Synergistic effect of silymarin and standardized extract of *Phyllanthus amarus* against CCl₄-induced hepatotoxicity in *Rattus norvegicus*

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**Abstract**

In search of the effective and standardized hepatoprotective combination therapy, silymarin and standardized extract of *Phyllanthus amarus* has been evaluated against CCl₄-induced hepatotoxicity in rats. Eight groups of rats were used. The animals of group A served as normal and were given only vehicle. The animals of group B served as toxin control and were administered with CCl₄ (50% solution of CCl₄ in liquid paraffin, 2 ml/kg b.w., intraperitoneally). The animals of groups C–H received silymarin (100 mg/kg b.w.), *Phyllanthus amarus* aqueous extract (100 mg/kg b.w.), *Phyllanthus amarus* ethanolic extract (100 mg/kg b.w.), silymarin (50 mg/kg b.w.) + *P. amarus* aq. ext. (50 mg/kg b.w.), silymarin (50 mg/kg b.w.) + *P. amarus* eth. ext. (50 mg/kg b.w.) and marketed formulation (M.F.) 5 ml/kg b.w. for 6 days orally as well as CCl₄ (2 ml/kg b.w.) on 4th day intraperitoneally. The test materials were found effective as hepatoprotective as evidenced by plasma and liver biochemical parameters. The combination of silymarin and *Phyllanthus amarus* showed synergistic effect for hepatoprotection and silymarin with ethanolic extract of *P. amarus* showed better activity due to the higher concentration of phyllanthin in ethanolic extract in comparison to aqueous extract of *P. amarus* as estimated by HPLC.

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**Keywords:** *Phyllanthus amarus*; Silymarin; CCl₄; Synergistic effect; Hepatotoxicity

**Introduction**

Living in a world of inadequately controlled environmental pollution and expanding therapy with potent drugs, the liver, which is the key organ of metabolism and excretion, is continually exposed to a variety of xenobiotics and therapeutic agents. Thus the disorders associated with this organ are numerous and varied. An actual curative therapeutic agent has not yet been found. In fact, most of the available remedies support or promote the process of healing or regeneration of the liver.

Silymarin is a flavonoid extracted from the milk thistle *Silybum marianum*. It has been reported to prevent liver injuries induced by various chemicals or toxins including ethanol (Farghali et al., 2000; Halim et al., 1997; Lieber et al., 2003). Although the hepatoprotective properties of silymarin have been reported both from *in vitro* and *in vivo* studies, its
mechanism of action still has not been established. Two major mechanisms that have been proposed include functioning as an antioxidative scavenger of free radicals (mainly active toward HO and HOCl and less so for H2O2 or O2) and as a regulator of immune functions by modulating cytokine production (Ferenci et al., 1989; Luper, 1998).

A standardized extract from the milk thistle Silybum marianum contains as its main constituents the flavonoids silybin, silydianin and silychristin (Flora et al., 1996). The flavonoid silybin, which constitutes 60–70% of silymarin, has been identified as the major active ingredient (Wagner et al., 1974; Sonnenbichler and Zetl, 1986). Silymarin enhances the activity of hepatocyte RNA-polymerase I (Sonnenbichler and Zetl, 1986), complexes toxic-free iron (Pietrangelo et al., 1995), protects the cell membrane from radical-induced damage (Mira et al., 1994), and blocks the uptake of toxins such as Amanita phalloides toxin (Hruby et al., 1983; Desplace et al., 1975). A potent scavenger, it prevents lipid peroxidation and normalizes the lipid profile of hepatocyte membranes (Muriel and Mourelle, 1990). Silymarin has also been reported to provide liver protection against CCl4 and paracetamol-induced liver damage in rat models (Mourelle et al., 1989; Muriel et al., 1992).

Phyllanthus amarus and related species are Indian plants that contain phyllanthin, hypophyllanthin and polyphenols with antiviral properties. Phyllanthus amarus whole plant powder administered at a dosage of 0.66 g/kg in rat showed hepatoprotective activity against CCl4-induced liver damage (Sane et al., 1995). An aqueous extract inhibited woodchuck hepatitis virus DNA polymerase and surface antigen expression (Venkateswaran et al., 1987; Ott et al., 1997) and several protein kinases such as cAMP-dependent protein kinase, protein kinase C and myosin light-chain kinase in rat liver (Polya et al., 1995). A nonrandomized clinical study showed a remarkable 59% (22 of 37 patients) clearance of HBsAg in chronic carriers who were treated for 30 days compared with only 4% (1 of 23 patients) given placebo (Thyagajaran et al., 1988). Sane et al. in 1997 reported the efficacy of the plant in inhibiting the hepatitis B virus. The leaves were found to possess antipyretic activity (Mehrotra et al., 1991). Nirtetralin and niranthin are reported to possess hepatoprotective and anti-inflammatory activities. Cytotoxic effect of nirtetralin, niranthin and phyllanthin on two human leukemia cell lines, K-562 and Lucena-1 suggests a potential action of Phyllanthus lignans as multidrug resistance (MDR) reversing agents (Srivastava et al., 2008).

In search of an effective, standardized and safe hepatoprotective combination therapy, we used the silymarin and standardized extract of Phyllanthus amarus against CCl4-induced hepatotoxicity in rats.

Materials and methods

Phyllanthus amarus whole plant was collected from the medicinal conservatory of the Central Institute of Medicinal and Aromatic Plants (CIMAP), and dried in the shade. This plant material was minced and soaked in water and ethanol separately with occasional shaking at room temperature for 18 h. The mixtures were centrifuged (4000 rpm x 30 min) and the supernatant were evaporated to dryness under reduced pressure at 40 °C in a rotary evaporator (Buchi B-480). The yields of dried residues were 19.95% and 5.22%, respectively. These extracts were solubilized using 0.7% carboxymethylcellulose (CMC) suspension. Silymarin containing silybin (32%) was procured from Sigma, USA and solubilized using 0.7% CMC suspension. The phyllanthus extracts were evaluated for phyllanthin content by HPLC. For HPLC studies, column-Waters Symmetry Shield™ RP-18 (4.6 × 150 mm; 5 μm) with mobile phase methanol:water (0.1% TFA) – 70:30 at flow rate – 0.7 ml/min was used. Photodiode array detector used for data acquisition and the calculation was performed at 220 nm to quantify the phyllanthin content using extracts and phyllanthin standard. The representative HPLC fingerprint of Ethanolic and aqueous extracts P. amarus thus obtained have been shown in Fig. 1. The reference silymarin (1.0 mg/ml) was chromatographed (Fig. 2) using the conditions (column-Waters symmetry C18, 250 mm × 4.6 mm, 5 μm; mobile phase – MeOH:water (30:70); flow rate 1.5 ml/min; detection λ = 288 nm) reported earlier (Ding et al., 2001).

Animals

Male Rattus norvegicus (150±10 g) of Charles Foster strain were the experimental subjects maintained under controlled conditions (temperature 25±2 °C; relative humidity 50±5%; 12 h light/dark cycle). The animals were maintained on certified pelleted rodent diet (Dayal Industries, Lucknow, India). Water was provided ad libitum. Institutional Animal Ethics Committee approved the animal experiments and the guidelines for Animal care were followed as recommended by the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA).

In vivo hepatoprotective activity studies

The model described by Yadav and Dixit (2003) was employed with some modifications. The rats were divided into eight groups consisting of five animals each. The animals of group A served as normal and were given only vehicle (0.7% CMC suspension 1 ml/kg b.w.) for 6 days. The animals of group B served as toxin control and administered with CCl4...
Fig. 1. HPLC Chromatograms of ethanolic and aqueous extracts of *P. amarus*.

Fig. 2. HPLC chromatogram of silymarin reference substance (UV spectra of major component is shown in insight).
(50% solution of CCl₄ in liquid paraffin, 2 ml/kg b.w., intraperitoneally (i.p.)) on 4th day and with vehicle on rest of the days. The animals of groups C–H received silymarin (100 mg/kg b.w.), Phyllanthus amarus aqueous extract (100 mg/kg b.w.), Phyllanthus amarus ethanolic extract (100 mg/kg b.w.), silymarin (50 mg/kg b.w.) + P. amarus aq. ext. (50 mg/kg b.w.), silymarin (50 mg/kg b.w.) + P. amarus eth. ext. (50 mg/kg b.w.) and marketed formulation (M.F.) 5 ml/kg b.w. for 6 days orally as well as CCl₄ (2 ml/kg b.w.) on 4th day i.p. The detailed dosage regimen is given in Table 1.

Assessment of hepatoprotective activity

On 7th day, the blood was collected from the retro orbital plexus of each animal and serum was separated which was analyzed for various biochemical parameters, i.e. serum glutamyl oxalacetic acid transaminase (SGOT), serum glutamyl pyruvate transaminase (SGPT) (Reitman and Frankel, 1957), alkaline phosphatase (ALKP) (Kind and King, 1954), serum bilirubin (SBLN) (Malloy and Evelyn, 1937), total protein and creatinine by using enzymatic reagents (Bayer Diagnostics, India).

Liver glycogen

After collecting the blood from each animal, they were sacrificed by cervical dislocation and liver was separated, washed in Ringer’s solution and soaked in filter paper. Immediately the liver was stored at −20 °C temperature and used for estimation of liver glycogen and liver triglycerides.

Liver triglyceride content determination

The liver triglyceride content was determined as per the method described by Zhenyuan Song et al. (2006). For this purpose, 50–100 mg of liver was homogenized in 4 ml of chloroform: methanol (2:1). A total of 0.8 ml of 50 mM NaCl was added to each sample. Samples were then centrifuged and the organic layer was removed and dried. The resulting pellet was dissolved in phosphate-buffered saline containing 1% Triton X-100 and the triglyceride contents were determined by using an enzymatic reagent (Bayer Diagnostics, India).

Statistical analysis

Results are presented as mean±S.E.M. Statistical analysis was performed using student’s t-test and one-way analysis of variance (ANOVA), wherever appropriate with the help of Graph Pad Prism 4.0 software. Difference between groups were considered to be
statistically significant at $p < 0.05$ (Kulkarni, 1993; Ostle, 1966).

**Results**

The results obtained in the biological experiment are presented in Table 2. Liver glycogen and liver triglycerides are presented in Figs. 3 and 4.

Administration of CCl$_4$ to rats caused significant increase in serum enzymes like SGOT, SGPT, ALKP, SBLN, compared to treated rats. It also caused the significant change in biochemical parameters estimated from liver homogenate, like liver triglyceride and liver glycogen.

Results presented in Table 2 indicate that the levels of serum enzymes namely SGOT, SGPT, ALKP and SBLN and total protein were affected after treatments of rats with silymarin, *P. amarus* aq. ext., *P. amarus* eth. ext., *silymarin + P. amarus* aq. ext., *silymarin + P. amarus* eth. ext. and marketed formulation (M.F.) when compared with toxin control group. SGOT levels were significantly ($p < 0.01$) reduced in all treated groups. It was most significantly reduced in silymarin + *P. amarus* eth. ext.-treated group of animals.

Levels of SGPT were also reduced in all treated groups, but it was significantly reduced only by marketed formulation followed by silymarin + *P. amarus* eth. ext. treatment. Similar results were obtained, when ALKP was estimated in all groups of animals, where alkaline phosphatase was significantly reduced by marketed formulation (M.F.) followed by *P. amarus* eth. ext. treatment. Serum bilirubin was significantly reduced in all treated groups except in *P. amarus* eth. ext.-treated group. It is almost coming to normalization by *silymarin + P. amarus* aq. ext. and *silymarin + P. amarus* eth. ext. treatment. Total protein was also estimated from serum, which exhibit significant reduction in *silymarin + P. amarus* aq. ext., *silymarin + P. amarus* eth. ext. and marketed formulation (M.F.)-treated animals.

Plasma creatinine levels did not show any significant change in any of the groups, when compared with normal control group. Liver triglycerides estimated from liver homogenate showed significant reduction in *silymarin + P. amarus* aq. ext., *silymarin + P. amarus* eth. ext. and marketed formulation (M.F.)-treated animals, where as liver glycogen was significantly reduced only in *silymarin + P. amarus* eth. ext.-treated animals, when compared with toxin group of animals.

The quality of the standardized *P. amarus* extracts were ensured using phyllanthin content as well as the reproducibility of other chemical profile of HPLC fingerprint. The phyllanthin content was found to be 1.98% and 0.08% in ethanolic and aqueous extract.
respectively. The phyllanthin was detected using a PDA detector at 220 nm.

**Discussion**

The ability of a hepatoprotective drug to reduce the injurious effects or to preserve the normal hepatic physiological mechanisms, which have been disturbed by a hepatotoxin, is the index of its protective effects. Protection of hepatic damage caused by carbontetrachloride administration has been widely used as an indicator of liver protective activity of drugs in general (Clauson, 1989). Since the changes associated with CCl4-induced liver damage are similar to that of acute viral hepatitis (Rubinstein, 1962), CCl4-mediated hepatotoxicity was chosen as the experimental model. It has been established that CCl4 is accumulated in hepatic parenchyma cells and metabolically activated by cytochrome P450-dependent monooxygenases to form a trichloromethyl radical (CCl3). The CCl3 radical alkylates cellular proteins and other macromolecules with a simultaneous attack on polyunsaturated fatty acids, in the presence of oxygen, to produce lipid peroxides, leading to liver damage (Bishayee et al., 1995). Thus, antioxidant or free radical generation inhibition is important in protection against CCl4-induced liver lesions (Castro et al., 1974).

Serum glutamyl oxalacetic acid transferase, serum glutamyl pyruvate transferase, alkaline phosphatase and total bilirubin in plasma have been reported to be sensitive indicator of liver injury (Molander et al., 1955). The disturbance in the transport function of the hepatocytes as a result of hepatic injury, causes the leakage of enzymes from cells due to altered permeability of membrane (Zimmerman and Seeff, 1970). This results in decreased levels of GOT, GPT and alkaline phosphatase in the hepatic cells and a raised level in
serum. The present study revealed a significant increase in the activities of AST, ALT, SALKP and SBLN after exposure to CCl₄, indicating considerable hepatocellular injury. Administration of silymarin and *P. amarus* extracts attenuated the increased levels of the serum enzymes, produced by CCl₄, and caused a subsequent recovery towards normalization. These recoveries have been presented in Table 3 in the form of percent recovery.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Silymarin</th>
<th><em>P. amarus</em> aq. ext.</th>
<th><em>P. amarus</em> eth. ext.</th>
<th>Sily+ <em>P. amarus</em> aq. ext.</th>
<th>Sily+ <em>P. amarus</em> eth. ext.</th>
<th>Marketed formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGOT</td>
<td>100</td>
<td>63.60 ± 6.26</td>
<td>73.30 ± 16.80</td>
<td>80.50 ± 6.80</td>
<td>94.57 ± 12.88</td>
<td>82.83 ± 16.01</td>
</tr>
<tr>
<td>SGPT</td>
<td>100</td>
<td>33.38 ± 14.95</td>
<td>62.4 ± 14.83</td>
<td>82.07 ± 6.95</td>
<td>84.66 ± 7.5</td>
<td>95.71 ± 6.95</td>
</tr>
<tr>
<td>ALKP</td>
<td>100</td>
<td>29.64 ± 14.31</td>
<td>89.29 ± 12.96</td>
<td>40.58 ± 11.6</td>
<td>70.58 ± 12.1</td>
<td>94.03 ± 18.43</td>
</tr>
<tr>
<td>Total bilirubin</td>
<td>100</td>
<td>89.62 ± 12.28</td>
<td>45.68 ± 5.79</td>
<td>96.36 ± 4.17</td>
<td>99.66 ± 7.5</td>
<td>98.11 ± 4.55</td>
</tr>
<tr>
<td>Total protein</td>
<td>100</td>
<td>14.04 ± 4.97</td>
<td>65.07 ± 14.8</td>
<td>130.07 ± 15.98</td>
<td>145.96 ± 9.5</td>
<td>141.11 ± 14.69</td>
</tr>
<tr>
<td>Creatinine</td>
<td>100</td>
<td>83.21 ± 4.94</td>
<td>91.15 ± 12.31</td>
<td>95.57 ± 7.9</td>
<td>98.01 ± 4.97</td>
<td>81.04 ± 9.89</td>
</tr>
</tbody>
</table>

For each group *n = 5*, the values are mean ± SEM.

Formula for calculation of liver protection (denoted by percent recovery).

\[
\text{Percent recovery} = \frac{\text{toxin group} - \text{treated group}}{\text{toxin group} - \text{control group}} \times 100.
\]

In conclusion, we have demonstrated that acute CCl₄ administration caused significant liver injury as indicated by the elevation of enzymes levels in the serum viz., SGOT, SGPT, ALKP and SBLN. In our experiment, treatment of animals with different extracts attenuated the liver injury. Ethanolic and aqueous extracts of *Phyllanthus amarus* showed the partial hepatoprotection, where as these extracts in combination with silymarin exhibited hepatoprotection as indicated by significant changes in various liver parameters in these groups of animals. The combination therapy is exhibiting synergistic activity because the drugs in combination are showing higher liver protection (Table 3, denoted by percent recovery) when compared with either drug alone as evidenced by the results (Chambers, 2001). Further, it was found that *Phyllanthus amarus* ethanolic extract in combination with silymarin was showing better hepatoprotective activity in comparison to that of aqueous extract which may be due to higher availability of phyllanthus lignans particularly phyllanthin in the ethanolic extract of *Phyllanthus amarus* as evidenced by chromatographic analysis.

**Acknowledgement**

The authors are thankful to Director, CIMAP (CSIR) for providing necessary facilities and financial assistance.
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