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Hepatoprotective activity of *Thymus vulgaris* extract against *Toxoplasma gondii* infection

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ABSTRACT

Objective: To evaluate the hepatoprotective activity of *Thymus vulgaris* (*T. vulgaris*) extract against *Toxoplasma gondii* (*T. gondii*) infection in experimentally infected mice.
Methods: Sixty mice were divided into six groups (Group I–Group VI). Group I was normal control (non-infected, non-treated); Group II was non-infected and treated with *T. vulgaris* extract (500 mg/kg); Group III was *T. gondii* infected-non-immunosuppressed control; Group IV consisted of infected immunosuppressed mice; Group V was infected and treated with *T. vulgaris* extract; Group VI consisted of infected immunosuppressed mice treated with *T. vulgaris* extract. Hepatoprotective effect of *T. vulgaris* extract was evaluated by histopathological examination of tissue sections stained with hematoxylin and eosin, determination of liver function parameters (alanine aminotransaminase, aspartate aminotransaminase and alkaline phosphates, total bilirubin, total protein concentrations) and assessment of hepatocytes genotoxicity by comet assay.Antigenotoxic effect of *T. vulgaris* was assessed by several comet assay parameters that were provided by the image analysis software, including % tailed cells, % of DNA in the tail, tail length, and tail moment.
Results: Treatment with *T. vulgaris* in both Groups V and VI improved *T. gondii* induced pathological lesions in the infected liver that regressed to near the normal picture especially in Group V. Also, it restored the altered values of liver function parameters near to the normal levels significantly ($P < 0.05$) compared with Groups III and IV respectively. Regarding comet assay parameters, all of them were significantly increased ($P < 0.05$) after *T. gondii* infection (Group III) and reached the greatest values in infected immunosuppressed group (Group IV) compared to the normal controls (Group I). With treatment by *T. vulgaris* in Groups V and VI, there was a significant decrease ($P < 0.05$) in all values compared to Groups III and V respectively. The results indicated that *T. vulgaris* reduced DNA damage induced by *T. gondii* infection in liver cells.
Conclusions: *T. vulgaris* ethanol extract exhibited notable hepatoprotective activity against *T. gondii* infection.

1. Introduction

Liver is frequently affected by parasitic infections. The parasites may either inhabit this organ or pass through it during their normal development. Mechanism of liver tissue damage is either due to the direct effect of the parasite on the tissues or related to the excessive immunological response to the parasite[1]. *Toxoplasma gondii* (*T. gondii*) is an obligate intracellular protozoan parasite, and is capable of infecting almost all the internal organs and tissues of the mammalian host. In the host cells, *T. gondii* causes DNA damage and rapid cell death with rupture and release of the organisms and soluble antigens that cause many pathological changes ranging from mild congestion to severe degeneration within the affected organs[2,3]. Within the liver, it causes pathological changes that progress to hepatomegaly, granuloma, hepatitis, and necrosis[4,5]. The association between *T. gondii* infection and chronic liver diseases and abnormal liver function has been confirmed by several researchers[6-8].

Many medicinal plants exhibit anti-*Toxoplasma* activity, including *Zingiber officinale*, *Nigella sativa*, *Piper nigrum*, myrrh, *Azadirachta indica*, *Curcuma longa*, and *Melia azedarach*. These plants have a beneficial effect in prophylaxis as well as treatment of both acute and chronic toxoplasmosis through being safer, acceptable and available at low cost[9]. Also, some scientific reports stated that certain medicinal plants have protective effect on the liver as they contain a variety of chemical constituents like flavonoids, phenols, triterpenoids, coumarins, lignans, essential

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All experimental procedures involving animals were conducted in accordance to EU Directive on the Protection of Animals Used for Scientific Purposes (2010/63/EU) and approved by Research Committee, Research Institute of Ophthalmology, Giza- Egypt.

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oil, monoterpenes, carotenoids, glycosides, organic acids, lipids, alkaloids, xanthenes and steroids[10,11]. The mechanism of hepatoprotection by these compounds is by exerting antioxidant, immunomodulatory and anti-inflammatory effects[10].

Thymus vulgaris (*T. vulgaris*), a well-known medicinal plant, possesses diverse activities including anti-inflammatory and antioxidant properties[12,13]. *T. vulgaris* and its major ingredients (thymol and carvacrol) were expected to exhibit a DNA-protective effect on DNA lesions induced by a strong oxidant (hydrogen peroxide) on mammalian cells cultured *in vitro*[14]. Additionally, it was found that *T. vulgaris* exhibited antiprotozoal activity against *Trypanosoma cruzi*, *Entamoeba histolytica*, and *Blastocystis hominis*[15-17]. Therefore, this study aimed to evaluate the hepatoprotective activity of *T. vulgaris* extract against *T. gondii* infection in experimentally infected mice.

2. Materials and methods

2.1. T. vulgaris extract preparation

T. vulgaris leaves were brought from the International Company (Cairo, Egypt), identified and recorded as a reference in Medicinal and Aromatic Plants Department, Horticulture Research Institute, Egypt. The leaves were dried and ground into fine powder. A total of 100 g of this powder was added to half liter of ethanol (95%) and left in a conical flask at 25 ℃ for three days with repeated shaking. The mixture was filtered through a filter paper (Whatman No. 1), and then the extract was concentrated by using a rotary evaporator (Sigma-Aldrich, USA). The residues were dissolved in Tween-20 (10%) to obtain a concentration of 100 mg/mL[17].

Preliminary experiment was carried out with successive doses (ranged from 100 to 500 mg/kg) for testing the acute toxicity according to the Organization for Economic Cooperation and Development (OECD) guideline 423[18]. A dose of 500 mg/kg daily for 10 days was selected for the oral administration of this extract as it showed neither death, nor other behavioral or toxicological changes in all tested mice.

2.2. Experimental animals

Sixty laboratory-bred male Swiss albino mice, 12 weeks old and weighing 35–40 g, were selected. They were fed with a balanced standard diet, and maintained under controlled environment with an average temperature of (25 ± 2) ℃ and standard cycle of light and dark through the experiment. The experiment was carried out in the animal house of the Research Institute of Ophthalmology, Giza, Egypt.

2.3. Infectious agent

Me49 non-virulent strain of *T. gondii* was used to infect mice in this study. It was obtained from the brains of the previously infected mice eight weeks prior. The mice brains were ground and diluted, and brain cysts suspension was obtained. Using the haemocytometer, the number of *Toxoplasma* cysts was adjusted to be 1×10^2 cysts/mL in this brain suspension[3]. For infection, 0.1 mL of the brain cysts suspension was injected intraperitoneally to each mouse. All infected mice were tested positive for *T. gondii* IgG antibodies on Day 21 post-infection using commercial mouse anti-toxoplasmosis antibody (IgG) ELISA kit (MyBioSource, Inc. California, USA) according to the instructions of the manufacturer.

2.4. Experimental design

Mice were divided into six groups (Groups I–VI) of 10 mice/group. Group I was non-infected, non-treated (normal control) and received 0.1 mL of sterile distilled water; Group II was non-infected and received *T. vulgaris* extract daily for 10 days; Group III was *T. gondii* infected-non-immunosuppressed control; Group IV consisted of *T. gondii* infected-immunosuppressed mice injected subcutaneously with methylprednisolone acetate (Depo-medrol®, Pfizer Inc.) 40 mg/day/mouse for five successive days one month after infection[3]. Six weeks after infection, both Group V (infected and non-immunosuppressed) and Group VI (infected-immunosuppressed)were treated by *T. vulgaris* extract daily for 10 days.

Eight weeks after infection, the blood was obtained from the mouse's orbital venous plexus under ether anesthesia. The sera were separated by centrifugation at 3 000 ×*g* for 10–15 min and stored at –20 ℃ for the determination of liver function parameters. Then, all mice were sacrificed and their livers were obtained. Each liver was divided into two parts; one part was used for assessment of hepatocytes DNA damage by single-cell gel electrophoresis (comet assay), and the other part was used for the histopathological evaluation.

2.5. Evaluation of hepatoprotective activity of T. vulgaris extract against T. gondii infection

2.5.1. Histopathological examination

Liver samples were washed in 0.9% sodium chloride solution and fixed in 10% formalin. Then, fixed liver tissues were dehydrated and embedded in paraffin blocks. Tissue sections of 5 μm thickness were stained with hematoxylin and eosin (H&E) and examined microscopically at magnifications of 100×, 400× and 1 000×.

2.5.2. Determination of liver function parameters

Serum levels of alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), total bilirubin and total protein were estimated by using Sigma diagnostic kits (Sigma Chemical Co., St. Louis, USA) following the manufacturer's instructions.

2.5.3. Assessment of hepatocyte cell's genotoxicity by comet assay

Crushed liver samples (0.5 g) were placed in 1 mL ice-cold PBS (pH 7.9), stirred for 5 min and filtered. Then 100 μL of each cell suspension were mixed with 600 μL of low melting agarose (0.8% in PBS). Then 100 μL from the mixture were pipetted onto the slides, and the slides were flooded by lysis buffer which consisted of 0.045 mol/L Tris-borate ethylenediaminetetraacetic acid (TBE, pH 8.4) and 2.5% sodium dodecyl sulfate (SDS) for 15 min. After that, the slides were transferred into an electrophoresis chamber containing TBE buffer only. The electrophoresis was conducted at 2 V/cm for 2 min and 100 mA. Finally, they were stained with ethidium bromide 20 μg/mL at 4 ℃ and the presence of comets was examined at 40× magnification using a fluorescence microscope [with excitation filter 420–490 nm (issue 510 nm)]. All chemicals were obtained from Sigma Chemical Co., USA.

The Komet 5 image analysis software (Kinetic Imaging, Ltd. Liverpool, UK) linked to a charge-coupled device camera was used to determine the quantitative and qualitative extent of DNA damage in the liver cells by measuring the length of DNA migration, migrated DNA percentage and tail moment through the observation of fifty to hundred cells per sample[19]. Tailed cells indicated by the ratio of the number of comet tails and the number of non-head shapes to the number of total cells. The percentage of tail DNA was calculated from the fraction of DNA in the tail divided by the amount of DNA in the nucleus multiplied by 100. The tail length was measured from the middle of the nucleus to the end of the tail.

The tail moment was calculated by multiplying the tail length and % of DNA in the tail[20].

2.6. Statistical analysis

The statistical analysis was performed by using SPSS 16.0 (SPSS Inc., Chicago, IL, USA). Data were represented as mean ± SD. The significant differences between the experimental groups were estimated by ANOVA followed by the student's *t*-test. Probability (*P* value) less than 0.05 was considered significant.

2.7. Ethical considerations

All experimental procedures involving animals were conducted in accordance to EU Directive on the Protection of Animals Used for Scientific Purposes (2010/63/EU) and approved by Research Committee, Research Institute of Ophthalmology, Giza- Egypt.

3. Results

The study has proven that daily administration of *T. vulgaris* by the oral route at a dose of 500 mg/kg for 10 days did not cause any mortality or any observable toxic effects in the mice of Group II. Mice were alert with no alteration of their behavioral pattern, any gastrointestinal tract disorder or respiratory distress. From the histopathological observations, there were not any observable changes in the livers at the giving dose compared to the normal controls (Figure 1).

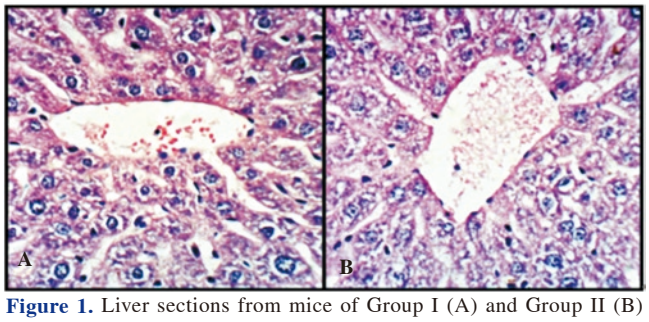

Figure 1. Liver sections from mice of Group I (A) and Group II (B) showing normal histological structure of the hepatic lobules (H&E, 400×).

3.1. Histopathological results

Macroscopically, the liver of *T. gondii* infected group showed a mild degree of enlargement and focally extensive necrosis. However, in *T. vulgaris* treated mice, the livers appeared healthy. Microscopically, the livers of *T. gondii*-infected mice (Group III) showed focal areas of necrosis with a mild degree of inflammatory cellular infiltrates; mainly lymphocytes that were very obvious in the portal area and *Toxoplasma* cysts were observed between the hepatocytes (Figure 2). Conversely, in the infected immunosuppressed group (Group IV), the histopathological features of liver progressed from moderate to severe, where there was a dissociation of hepatic cords pattern with generalized necrosis of the hepatocytes. Also, there was marked dilatation and congestion of the hepatic portal blood vessels. It was observed that some of *Toxoplasma* cysts ruptured, releasing tachyzoites to the sinusoids and invading the other hepatocytes and Kupffer cells. Also, there was Kupffer cell hyperplasia, and proliferation of epithelial lining bile duct associated with chronic cholangitis (Figure 3).

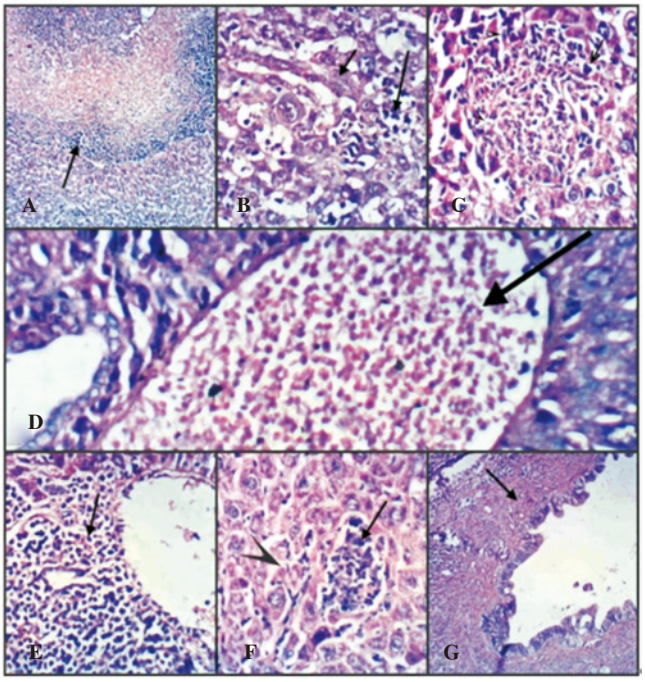

Figure 3. Liver sections from mice of Group III stained with H&E showing large focal coagulative necrosis of hepatocytes associated with inflammatory cells infiltration (A) (100×); dissociation of hepatic cords pattern with generalized necrosis of hepatocytes and sinusoidal leucocytosis (B) (400×); necrosis, vacuolation and dissociation of hepatocytes associated with mononuclear inflammatory cells infiltration and *T. gondii* tachyzoites distributed throughout the liver tissues (C) (400×); marked dilatation and congestion of hepatic portal blood vessel (D) (400×); portal infiltration with massive inflammatory infiltrate (E) (400×); Kupffer cell hyperplasia and *T. gondii* tachyzoites invading the cells and lying on the endothelial surface of the sinusoidal capillaries (F) (400×); hyperplasia and proliferation of epithelial lining bile duct associated with chronic cholangitis (G) (100×).

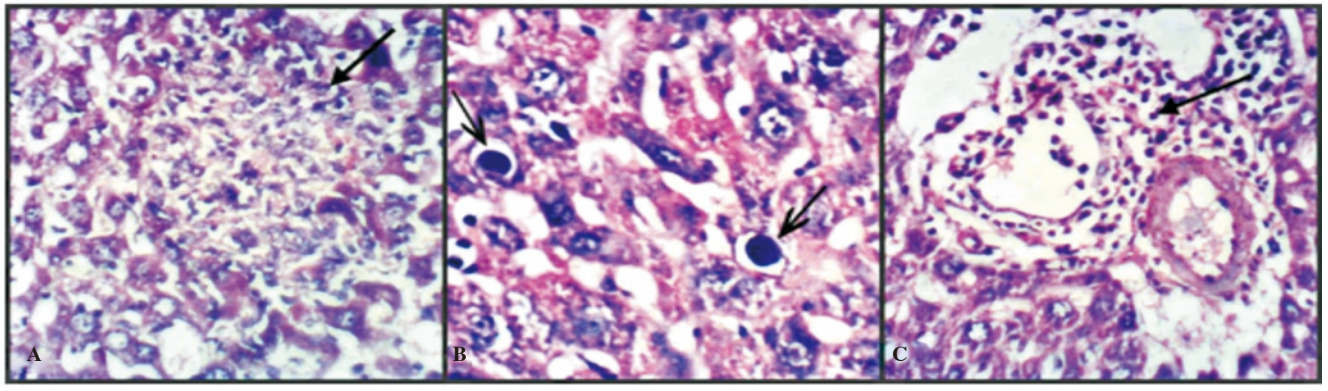

Figure 2. Liver sections from mice of Group III showing focal hepatic necrosis associated with mononuclear inflammatory cells infiltration (A); *Toxoplasma* cysts between the hepatocytes (B) and portal infiltration with inflammatory cells (C) (H&E, 400×).

These marked histological changes regressed to near the normal picture after treatment with *T. vulgaris* extract; liver tissues of Group V appeared healthy with small foci of inflammatory reaction and Group VI showed hydropic degeneration of hepatocytes and focal hepatic necrosis associated with inflammatory cells infiltration (Figure 4).

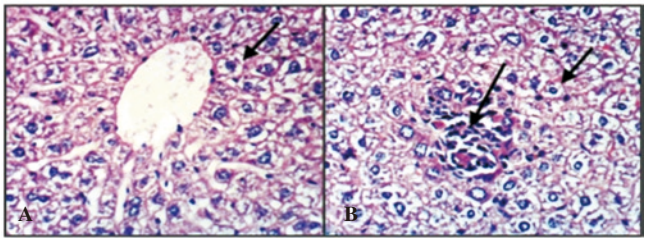

Figure 4. Liver sections from the mice treated with *T. vulgaris* extract
A: Section from Group V appeared healthy with small foci of inflammatory reaction; B: Section from Group VI showed hydropic degeneration of hepatocytes and focal hepatic necrosis associated with inflammatory cells infiltration (H&E, 400×).

3.2. Effect of T. vulgaris treatment on liver function parameters

It was found that *T. gondii* infected mice (Group III) and infected immunosuppressed mice (Group IV) showed a significant elevation in ALT, AST, ALP, total bilirubin and reduction in total protein concentration. However, treatment with *T. vulgaris* in Groups V and VI reduced the levels of ALT, AST, ALP, total bilirubin and increased total protein concentration significantly ($P < 0.05$) compared with Groups III and V respectively as shown in Table 1.

3.3. Antigenotoxic effect of T. vulgaris

T. gondii infection induced a statistically significant increase in the tailed nuclei (DNA damage) in mice liver cells (Group III) compared to the normal control group (Group I) which showed some degree of DNA damage. In infected immunosuppressed group (Group IV), the frequency of tailed nuclei in liver cells increased in comparison to both control (Group I) and infected group (Group III). After treatment with *T. vulgaris* in both Groups V and VI, DNA damage in liver cells decreased comparing with Groups III and IV respectively (Figure 5). Also, antigenotoxic effect of *T. vulgaris* was assessed by various comet assay parameters including % tailed cells, % of DNA in the tail, tail length, and tail moment. All these parameters were significantly increased ($P < 0.05$) after *T. gondii* infection (Group III) and reached the greatest values in infected immunosuppressed group (Group IV) compared to the controls (Group I). After treatment with *T. vulgaris* in Groups V and VI, there was significant decrease ($P < 0.05$) in all values compared to Groups III and IV respectively (Table 2). These results indicated that *T. vulgaris* reduced the degree of damage induced by *T. gondii* infection.

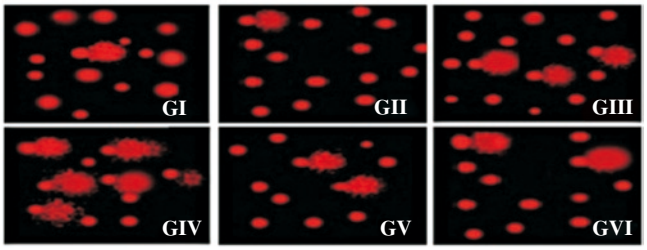

Figure 5. Representative photographs of a comet showing DNA migration pattern in hepatocytes of mice stained with ethidium bromide.
Group I (non-infected) and Group II (non-infected mice received *T. vulgaris* extract) showed that the most cells appeared with no comet and DNA was tightly compressed and maintained the circular disposition of the normal nucleus; Group III (*T. gondii* infected mice) showed increase in the number of damaged DNA in hepatocytes, and the profile of the nuclear DNA in this group was altered with the appearance of a fluorescent streak extending from the nucleus; Group IV (infected immunosuppressed mice) showed marked DNA damage in hepatocytes; Group V (infected mice treated with *T. vulgaris*) showed less damage of hepatocytes; Group VI (Infected immunosuppressed mice treated with *T. vulgaris*) showed less damage of hepatocytes.

4. Discussion

In this study, the hepatoprotective activity of *T. vulgaris* against

Table 1
Effect of *T. vulgaris* treatmenton liver function parameters in sera of *T. gondii* infected mice.

Experimental Groups (n = 10)	Liver function parameters				
	ALT (IU/L)	AST (IU/L)	ALP (IU/L)	Total bilirubin (mg/dL)	Total protein (g/dL)
Group I (non-infected, non-treated)	23.20 ± 5.61	37.80 ± 41.15	95.20 ± 5.19	0.80 ± 0.12	6.69 ± 0.77
Group II (non-infected + *T. vulgaris*)	21.90 ± 3.16[a]	35.80 ± 10.55[a]	91.40 ± 91.72[a]	0.78 ± 0.52[a]	7.01 ± 0.15[a]
Group III (infected-non-immunosuppressed)	51.30 ± 4.42[b]	67.40 ± 14.36[b]	188.90 ± 32.12 [b]	2.30 ± 0.10[b]	4.00 ± 0.10[b]
Group IV (infected-immunosuppressed)	66.80 ± 21.26[b,c]	88.30 ± 17.25[b,c]	229.60 ± 34.71[b,c]	4.10 ± 0.16[b,c]	3.38 ± 0.05[b,c]
Group V (infected-non-immunosuppressed + *T. vulgaris*)	36.90 ± 6.18[c]	41.80 ± 7.22[a,c]	119.50 ± 71.19[c]	1.96 ± 0.12[c]	5.99 ± 0.68[c]
Group VI (infected-immunosuppressed + *T. vulgaris*)	43.10 ± 7.33[d]	44.90 ± 9.32[a,d]	159.50 ± 71.19[d]	2.68 ± 0.60[d]	4.40 ± 0.50[d]

Data were expressed as mean ± SD. [a]: No significant difference compared with Group I; [b]: Significant difference compared with Group I; [c]: Significant difference compared with Group III; [d]: Significant difference compared with Group IV.

Table 2
Antigenotoxic effect of *T. vulgaris* in liver cells of mice infected by *T. gondii* assessed by comet assay parameters.

Experimental Groups (n = 10)	Comet assay parameters			
	% Tailed cells	% Tail DNA	Tail length (μm)	Tail moment (Unit)
Group I (non-infected, non-treated)	3.6 ± 0.9	1.57 ± 0.30	1.44 ± 0.05	2.26 ± 0.40
Group II (non-infected + *T. vulgaris*)	3.1 ± 0.9[a]	1.44 ± 0.50[a]	1.38 ± 0.10[a]	2.17 ± 0.20[a]
Group III (infected-non-immunosuppressed)	12.3 ± 1.9[b]	4.85 ± 0.30[b]	4.51 ± 0.20[b]	21.87 ± 1.00[b]
Group IV (infected-immunosuppressed)	22.0 ± 1.6[b,c]	6.46 ± 0.40[b,c]	8.13 ± 0.60[b,c]	52.52 ± 5.00[b,c]
Group V (infected-non-immunosuppressed + *T. vulgaris*)	5.2 ± 1.7[c]	1.82 ± 0.10[a,c]	1.59 ± 0.30[a,c]	2.89 ± 0.40[a,c]
Group VI (infected-immunosuppressed + *T. vulgaris*)	10.2 ± 1.3[d]	4.21 ± 0.20[d]	3.79 ± 0.20[d]	15.95 ±1.00[d]

Data were expressed as mean ± SD. [a]: No significant difference compared with Group I; [b]: Significant difference compared with Group I; [c]: Significant difference compared with Group III; [d]: Significant difference compared with Group IV.

T. gondii infection in experimentally infected mice was evaluated. The efficacy of a hepatoprotective drug is dependent on its ability to reduce the harmful effect with the healing of liver parenchyma and regeneration of hepatocytes or restore the normal hepatic physiology that has been changed by this parasitic infection.

The effect of *T. gondii* on liver tissue showed a mild degree of inflammation in the infected immunocompetent group and progressed from moderate to severe in the infected immunosuppressed group compared with the uninfected controls. The same histopathological features were more or less reported by several investigators[2,21]. In chronic toxoplasmosis, *T. gondii* cysts containing low metabolically active bradyzoites may persist in the host tissues for years without causing any local inflammatory reaction, controlled mainly by cellular immune mechanisms[22]. In immune disturbed host, *Toxoplasma* tissue cysts may rupture, and the bradyzoites will transform to the active tachyzoites which rapidly infect neighboring cells, multiply, proliferate in specified parasitophorous vacuoles till the cells rupture and disseminate throughout the tissues producing larger lesions[23].

In this study, ethanol extract of *T. vulgaris* improved the pathological lesions induced by *T. gondii*. The noticeable restoration to normal hepatocytes could be attributed to its active constituents, thymol and carvacrol that stimulate the immune responses and have potent antioxidant, anti-inflammatory, antihepatotoxic and hepatoprotective activities[13,24]. In addition, these phenolic compounds interfere with cell metabolism and inhibit protein or DNA synthesis[17]. They can alter the cell's membrane permeability in addition to having an effect on the membrane organization and the surface electrostatics, resulting in release of membrane associated materials from the cells to the external medium and causing destruction of the pathogenic organisms[25]. It was suggested that treatment of the parasitic lesions with hydroalcoholic extract of *T. vulgaris* stimulates natural killer cells activity and releases nitric acid and tumor necrosis factor (TNF-α) from macrophages[26]. TNF-α plays a crucial role in controlling the infection caused by *T. gondii* because it can activate CD8+ T cytotoxic cells to transform into major cytotoxic effector cells for destroying tachyzoite-infected cells, restricting parasite dissemination throughout acute infection and inhibiting cyst formation throughout chronic infection[27,28].

Additionally, hepatoprotective activity of *T. vulgaris* against *T. gondii* was assessed by measuring liver function parameters. *T. gondii* infected mice showed a significant elevation in ALT, AST, and ALP that reflects the hepatocellular injury and necrosis due to the parasite replication resulting in a leakage of the liver enzymes into circulation and elevation in their levels in the blood. These results were in agreement with El-Sayed *et al*.[8] who reported a significant rise associated with *Toxoplasma* infection. Total serum bilirubin was also of high value in the infected group compared with non-infected controls; this may be because liver damage impairs the body's ability to get rid of itself from bilirubin[29]. Moreover, serum total protein concentration decreased in the infected group, documenting the association of liver dysfunction with *Toxoplasma* infection. In the current study, *T. vulgaris* restored the values of liver function parameters near to the normal levels with the healing of liver parenchyma and regeneration of hepatocytes. Restoration of the previous parameters may be via suppression of the oxidative stress induced by the hepatotoxic agent and enhancement of antioxidant defense system as *T. vulgaris* has antioxidant activity against a variety of free radicals, especially reactive oxygen species (ROS) which are considered the important cause of liver tissue damage[12].

Another parameter for evaluating the hepatoprotective effect of *T. vulgaris* extract in this study was the assessment of DNA damage in the liver cells by comet assay. Comet assay, a simple, rapid, visual and biochemical technique, was used for the detection of various genotoxic damages in mammalian cells[20]. It has the ability to detect single/double-strand DNA breaks, DNA crosslink, oxidation and alkylation of bases, base/base-pair damages and apoptotic nuclei in eukaryotic cells[19]. DNA damage can result in multiple lesions including mutations, insertions, deletions, translocations, and loss of chromosomes and essential genetic information. This genome instability may lead to apoptosis and fatal diseases[30]. It was demonstrated that *T. gondii* induced DNA damage in the liver cells agreeing with the other investigators who found that *T. gondii* induced DNA damage in the blood leukocytes, brain and retina[3,31,32]. DNA damage may be attributed to the activation of the host immune response against *T. gondii* infection. In cellular immune response, macrophages liberate nitric oxide, interferon-gamma (IFN-γ), TNF-α and ROS that help the eradication of *T. gondii*, and at the same time they expose target organs to certain endogenous genotoxic agents that react with DNA directly[33].

In treated groups, *T. vulgaris* reduced DNA damage of the liver cells induced by *T. gondii* infection. This reduction might be due to the repair of the induced lesions in which the number of damage cells decreased and the accumulation of DNA damage inhibited[34]. The observed antigenotoxic effect of *T. vulgaris* may be attributed to its major ingredients, carvacrol and thymol essential oils. Aydin *et al*.[35] showed that a short-term treatment of human lymphocytes with low concentrations of these phenolic compounds protected DNA against some genotoxins. As both components of essential oils are considered antioxidants, Slameňová *et al*.[14] noticed the DNA-protective efficiency of these essential oils against DNA lesions induced by a strong oxidant (hydrogen peroxide) on mammalian cells cultured *in vitro*. Also, Collins and Horváthová[36] stated that oxidation of mammalian DNA is a useful marker of oxidative stress, and this can be reduced by supplementation with pure antioxidants or with foods rich in antioxidants.

T. vulgaris ethanol extract exhibited notable hepatoprotective activity against *T. gondii* infection via improving the pathological lesions, alleviating the altered liver function and reducing the genotoxic damage. The need of more studies about its clinical safety must be investigated.

Conflict of interest statement

We declare that we have no conflict of interest.

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