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The protective effect of p-coumaric acid on toluene-induced hepatotoxicity, nephrotoxicity and neurotoxicity in rats

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ABSTRACT

Objective. The aim of this study was to determine the protective effect of p-coumaric acid (p-CA) against toluene-induced hepatotoxicity, nephrotoxicity and neurotoxicity in rats. Materials and methods. A total of 32 Sprague-Dawley male rats, 8 in each group, were used. 4 groups were formed as control, toluene, p-CA and toluene+p-CA. Animals in the control group, toluene group and p-CA group were given 0.9% NaCl, 0.9 mg/kg b.w toluene and 100 mg/kg b.w p-CA orally for 21 days, respectively. The animals in toluene+p-CA group were received p-CA for 3 days and from day 4, toluene and p-CA were applied together daily until day 25. On the 25th day, the study was terminated, blood and tissue samples were collected. Aspartate aminotransferase (AST), alanine aminotransferase (ALT) and creatinine levels in serum, glutathione peroxidase (GSH-Px) activity and malondialdehyde (MDA) and glutathione (GSH) levels in the tissue samples were determined. Results. In this study, it was determined that there were significant increases in ALT and AST activities, and creatinine levels in toluene-induced group compared to control group. Moreover, there was a decrease in the GSH-Px activities and GSH levels, and an increase in the MDA levels compared to the control group. However, in the toluene+p-CA group, significant decreases in aminotransferases activities, creatinine and MDA levels, and significant increases in GSH-Px activities and GSH levels were determined compared to the toluene group. Conclusions. It has been determined that p-CA has a protective effect against toluene-induced hepatotoxicity, nephrotoxicity and neurotoxicity.

Keywords: Brain; coumaric acid; kidney; liver; oxidative stress; toluene (Source: CAB).

RESUMEN

Objetivo. El objetivo de este estudio ha sido determinar el efecto protector del ácido p-cumárico (p-CA) contra la hepatotoxicidad, nefrotoxicidad y neurotoxicidad inducida por tolueno en ratas. Materiales y métodos. Se utilizaron un total de 32 ratas macho Sprague-Dawley, 8 en cada grupo. Se formaron 4 grupos: el de control, tolueno, p-CA y tolueno + p-CA. Los animales del grupo de control, el grupo de tolueno y el grupo de p-CA recibieron NaCl al 0,9%, 0,9 mg / kg de peso corporal de tolueno y 100 mg / kg de peso corporal de p-CA por vía oral durante 21 días, respectivamente. Los animales del grupo tolueno + p-CA recibieron tolueno y p-CA durante 3 días y desde el día 4, el tolueno y el p-CA se aplicaron juntos diariamente hasta el día 25. El día 25, se terminó el estudio, se tomaron muestras de sangre y tejido. Se determinaron los...
Organic solvents such as toluene, benzene and xylene pose a great risk to public health as they are widely used in a variety of industries such as construction, manufacturing, painting, solvent degreasing, cleaning products, and various other applications. They are classified as volatile organic compounds (VOCs) and can be rapidly absorbed through inhalation, skin contact or ingestion. More than 100 million people are exposed to these solvents every day, with significant occupational and non-occupational exposure levels. Exposure to VOCs has been associated with numerous health effects, including respiratory tract irritation, headaches, dizziness, nausea, and organ damage.

**INTRODUCTION**

Organic solvents such as toluene, benzene and xylene are widely used in various industries, posing a risk to public health due to their potential for inhalation, skin contact, and ingestion. In this study, we aimed to investigate the protective effect of p-coumaric acid (p-CA) on toluene-induced hepatotoxicity, nephrotoxicity, and neurotoxicity in rats. Toluene is a commonly used industrial solvent, known to cause oxidative stress and damage to the liver, kidneys, and nervous system. p-CA is a phenolic compound commonly found in fruits, vegetables, and beverages, known for its antioxidant properties. The study design involved administering p-CA and toluene to Sprague-Dawley rats and monitoring their response.

**MATERIALS AND METHODS**

A total of 32 male rats weighing approximately 200-300 g were divided into four groups of 8 animals each (Table 1). All animals were anesthetized with 2-3% isoflurane (inhalation). The study was terminated at the 25th day of the experiment. The design of the experimental study is shown in Table 1. The treatments were as follows: Control, 0.9 % NaCl by gavage (1 mg/kg); 0.9 mg/kg b.w toluene by gavage; 100 mg/kg/b.w p-CA by gavage; 4-24. Toluene+p-CA. The experiment was carried out according to decision at the meeting of the Animal Experiments Local Ethics Committee of Burdur Mehmet Akif Ersoy University, Turkey (Ethics No:126-01/04/2015).

**Experimental animals & design.** The animals were euthanized by cervical dislocation under anesthesia. Blood and tissue samples were collected. The study was terminated at the 25th day of the experiment. The design of the experimental study is shown in Table 1. The treatments were as follows: Control, 0.9 % NaCl by gavage (1 mg/kg); 0.9 mg/kg b.w toluene by gavage; 100 mg/kg/b.w p-CA by gavage; 4-24. Toluene+p-CA. The experiment was carried out according to decision at the meeting of the Animal Experiments Local Ethics Committee of Burdur Mehmet Akif Ersoy University, Turkey (Ethics No:126-01/04/2015).

**Table 1. The design of experimental study**

| Groups                  | Days | Treatments                  |
|------------------------|------|-----------------------------|
| Control                | 1-24 | 0.9 % NaCl by gavage (1 mg/kg) |
| Toluene                | 1-24 | 0.9 mg/kg b.w toluene by gavage |
| p-CA                   | 1-24 | 100 mg/kg/b.w p-CA by gavage |
| Toluene+p-CA           | 1-24 | 0.9 mg/kg b.w toluene by gavage + 100 mg/kg/b.w p-CA by gavage |

**Experimental aspects.** The rats were assigned to four experimental groups: control, toluene, p-CA, and toluene+p-CA. Daily treatments were administered as follows: control group received 0.9% NaCl by gavage (1 mg/kg); the toluene group received 0.9 mg/kg b.w toluene by gavage; the p-CA group received 100 mg/kg/b.w p-CA by gavage; and the toluene+p-CA group received 0.9 mg/kg b.w toluene by gavage + 100 mg/kg/b.w p-CA by gavage. The design of the experimental study is shown in Table 1. All animals were anesthetized with 2-3% isoflurane (inhalation). The experiment was terminated at the 25th day of the experiment. The design of the experimental study is shown in Table 1. The treatments were as follows: Control, 0.9 % NaCl by gavage (1 mg/kg); 0.9 mg/kg b.w toluene by gavage; 100 mg/kg/b.w p-CA by gavage; 4-24. Toluene+p-CA. The experiment was carried out according to decision at the meeting of the Animal Experiments Local Ethics Committee of Burdur Mehmet Akif Ersoy University, Turkey (Ethics No:126-01/04/2015).

**Materials and methods.** The animals were euthanized by cervical dislocation under anesthesia. Blood and tissue samples were collected. The study was terminated at the 25th day of the experiment. The design of the experimental study is shown in Table 1. The treatments were as follows: Control, 0.9 % NaCl by gavage (1 mg/kg); 0.9 mg/kg b.w toluene by gavage; 100 mg/kg/b.w p-CA by gavage; 4-24. Toluene+p-CA. The experiment was carried out according to decision at the meeting of the Animal Experiments Local Ethics Committee of Burdur Mehmet Akif Ersoy University, Turkey (Ethics No:126-01/04/2015).

**Ethical aspects.** The research was carried out according to decision at the meeting of the Animal Experiments Local Ethics Committee of Animal Production and Experimental Research Center and experimental applications were made in the same place. The animals were euthanized by cervical dislocation under anesthesia. Blood and tissue samples were collected. The study was terminated at the 25th day of the experiment. The design of the experimental study is shown in Table 1. The treatments were as follows: Control, 0.9 % NaCl by gavage (1 mg/kg); 0.9 mg/kg b.w toluene by gavage; 100 mg/kg/b.w p-CA by gavage; 4-24. Toluene+p-CA. The experiment was carried out according to decision at the meeting of the Animal Experiments Local Ethics Committee of Burdur Mehmet Akif Ersoy University, Turkey (Ethics No:126-01/04/2015).

**Discussion.** The study results showed significant increases in the activities of ALT and AST, and creatinine levels in serum and GSH-Px and GSH levels in tissue samples after treatment with toluene. In contrast, treatment with p-CA led to a decrease in these parameters. In addition, MDA levels were increased in the toluene group, while the toluene+p-CA group showed a significant decrease. These findings suggest that p-CA has a protective effect on toluene-induced toxicity, possibly by scavenging free radicals and preventing oxidative stress.

**Conclusion.** In conclusion, the results of this study indicate that p-coumaric acid has a protective effect on toluene-induced hepatotoxicity, nephrotoxicity, and neurotoxicity in rats. Further studies are needed to explore the mechanism of action of p-CA in the context of oxidative stress and to determine its potential as a therapeutic agent in toluene exposure.
Biochemical estimations. Blood samples were taken into tubes with and without EDTA. They were centrifuged for 10 minutes at 4000 rpm. Aspartate aminotransferase (AST), alanine aminotransferase (ALT) and creatinine in blood were measured in Gesan Chem 200 autoanalyzer (Gesan chem 200 Gesan Production srl, Campobello, Italy). Kinetic UV optimized The International Federation of Clinical Chemistry (IFCC) methods were used in ALT and AST measurements and Jaffé method was used in creatinine measurement (17).

Preparation of tissue samples. The tissue samples were prepared for homogenization by washing with 0.9% ice-cold isotonic saline. Buffer solution was prepared as follows: 140 mM KCl, 10 mM NaHCO₃, 3 mM KH₂PO₄ and 2 mM K₂HPO₄; dissolved in 950 ml of deionized water and adjusted to pH 7.2 with NaOH (SN) and completed to 1000 ml. The tissue samples were homogenized with the buffer (1/10 w/v). For 45 minutes at 15000 rpm and 4°C, homogenates were centrifuged, supernatants were separated and kept at -20°C until analysis.

Estimations of antioxidant/oxidant parameters in brain, kidney and liver tissues. Glutathione (GSH) levels were measured using the method reported by Sedlak and Lindsay (18) and expressed in µmol/g protein. Glutathione peroxidase (GSH-Px) activities were measured according to the method reported by Paglia and Valentine (19) and expressed in U/g protein. Malondialdehyde (MDA) levels were measured according to the method reported by Ohkawa et al (20) and expressed in µmol/g protein. Determination of total protein was performed based on the Biuret method reported by Gornall et al (21).

Statistical evaluation. Data of the study were evaluated using the “SPSS 22.0” program (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY). Results are expressed with arithmetic mean ± standard error of the mean (SEM). To determine the comparisons of means between groups, one-way analysis of variance (ANOVA) was applied. For determination of the differences between the groups, Tukey’s post hoc test was used. p<0.05 was considered as statistically significant.

RESULTS

Significant (p<0.05) increases in serum AST and ALT activities, and creatinine level were detected in toluene group compared to the control. In the toluene+p-CA group, significant (p<0.05) decreases in the activities of AST, ALT and level of creatinine, which were increased when toluene was administered alone, were determined. No significant changes were found in the group where p-CA was administered alone compared to the control (Table 2).

Significant (p<0.05) increases in the levels of MDA and significant (p<0.05) decreases in the levels of GSH and the activities of GSH-Px were detected in the brain, kidney and liver tissues in the toluene group, compared to the control group. In the toluene+p-CA group, significant (p<0.05) decreases in the levels of MDA and significant (p<0.05) increases in the levels of GSH and the activities of GSH-Px were detected in the brain, kidney and liver tissues compared to toluene group (Table 3,4,5).

Table 2. Serum AST,ALT and creatinine activities of the groups.

| Parameters | Groups | Control | Toluene | p-CA | Toluene+p-CA |
|------------|--------|---------|---------|------|--------------|
| AST        |        | 154.57±2.84⁺ | 327.42±6.49⁺ | 150.69±9.98⁺ | 243.17±4.76⁺ |
| ALT        |        | 83.90±0.82⁺ | 147.33±5.38⁺ | 85.34±2.34⁺ | 96.42±0.99⁺ |
| Creatinine |        | 0.50±0.02⁺ | 2.22±0.03⁺ | 0.57±0.03⁺ | 0.89±0.03⁺ |

* Values are expressed as arithmetic mean ± SEM.
** (⁺⁻) shows differences between groups in the same line, p<0.05
p-CA: p-coumaric acid; AST: Aspartate aminotransferase (U/L); ALT: Alanine aminotransferase (mg/dL); Creatinine: mg/dL

Significant (p<0.05) increases in the levels of MDA and significant (p<0.05) decreases in the levels of GSH and the activities of GSH-Px were detected in the brain, kidney and liver tissues in the toluene group, compared to the control group. In the toluene+p-CA group, significant (p<0.05) decreases in the levels of MDA and significant (p<0.05) increases in the levels of GSH and the activities of GSH-Px were detected in the brain, kidney and liver tissues compared to toluene group (Table 3,4,5).

Table 3. GSH and MDA levels and GSH-Px activities in liver tissues of the groups.

| Parameters | Groups | Control | Toluene | p-CA | Toluene+p-CA |
|------------|--------|---------|---------|------|--------------|
| GSH        |        | 14.02±0.65⁺ | 6.34±0.38⁺ | 14.56±0.64⁺ | 10.03±0.29⁺ |
| GSH-Px     |        | 132.08±7.22⁺ | 59.80±3.33⁺ | 114.47±6.10⁺ | 88.32±1.65⁺ |
| MDA        |        | 4.09±0.07⁺ | 9.86±0.69⁺ | 3.73±0.22⁺ | 6.38±0.48⁺ |

* Values are expressed as arithmetic mean ± SEM.
** (⁺⁻) shows differences between groups in the same line, p<0.05
p-CA: p-coumaric acid; GSH: Glutathione (µmol/g protein); GSH-Px: Glutathione peroxidase (U/g protein); MDA: Malondialdehyde (µmol/g protein)
**DISCUSSION**

The findings of the present study revealed that p-CA has a protective effect against toluene-induced tissue damage. In this study, it was determined that toluene given to rats at a dose of 0.9 mg/kg b.w for 21 days significantly changed the oxidant/antioxidant balance and increased aminotransferases activities and creatinine level. Results of this study showed that toluene could induce oxidative stress in the brain, liver and kidney tissues. On the other hand, p-CA revealed protective effects by improving the antioxidant system defence, suppressing oxidative stress in tissues.

The liver is the primary organ in which drugs and xenobiotics are primarily metabolized. In the present study, significant (p<0.05) decreases in GSH level and GSH-Px activity; a significant (p<0.05) increase in MDA level were detected in liver samples of toluene group compared to control. In previous studies (22, 23, 24, 25) it was emphasized that toluene causes decrease in the efficiency of the antioxidant systems and increases lipid peroxidation in liver tissues. Mattia et al (22, 23) administered toluene (1.5 mg/kg intraperitoneally) to rats and determined a significant (p<0.05) decrease in GSH level and increase in MDA level in the liver tissues. El-Nabi Kamel and Shehata (24) gave toluene (650 mg/kg single dose) to rats and found a significant (p<0.05) increase in MDA level and decrease in GSH level in the toluene group. Tas et al (25) reported that liver MDA level in the toluene group were significantly (p<0.05) higher than in control group. In the present study, in liver samples significant (p<0.05) increases in GSH-Px activity and GSH level and decrease in MDA level were detected in toluene+p-CA compared to toluene group. There are studies in which p-CA is used as a protector against oxidative damage induced by different agents. Similar to the current study, p-CA in liver tissues increased GSH levels and GSH-Px activities, and decreased MDA levels in previous studies (26,27,28).

The kidney is the primary excretion organ for most xenobiotics. In this study, MDA level was significantly (p<0.05) increased and GSH-Px activity and GSH level were significantly (p<0.05) decreased in toluene group when compared to the control group in the kidney tissues. El-Nabi Kamel and Shehata (24) administered toluene (650 mg/kg b.w) to rats and found a significant (p<0.05) increase in MDA level and a significant (p<0.05) decrease in GSH level in the toluene group. Ahmadizadeh et al (8) reported that rats administered to rats determined a significant (p<0.05) decrease in GSH level in kidney tissues compared to the control. Afravy et al (3) gave toluene (300, 600 and 900 mg/kg intraperitoneally) to the rats and investigated on toluene-induced kidney damage. In the toluene group compared to the control, the researchers stated that there was a significant (p<0.05) dose-dependant increase in MDA level. The results of the present study are agreed with those of previous studies. In the present study, in kidney samples significant (p<0.05) increases in GSH-Px activity and GSH level and decrease in MDA level were detected in toluene+p-CA group compared to toluene group. Similar to the present study, p-CA in kidney tissues increased GSH levels and GSH-Px activities and decreased in MDA levels in previous studies (26,27,28).

Brain is one of the target organs of toluene-induced toxicity due to its lipid-rich characteristics (31). In this study, in brain samples significant (p<0.05) increase in MDA level and significant (p<0.05) decreases in GSH-Px activity and GSH level were detected in toluene group compared to the control group. Mattia et al (22) administered toluene (a single intraperitoneal dose of 1.5 mg/kg b.w) to rats and determined a significant (p<0.05) decrease in GSH levels in brain tissues (hippocampus, cerebellum and striatum). Coskun et al (32) gave toluene (3000 ppm by inhalation for 16 weeks, 8 hour/day, 6 day/week) to rats and detected significant (p<0.05) decrease in GSH-Px activity and significant (p<0.001)
increase in MDA level in sciatric nerve tissues of rats. El-Nabi Kamel and Shehata (24) administered toluene (650 mg/kg a single dose) to rats and found a significant (p<0.05) decrease in GSH level and a significant (p<0.05) increase in MDA level depending on time in the toluene group. Kodavanti et al (33) treated rats with toluene (4, 12 and 24 months old rats with 0, 0.65 or 1 g/kg b.w single oral) and stated that there was a significant (p<0.001) decrease in GSH-Px activities in striatum tissues of 24-month-old rats and hippocampus tissues of toluene-treated 4-month-old rats. Abdel-Salam et al. (31) administered toluene (900 mg/kg b.w/day intraperitoneally) to rats and determined a significant (p<0.05) decrease in GSH level and a significant (p<0.05) increase in MDA level compared to control group. Montes et al. (34) treated mice with toluene (0 or 4000 ppm) for 4 weeks and 30 min in a day by inhalation. They indicated that there was a significant (p<0.05) decrease in GSH/GSSG level in both hippocampus and prefrontal cortex tissues of toluene-treated mice. In the present study, in brain samples significant (p<0.05) decrease in MDA level and significant (p<0.05) increases in GSH-Px activity and GSH level were detected in the toluene+p-CA group compared to toluene group. Similar to the present study, p-CA in brain tissues increased GSH levels and GSH-Px activities and decreased in MDA levels in previous studies (35,36).

In organ damage, significant changes occur in biochemical parameters. Increases in serum ALT and AST enzyme levels indicate liver damage. Creatinine and urea are markers of kidney damage or failure. Serum aminotransferase levels increase due to hepatitis, cirrhosis, liver cancer, and toxicity of drugs and various xenobiotics (37). In this study, in the toluene group compared to the control, significant (p<0.05) increases in serum ALT and AST activities and creatinine level were detected. Bae and Yoon (38) stated that toluene caused a significant (p<0.01) increase in ALT and AST levels in rat liver tissues. Tas et al. (25) administered 3000 ppm/hour/day toluene with inhalation to male rats for 4 weeks. It is stated that levels of serum ALT and AST were significantly (p<0.05) high in toluene-treated group. Moro et al (39) found that ALT and AST values were significantly (p<0.05 and p<0.001, respectively) higher in subjects exposed to toluene compared to control. Meydan et al (40) stated that there was a significant (p<0.001) increase in serum creatinine levels in toluene group compared to control. Aفرح et al (3) applied different doses of toluene to rats (600 and 900) and reported a significant (p<0.05) dose-dependant increase in creatinine levels of toluene group. Meydan et al (37) reported that in serum ALT and AST levels there was a significant (p<0.001) increase in toluene group compared to the control group. These studies are in line with our results. In the present study, ALT and AST activities in the toluene+p-CA group were significantly (p<0.05) higher than in the toluene group. Similar to the present study, p-CA in serum samples decreased ALT and AST activities, and creatinine level (41,42,43,44).

In this study, it was found that the organs most sensitive to lipid peroxidation are brain, kidney and liver, respectively. This shows that toluene, which is a quite lipophilic solvent, accumulates primarily in lipid-rich tissues. The results of this study showed that toluene caused oxidative stress in brain, kidney and liver tissues at the dose administered and the period indicated. Also, it was found that p-CA has not any toxic effects on these tissues. As a result, it has been determined that p-CA (at the indicated dose and period) has a protective effect against toluene-induced hepatotoxicity, nephrotoxicity and neurotoxicity.

Conflict of Interest

Authors have declared no conflict of interest.

Author’s Contributions

Authors declares the contribution of the authors is equal.

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