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# Ginger and vitamin C as protective agents against oxidative stress and liver injury induced by methyl parathion

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## SUMMARY

Methyl parathion is one of the highly toxic organophosphorus (OP) compounds. It induces hepatotoxicity, which might be related to generation of reactive oxygen species. This study was carried out to investigate the protective roles of vitamins C and ginger against hepatotoxicity induced by methyl parathion in male albino rats.

Sixty male albino rats were randomly divided into 6 groups (ten rats each). Group I was considered as controls. Animals of groups II, III and IV were given methyl parathion (2 mg/kg), ginger (200 mg/kg) and vitamin C (100 mg/kg) respectively. Groups V and VI were given ginger (200 mg/kg) and vitamin C (100 mg/kg) respectively 2 hours before methyl parathion administration. All animals were treated orally, once daily, for four weeks. Blood and liver samples were obtained for biochemical, immunohistochemistry and histopathological examinations.

Administration of either ginger or vitamin C along with methyl parathion significantly reduced the alanine aminotransferase (ALT) and malondialdehyde (MDA) levels in rats compared to those only treated with methyl parathion. Treatment with either ginger or vitamin C in combination with methyl parathion resulted in increased level of reduced glutathione compared to the methyl parathion treated group. However, oral ginger significantly increased glutathione-*S*-transferase levels compared to the control group, and this may outbalance the protective value of ginger over vitamin C to guard against liver injury and oxidative stress. The immunohistochemical and histopathological examinations showed that ginger or vitamin C combination with methyl parathion resulted in less hepatocytes degeneration and milder portal tract infiltration compared to the methyl parathion group.

In conclusion, pre-treatment with either ginger or vitamin C appears to alleviate methyl parathion-inducted hepatotoxicity. However, their protective role is still limited and needs further investigation.

**Key words:** Methyl parathion – Ginger – Vitamin C – Oxidative stress – Liver injury

## INTRODUCTION

Organophosphorus (OP) compounds are one of the most commonly used pesticides worldwide, the low cost and high efficacy of these compounds are the leading factors for their extensive use in homes and businesses (Garcia et al., 2003).The widespread utilization of OP compounds includes industrial applications as softening agents and agricultural applications as pesticides, insecticides, or acaricides (Minton and Murray, 1988). However, OP poisoning is a major health issue in developing countries. According to the World Health Organization (WHO), OP pesticide poisoning is the most common method of suicide worldwide, with up to 300,000 fatalities annually (Eddleston and Phillips, 2004; Bertolote et al., 2006).

OP pesticide contamination can lead to toxic ef-

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fects on non-target organisms and humans (Wu et al., 2007). Methyl parathion or parathion-methyl is a restricted- use OP insecticide, which is used mainly to control insects and mites on a number of economically important crops, such as cotton, soybeans, and other vegetables (Hawley and Lewis, 1997). Moreover, methyl parathion is classified as extremely toxic by the WHO and United States Environmental Protection Agency, which led to its restriction in the United States since 1978 (Garcia et al., 2003).

The primary toxicity of methyl parathion occurs mainly in the nervous system due to its ability to inhibit acetylcholinesterase, which leads to an excess of acetylcholine and overstimulation of the cholinergic system (Kramer and Ho, 2002). Moreover, previous studies reported toxic effects of methyl parathion in different body organs, such as heart, kidney, and liver (Jaga and Dharmani, 2006). The hepatotoxic effect of methyl parathion was associated with atrophy and necrosis of hepatocytes (Butler and Murray, 1997). Although the exact mechanism of methyl parathion-induced tissue injury is not fully understood, previous studies reported that it may result from pesticide- induced generation of reactive oxygen species (Bagchi et al., 1995; Edwards et al., 2013).

Vitamin C (ascorbic acid) is one of the water soluble vitamins, and is also a low molecular weight antioxidant that protects the cellular compartment from free radicals (Jurczuk et al., 2007) and chlorpyriforms-induced oxidative stress through inhibition of lipid peroxidation (Verma et al., 2007). Ginger belongs to the family Zingiberaceae, and has powerful antioxidant properties. Animal models showed that ginger significantly lowered induced lipid peroxidation and raised the levels of antioxidant enzymes, together with serum glutathione (Ahmed et al., 2000; El-Sharaky et al., 2009).

Given that both substances have antioxidative properties, it has been proposed that vitamin C and ginger may alleviate methyl parathion-induced oxidative damage and hepatotoxicity. A recent report from (Uzunhisarcikli and Kalender, 2011) showed that treatment with a combination of vitamins C and E decreased methyl parathion-induced hepatotoxicity, but did not result in complete protection. Similar results were reported in malathion-induced hepatotoxicity (Kalender et al., 2010).

Until now, there are scanty reports regarding the efficacy of vitamin C and ginger on methyl parathion-induced hepatotoxicity. Therefore, we aimed to investigate the protective roles of vitamins C and ginger against hepatotoxicity induced by methyl parathion in rats.

## MATERIALS AND METHODS

Technical grade methyl parathion was obtained from Kafr El-Zayat Chemical Co. (Kafr El-Zayat, Egypt). Thiobarbituric acid, 1, 1, 3, 3–tetraethoxypropane, oxidized glutathione, reduced glutathione; l-chloro-2, 4-dinitrobenzene, and glutathione reductase enzyme were obtained from Sigma-Aldrich Chemical Co. (St. Louis, USA). Reduced nicotinamide adenine dinucleotide phosphate, survivin and caspase-3 were obtained from Bark Chemical Co. (Northampton, UK) , Novus Biologicals Co. (Littleton, USA) and Neo Markers Fremont CA, Lab Vision), respectively. (All other reagents were of analytical grade and were obtained from ADWIC Chemical Co. (Cairo, Egypt).

### *Animals*

Sixty adult male albino rats weighing (200 ± 20 g) were used in this study. Animals were obtained from the animal house of the Faculty of Medicine, Tanta University, Tanta, Egypt. They were housed under standard conditions of temperature (23 ± 2° C) and lighting (12 h light/dark cycles) and were allowed free access to food and drinking water. All rats received care in accordance with the rules and regulations of the Medical Research Ethics Committee of Faculty of Medicine, Tanta University.

The animals were randomly divided into six groups (ten rats each). Group I animals served as a control. Animals of groups II, III and IV received methyl parathion (2 mg/kg), ginger (200 mg/kg) and vitamin C (100 mg/kg) respectively. Groups V and VI rats were given ginger (200 mg/kg) and vitamin C (100 mg/kg) respectively, 2 hours before methyl parathion administration. All animals were treated orally, once daily, for four weeks. At the end of the treatment period, the overnight-fasted rats were anaesthetized by diethyl ether and blood samples were withdrawn from the heart. Animals were sacrificed by cervical dislocation, dissected and their livers were removed.

### *Liver Enzymes activity*

Blood samples were centrifuged at 3000 rpm for 10 minutes; then the sera were used for determination of serum alanine aminotransferase (ALT) according to the method of (Reitman and Frankel, 1957).

Portions of the liver were immediately washed in cold saline and used for determination of lipid peroxidation products, reduced glutathione (GSH), glutathione reductase (GR), glutathione peroxidase (GPx) and glutathione-*S*- transferase (GST) enzymes. Livers were homogenized in ice-cold 0.15 M KCl (10% w/v). The levels of malondialdehyde (MDA) were measured by thiobarbituric acid test (Ohkawa et al., 1979). The breakdown product of 1,1,3,3- tetraethoxypropane was used as a standard. Liver GSH levels were measured with 5,5-dithiobis-(2-nitrobenzoate) at 412 nm (Ellman, 1959). The enzyme activities of GR, GPx and GST were determined in post-mitochondrial fractions of the liver, which were separated by sequential centrifugation. In brief, liver homogenates were centrifuged at 600 g for 10 min at 4°C to remove crude fractions. Then, supernatants were centrifuged at 10,000 g for 20 min to obtain the post- mitochondrial fractions. The enzyme activities of GR (Carlberg and Mannervik, 1985), GPx (Paglia and Valentine, 1967) and GST (Habib and Jakoby, 1981) were measured using NADPH, cumene hy-

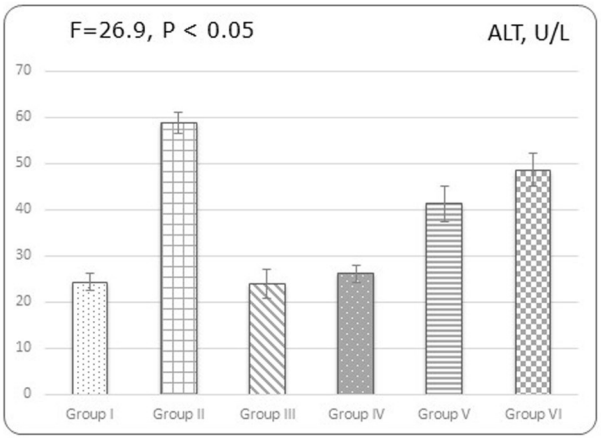


**Figure (1 A) :** Pairwise significant differences ($p < 0.05$) were detected between: **Group I** and each of Group II, V and VI; **Group II** and each of other groups; **Group III** and each of Group II, V and VI; **Group IV** and each of Group II, V and VI; **Group V** and each of Group I, II, III and IV; **Group VI** and each of other groups.

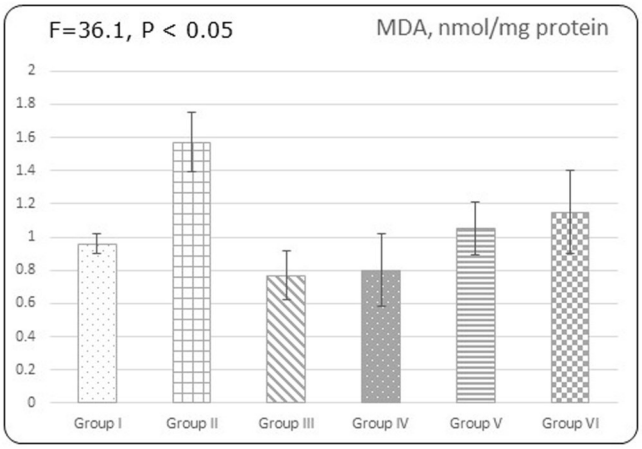


**Figure (1 B) :** Pairwise significant differences ($p < 0.05$) were detected between: **Group I** and Group II; **Group II** and each of other groups; **Group III** and each of Group II, V and VI; **Group IV** and each of Group II, V and VI; **Group V** and each of Group II, III and IV; **Group VI** and each of Group II, III and IV.

**Group I** : control. **Groups II** : methyl parathion treated , **Group III**: ginger treated , **Group IV** : vitamin C treated, **Group V** : methyl parathion and ginger treated and **Group VI** : methyl parathion and vitamin C treated

droperoxide and 1-chloro-2,4- dinitrobenzene, respectively, as substrates.

***Histological study***

Portions of liver samples were fixed in 10% formalin-saline, embedded in paraffin wax, cut, stained with hematoxylin and eosin (H&E) according to the method of (Bancroft and Stevens, 1975) and examined by light microscopy.

***Immunohistochemistry study***

For immunohistochemical study, the 5um sections were deparaffinized in xylol and rehydrated with a graduated series of ethanol solutions and incubated with 3% hydrogen peroxide to block the endogenous activity of peroxidase. Antigen retrieval was carried out by putting the slides in a microwave for 20 minutes.

Primary rabbit anti-rat caspase-3 antibody directed against activated caspase-3 was applied to slides of liver sections and incubated for two hours. The sections were then rinsed three times in PBS and incubated with goat anti rabbit peroxidase-conjugated secondary antibody (Peroxidase–labelled streptavidin) for one hour and rinsed again three times in PBS. The immunoreactivity was visualized by applying streptavidin peroxidase as 3,3 Diaminobenzidine (DAB)- hydrogen peroxide as a chromogen. Counterstaining was performed by haematoxylin. Caspase 3 positive hepatocytes portrayed brown coloration in their cytoplasm. For negative control, the primary antibody was replaced by phosphate buffer solution (Bancroft and Gamble, 2008).

Survivin antibody was added to the slides, then incubated overnight at 4°C with it. After washing with phosphate buffer solution, sections were incubated with biotinylated goat anti rabbit secondary antibody for 30 minutes, followed by streptavidin peroxidase conjugate for 30 minutes, and then incubated with diaminobenzidine chromogen to detect immunoreactivity. Mayer's hematoxylin was used for counterstaining. Positive immune reaction was detected as brown coloration of the nucleus and cytoplasm of the hepatocytes. Negative controls were done using the same steps except that phosphate buffered saline was applied instead of the primary antibodies (Bancroft and Gamble, 2008).

***Statistical analysis***

Statistical analysis was performed using the Statistical Package for Social Sciences for Windows (SPSS Inc., Chicago, IL, USA, Version 16.0). The results were recorded as mean and standard deviation for each group, and then the differences between treated and control groups were statistically evaluated using one-way analysis of variance (ANOVA) test. Significance was considered when $p \leq 0.05$.

**RESULTS**

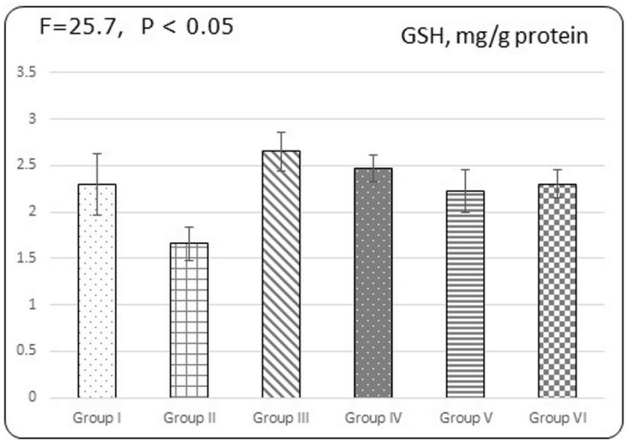


**Figure (1 C) :** Pairwise significant differences ($p < 0.05$) were detected between: **Group I** and each of group II and III; **Group II** and each of other groups : **Group III** and each of group I ,II,V and VI; **Group IV** and group II; **Group V** and each of group II and III; **Group VI** and each of group II and III.

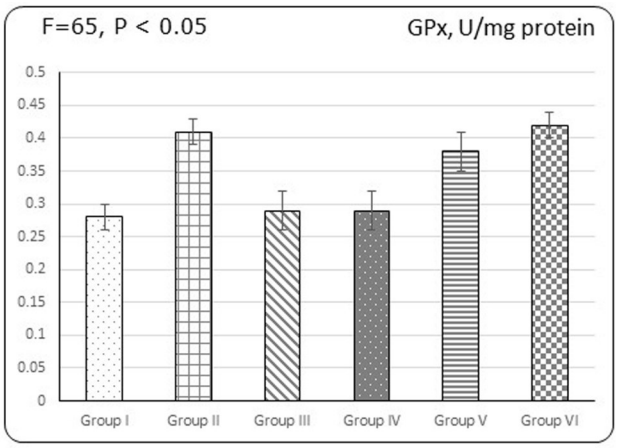


**Figure (1 D) :** Pairwise significant differences ($p < 0.05$) were detected between: **Group I** and each of group II,V and VI; **Group II** and each of group I,III, and IV; **Group III** and each of group II,V, and VI; **Group IV** and each of group II,V, and VI; **Group V** and each of group I,III ,IV and VI; **Group VI** and each of group I,III , IV and V.

Methyl parathion produced significant elevation in liver ALT compared to the control group. This confirms the methyl parathion-induced liver injury. Treatment with ginger or vitamin C only, produced no significant effect on ALT level compared to the control group. Treatment with methyl parathion along with ginger and vitamin C, significantly reduced the ALT levels compared to the methyl parathion-treated group (Fig. 1A).

There was a significant increase in MDA levels in liver tissue in the methyl parathion-treated group compared to the control group, while treatment with methyl parathion, ginger and vitamin C significantly reduced MDA level compared to the group only treated with methyl parathion. (Fig. 1B). Compared to the control group, methyl parathion induced significant reduction in the GSH level. Oral ginger and vitamin C treated groups combined with methyl parathion resulted in increase of GSH level when compared to the methyl parathion only treated group. Interestingly, oral ginger produced a significant increment in the GSH level compared to the control group. On the contrary, vitamin C had a non-significant effect on the control group. (Fig. 1C). The level of glutathione peroxidase and glutathione-*S*-transferase were significantly elevated in methyl parathion treated group when compared to the control group. In methyl parathion treated rats, neither ginger nor vitamin C had a significant effect on the elevated GPx compared to the methyl parathion treated group. On the other hand, further significant elevations of GST were produced by both ginger and vitamin C oral administration in the methyl parathion treated rats when compared to methyl parathion-only treated group. Unlike vitamin C, oral ginger significantly increased the level of GST compared to the control group. The significant effects of ginger on both GSH and GST compared to the control group outbalance the preventive value of ginger over vitamin C to guard against liver injury and oxidative stress (Fig. 1 D, E).

On the other hand, methyl parathion produced a non-significant change in the glutathione reductase enzyme level. Although the ginger on its own had a non- significant effect on GR level, combination of methyl parathion and ginger exhibited a significant elevation of the GR level. Results also revealed that vitamin C has a non-significant effect on GR level either alone or when combined with methyl parathion. (Fig. 1F).

Histological examination of liver sections collected from the control group showed that hepatocytes were arranged into cords radiating from the central vein and separated by blood sinusoids. The hepatocytes exhibited acidophilic cytoplasm and vesicular nuclei (Fig. 2A). In ginger- and vitamin C-treated groups, the same results were obtained compared to the control group with more or less normal liver architecture (Fig. 2B). Histological examination of sections of the liver collected from methyl parathion-treated group showed hydropic degeneration of liver cells with loss of architecture. The hepatocytes appeared swollen with vacuolated cytoplasm, ill- defined cell boundaries and pyknotic nuclei. Some hepatocytes were collapsed and their central veins and blood sinusoids were severely dilated and congested. Many hepatocytes were necrotic lacking their nuclei with fragmentation of cytoplasm. (Fig. 2 C, D). Histological examination of sections of the liver collected from rats given ginger prior to methyl parathion showed normal hepatocytes with mildly dilated sinusoids (Fig. 2E). Histological examination of sections of the liver collected from rats belonging to Vitamin C-

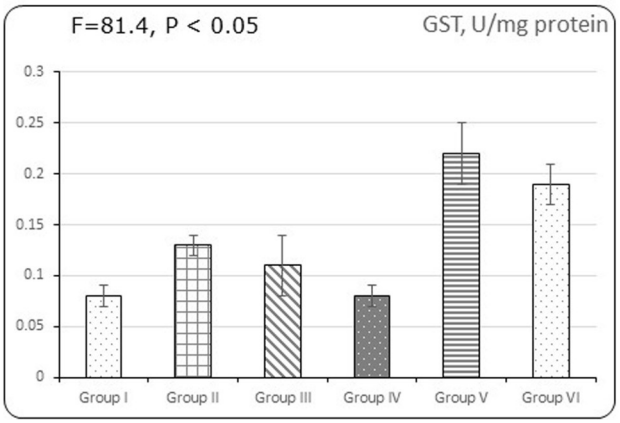


**Figure (1 E) :** Pairwise significant differences ($p < 0.05$) were detected between: **Group I** and each of group II,III,V and VI; **Group II** and each of group I ,IV,V and VI; **Group III** and each of group I ,IV,V and VI; **Group IV** and each of group II,III,V and VI; **Group V** and each of group I, II,III and IV; **Group VI** and each of group I, II,III and IV.

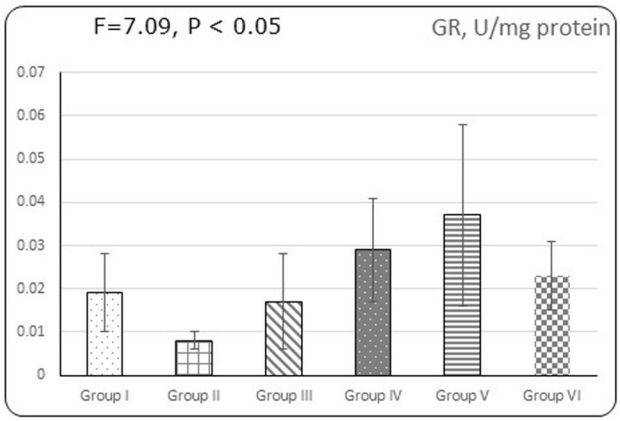


**Figure (1 F) :** Pairwise significant differences ($p < 0.05$) were detected between: **Group I** and group VI; **Group II** and each of group IV and V; **Group III** and group V; **Group IV** and group II; **Group V** and each of group I and III **Group VI** showed no significance with any of other groups

treated group prior to methyl parathion, the liver sections showed mild hydropic degeneration of hepatocytes with mildly dilated central veins (Fig. 2F).

Light microscopic examination of immunostained liver sections for activated caspase 3 showed negative expression in the hepatocytes' cytoplasm of the control group (Fig. 3A). Similarly, ginger and vitamin C treated groups disclosed identical findings (Fig. 3 B, C). However, the methyl parathion-treated group exhibited strong immune reaction in the cytoplasm of many hepatocytes (Fig. 3D). On the contrary, hepatocytes of liver sections of the group treated with ginger and vitamin C prior to methyl parathion depicted mild immune expression in the cytoplasm of many hepatocytes (Fig. 3 E, F).

Light microscopic examination of survivin immunostained liver sections of the control rats revealed mild expression in the cytoplasm of few hepatocytes (Fig. 4A). Moreover, light microscopic examination of survivin immunostained liver sections of ginger-treated and vitamin C-treated groups showed no deviation from results presented in the control group (Fig. 4 B, C). Light microscopic examination of survivin immunostained liver sections of methyl parathion-treated group exhibited negative immune reaction in the cytoplasm of many hepatocytes (Fig. 4D). The administration of ginger and vitamin C prior to methyl parathion depicted strong immune expression of survivin in the cytoplasm of many hepatocytes (Fig. 4 E, F).

## DISCUSSION

Methyl parathion is an extremely toxic substance that exerts its effects in many organs through generating reactive oxygen species (Bagchi et al., 1995; Edwards et al., 2013). The present study showed that oral administration of ginger (200 mg/kg) and vitamin C (100 mg/kg) before methyl parathion administration resulted in significant reduction of methyl parathion-induced hepatotoxicity among male albino rats. In rats treated with methyl parathion, ginger and vitamin C administration significantly reduced ALT levels, MDA levels, and increased GSH levels compared to the methyl parathion-treated group. Histopathological results also supported the biochemical findings, where ginger or vitamin C combined with methyl parathion resulted in less hepatocytes degeneration with mild portal tract infiltration compared to the methyl parathion treated group. Administration of oral ginger significantly increased the level of GST compared to the control group.

OP compounds induce oxidative stress due to free radical generation and changes in the antioxidant defense system, which may result in acute or chronic liver injury (Abdollahi et al., 2004; Altuntas et al., 2004). The previous report by (Khan et al., 2005) showed that OP exposure increased lipid peroxidation and reduced the level of antioxidants. These results were further supported by (Celik and Suzek, 2008), who showed that sub-lethal dosages of methyl parathion affected antioxidant defense systems, such as GSH, GR, superoxide dismutase, and GST in various tissues, including the liver. OP compounds exposure was associated with cloudy swelling, bile stagnation, and focal necrosis of hepatocytes (Fanta et al., 2013). In addition, it has been reported that OP insecticides may

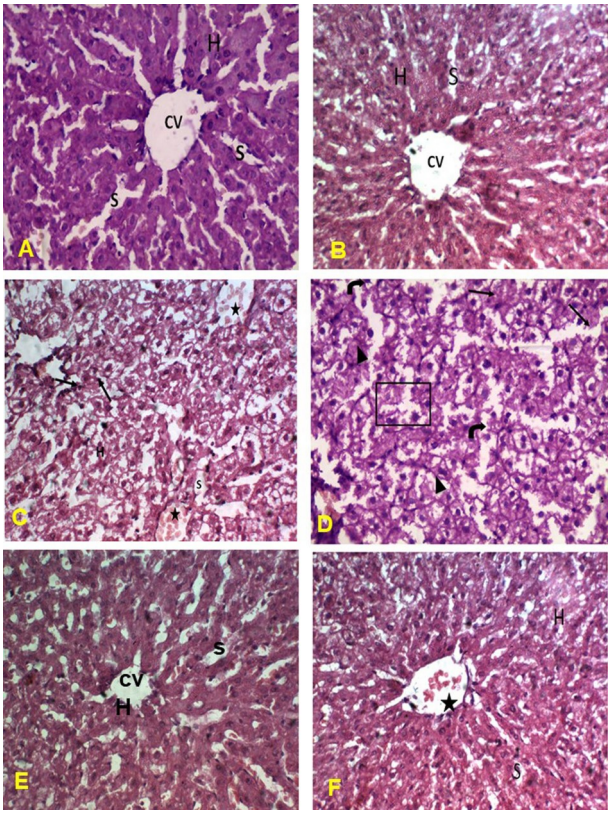


**Fig 2**. Liver sections of the different groups. (A) Control rat showing the hepatocytes (H) with acidophilic cytoplasm and vesicular nuclei. They are arranged into cords radiating from the central vein (cv) and separated by blood sinusoids (S). (B) Rat from the ginger-treated group showing the hepatocytes (H) with acidophilic cytoplasm and vesicular nuclei. They are arranged into cords radiating from the central vein (cv) and are separated by blood sinusoids (S). (C) Rat from methyl parathion-treated group showing loss of architecture with dilated congested central veins (star) and blood sinusoids (S). The hepatocytes (H) are swollen with ill-defined cell boundaries and pyknotic nuclei (arrows). (D) Rat from methyl parathion-treated group showing loss of architecture and many necrotic hepatocytes lacking their nuclei (karyolysis) (arrow head) or disclosing pyknotic one (arrow). Disrupted cell outline (rectangle) and vacuolated and empty cytoplasm in association with its fragmentation into nearby small irregular bodies (curved arrow) also are observed. (E) Rat treated by ginger prior to methyl parathion showing mild dilated hepatic sinusoid (S) and normal hepatocytes (H) around central vein (cv). (F) Rat treated with vitamin C prior to methyl parathion showing hepatocytes (H) with mild hydropic degeneration, mildly dilated central vein (star) and normal sinusoids (S). (A-F: H&E staining, x 400).

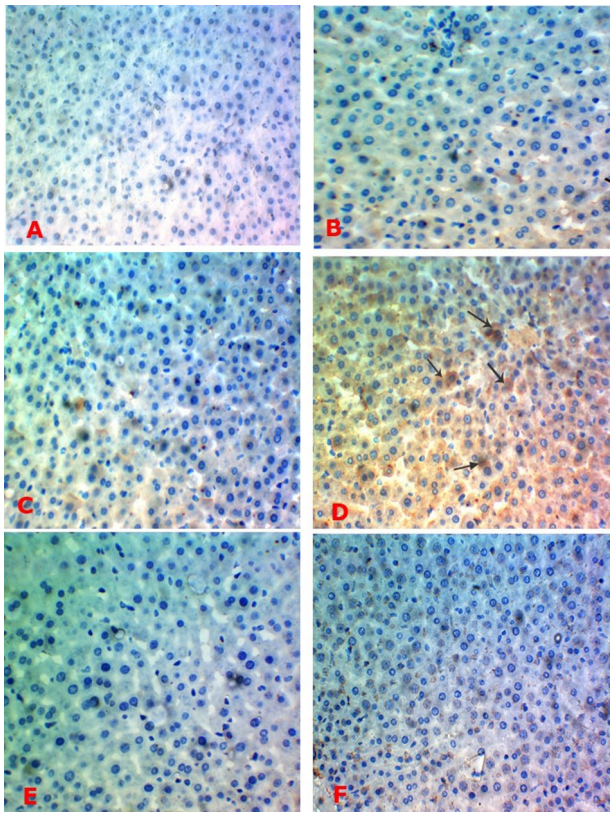


**Fig 3.** Activated caspase3 immunostained liver sections of the different groups. (A) Control group showing negative immune reaction in hepatocytes for activated caspase 3. (B and C) Ginger-treated and Vitamin C-treated groups showing negative immunoreactions for activated caspase 3 in the cytoplasm of hepatocytes (D) Methyl parathion-treated group showing a strong positive 2 immunoreaction for activated caspase 3 in the cytoplasm of many hepatocytes (arrows). (E and F) Animals treated by ginger and methyl parathion and vitamin C plus methyl parathion treated rats showing mild immunoreactions for activated caspase 3 in the cytoplasm of hepatocytes. (A-F= x 400).

increase the enzymatic activities of ALP, ALT, AST, GGT, and LDH, which reflects hepatic dysfunction and damage (Kalender et al., 2010).

In concordance with previous reports, our study showed that methyl parathion produced a significant elevation of ALT level, lipid peroxidation, and antioxidant system enzymes, with a significant reduction in GSH level. Moreover, the methyl parathion-treated group showed hydropic degeneration of liver cells, with swollen hepatocytes and portal tract fibrosis.

Liver cell damage could be produced by different causes: for instance, viral infection, alcohol intake or toxins as pesticides. The cell death types in damaged liver cells include apoptosis, necroptosis, necrosis and autophagy (Neuman et al., 1999). Caspases are known as pro-inflammatory or pro-apoptotic agents (Pop and Salvesen, 2009). They produce intracellular proteolysis cascade, which initiates apoptosis (Morris et al., 2017). Moreover Caspase 3 was stimulated in response to diverse cell death incentives (Porter and Janicke, 1999).

Furthermore, Caspase activity blockage was used in the diagnosis and treatment of numerous diseases, such as steohepatitis (Feldstein and Gores, 2004).

Our results showed elevated caspase 3 activity in the methyl parathion treated group compared with the control ones. The same results were found by Saquib et al. (2012), who noticed increased levels of caspase 3 and caspase 9 in phorate-treated rats. Previously, the liver of carbamate bendiocarb-treated rabbit exhibited positive caspase 3 activity (Petrovova et al., 2015). Moreover, spinosad (an insecticide) produced apoptosis

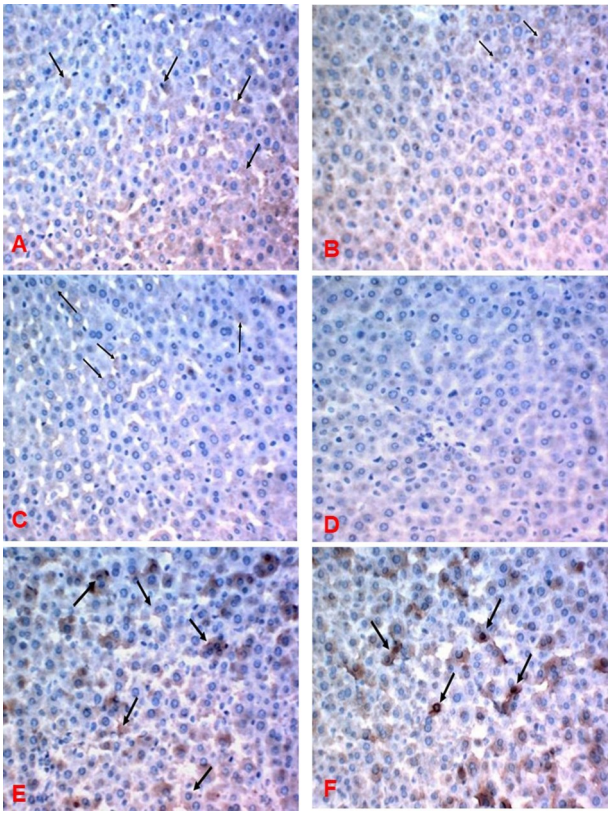


**Fig 4.** Survivin immunostained liver sections of the different groups. (A) Control group showing mild positive immune reaction in hepatocytes for survivin (arrow). (B and C) Ginger-treated and Vitamin C-treated groups showing mild positive immune reaction for survivin in few hepatocytes (arrows). (D) Methyl parathion-treated group showing negative immune reaction for survivin in hepatocytes. (E) Animals treated with ginger and methyl parathion showing strong positive immune reaction for survivin in the cytoplasm of many hepatocytes (note prominence of binucleated hepatocytes) (arrows). (F) Animals treated with vitamin C and methyl parathion showing strong positivity in hepatocytes for survivin (arrows). (A-F= x 400).

in liver cells, which was detected by elevated Caspase 3 immunoreactivity (Piner and Üner, 2013).

Furthermore, (Zhou et al., 2001) detected liver apoptosis in ethanol-treated rat using TUNEL assay, and also showed positive caspase 3 immunoreactivity in the same group.

Clinically, in patients with Hepatitis C virus (HCV) infection (Bantel et al., 2001) detected apoptotic hepatocellular cells and confirmed it with caspase 3, which was detected earlier than TUNEL assay activity.

Vitamin C is an electron donor that acts as a potent water-soluble antioxidant in humans (Mahfouz and Kummerow, 2004). In addition, a previous report by Frei et al. (1989) showed that high concentration of vitamin C in blood is strongly associated with reduced lipid peroxidation. Given the antioxidant property of vitamin C, it has been proposed that a diet rich in vitamin C may be associated with reduced lower risk of cardiovascular disease, stroke and cancer, and with increased longevity (Padayatty et al., 2003). Vitamin C can also be used in guarding against the development of oxidative stress toxicity induced by a number of toxins, such as lead. In addition, the effect of vitamin E and C supplementation on oxidative damage and total antioxidant capacity was reported for workers exposed to lead, cadmium (Tarasub et al., 2012), carbofuran (Sharma and Sharma, 2012) and OP compounds (Chakraborty et al., 1978). A previous study by Uzunhisarcikli and Kalender (2011) examined the protective effect of vitamins C and E combination against methyl parathion- induced hepatotoxicity; they reported a potent protective effect of the combination, with a statistically significant difference for all biochemical parameters between the vitamin-treated group and methyl parathion-treated group. Similar reports showed a significant protective effect of vitamin C in Malathion (Kalender et al., 2010) and Diazinon (Altuntas et al., 2004) toxicity. The present study showed that pre- treatment with oral vitamin C is associated with more favourable biochemical and histological outcomes compared to the methyl parathion only treated group.

Ginger is widely used in traditional herbal medicine due to its rich phytochemistry. Furthermore, the anti-inflammatory properties of ginger raised its potentials in treating a number of degenerative and cardiovascular disorders (Nicoll and Henein, 2009). It has been shown that the bioactive molecules of ginger have a strong antioxidant activity in various modules (Dugasani et al., 2010). A previous animal study by (El-Sharaky et al., 2009) reported that different doses of ginger extract are associated with a significant decrease in lipid peroxidation and activities of the antioxidant enzymes, while enhancing the activities of GR and drug metabolizing enzymes, GSTs and Cytochrome P450. These findings were further supported by a large number of animal studies, which showed significant attenuation of toxin-induced hepatotoxicity by ginger administration (Mashhadi et al., 2013). There is a lack in published literature about the effect of ginger on methyl parathion-induced hepatotoxicity. Ginger alone showed a significant increase in both GSH and GST compared to the control group, and these findings may outbalance the protective value of ginger over vitamin C to guard against liver injury and oxidative stress.

In conclusion, pre-treatment with oral vitamins C or ginger appears to alleviate methyl parathion-inducted hepatotoxicity. However, the significant effects of ginger on both GSH and GST compared to the control group outbalance the protective value of ginger over vitamin C to guard against liver injury and oxidative stress. Further investigation is still needed to assess the exact mechanisms behind the protective role of both compounds against methyl parathion-induced toxicity.

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