Original article

*Chenopodium album* extract ameliorates carbon tetrachloride induced hepatotoxicity in rat model

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**Abstract**

Major objective of this study was to explore the protective effect of the methanolic extract of *Chenopodium album* against carbon tetrachloride induced hepatotoxicity in rats. *Chenopodium album* has locally been used for multiple medicinal proposes. Methanolic extract of *Chenopodium album* (whole plant) was prepared with Soxhlet extractor and rotatory evaporator. Antioxidant activity of *Chenopodium album* was determined by DPPH free radical scavenging assay. Thirty Wister (albino) rats (150–200 g) were divided into six groups for the evaluation of hepatoprotective potential of different concentrations of *Chenopodium album* against carbon tetrachloride (1:1 CCl₄: Olive oil) under the controlled laboratory conditions. Group-I rats were administrated with olive oil (Normal control), Group-II with CCl₄ only, Group-III with Silymarin (positive control), Group-IV with *Chenopodium album* (100 mg/kg), Group-V with *Chenopodium album* (200 mg/kg) and Group-VI rats with *Chenopodium album* (300 mg/kg) for the period of 28 days. Serum was taken to determine the levels of alanine transaminase, aspartate transaminase, alkaline phosphatase, cholesterol, triglyceride, creatinine and urea in the blood. Formalin stored tissues were examined for histopathological analysis. DPPH assay showed that *Chenopodium album* has the potential for reduction of oxidative stress. *Chenopodium album* minimized the levels of ALT (70 ± 8.68 U/L, 68.75 ± 8.38 U/L & 73.5 ± 10.28 U/L), AST (219.5 ± 19.16 U/L, 140.75 ± 13.35 U/L & 221.25 ± 13.33 U/L) and ALP (289.5 ± 28.21 U/L, 258 ± 11.12 U/L & 248.25 ± 4.03 U/L) at different concentrations (100 mg/kg, 200 mg/kg, 300 mg/kg respectively). *Chenopodium album* enhanced triglyceride level (64.75 ± 12.66 mg/dl at 200 mg/kg) as compared to CCl₄ treated group (33.25 ± 1.26 mg/dl). Carbon tetrachloride elevated urea level (43.25 ± 6.6) was decreased by high dose of *Chenopodium album* (18 ± 8.17). Moreover, *Chenopodium album* also improved WBC level (9.69 \times 10^3 /Cu.mm & 10.59 \times 10^3 /Cu.mm at low and medium doses respectively), RBCs level (6.97 \times 10^6 /Cu.mm), hemoglobin level (13.95 G/dL, 13.467 G/dL & 14.05 G/dL at low, medium and high doses). In vivo study of *Chenopodium album* methanolic extract demonstrates the potential for protection of liver and after pre-clinical studies the plant can be used as a safe alternative of commercially available hepatoprotective medicines.

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1. Introduction

The liver is a vital organ that deals with several biochemical reactions for different physiological processes. Liver plays important role in maintenance of immune system, regulation of blood volume by maintaining glucose and plasma proteins level, metabolism of macronutrients, production of bile, endocrine regulation of signaling pathways for growth and homeostasis of lipid & cholesterol. Catalysis of xenobiotic compounds including numerous drugs also takes place in the liver, as liver comes into contact with absorbed nutrients and also with xenobiotics via portal vein (Treffs et al., 2017; Michalopoulos & Bhushan, 2021). Liver disorders are one of the main reasons for mortality worldwide and also a direct burden to economy. In a recorded data, about 5% of total patients present in a general hospital are facing drug induced liver injuries (Zhao et al., 2018; Zhou et al., 2021). Liver disorders are one of the main reasons for mortality worldwide and also a direct burden to economy. In a recorded data, about 5% of total patients present in a general hospital are facing drug induced liver injuries (Zhao et al., 2018; Zhou et al., 2021). Toxins are present in our daily life, from pesticides to chemical production, alcohol drinks and detergents; we are in contact with different types of chemicals. Hepatotoxicity can also be induced with different xenобiotics.
including chemicals like carbon tetrachloride for the experimental purposes (Weber et al., 2003).

The consumption of various fruits and vegetables, as well as the usage of some plants played important part in human health care. Traditional medicine, which is based primarily on plant materials, is used by around 80% of the world’s population for health care (Deshwal et al., 2011). Around 160 phyto constituents taken from 101 plant species have been proved to possess hepatoprotective activity (Ali et al., 2019). Despite developments in modern medicine system, there are just a few effective natural medicines in the market that can be used to boost the liver function, protect the damage or help to regenerate hepatic cells (Bansal et al., 2014).

Chenopodium album locally known as lamb’s quarters, is not only a natural weed and commonly used as a vegetable, salad & animal feed but also for medicinal uses. This plant belongs to the Chenopodium genus, which has the diversity of plants with medicinal importance. The plant has been used as an antiscorbutic, laxative, sedative, blood purifier, diuretic drug and anthelmintic against hookworms and other helminthic parasites (Poonia & Upadhayay, 2015). Chenopodium album has flavonoids like phenolic amide, which has hypotensive properties (Goel and Elmarz, 1997). Cinnamic acid amide (Cutillo et al., 2003), alkaloid chenoalbicin (Cutillo et al. 2004) and saponins are also found in the plant (Lavaud et al., 2007). Other potential compounds reported from the Chenopodium album are phyto-hormones (DellaGreca et al. 2004), phenols, lignans and xylosides (Poonia & Upadhayay, 2015). The plant also contains potassium, magnesium, calcium, iron, phosphorous and manganese (Shahi, 1977). Tropolone derivated compounds, isolated from Chenopodium album, have been reported to lowers the ALT, AST and ALP levels and proved to be effective hepatoprotective agents against HepG2 cell line (Ma et al., 2020).

2. Materials and methods

2.1. Plant collection and extract preparation

Aerial parts of Chenopodium album were collected from desert zone of Bhakkar (Punjab, Pakistan) in 2018. Locally identified plants were authenticated by Dr. Qasim Ali from the department of Botany. The plant was washed, shade dried for 2 weeks and grinded into course powder. Methanolic extract of Chenopodium album (MECA) was prepared by using Soxhlet apparatus. 250 ml of solvent (methanol 95%) was filled in distillation flask for 40 g (MECA) was prepared by using Soxhlet apparatus. 250 ml of solvent (methanol 95%) was filled in distillation flask for 40 g.

2.2. Determination of antioxidant activity

Antioxidant activity of Chenopodium album methanolic extract was measured by DPPH assay. DPPH solution was initially prepared by dissolving DPPH solution (2 mg) into methanol (50 ml). Different concentrations of CAME were mixed with DPPH solution in 96 well plate. Methanol and Ascorbic acid were used as blank and control respectively. Absorbance was measured at 517 nm (De-torre et al., 2019). Following formula was applied for calculation of antioxidant percentage

\[
\% \text{ of Antioxidant} = 1 - \frac{Abs_{\text{Sample}} - Abs_{\text{Blank}}}{Abs_{\text{Control}} - Abs_{\text{Blank}}} \times 100
\]

Where: Abs, Absorbance

2.3. Experimental animals

Thirty healthy 8–10 week-old Wister rats (weight 150–200 g) were purchased from department of Physiology, Government College University Faisalabad. The animals were kept under the standard laboratory conditions, with controlled temperature (24 ± 2), relative humidity (55 ± 5%) & 12 h day/night cycle and had free access to standard diet and water. The rats were housed in controlled condition for 7 days with the attention of acclimatization. Government College University Faisalabad’s Ethics Review Committee authorized the experimental protocol.

2.4. Experimental design

To test the hepatoprotective potential of Chenopodium album against CCl₄ induced hepatotoxicity, research experiment was conducted for the period of 28 days.

- The rats were uniformly divided into 6 groups

  - Group I (Normal control)
  - Olive oil treatment (Orally gavage)
  - Group II
  - Carbon tetrachloride treatment (Orally gavage)
  - Group III (Positive control)
  - Silymarin treatment (100 mg/kg b.w) & Carbon tetrachloride treatment (Orally gavage)
  - Group IV
  - Chenopodium album methanolic extract (100 mg/kg b.w) treatment & Carbon tetrachloride treatment (Orally gavage)
  - Group V
  - Chenopodium album methanolic extract (200 mg/kg b.w) treatment & Carbon tetrachloride treatment (Orally gavage)
  - Group VI
  - Chenopodium album methanolic extract (300 mg/kg b.w) treatment & Carbon tetrachloride treatment (Orally gavage)

Olive oil was used as a vehicle (1:1 ratio of carbon tetrachloride: olive oil) for carbon tetrachloride treated (2 ml/kg b.w) rats of group II, III, IV, V & VI.

2.5. Sample collection

After 24 h of last dose of carbon tetrachloride, rats had been sacrificed by decapitation of the cervical region. Blood samples were collected by cardiac puncture using a sharp syringe. Blood collected in the purple top bottle (lavender) was mixed with EDTA by inverting the tube about 8–10 times. For the purpose of serum blood was collected into red top bottles, and the tubes were kept vertically for 30 min, and then centrifuged at 3000 rpm for 15 min. Supernatant (serum) was gently taken into eppendorf tubes. Liver was taken and stored in 10% formalin for the purpose of histopathology.

2.6. Assay of liver marker enzymes

Level of alanine transaminase (ALT), aspartate transaminase (AST) and alkaline phosphatase (ALP) in the serum was measured by using commercially available diagnostic kits. These biomarkers of liver functions were analyzed by using Dimension EXL 200 automatic biochemistry analyzer.

2.7. Assays for lipid profile and renal function tests

Serum stored at −40 °C, was utilized for the determination of cholesterol, triglycerides, urea and creatinine levels. Dimension 200 EXL automatic biochemistry analyzer was used for the analysis of cholesterol, triglycerides, urea and creatinine in the serum samples of rats.
2.8. Determination of hematological parameters

Hematological analyzer was used for the determination of red blood cells count, white blood cells count and hemoglobin level.

2.9. Histopathological examination

Formalin preserved liver was cut with the help of sharp blade, and a section of liver tissue was placed in labeled histology cassettes. Tissues were fixed in formalin, and dehydrated in gradually increasing concentrations of ethanol. Dehydrated tissues were embedded in wax. Tissues were taken out from wax and mounted on microtome (Histo-line MR 2258) and about 5 um thin sections were cut, transferred on albumenized glass slides. Hematoxylin and eosin were used as stain (Kakadia et al., 2020). Microscopy of liver tissue damage was done under optical microscope (Nikon DS-Fi2) & photos were captured with camera attached with microscope.

2.10. Statistical analysis

All of the data was analyzed using IBM SPSS statistics. To analyze differences across groups, one-way analysis of variance (ANOVA) and Tukey’s tests were applied. The processed data was expressed using the mean and standard deviation (mean SD). The results were considered significant unless the P value was less than 0.05.

3. Results

3.1. Antioxidant activity

Chemicals like CCl₄ initially damage the tissues by causing oxidative stress. With the entry of carbon tetrachloride in liver, CCl₄ is bio-transformed by Cyt-P₄₅₀ enzymes and metabolized by CyP2E1 into CCl₃ and CCl₂OO⁻. A chain of free radicals is started, generating oxidative stress. Different concentrations of CAME were used to determine the antioxidant activity, and plant showed maximum DPPH free radical scavenging activity at its highest concentration, as results are shown in Fig. 1.

![Antioxidant activity of Chenopodium album methanolic extract Group I. Normal control; Group II, carbon tetrachloride intoxicated rats; Group III, Silymarin (100 mg/kg) + CCl₄; Group IV, CAME (100 mg/kg) + CCl₄; Group V, CAME (200 mg/kg) + CCl₄; Group VI, CAME (300 mg/kg) + CCl₄.](image)

3.2. Effect of Chenopodium album extract on liver enzyme activities in CCl₄ intoxicated rats

The levels of ALT, AST, and ALP showed notable increase in the serum samples of carbon tetrachloride administered rats compared with normal control group (80 ± 14.9 U/L, 247.75 ± 24.9 U/L & 308.25 ± 5.62 U/L Vs 73.25 ± 8.34 U/L, 213.5 ± 12.92 U/L & 261 ± 14.97U/L respectively). Pre-treatment of Chenopodium album methanolic extracts (100 mg/kg, 200 mg/kg & 300 mg/kg) for 28 consecutive days showed considerable decrease in the activity of alanine transaminase (70 ± 8.68 U/L, 68.75 ± 8.38 U/L & 73.5 ± 10.28 U/L respectively), aspartate transaminase (219.5 ± 19.16 U/L, 140.75 ± 13.35 U/L & 221.25 ± 13.33 U/L respectively) and alkaline phosphatase (289.5 ± 28.21 U/L, 258 ± 11.12 U/L & 248.2 ± 5 ± 4.03 U/L respectively) in the rats with CCl₄ induced hepatotoxicity, as showed in Table 1.

3.3. Effect of Chenopodium album extract on lipid profile of serum in CCl₄ intoxicated rats

The levels of triglycerides in carbon tetrachloride administrated rats decreased significantly as compared to normal control rats (33.25 ± 1.26 mg/dl Vs 91.5 ± 9.75 mg/dl respectively). The rat administrated with Silymarin and CAME (Chenopodium album methanolic extract) chronically, showed significant increase in the levels of triglycerides (Table 2). Medium dose (200 mg/kg) of CAME showed maximum increase in triglyceride level (64.75 ± 12.66 mg/dl). Low dose (100 mg/kg) showed significant decrease in total cholesterol level as compared to CCl₄ intoxicated rats (42 ± 3.56 mg/dl Vs 49.25 ± 12.5 mg/dl respectively).

3.4. Effect of Chenopodium album extract on serum RFTs in CCl₄ intoxicated rats

Carbon tetrachloride elevated the level of urea and Creatinine as compared to normal control group. Positive control (silymarin), CAME 100 mg/kg and CAME 300 mg/kg reduced the level of urea (39 ± 4.76 U/L vs 27.5 ± 6.61 U/L & 18 ± 8.17 U/L respectively). The decrease in Creatinine in Group III (silymarin treated), Group IV (CAME 100 mg/kg treated) & group V (CAME 200 mg/kg treated rats) was observed as 0.425 ± 0.13 mg/dl, 0.425 ± 0.26 mg/dl & 0.467 ± 0.24 mg/dl respectively (Table 3).

3.5. Effect of Chenopodium album extract on hematological parameters in CCl₄ intoxicated rats

Chenopodium album methanolic extract showed slight increase in white blood cell count, red blood cell count and hemoglobin level as compared to carbon tetrachloride intoxicated rat group, as results shown in Fig. 2. Treatment of 100 mg/kg & 200 mg/kg CAME showed significant increase in WBC count as compared to CCl₄ intoxicated group (9.69 × 10⁴ /Cu.mr & 10.59 × 10⁴ /Cu.mr Vs 8.88 × 10⁴ /Cu.mr). Along with carbon tetrachloride, silymarin also showed decrease in WBC level (8.88 × 10⁴ /Cu.mr & 8.61 × 10⁴ /Cu.mr respectively). Chenopodium album Treatment of 100 mg/kg & 200 mg/kg CAME showed slight increase in RBC count as compared to CCl₄ intoxicated group (6.97 × 10⁴ /Cu.mr & 7.54 × 10⁴ /Cu.mr Vs 6.76 × 10⁴ /Cu.mr). Low, medium and high doses of Chenopodium album showed significant increase in hemoglobin level as 13.95 G/dL, 13.467 G/dL & 14.05 G/dL respectively.

3.6. Histopathological examination

After the dissection of rats, morphological changes were observed with naked eye, and liver images were captured as shown in supplementary Fig. 2. Histopathological examination detected...
Table 1
Effect of *Chenopodium album* methanolic extract on biochemical parameters of CCl$_4$ damaged livers in rats.

| Group     | Treatment                      | AST (U/L)         | ALT (U/L)         | ALP (U/L)         |
|-----------|--------------------------------|-------------------|-------------------|-------------------|
| Group I   | Negative Control               | 213.5 ± 12.92     | 73.25 ± 8.34      | 261 ± 14.97       |
| Group II  | CCl$_4$ Treated                | 247.75 ± 24.9     | 80 ± 14.99        | 308.25 ± 5.62     |
| Group III | Silymarin & CCl$_4$ Treated   | 189.5 ± 13.53     | 79.75 ± 9.91      | 229.75 ± 13.87    |
| Group IV  | 100 mg/kg CAME & CCl$_4$ Treated | 219.5 ± 19.16  | 70 ± 8.68         | 289.5 ± 28.21     |
| Group V   | 200 mg/kg CAME & CCl$_4$ Treated | 140.75 ± 13.35  | 68.75 ± 8.38      | 258 ± 11.12       |
| Group VI  | 300 mg/kg CAME & CCl$_4$ Treated | 221.25 ± 13.33  | 73.5 ± 10.28      | 248.25 ± 4.03     |

CAME: *Chenopodium album* methanolic extract, CCl$_4$: Carbon tetrachloride, ALT: Alanine transaminase, AST: Aspartate transaminase, ALP: Alkaline Phosphatase.

Table 2
Effect of *Chenopodium album* methanolic extract on cholesterol and triglycerides of CCl$_4$ damaged livers in rats.

| Group I   | Treatment                      | Cholesterol (mg/dl)    | Triglycerides (mg/dl)    |
|-----------|--------------------------------|------------------------|--------------------------|
| Group II  | CCl$_4$ Treated                | 49.25 ± 12.5           | 44.25 ± 15               |
| Group III | Silymarin & CCl$_4$ Treated   | 48.75 ± 11.03          | 42 ± 3.56                |
| Group IV  | 100 mg/kg CAME & CCl$_4$ Treated | 63.75 ± 8.96          | 61.75 ± 17.15            |
| Group V   | 200 mg/kg CAME & CCl$_4$ Treated | 50 ± 23.48            | 64.75 ± 12.66            |
| Group VI  | 300 mg/kg CAME & CCl$_4$ Treated | 37.75 ± 18.61         | 37.75 ± 18.61            |

CAME: *Chenopodium album* methanolic extract CCl$_4$: Carbon tetrachloride.

Table 3
Effect of *Chenopodium album* methanolic extract on renal parameters of CCl$_4$ damaged livers in rats.

| Group I   | Treatment                      | Urea (U/L)          | Creatinine (mg/dl) |
|-----------|--------------------------------|---------------------|--------------------|
| Group II  | CCl$_4$ Treated                | 43.25 ± 6.6         | 0.500 ± 0.14       |
| Group III | Silymarin & CCl$_4$ Treated   | 39 ± 4.76           | 0.425 ± 0.13       |
| Group IV  | 100 mg/kg CAME & CCl$_4$ Treated | 27.5 ± 6.61         | 0.425 ± 0.26       |
| Group V   | 200 mg/kg CAME & CCl$_4$ Treated | 48.25 ± 4.5         | 0.467 ± 0.24       |
| Group VI  | 300 mg/kg CAME & CCl$_4$ Treated | 18 ± 8.17           | 0.525 ± 0.15       |

CAME: *Chenopodium album* methanolic extract CCl$_4$: Carbon tetrachloride.

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**Fig. 2.** Effect of *Chenopodium album* methanolic extract on hematological parameters Group I, Normal control; Group II, carbon tetrachloride intoxicated rats; Group III, CCl$_4$ + Silymarin (100 mg/kg); Group IV, CCl$_4$ + CAME (100 mg/kg); Group V, CCl$_4$ + CAME (200 mg/kg); Group VI, CCl$_4$ + CAME (300 mg/kg).
the evidences of liver damage in carbon tetrachloride intoxicated rats, particularly in hepatocytes, central vein and hepatic sinusoids. Low and medium doses of CAME improved the tissue, damaged by carbon tetrachloride as shown in Fig. 3.

4. Discussion

In this study, Chenopodium album methanolic extract is used for the protection of liver cells of selected rats against carbon tetrachloride induced toxicity. Different parameters were analyzed to assess the potential of Chenopodium album methanolic extract, and the extract accelerated the white blood cells & hemoglobin levels. The extract showed potential antioxidant capability and also lowered ALT, AST and ALP levels of serum, which indicated the hepatoprotective potential of the extract.

Hepatoprotective activity of C. album was primarily reported by Ma et al. (2020), the researchers isolated 23 tropolones derived compounds from C. album. Efficacy of tropolones was identified by using HepG2 cell line against $H_2O_2$ induced toxicity. In the results of the study, tropolones derived from EtOH extracted Chenopodium album, lowered the ALT ($\sim 15.21 \pm 1.18$ to $\sim 20.29 \pm 2.1$ $1 \text{U/L})$ and AST ($\sim 19.63 \pm 2.34$ to $\sim 29.87 \pm 1.27$U/L) levels against $H_2O_2$ induced hepatotoxicity. In the same manner our findings showed the protective potential of Chenopodium album in rat model. In the In vivo studies Alanine transaminase, Aspartate transaminase and alkaline phosphatase levels dropped by different concentrations of Chenopodium album methanolic extract against carbon tetrachloride.

Amodeo et al. (2019) examined the In vitro antioxidant activity of Chenopodium album methanolic extracts by $\beta$-carotene bleaching test and DPPH assay. C. album along with Sisymbrium officinale showed significant radical scavenging activity, and overall results verified our findings. In our studies, antioxidant activity was measured by DPPH assay at different concentrations; at 500 $\mu$l/g of concentration the maximum antioxidant activity was recorded at 517 nm absorbance.

In this study, hematological parameters were also focused, and CAME elevated the levels of white blood cells and hemoglobin. Although Positive control (Silymarin) shows hepatoprotective capabilities, but silymarin and its source (milk thistle) decline the level of white blood cells. Like many other authors, Jamalian et al. (2020) also reported the decrease in white blood cells due to silymarin. On the other hand, like other Chenopodium species CAME also showed distinct increase in white blood cells as well as hemoglobin because of its iron containing property.

Carbon tetrachloride has been used to expose liver and kidney damage in experimental animals. Carbon tetrachloride induced toxicity in kidney elevates the levels of urea and creatinine, while different doses of our extract decreased the levels of urea and creatinine. Jahan et al. (2019) worked on Sprague Dawley rats and reported that Chenopodium album decreased the levels of urea and creatinine in serum of rats, which also support our findings.

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.

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References

Ali, S.A., Sharief, N.H., Mohamed, Y.S., 2019. Hepatoprotective Activity of Some Medicinal Plants in Sudan. Evidence-Based Complementary and Alternative Medicine 2019, 1–16.

Amodeo, V., Marrelli, M., Pontieri, V., Cassano, R., Trombino, S., Conforti, F., Statti, G., 2019. Chenopodium album L. and Sisymbrium officinale (L.) Scop.: Phytochemical Content and In Vitro Antioxidant and Anti-Inflammatory Potential. Plants 8 (11), 505.

Bansal, J., Kumar, N., Malviya, R., Sharma, P.K., 2014. Hepatoprotective Models and Various Natural Product Used in Hepatoprotective Agents: a Review. Pharmacogn. Commun. 4 (3).

Cutillo, F., Abrosca, B., Dellagreca, M., Marino, C.D., Golino, A., Previtera, L., Zarrellia, A., 2003. Cinnamic acid amides from Chenopodium album: effect on seed germination and plant growth. Phytochemistry 64, 1381–1387.

Cutillo, F., D’Abrosca, B., Dellagreca, M., Zarrelli, A., 2004. Chenoalbicin, a novel cinnamic acid amide alkaloid from Chenopodium album. Chem. Biodivers. 1 (10), 1579–1583.

De-torre, M.P., Cavero, R.Y., Calvo, M.I., Vizmanos, J.L., 2019. A Simple and a Reliable Method to Quantify Antioxidant Activity In Vivo. Antioxidants 8 (5), 142.

DellaGreca, M., Di Marino, C., Zarrelli, A., D’Abrosca, B., 2004. Isolation and phytotoxicity of apocarotenoids from Chenopodium album. J. Nat. Prod. 67 (9), 1492–1495.

Deshwal, N., Sharma, A.K., Sharma, P., 2011. Review on hepatoprotective plants. Int. J. Pharmacol. Res. 7, 15–26.

Gohara, A.A., Elmazar, M.M.A., 1997. Isolation of hypotenous flavonoids from Chenopodium species growing in Egypt. Phytother. Res. 11 (8), 564–567.

Jamalian, M., Mahmodiyeh, B., Saveeie, S., Solhi, H., 2020. Investigating the impact of silymarin on liver oxidative injury. Fam. Med. Prim. Care Rev. 9 (3), 1707–1711.

Lavaud, C., Voutquenne, L., Bal, P., Pouy, I., 2000. Saponins from Chenopodium album. Fitoterapia 71 (3), 338–340.

Kakadia, N.P., Amin, M.A., Deshpande, S.S., 2020. Hepatoprotective and antioxidant effect of Adiantum lunulatum Burm. F. leaf in alcohol-induced rat model. J. Complement. Integr. 17 (3).

Ma, Q.-G., Wei, R.-R., Zhang, X.-D., Sang, Z.-P., Dong, J.-H., Lu, Q.-X., Huang, H.-F., Guo, D.-M., Jiang, L., 2020. Tropolone derivatives with hepatoprotective and antiproliferative activities from the aerial parts of Chenopodium album Linn. Fitoterapia 146, 104733. https://doi.org/10.1016/j.fitote.2020.104733.

Michalopoulos, G.K., Bhushan, B., 2021. Liver regeneration: biological and pathological mechanisms and implications. Nat. Rev. Gastroenterol. Hepatol. Nat. Rev. 18 (1), 40–55.

Poonia, A., Upadhayay, A., 2015. Chenopodium album Linn: review of nutritive value and biological properties. J. Food Sci. Technol. 52 (7), 3977–3985.

Shahi, H.N., 1977. Studies on chemical composition of Chenopodium album L. Plant and Soil 46 (1), 271–273.

Trefts, E., Cannon, M., Wasserman, D.H., 2017. The liver. Curr. Biol. 27 (21), R1147–R1151.

Weber, L.W.D., Boll, M., Stampfl, A., 2003. Hepatotoxicity and mechanism of action of halogenated carbon tetrachloride as a toxicological model. Crit. Rev. Toxicol. 33 (2), 105–136.

Zhao, Z.W., Chang, J.C., Lin, L.W., Tsai, F.H., Chang, H.C., Wu, C.R., 2018. Comparison of the Hepatoprotective Effects of Four Endemic Cirsium Species Extracts from Taiwan on CCl4-Induced Acute Liver Damage in C57BL/6 Mice. International journal of molecular sciences, 19(5), 1329.