Protective Effects of Selenium Against Acrylamide-Induced Hepatotoxicity in Rats

Mehmet Enes Sozen1*, Hasan Basri Savas2 and Gokhan Cuce3

1Alanya Alaaddin Keykubat University, School of Medicine, Department of Histology and Embryology, Antalya, Turkey
2Mardin Artuklu University, School of Medicine, Department of Medical Biochemistry, Mardin, Turkey
3Necmettin Erbakan University, Meram School of Medicine, Department of Histology and Embryology, Konya, Turkey

*Corresponding author: enes.sozen@alanya.edu.tr

INTRODUCTION

Acrylamide (ACR) occurs with the Maillard reaction and is caused by asparagines and sugar reacting, giving the food a brown color and distinctive flavor when cooked at high temperatures. ACR is formed while frying, baking, and roasting. Therefore, it can be found in bread, baked goods, biscuits, toast, cereals, breakfast cereals, french fries, and potato chips. Due to the prevalence of ACR in a wide range of consumed products, there is a significant risk of dietary exposure (Semla et al., 2017).

ACR causes toxic effects by reacting with DNA, hemoglobin, and enzymes in the circulatory system and various target organs (Ibrahim and Ibrahim 2020). The liver is vital for ACR metabolism and toxicity. ACR undergoes oxidative biotransformation by the enzyme cytochrome P450 (CYP2E1) and is converted to glycidamide, an epoxide derivative (Chen et al., 2020). It has been shown that ACR causes injury in the brain, lungs, liver, kidney, heart, and testicles due to increased oxidative stress (Semla et al., 2017; Chorbhel et al., 2015a; Koszucka et al., 2020; Ghasemzadeh et al., 2021). ACR also decreases antioxidant capacity, and trace element levels (Yerlikaya and Yener 2013; Catalgol et al., 2009; Cerrah et al., 2023).

Selenium (Se) is an essential trace element, that is vital in regulating the antioxidant system and it has been reported that ACR exposure decreased Se levels (Hayes et al., 2020). Se takes place in the structure of glutathione peroxidase, which catalyzes the reduction reaction of glutathione and ensures its oxidation (Kielczykowska et al., 2018). Se also eliminates hydrogen peroxide and fatty acid hydroperoxides. Thus, Se contributes significantly to the viability and integrity of cells by protecting membrane lipids and helps prevent cell damage caused by free radicals (Ali et al., 2014). For these reasons, Se may act as an essential protector in preventing oxidative stress and damage induced by ACR exposure.

Apoptosis is a cell-suicide program that maintains tissue homeostasis. Apoptosis is required for various activities, including cell turnover, proper development, and chemical-induced cell death. Bax and Bcl-2 are members of the Bcl-2 protein family, which regulates apoptosis. Bax promotes apoptosis by triggering...
mitochondrial cytochrome c release, whereas Bcl-2 inhibits it. The balance between Bax and Bcl-2 is critical in deciding whether a cell dies or survives (Elmore, 2007).

The present research aims to demonstrate the potential protective effects of Se against ACR toxicity in the liver and blood in a rat toxicity model.

MATERIALS AND METHODS

Study design: This experimental research received ethical approval from the SDU Animal Experiments Local Ethics Committee (decision 17/06, October 23, 2018). Thirty-two male Wistar-Albino rats, sourced from the SDU Experimental Animals Laboratory, were utilized for the study. The rats, aged 9-10 weeks, were stratified into four groups: Control, ACR, Se, and ACR+Se, and subjected to a 28-day experimental protocol. In the Control Group (n=8), oral administration of 1 ml saline solution occurred from day 0 to day 27. The ACR Group (n=8) received an oral solution of 20 mg/kg ACR dissolved in 0.5 cc saline over the same period. The Se Group (n=8) was orally administered a solution of 0.1 mg/kg Se, dissolved in 0.5 cc saline, from day 0 to day 27. The ACR+Se Group (n=8) underwent oral gavage of 20 mg/kg ACR (0.5 cc) and 0.1 mg/kg Se (0.5 cc) from day 0 to day 27. Intraperitoneal induction of general anesthesia (Ketamine 80 mg/kg) was conducted in all animals 24 hours post the final ACR administration (day 28). Following an abdominal incision, exsanguination was carried out by withdrawing blood from the Inferior Vena Cava.

Methods of biochemical analysis: Blood cell count analysis was performed with whole blood in tubes containing Ethylenediaminetetraacetic acid (EDTA). Lymphocytes, leukocytes, and neutrophils were counted. Whole blood taken gel biochemistry tubes were cooled and then centrifuged at 4,000 g for 10 minutes to obtain serum samples (Thermo Scientific SL, 40R, USA). C reactive protein (CRP), Alanine aminotransferase (ALT), Aspartate aminotransferase (AST), and glucose levels were measured on an Abbott Architect c8000 clinical chemistry autoanalyzer using commercial kits (Abbott, Park Ridge, IL). Commercial kits (Rel Assay Diagnostics, Mega Tip, Gaziantep, Turkey) based on a colorimetric method were then used to measure total oxidant status (TOS) (RL0024) and total antioxidant status (TAS) (RL0017) levels by a microplate reader (Biotek Synergy H1, USA). The TOS/TAS ratio was used to calculate the oxidative stress index (OSI) (Savas and Sayar 2021).

Histopathological evaluation of liver: Liver tissues were examined macroscopically after opening the abdomen, fixed, and embedded after processing. 5 µm thick sections were cut and stained with Hematoxylin and Eosin (H&E). Morphological changes were evaluated via a light microscope Nikon H5505 and DS-Fi2 analysis system. Hepatocyte degeneration, sinusoid dilatation, lymphocyte infiltration, and congestion were evaluated in the sections. Histopathological changes were scored for each criterion (as absent =0, mild =1, moderate=2, or severe=3).

Immunohistochemistry: Xylene was used for deparaffinization for 30 min. After antigen retrieval, endogenous peroxidase activity was inhibited with 3% hydrogen peroxide (3%H2O2). Super Block (ScyTek Laboratories, Logan, UT) prevents nonspecific antigen binding for 10 min. The sections were incubated for 60 min with Interleukin 6 (IL-6) (ab208113, Abcam, UK), Anti-B-cell lymphoma 2 (Bcl-2) (PAS-27094, Thermo Fisher Scientific, WA, USA), and Anti-Bcl-2-associated X protein (Bax) (ab79777, Abcam, UK) primary antibodies. The sections were treated with a secondary antibody for 20 min. Streptavidin-peroxidase was used to detect antigen-antibody complex for 20 min. 3-3′-Diaminobenzidine (DAB) chromogen was added for 10 min. Mayer’s hematoxylin was used for counterstaining for 5 min. Then sections staining were evaluated following criteria (0 expresses=no; 1 expresses=weak; 2 expresses= moderate; 3 expresses=intense).

Statistical analysis: For histological and biochemical examination, significant data were compared using one-way analysis of variance (ANOVA) with the Tukey post hoc test. The immunohistochemical analysis results were compared with the Kruskal–Wallis test. Differences between the pairs of groups were assessed with the Mann–Whitney U test. A p-value under 0.05 was considered statistically significant for all findings.

RESULTS

Biochemical parameters: TAS values in the Se group were significantly higher than the control group (p=0.01). There was no significant difference in the ACR+Se and ACR group between the control group in terms of TAS values (p> 0.05). TOS (p=0.003) and OSI (p=0.006) values were significantly higher in the ACR group compared to the control group. There was no significant difference in the Se and ACR+Se groups compared to the control group in terms of TOS and OSI values (p> 0.05). In the ACR group, there was a statistically significant increase in AST and ALT compared to the control group, but AST and ALT levels were significantly lower in the ACR+Se group (p<0.0001). Although glucose levels were slightly elevated in the ACR group compared to the control group, glucose levels decreased significantly in the ACR+Se group (p<0.022) (Table 1).

Histopathological evaluation: Liver sections were used to examine histopathological changes. The typical histological structure was seen in the control and Se group. The histopathological score was significantly higher in the ACR group compared to other groups (p<0.05). The ACR+Se group had a significantly higher histopathological score than the control and Se groups (p<0.05), and there were no differences between the control and Se groups (Fig. 1 and 2).

Immunohistochemistry: ACR caused increased expression of IL-6 (Table 2, Fig. 3) compared to the other groups. IL-6 expression was significantly higher in the ACR+Se group compared to the control group. Also, no statistically significant difference between the control and the Se group was observed. ACR caused increased expression of Bax (Table 3, Fig. 3) compared to the other groups.
Table 1: Comparison of Biochemical and Oxidative Stress Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Control; mean±SD</th>
<th>ACR; mean±SD</th>
<th>Se; mean±SD</th>
<th>ACR+Se; mean±SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lymphocytes</td>
<td>Cells per microliter of blood</td>
<td>1.779±0.899</td>
<td>1.488±0.726</td>
<td>2.713±1.269</td>
<td>1.295±0.665</td>
<td>0.022</td>
</tr>
<tr>
<td>Neutrophils</td>
<td>Cells per microliter of blood</td>
<td>1.364±0.578</td>
<td>1.188±0.712</td>
<td>1.816±1.025</td>
<td>0.804±0.548</td>
<td>0.074</td>
</tr>
<tr>
<td>Neutrophils/ Lymphocytes</td>
<td>Ratio</td>
<td>0.841±0.307</td>
<td>0.840±0.296</td>
<td>0.714±0.301</td>
<td>0.690±0.467</td>
<td>0.736</td>
</tr>
<tr>
<td>Leukocytes</td>
<td>Cells per microliter of blood</td>
<td>3.275±1.509</td>
<td>2.885±1.473</td>
<td>4.714±2.101</td>
<td>2.528±1.151</td>
<td>0.053</td>
</tr>
<tr>
<td>CRP</td>
<td>mg/l</td>
<td>0.380±0.047</td>
<td>0.490±0.112</td>
<td>0.480±0.089</td>
<td>0.463±0.151</td>
<td>0.175</td>
</tr>
<tr>
<td>Glucose</td>
<td>mg/dl</td>
<td>214.550±21.200</td>
<td>245.025±30.708</td>
<td>189.800±27.881</td>
<td>191.800±59.331</td>
<td>0.022</td>
</tr>
<tr>
<td>AST</td>
<td>IU/l</td>
<td>55.300±2.435</td>
<td>76.300±7.344</td>
<td>63.802±2.659</td>
<td>66.80±3.495</td>
<td>0.0001</td>
</tr>
<tr>
<td>ALT</td>
<td>U/l</td>
<td>27.550±2.720</td>
<td>39.300±5.726</td>
<td>27.85±5.42</td>
<td>21.10±4.25</td>
<td>0.000</td>
</tr>
<tr>
<td>Total Antioxidant Status</td>
<td>mmol Trolox equivalent/l</td>
<td>0.909±0.06</td>
<td>0.991±0.12</td>
<td>1.122±0.177</td>
<td>0.988±0.07</td>
<td>0.01</td>
</tr>
<tr>
<td>Total Oxidant Status</td>
<td>μmol H₂O₂ equivalent/l</td>
<td>27.16±4.252</td>
<td>37.88±7.355</td>
<td>31.79±7.191</td>
<td>29.38±7.376</td>
<td>0.003</td>
</tr>
<tr>
<td>Oxidative Stress Index</td>
<td>Ratio</td>
<td>30.02±3.376</td>
<td>39.023±7.547</td>
<td>28.339±6.919</td>
<td>29.44±6.025</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Acrylamide (ACR), Selenium (Se), Alanine aminotransferase (ALT) and aspartate aminotransferase (AST); #: Statistically significant difference with the control group (p<0.05); #: Statistically significant difference with the acrylamide group (p<0.05); !: Statistically significant difference with the selenium group (p<0.05).

Table 2: Immunohistochemical analysis of liver IL-6 staining

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>8</td>
<td>0.25</td>
<td>0</td>
<td>0.75</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Se</td>
<td>8</td>
<td>0.37</td>
<td>0</td>
<td>0.75</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>ACR</td>
<td>8</td>
<td>2.75</td>
<td>3</td>
<td>2.25</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>ACR+Se</td>
<td>8</td>
<td>0.87</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

A significant difference in the IL-6 was detected between the Control group- Acrylamide (ACR) group, the Control group - ACR+Selenium (Se) group, the Se group - ACR group, and between the ACR group and the ACR+Se group (p<0.05).

Table 3: Immunohistochemical analysis of liver Bax staining

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>8</td>
<td>0.25</td>
<td>0</td>
<td>0.75</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Se</td>
<td>8</td>
<td>0.12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ACR</td>
<td>8</td>
<td>2.87</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>ACR+Se</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

A significant difference in the Bax was detected between the Control group- Acrylamide (ACR) group, Control group- ACR+Selenium (Se) group, Se group- ACR group, Se group- ACR +Se group, and between the ACR group and ACR+Se group (p<0.05).

Fig. 1: Histopathological scores of liver tissue that consists of hepatocyte degeneration, sinusoid dilatation, lymphocyte infiltration, and congestion. Different letters indicate statistical significance (p<0.05). Compared by one-way analysis of variance (ANOVA) with the Tukey post hoc test.

Fig. 2: Hematoxylin-Eosin (H&E)-stained liver sections. A: Control group: No significant pathological condition is observed in this group. It represents the normal liver morphology. B: Selenium (Se) Group: This group exhibits a morphology similar to the control group. C-D: Acrylamide (ACR) Group: Histopathological changes caused by the ACR exposure. C: Blonde arrows indicate sinusoid dilatation. D: Blue arrows indicate; hepatocyte degeneration. E: Green arrows indicate; lymphocyte infiltration. F: ACR+Se Group: there may be a protective effect of selenium against acrylamide effects. Scale bar = 100 μm.

Bax expression was significantly higher in the ACR+Se group compared to the control and Se groups. Also, no statistically significant difference between the control and Se group was observed. ACR caused decreased expression of Bcl-2 (Table 4, Fig. 3) compared to the control, Se, and ACR+Se groups.

DISCUSSION

ACR is an important chemical that can lead to a serious increase in oxidative stress and toxic effects due to widespread exposure through nutrition. On the other hand,
Dasdelen molecule is a
and lead to
ax and suppresses cell death
factors cause activation of the caspase cascade a
released into the cytosol by these pores. Then, these
formation. The proapoptotic factors like cytochrome c are
mitochondrial outer membrane and causes a pore
2015,
substances were used against ACR toxicity and the
in
examination of the liver demonstrates that the ACR+Se
group has a decreased histopathological score compared to
the ACR group. It’s thought that Se has a protective
effect against ACR toxicity in the liver. These findings are
in accordance with other studies that antioxidant
substances were used against ACR toxicity and the
damage caused by ACR in the liver was ameliorated by
antioxidant substances (Acaroz et al., 2018, Altinoz et al.,
2015, Ansar et al., 2016, Gedik et al., 2017).
Bax is a proapoptotic effector protein that disrupts the
mitochondrial outer membrane and causes a pore
formation. The proapoptotic factors like cytochrome c are
released into the cytosol by these pores. Then, these
factors cause activation of the caspase cascade and lead to
cell death. Bcl-2 is an antiapoptotic effector protein that
binds and inhibits Bax and suppresses cell death (Peña-
Blanco and García-Sáez 2018). Our results showed that
ACR increased Bax levels and decreased Bcl-2 levels,
indicating increased cell death. Our findings are consistent
with other studies, which showed that ACR has apoptotic
effects in hepatocytes (Seydi et al., 2015, Ghasemzadeh
etal., 2021). It has been found that 50 mg/kg i.p. ACR
exposure caused apoptosis in the liver for 11 days in the
liver and 0.6 mg/kg i.p. Se or 200 mg/kg vitamin E
supplementation decreased this effect (Ghasemzadeh et al.,
2021). In the present study, although there was a
lower dose of ACR exposure, ACR caused apoptosis in
the liver. The reason for this may be the supplementation
of ACR at a low dose but for a longer period in our study.
On the other hand, ACR+Se decreased Bax levels and
increased Bcl-2 levels compared to ACR group; these
findings indicate cell survival. In this way, it’s found that
Se suppresses cell death caused by ACR.
IL-6 is a proinflammatory cytokine and plays a vital
role in inflammation (Drutskaya et al., 2018). Results of
this study showed that ACR increased the IL-6 levels and
caused inflammation, and we know that suppressing
inflammation in the liver decreases liver injury (Dasdelen
etal., 2023, Calis et al., 2022). Like other studies
(Ghorbel et al., 2015b, Elhelaly et al., 2019, Alturfan et al.,
2012, Cerrah et al., 2023), our results showed that
ACR increased IL-6 concentrations. In our study, Se
supplementation decreased IL-6 levels and suppressed
inflammation caused by ACR in the liver.
About 90% of inhaled oxygen is used for oxidative
phosphorylation in humans. The oxygen molecule is a
strong oxidizer. Oxygen routinely forms some
superoxide, hydrogen peroxide, and hydroxyl radicals
during metabolic processes. The organism’s antioxidant
system tries to eliminate these radicals’ harmful effects.
If this balance between the oxidant-antioxidant system is
disturbed, oxidative stress causes damage to cells and
tissues. The measurement of TOS, TAS, and OSI values

---

**Table 4: Immunohistochemical analysis of liver Bcl-2 staining**

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>8</td>
<td>2.87</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td>8</td>
<td>2.75</td>
<td>3</td>
<td>2.25</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>ACR</td>
<td>8</td>
<td>1.12</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>ACR+Se</td>
<td>8</td>
<td>2.37</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

A significant difference in the Bcl-2 was detected between the Control group- Acrylamide (ACR) group, the Selenium (Se) group- ACR group, and between the ACR group and the ACR+Se group (p <0.05).

---

Se is a trace element with essential roles in the antioxidant
system and positively affects immunity. For this reason, Se might protect against the toxic effects of ACR. Our experimental toxicity model aims to demonstrate the possible protective effects of Se, against the potential toxic effects of oral ACR exposure on the liver in rats.

ACR results in a variety of histological abnormalities in the liver (Belhadj et al., 2019, Gedik et al., 2017, Acaroz et al., 2018). ACR causes hepatocyte degeneration, congestion, and lymphocyte infiltration (Belhadj et al., 2019), necrosis (Gedik et al., 2017), sinusoidal dilatation, hyperemia, and Kupffer cell activation (Acaroz et al., 2018). The histopathological examination of the liver demonstrates that the ACR+Se group has a decreased histopathological score compared to the ACR group. It’s thought that Se has a protective effect against ACR toxicity in the liver. These findings are in accordance with other studies that antioxidant substances were used against ACR toxicity and the damage caused by ACR in the liver was ameliorated by antioxidant substances (Acaroz et al., 2018, Altinoz et al., 2015, Ansar et al., 2016, Gedik et al., 2017).

---

**Fig. 3: Liver sections of immunohistochemical staining of Bcl-2, Bax, and IL-6.**
are important to indicate oxidative damage. OSI increase can be evaluated as an indicator of significant oxidative stress and damage (Seydi et al., 2015). It has been reported that 20 mg/kg oral ACR supplementation increased liver TOS levels and decreased TAS levels (Cerrah et al., 2023). In parallel with this study, it was seen in our research that the ACR group caused significantly higher OSI in blood compared to the control group (p=0.032). With the Se supplementation, the OSI values were decreased to a value lower than the control group, and the statistically significant difference with the control group disappeared (p=0.998). For this reason, it can be said that ACR causes a significant increase in the OSI, and additional Se balances the increase in oxidative stress.

In a study, Se significantly increased the levels of glutathione (GSH) and glutathione peroxidase (GPx) and decreased the levels of malondialdehyde (MDA) compared to the group that received only ACR (Teodor et al., 2011). This study in the literature supports our findings in terms of oxidative stress reduction and antioxidant capacity increase with the addition of Se in ACR toxicity, although the measured parameters are different. In a recent study, ACR induced oxidative stress; in the same way, these were suppressed by high doses of Se (Sengul et al., 2021). In this respect, the results of the research support our findings of increased oxidative stress, although different parameters have been measured. A recent experimental study demonstrated that Se is an essential micronutrient with significant antioxidant activity that may be beneficial in reducing ACR formation during high-temperature roasting (Alafeef et al., 2020). These results support our research. A similar recent study revealed that Se nanoparticles (Ch-SeNPs) stabilized with chitosan have strong antioxidant effects, can function stably, and have a protective potential against ACR toxicity in rats (Khiralla et al., 2020). Considering the results of our research showing the properties of Se to reduce ACR toxicity and protect the liver, the application of Se to foods containing ACR in limited numbers should be increased and expanded.

It has been shown that ACR causes an increase in oxidative stress and decreases antioxidant capacity, and naringin reduces the oxidative stress induced by ACR (Gelen et al., 2022). These research results are consistent with our results.

ALT and aspartate AST are general indicators of liver tissue damage. The fact that the AST and ALT values measured in our study increased in the ACR group with a statistically significant difference with the control group and decreased with the addition of Se, indicating that ACR causes liver tissue damage, and Se supplementation has a positive effect on preventing this damage. In this respect, our research is compatible with the literature (Teodor et al., 2011; Sengul et al., 2021).

As it can be understood from the articles we compared in the discussion, the protective role of Se in ACR toxicity has been investigated before (Teodor et al., 2011). However, our research’s original aspect is examining the liver tissue for histopathological changes. Unlike the previous ones, it provides a comprehensive evaluation opportunity by measuring TAS and TOS, a more general indicator, and calculating the OSI instead of measuring a few of the antioxidant enzymes and oxidative damage products.

Conclusions: The histopathological and biochemical evaluation showed that ACR has toxic effects on the liver, and Se supplementation decreases these toxic effects. ACR appears to increase oxidative stress and produce toxic effects significantly. Se is known to be a powerful antioxidant trace element. Oxidative stress has an important role in forming damage and diseases in ACR toxicity. Our research showed that Se has a protective effect on the liver against ACR toxicity. Se supplementation may be protective against toxic effects of ACR such as oxidative stress, inflammation, and apoptosis. Our data should be supported by further clinical studies on volunteers with identified dietary ACR exposure to demonstrate the antioxidant, anti-apoptotic, and anti-inflammatory effects of Se in humans. New research should be conducted for this purpose.

Ethical issue: This experimental research was carried out in the licensed Suleyman Demirel University Animal Experiments Laboratory, with the permission of the Ethics Committee to be obtained from the Animal Experiments Local Ethics Committee of the Rectorate of Suleyman Demirel University (decision 17/06, October 23, 218).

Conflicts of interest: The authors declare no conflict of interest.

Acknowledgments: The authors gratefully acknowledge the Alanya Alaaddin Keykubat University Scientific Research Projects Coordination Office for financial support and Halil Asci, Mehtap Savran, Fatma Nihan Cankara, Ibrahim Aydin Candan, and Yasemin Sahin for contributions. Alanya Alaaddin Keykubat University, Scientific Research Projects Coordination Office, supported this project (Project No: 2019-04-01-MAP03). The preliminary data of this research were presented in summary at the International Harran Health Sciences Congress and 4th International Hippocrates Congress on Medical and Health Sciences in 2020.

Authors contribution: HBS and MES conceived and designed the study. HBS and MES executed the experiment. HBS analyzed the sera. MES and GC analyzed tissue samples. All authors analyzed the results, the paper was critically edited for key intellectual content, and the final version was approved.

REFERENCES


Alturfan AA, Tozan-Becerken A, Sehirli AO, et al., 2012. Resveratrol...
ameliornates oxidative DNA damage and protects against acrylamide-induced oxidative stress in rats. Mol Biol Rep 39: 4589-4596.


Ibrahim MA and Ibrahim MD, 2020. Acrylamide-Induced hepatotoxicity, oxidative stress, and DNA damage in liver, kidney, and brain of catfish (Clarias gariepinus), Environ Toxicol 35: 300–308.


