P450 1A1, silymarin inhibits the metabolic activation of pyridine and regulates the upregulation of inducible nitric oxide synthase expression. Each of these elements protects against liver damage. Silymarin's hepatoprotective effects are mostly due to its prevention of elevated intracellular Ca^{2+} in addition to its inhibition of lipid peroxidation. Additionally, it was found that in male Swiss albino mice, silymarin reverses the alterations in glutathione-S-

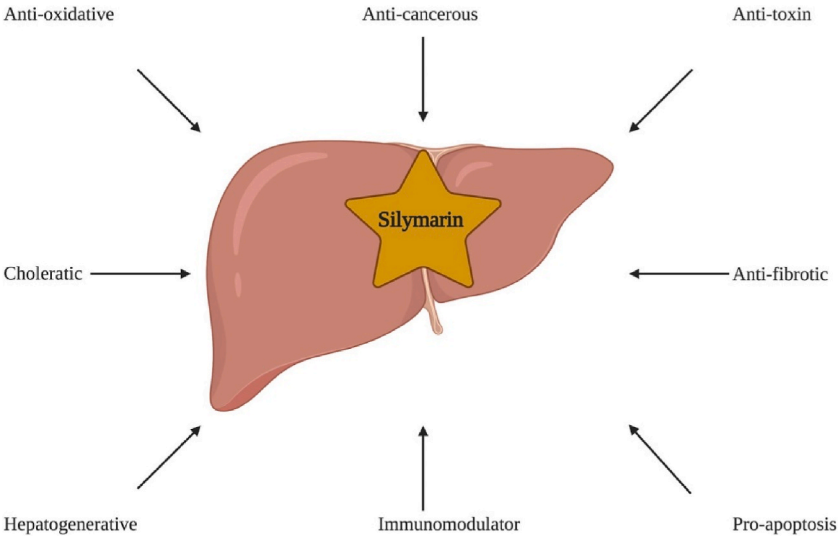

Fig. 3. Mechanism of action of silymarin on liver [251].

transferase, glutathione reductase, glutathione peroxidase, and lipid peroxidation. It also restores the expression and activity of CYP450 (CYP) enzymes (CYP1A1, CYP1A2, and CYP2E1) [250]. Silymarin's antioxidative, antifibrotic, regenerative, choleretic, immunomodulatory, and anti-inflammatory qualities contribute to its hepatoprotective benefits [251] (see Fig. 3).

4.8.3. Fucoidan

Chronic ethanol intake increased the levels of triglycerides (TG) and hepatic enzymes (ALT, AST, and GGT). It also decreased liver antioxidant enzymes and increased lipid peroxidation products, which in turn started the mitochondria-induced endogenous apoptotic pathway. Moreover, ethanol-induced extreme oxidative stress reduced mitochondrial function and encouraged the build-up of damaged mitochondria, which activated the liver's PTEN-induced putative kinase 1 (PINK1) and Parkin-associated mitophagic pathway. On the other hand, the ethanol-induced histopathological alterations, lipid metabolism disorders, and oxidative damage were mitigated by the fucoidan pretreatment, leading to the restoration of normal levels of proteins related to mitophagy and mitochondrial dynamics. These proteins include mitochondrial E3 ubiquitin ligase 1 (Mul1), mitofusin 2 (Mfn2), and dynamin-related protein 1 (Drp1) [252,253] (see Fig. 4).

4.8.4. Phyllanthin

Chronic liver injury causes the production of extracellular matrix components, which leads to the progressive development of fibrosis and ultimately cirrhosis. By attaching to TGF-β type 1 receptor kinase or activin like kinase (ALK5) receptor, transforming growth factor-β1 (TGF-β1) transduces its signal. It then promotes hepatic fibrosis by boosting the transcription of downstream entities like collagen via Smad2 and Smad3. Phyllanthin's in vivo protective effect against carbon tetrachloride (CCl4)-induced hepatic fibrosis was determined by analyzing several biochemical and histological parameters as well as by examining the protein expressions of TGF-

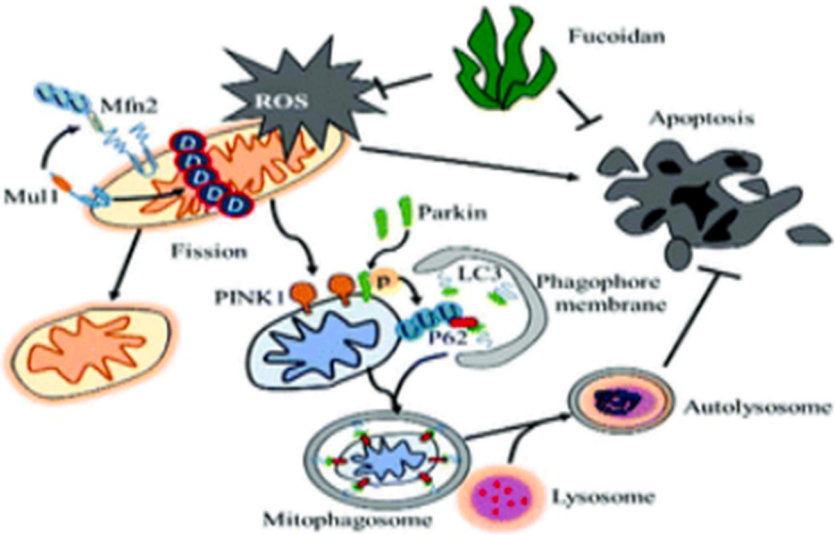

Fig. 4. Mechanism of action of fucoidan on liver [252].

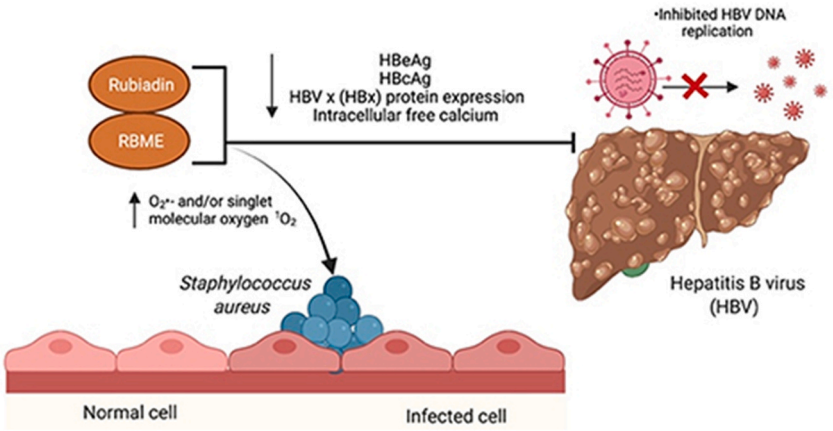

Fig. 5. Mechanism of action of rubiadin on liver [256].

β1, ALK5, Smad2, and 3. It was discovered that phyllanthin's anti-fibrotic action was achieved by inhibiting the TGF signaling cascade through ALK5, Smad2, and Smad3 [254].

4.8.5. Rubiadin

The hepatoprotective effect of Rubiadin was tested against carbon tetrachloride (CCl_4)-induced liver injury in rats. In CCl_4-induced rats, it was found that rubiadin restored serum glutamic oxaloacetic transaminase, glutamate pyruvate transaminase, alkaline phosphatase (ALP), γ-glutamyltransferase (γ-GT), glutathione S-transferase and glutathione reductase levels to normal. Rubiadin also inhibited the development of hepatic malondialdehyde and the depletion of reduced glutathione level in the liver of CCl_4-intoxicated rats in a dose-dependent manner, thus strongly suggesting that Rubiadin has a hepatoprotective effect against CCl_4-induced hepatic damage in rats [255,256] (see Fig. 5).

4.8.6. Curcumin

Through a variety of cellular and molecular mechanisms, curcumin exhibits exceptional preventive and therapeutic actions against liver disorders related to oxidative stress. These processes include ameliorating cellular responses to oxidative stress, such as the production of Nrf2, SOD, CAT, GSH, GPx, and GR, as well as decreasing proinflammatory cytokines, lipid perodixation products, PI3K/Akt, and activation of hepatic stellate cells. When combined, curcumin's phenolic, β-diketone, and methoxy groups work as a free radical scavenger to inhibit the effects of various ROS. Curcumin can reduce blood lipid levels, enhance liver function, and treat hepatic steatosis. Furthermore, curcumin reduces inflammation by raising the anti-inflammatory cytokine adiponectin and lowering the levels of IL-6, TNF-α, hs-CRP, and MCP-1 [257–259] (see Fig. 6).

4.8.7. Catechins

The polyphenol green tea catechin epigallocatechin-3-gallate (EGCG) has been shown to have therapeutic potential in the treatment of non-alcoholic fatty liver disease (NAFLD), a prevalent liver illness that negatively impacts lipid metabolism and liver function. Supplementing with EGCG decreased food consumption, body weight, and fat tissue deposits. Mechanistically, most of these investigations verified that supplementing with EGCG is important for controlling glucose and lipid metabolism as well as the expression of genes related to lipid synthesis. Significantly, it has been demonstrated that supplementing with EGCG and GTE has positive effects on pathways linked to oxidative stress, which in turn trigger pro-inflammatory reactions and cause damage to the liver. To sum up, green tea catechins may be a helpful NAFLD therapeutic choice. Catechin's anti-inflammatory properties on gut barrier function, along with its prebiotic and antimicrobial effects on gut microbial ecology, aid in preventing gut-derived endotoxins (like lipopolysaccharides) from translocating to the liver, where they would otherwise increase the activation of NFκB via Toll-like receptor-4 signaling [260–262].

5. Conclusion

This review article has explored the diverse range of hepatoprotective plants and their potential in the prevention and treatment of liver diseases. Through extensive research and analysis, numerous plant-based compounds and extracts have demonstrated promising hepatoprotective effects. These natural sources offer a rich reservoir of bioactive compounds such as triterpenoids, flavonoids, alkaloids, saponins, and tannins that exhibit potent antioxidant, anti-inflammatory, and anti-fibrotic properties. The findings presented in this review highlight the importance of harnessing the therapeutic potential of hepatoprotective plants for liver health. These natural remedies offer a holistic approach to liver protection, as they not only target specific liver conditions but also possess broader benefits

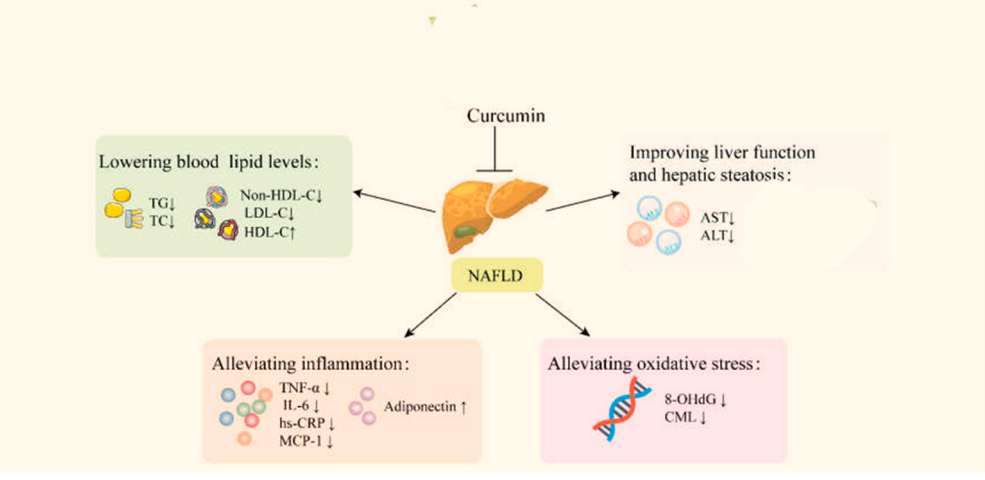

Fig. 6. Mechanism of action of curcumin on liver [259].

for overall liver function. Moreover, the use of plant-based interventions may provide an alternative or adjunctive approach to conventional treatments, potentially reducing the risk of adverse effects and promoting long-term liver health. However, further research is warranted to elucidate the underlying mechanisms of action, optimize dosage and formulation, and conduct clinical trials to validate the efficacy and safety of these hepatoprotective plants. Additionally, efforts should be directed toward exploring synergistic effects between different plant components and assessing their potential interactions with conventional medications. This review article will also help medicinal chemists find a lead compound for studying structure-activity-relationship of hepatoprotective agents as hepatoprotective phytoconstituents have been identified (Fig. 1).

Data availability

As this is a review study, no data was used for the research described in the article.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Shahparan Islam Shawon: Investigation, Methodology, Writing – original draft. **Rashmia Nargis Reyda:** Writing – original draft, Writing – review & editing. **Nazmul Qais:** Conceptualization, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Abbreviations

SGPT	Serum Glutamic Pyruvic Transaminase
ALT	alanine transaminase
SGOT	serum glutamic-oxaloacetic transaminase
AST	Aspartate aminotransferase
ALP	Alkaline phosphatase
GGT	gamma-glutamyl transferase
TP	Total protein
TB	Total bilirubin
LPO	Lactoperoxidase
SOD	Superoxide dismutase
CAT	catalase
MDA	malondialdehyde
GSH	reduced glutathione
LDH	Lactate dehydrogenase
GPx	Glutathione peroxidase
LDL	Low density lipoprotein
HDL	High density lipoprotein
TG/TGL	Triglycerides
TBARS	Thiobarbituric acid reactive substances
GST	Glutathione-S-transferase
QR	Quinone reductase
INH/INZ	Isoniazid
RIF	Rifampicin
PCM	Paracetamol
APAP	Acetaminophen
STZ	Streptozotocin
DM	Diabetes mellitus
p.o.	per os (by mouth)
EGCG	Epigallocatechin-3-gallate

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