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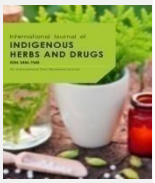

HERBAL DRUG TREATMENT FOR LIVER DISORDERS: THERAPEUTIC POTENTIAL OF PHYLLANTHUS AMARUS

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ABSTRACT

Liver disorders constitute a major global health challenge due to their increasing prevalence and limited therapeutic options in conventional medicine. Chronic exposure to hepatotoxins, viral infections, alcohol consumption, and metabolic imbalances often leads to progressive liver damage, including hepatitis, fatty liver disease, fibrosis, and cirrhosis. In recent years, herbal drugs have gained considerable attention as alternative or complementary therapies because of their multi-targeted actions, better safety profiles, and long history of traditional use. Medicinal plants rich in bioactive phytoconstituents such as flavonoids, lignans, tannins, and polyphenols exhibit significant hepatoprotective, antioxidant, anti-inflammatory, and antiviral activities. Among these, Phyllanthus amarus has emerged as a well-recognized hepatoprotective herb widely used in traditional systems of medicine, particularly Ayurveda, for the treatment of jaundice and other liver disorders. The therapeutic efficacy of P. amarus is attributed to its rich phytochemical composition, especially lignans such as phyllanthin and hypophyllanthin, which play a crucial role in protecting hepatocytes from oxidative stress and toxin-induced damage. Experimental studies have demonstrated its ability to normalize liver enzymes, inhibit lipid peroxidation, and enhance endogenous antioxidant defense mechanisms. Furthermore, clinical investigations suggest its potential in managing chronic hepatitis B by suppressing viral replication and improving liver function parameters.

Keywords: *Herbal drugs; Liver disorders; Hepatoprotective agents; Phyllanthus amarus; Medicinal plant for liver diseases.*

INTRODUCTION

Phyllanthus amarus Schumach. & Thonn. is a well-known medicinal plant belonging to the family Euphorbiaceae, widely distributed in tropical and subtropical regions of the world, particularly in India, Southeast Asia, Africa, and South America. In India, the plant is commonly known as Bhumyamalaki, Bhuiamla, or Stonebreaker, and has been extensively used in traditional systems of medicine such as Ayurveda, Siddha, and Unani for the management of liver disorders, jaundice, hepatitis, and other metabolic ailments. The plant is a small, erect, annual herb characterized by slender stems, simple leaves arranged alternately, and small greenish flowers. The entire plant-including leaves, stems, and roots-is used for medicinal purposes. Phyllanthus amarus has gained significant scientific attention due to its broad spectrum of pharmacological activities, particularly its hepatoprotective, antioxidant, antiviral, anti-inflammatory, and immunomodulatory properties [1].

Phytochemical investigations have revealed that P. amarus is rich in bioactive compounds such as lignans (phyllanthin and hypophyllanthin), flavonoids, tannins, alkaloids, terpenoids, and phenolic compounds, which are believed to contribute to its therapeutic efficacy. Among these, phyllanthin and hypophyllanthin are considered the principal constituents responsible for liver-protective effects. Numerous experimental and clinical studies have demonstrated the ability of P. amarus extracts to protect hepatocytes against toxin-induced damage by modulating oxidative stress, inhibiting lipid peroxidation, and enhancing endogenous antioxidant defense mechanisms [2]. Due to its long-standing traditional use and growing scientific validation, Phyllanthus amarus is increasingly recognized as a promising herbal candidate for the

development of safe and effective therapies for liver disorders [3].

Fig 01: Phyllanthus amarus plant.

OVERVIEW OF LIVER DISORDERS

Liver disorders encompass a broad spectrum of acute and chronic pathological conditions that impair normal hepatic structure and function, ultimately affecting metabolism, detoxification, bile formation, and immune regulation. Acute and chronic hepatitis, most commonly caused by hepatotropic viruses, alcohol, drugs, or autoimmune mechanisms, result in hepatocellular inflammation and necrosis and can progress to chronic liver disease, fibrosis, and cirrhosis if not adequately treated. Fatty liver disease, including alcohol-associated liver disease and metabolic-associated fatty liver disease (MAFLD), is characterized by excessive triglyceride accumulation in hepatocytes, which may advance from simple steatosis to steatohepatitis, fibrosis, cirrhosis, and hepatocellular carcinoma through a sequence of lipotoxicity, oxidative stress, and chronic inflammation. Cirrhosis represents the end stage of many chronic liver injuries and is associated with portal hypertension, hepatic insufficiency, and a markedly increased risk of hepatocellular carcinoma, contributing substantially to global morbidity and mortality. In addition, drug-induced liver injury (DILI) continues to be a major clinical and regulatory concern because the liver is the principal site of xenobiotic biotransformation, and both dose-dependent (e.g., acetaminophen) and idiosyncratic reactions can result in acute liver failure [3].

At the cellular and molecular levels, oxidative stress, mitochondrial dysfunction, dysregulated immune responses, and chronic inflammation are central, interrelated drivers of liver disease pathogenesis. Excessive production of reactive oxygen species (ROS) and reactive nitrogen species (RNS) from damaged mitochondria, cytochrome P450 enzymes (such as CYP2E1), NADPH oxidases, and inflammatory cells disrupts the hepatic redox balance, leading to lipid peroxidation, protein oxidation, DNA damage, and activation of cell death pathways. In fatty liver states, mitochondrial β-oxidation overload, impaired respiratory chain activity, and accumulation of free fatty acids further amplify oxidative stress in a vicious cycle that promotes progression from simple steatosis to steatohepatitis and fibrosis [4]. In DILI, many drugs or their reactive metabolites directly injure mitochondria, trigger glutathione depletion, induce mitochondrial permeability transition, and activate stress-sensing kinases such as JNK, culminating in hepatocyte apoptosis or necrosis. Persistent oxidative stress and mitochondrial damage also stimulate Kupffer cells and recruited immune cells, driving the release of pro-inflammatory cytokines, chemokines, and profibrogenic mediators that activate hepatic stellate cells and contribute to extracellular matrix deposition and fibrosis [5].

Conventional hepatoprotective and disease-modifying drugs often target single molecular pathways, such as viral replication, immune suppression, or specific metabolic pathways, and may themselves impose an additional metabolic burden on the liver through extensive biotransformation [6]. In contrast, herbal drugs and plant-derived phytoconstituents typically exhibit multi-target actions, simultaneously modulating oxidative stress, inflammation, apoptosis, and fibrogenesis, which is particularly advantageous in complex, multifactorial liver diseases. Numerous hepatoprotective medicinal plants, including Silybum marianum, Phyllanthus species, Picrorhiza kurroa, and others, have demonstrated antioxidant, anti-inflammatory, antifibrotic, and cytoprotective effects by scavenging ROS, upregulating endogenous antioxidant enzymes (such as superoxide dismutase, catalase, and glutathione peroxidase), inhibiting pro-inflammatory signaling (e.g., NF-κB and MAPK pathways), and attenuating stellate cell activation. This multi-component, multi-pathway pharmacology supports the growing interest in standardized herbal formulations as adjuncts or alternatives to conventional therapies for the prevention and management of diverse liver disorders [7].

ROLE OF HERBAL DRUGS IN LIVER DISEASE MANAGEMENT

Herbal drugs play a pivotal role in the prevention and management of liver disorders owing to their multi-targeted pharmacological actions and long history of traditional use. Many classical hepatoprotective plants, including Silybum marianum (milk thistle), Picrorhiza kurroa, Glycyrrhiza glabra, Andrographis paniculata, and Phyllanthus species, have been evaluated in preclinical and clinical studies and consistently shown to ameliorate biochemical, histological, and functional markers of liver injury induced by toxins, drugs, alcohol, or metabolic stress. The hepatoprotective effects of these plants are largely attributed to their rich content of flavonoids, flavonolignans (e.g., silymarin), diterpenoids (e.g., andrographolide), iridoid glycosides (e.g., picrosides), triterpenoid saponins (e.g., glycyrrhizin), lignans, and polyphenols, which together mitigate oxidative stress, stabilize hepatocyte membranes, and attenuate inflammatory and fibrogenic responses [8].

A key advantage of herbal therapy is its capacity to modulate multiple biochemical and molecular pathways that underlie the complex pathogenesis of liver diseases, rather than acting on a single target [9]. Many phytoconstituents directly scavenge reactive oxygen and

nitrogen species and upregulate endogenous antioxidant defense systems, including superoxide dismutase, catalase, glutathione peroxidase, and reduced glutathione, thereby restoring hepatic redox balance and preventing lipid peroxidation of cellular and mitochondrial membranes(2 [10]. In parallel, herbal medicines frequently inhibit pro-inflammatory signaling cascades such as NF-κB and MAPK, down-regulate the production of cytokines and chemokines, and suppress activation of hepatic stellate cells and profibrotic pathways (e.g., TGF-β/Smad), leading to antifibrotic effects and attenuation of progressive liver scarring. Emerging evidence also indicates that several phytochemicals activate the Nrf2/Keap1 pathway, enhance phase II detoxifying enzymes, and modulate the gut–liver axis, which together contribute to hepatocyte regeneration and improved resilience against chemical and metabolic insults [11].

From a clinical standpoint, standardized herbal preparations such as silymarin and glycyrrhizin have shown benefits in patients with toxin-induced liver injury, chronic viral hepatitis, and other chronic liver diseases, with improvements in serum transaminases, oxidative stress markers, and, in some cases, histological fibrosis [12]. These agents are generally well tolerated, and long-term administration in chronic liver disorders has demonstrated a favorable safety profile, especially when compared with certain synthetic hepatoprotective drugs that may themselves cause hepatotoxicity or systemic adverse effects [13]. Nevertheless, challenges remain regarding variability in plant material, lack of uniform standardization, potential herb–drug interactions, and limited large-scale, well-designed clinical trials; therefore, rigorous quality control, dose optimization, and robust clinical validation are essential to fully integrate herbal hepatoprotective drugs into evidence-based liver disease management [14].

BOTANICAL DESCRIPTION OF PHYLLANTHUS AMARUS

Phyllanthus amarus is a small, erect, glabrous annual herb of the family Euphorbiaceae (often treated as Phyllanthaceae), typically reaching 10–60 cm in height and displaying a characteristic phyllanthoid branching pattern in which numerous slender, drooping branchlets resemble compound leaves [15]. It is widely distributed throughout tropical and subtropical regions and occurs abundantly as a pantropical weed in India, Sri Lanka, Southeast Asia, Africa, the Caribbean, and South America, thriving in moist, disturbed habitats such as agricultural fields, roadsides, gardens, and wastelands. In Ayurvedic medicine it is known as Bhumyamalaki, and the entire plant is traditionally used for the management of jaundice, liver enlargement, dyspepsia, and urinary tract disorders [1, 16].

The plant has a thin, green, smooth, cylindrical main stem that branches into many short, distichous lateral branchlets, each bearing numerous small leaves arranged in two rows, giving a feather-like appearance. Leaves are simple, oblong to elliptic, about 6–15 mm long and 2–5 mm wide, with entire margins, rounded or obtuse apex, and slightly asymmetrical base; they are sessile or shortly petiolate with tiny lanceolate stipules at the base [17]. Flowers are minute, greenish to yellowish, unisexual, and axillary; male flowers are typically found towards the distal parts of the branchlets, while female flowers occur slightly lower down, often solitary or in small clusters. The fruit is a small, smooth, globose capsule that turns brown when mature and dehisces to release several minute, longitudinally ridged seeds, contributing to prolific self-seeding and wide natural spread.

From a pharmacognostic and cultivation perspective, the whole plant-including roots, stems, leaves, and fruits-is considered medicinally valuable and is generally harvested during the flowering and fruiting stage, when the concentration of bioactive lignans and polyphenols is highest. The herb grows rapidly, adapts well to a range of tropical agro-climatic conditions, and can be easily propagated by seed, making it a practical and economically viable source of raw material for hepatoprotective herbal formulations and phytopharmaceutical development [18].

PHYTOCHEMICAL CONSTITUENTS OF PHYLLANTHUS AMARUS

The therapeutic efficacy of Phyllanthus amarus is attributed to its rich and diverse phytochemical profile. The plant contains lignans, flavonoids, tannins, alkaloids, terpenoids, and phenolic compounds. Among these, lignans such as phyllanthin and hypophyllanthin are considered the principal bioactive constituents responsible for hepatoprotective activity. Other important compounds include geraniin, corilagin, ellagic acid, quercetin, rutin, and gallic acid. These compounds exhibit strong antioxidant and free-radical-scavenging properties, which are crucial in preventing liver cell damage.

Chemistry and Structure of Major Active Compounds:

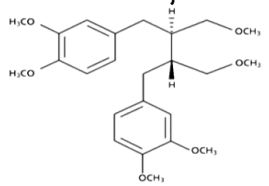

Fig 02: Chemical Structure of Phyllanthin

Phyllanthin is a dibenzylbutane lignan with the molecular formula $C_{24}H_{34}O_6$. Structurally, it consists of two aromatic rings connected by a carbon chain, with multiple methoxy (–OCH_3) groups and ether linkages. These functional groups contribute to its lipophilicity and antioxidant potential. The presence of phenolic structures enables phyllanthin to neutralize reactive oxygen species and protect hepatocyte membranes from lipid peroxidation [19].

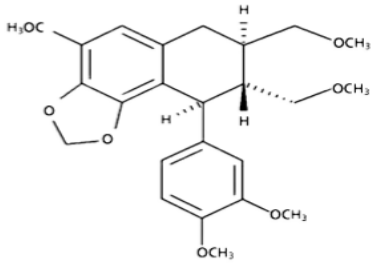

Fig 03: Chemical Structure of Hypophyllanthin

Hypophyllanthin is structurally similar to phyllanthin, with the molecular formula $C_{24}H_{32}O_6$. Minor differences in

methoxy group positioning result in variations in biological activity(14). Like phyllanthin, hypophyllanthin exhibits strong antioxidant and hepatoprotective properties and plays a significant role in the overall therapeutic action of Phyllanthus amarus extracts.

In chemical research, these structures are typically represented using skeletal diagrams that highlight aromatic rings, methoxy substituents, and ether bonds.

MECHANISMS OF HEPATOPROTECTIVE ACTION

The hepatoprotective effects of Phyllanthus amarus are mediated by a network of antioxidant, anti-inflammatory, membrane-stabilizing, and antiviral actions that act together to protect hepatocytes from toxic, metabolic, and viral insults. Experimental studies show that standardized extracts significantly enhance endogenous antioxidant defenses by increasing the activities of superoxide dismutase, catalase, glutathione peroxidase, glutathione-S-transferase, and the levels of reduced glutathione, thereby lowering reactive oxygen species and thiobarbituric acid reactive substances in liver tissue. This antioxidant reinforcement leads to marked inhibition of lipid peroxidation, reduction of malondialdehyde formation, and stabilization of hepatocyte and mitochondrial membranes, which prevents leakage of serum liver enzymes and preserves cellular integrity in toxin-induced hepatotoxicity models [20].

Polyphenols and lignans such as phyllanthin, hypophyllanthin, geraniin, and related tannins contribute to free-radical scavenging and cytoprotective effects in both in vivo and HepG2 cell studies, where P. amarus reverses toxin-induced oxidative damage and improves cell viabilit. In addition to redox modulation, P. amarus exerts pronounced anti-inflammatory activity by inhibiting inducible nitric oxide synthase and COX-2 expression, reducing nitric oxide and prostaglandin E2 production, and suppressing key pro-inflammatory cytokines such as TNF-α and interleukins via blockade of IKK/IκB/NF-κB, MAPK, and PI3K/Akt signaling pathways [21]. These effects mitigate Kupffer cell–mediated inflammatory damage in the liver and indirectly limit fibrogenic signaling [22]. Furthermore, P. amarus demonstrates antiviral activity against hepatitis B virus, with reports of inhibition of HBV DNA polymerase, suppression of viral transcription and replication, and down-regulation of viral markers in experimental and clinical settings, which contributes to improvement in liver function tests in HBV-associated liver disease.

Experimental Evidence

A substantial body of in vivo and in vitro evidence supports the hepatoprotective activity of Phyllanthus amarus in chemically induced liver injury models. In experimental animals, aqueous, ethanolic, and standardized extracts of P. amarus have shown significant protection against carbon tetrachloride-, ethanol-, rifampicin-, and paracetamol-induced hepatotoxicity, with treated groups demonstrating marked reductions in serum alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, bilirubin, and triglycerides compared with toxin-only controls. These biochemical improvements are accompanied by restoration of endogenous antioxidant status, including normalized or increased activities of superoxide dismutase, catalase, and glutathione-related enzymes, along with reduced lipid peroxidation indices such as thiobarbituric acid reactive substances and malondialdehyde in liver tissue(8). Histopathological examinations further reveal attenuation of centrilobular necrosis, fatty degeneration, inflammatory cell infiltration, and architectural distortion in the livers of P. amarus-treated animals, often comparable to the reference hepatoprotective drug silymarin at similar doses [23].

In vitro studies have provided mechanistic support for these observations by confirming the direct cytoprotective effects of P. amarus extracts and isolated constituents on hepatocyte and hepatoma cell lines [24]. Standardized extracts enriched in phyllanthin significantly counteract CCl_4- or drug-induced toxicity in HepG2 cells by preserving cell viability, reducing transaminase leakage into the culture medium, and maintaining mitochondrial function and antioxidant defenses [25]. Similar protective effects have been reported against ethanol- and paracetamol-induced cytotoxicity, where P. amarus preparations decrease reactive oxygen species generation, inhibit lipid peroxidation, and restore glutathione levels, indicating that lignans and polyphenolic compounds are key contributors to its antioxidant and membrane-stabilizing actions [26]. Collectively, these in vivo and in vitro findings validate the traditional use of P. amarus as a hepatoprotective herb and support its development as a phytopharmaceutical agent for liver disorders [27].

CLINICAL STUDIES AND THERAPEUTIC APPLICATIONS

Clinical investigations of Phyllanthus amarus and related Phyllanthus species in chronic liver disease, particularly chronic hepatitis B (CHB), indicate potential benefits but also highlight variability and methodological limitations [28]. Early open and randomized trials from India reported that 30-day treatment with P. amarus preparations in chronic HBV carriers led to hepatitis B surface antigen (HBsAg) loss in approximately 59% of treated patients versus about 4% in placebo groups, with sustained seronegativity during follow-up and minimal adverse effects, suggesting a favorable impact on viral clearance and liver function recovery [29]. Subsequent comparative studies using combination products containing P. amarus with interferon or other antivirals showed improved normalization of liver enzymes and higher rates of HBeAg or HBV-DNA negativity compared with monotherapy, supporting its use as an adjunct rather than a standalone antiviral.

However, later randomized trials and systematic reviews have produced more conservative conclusions, with some studies failing to demonstrate significant HBsAg clearance in asymptomatic carriers and comprehensive meta-analyses rating the overall evidence as heterogeneous and at high risk of bias. A systematic review of Phyllanthus species in CHB found a positive effect on clearance of serum HBsAg, HBeAg, and HBV-DNA and on liver enzyme normalization compared with no treatment or nonspecific therapy, but no clear superiority over interferon when used alone, while

combinations with interferon appeared more effective than interferon alone. Beyond viral hepatitis, clinical and observational data from herbal liver formulations containing P. amarus suggest improvements in transaminases, symptoms, and quality of life in patients with toxic or metabolic liver injury, with good tolerability and few serious adverse reactions reported, particularly in short- to medium-term use. Overall, current clinical evidence supports P. amarus–based preparations as promising adjunct therapies in chronic liver diseases, especially CHB, but underscores the need for well-designed, large-scale trials with standardized extracts and clearly defined endpoints before routine monotherapeutic use can be recommended.

Safety

Phyllanthus amarus is generally regarded as safe at therapeutic doses, with preclinical studies showing a wide margin of safety in both acute and sub-chronic administration. Acute oral toxicity tests in rodents using standardized extracts report no mortality, no major behavioral changes, and no significant alterations in hematological, hepatic, or renal parameters even at doses up to 2,000–5,000 mg/kg, suggesting an LD_{50} greater than 5,000 mg/kg. Sub-chronic dosing over several weeks similarly shows preserved liver and kidney histology, and some studies even document improved antioxidant status, supporting its traditional use as a hepatoprotective rather than hepatotoxic herb. Clinical reports and small trials in patients with liver disease describe good overall tolerability, with only mild gastrointestinal discomfort and no consistent pattern of serious adverse events.

TOXICITY

Although available data indicate low intrinsic toxicity, some experimental work has explored potential adverse effects at very high doses or prolonged exposure. In certain models, extremely high doses or poorly characterized extracts have been associated with subtle biochemical changes, underscoring that "natural" does not equate to entirely risk-free and that excessive or unsupervised use should be avoided. In vitro studies also show that P. amarus and its major lignans can inhibit cytochrome P450 enzymes-particularly CYP3A4-raising theoretical concerns about altered metabolism of co-administered drugs and possible accumulation or toxicity in susceptible individuals. Moreover, case-based reviews of herb-induced liver injury emphasize that adverse reactions may arise from contamination, misidentification, or inclusion of other hepatotoxic herbs in polyherbal formulations marketed with P. amarus.

LIMITATIONS

Key limitations to the wider clinical application of Phyllanthus amarus include marked variability in phytochemical composition, lack of standardized products, and incomplete clinical evidence. Differences in species identity, geographical origin, cultivation practices, harvest time, and post-harvest processing lead to fluctuating levels of phyllanthin, hypophyllanthin, and polyphenols, making reproducible dosing and efficacy difficult without rigorous standardization. Many experimental and clinical studies rely on crude or poorly characterized extracts with small sample sizes and heterogeneous designs, limiting the strength of current efficacy and safety conclusions. Potential herb–drug interactions via CYP inhibition, limited pharmacokinetic data, and absence of universally accepted dosing guidelines further constrain its integration into evidence-based practice. Future work must focus on developing chemically standardized, bioavailable formulations, defining optimal therapeutic doses and treatment durations, and conducting large, well-controlled clinical trials to firmly establish its therapeutic role and monitoring requirements in liver disease management.

DISCUSSION

Liver disorders remain a significant global health problem due to their increasing prevalence and the limited efficacy and safety concerns associated with conventional hepatoprotective drugs. In this context, herbal medicines have gained considerable attention as alternative or complementary therapeutic agents because of their long history of traditional use, multi-targeted mechanisms of action, and relatively low toxicity. Among these medicinal plants, Phyllanthus amarus has emerged as a promising hepatoprotective herb with substantial experimental and clinical evidence supporting its therapeutic potential.

The hepatoprotective activity of Phyllanthus amarus is primarily attributed to its rich phytochemical composition, particularly lignans such as phyllanthin and hypophyllanthin, along with flavonoids, tannins, polyphenols, and hydrolysable tannins like geraniin. These bioactive constituents collectively contribute to the antioxidant, anti-inflammatory, and membrane-stabilizing effects of the plant. Oxidative stress plays a central role in the pathogenesis of liver injury, and P. amarus has been shown to enhance endogenous antioxidant defense systems, including superoxide dismutase, catalase, and glutathione peroxidase, thereby reducing reactive oxygen species–mediated hepatic damage.

Another important mechanism underlying the hepatoprotective effect of Phyllanthus amarus is its ability to inhibit lipid peroxidation and stabilize hepatocyte membranes. This action prevents the leakage of liver enzymes such as alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase into the bloodstream, which are key biochemical markers of liver injury. Experimental studies using toxin-induced liver damage models, including carbon tetrachloride, paracetamol, and alcohol-induced hepatotoxicity, have consistently demonstrated the protective and restorative effects of P. amarus extracts on liver architecture and function. Phyllanthus amarus has exhibited anti-inflammatory activity by modulating pro-inflammatory cytokines and inhibiting inflammatory mediators involved in hepatic injury. Additionally, its antifibrotic potential has been linked to the suppression of hepatic stellate cell activation, suggesting a role in preventing the progression of liver fibrosis and cirrhosis. These multifaceted actions highlight the advantage of herbal drugs like P. amarus, which act on multiple pathological pathways simultaneously, unlike single-target synthetic drugs [30].

CONCLUSION

Phyllanthus amarus emerges as a promising hepatoprotective medicinal plant that aligns well with the growing interest in safe, multi-target herbal strategies for liver disorders. Its rich phytochemical profile-dominated by lignans such as phyllanthin and hypophyllanthin, along with flavonoids, tannins, and polyphenols-underpins potent antioxidant, anti-inflammatory, antiviral, and membrane-stabilizing activities that directly address key pathogenic mechanisms like oxidative stress, inflammation, and hepatocyte injury. A substantial body of in vivo and in vitro evidence demonstrates protection against diverse hepatotoxins, normalization of liver enzyme levels, improved histopathology, and cytoprotection in hepatocyte models, while clinical studies in chronic hepatitis B and other liver disorders indicate meaningful, though variable, improvements in liver function and viral markers when used particularly as an adjunct therapy. Overall, P. amarus can be regarded as a strong candidate for phytopharmaceutical development in liver disease, but its translation into standardized, evidence-based therapy is still constrained by variability in plant material, limited high-quality clinical trials, and unresolved questions on herb–drug interactions and optimal dosing. Future research should prioritize chemically standardized, bioavailable formulations, rigorous pharmacokinetic and safety evaluations, and large, well-designed clinical studies to firmly establish its therapeutic role alongside conventional hepatoprotective and antiviral agents.

AUTHOR CONTRIBUTIONS

All authors contributed equally.

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Not applicable.

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