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INTERACTIONS OF NANOPARTICLES AND BIOLOGICAL SYSTEMS

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Abstract. This article investigates the effects of licorice root (*Glycyrrhiza L.)* syrup on laboratory rats exposed to ionizing gamma radiation, focusing on its potential radioprotective properties. Ionizing gamma radiation induces oxidative stress, characterized by an increase in free radicals and subsequent tissue damage, which can contribute to the development of various diseases such as neurodegenerative, cardiovascular, diabetes and kidney diseases. The body's antioxidant defense mechanisms, including superoxide dismutase (SOD), catalase (CAT) and malondialdehyde (MDA), play crucial roles in combating oxidative stress. Historically recognized for its medicinal properties, licorice root may mitigate the harmful effects of radiation. The research employed Electron Paramagnetic Resonance (EPR) spectroscopy to analyze structural and functional changes in various biological systems under the influence of radiation and other stressors. This investigation aims to provide insights into the protective effects of licorice syrup, contributing to the understanding of potential therapeutic strategies against radiation-induced oxidative damage. As a continuation of the experiments, the levels of antioxidant enzymes in the rat's erythrocytes were measured using various methods. Biochemical analyses conducted on the erythrocytes of the rats indicated positive effects of licorice syrup on the levels of SOD, CAT and MDA.

Keywords: *Licorice syrup, biochemical analyse, ionizing gamma radiation, laboratory rat, EPR spectra.*

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1. Introduction

Ionizing gamma radiation causes significant structural and functional changes in living systems. As a result of these changes, oxidative stress occurs in cells, the amount of free radicals increases and tissue damage ensues. The accumulation of free radicals is a consequence of oxidative stress, which can lead to the pathogenesis of various diseases, including neurodegenerative, cardiovascular, diabetes and kidney diseases (Hasanzadeh

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et al., 2017; Nasibova *et al*., 2015). The body's antioxidant defense system serves as the primary line of defense against the harmful effects of free radicals. Key components of this system include superoxide dismutase (SOD), catalase (CAT) and malondialdehyde (MDA). Licorice root (*Glycyrrhiza L.)* has been recognized for its medicinal properties since ancient times. The aim of this research was to investigate the radioprotective effect of licorice syrup in laboratory rats exposed to ionizing gamma radiation. To date, structural-functional changes arising in various living systems under the influence of ionizing gamma radiation, UV radiation, radioactive contamination and other stress factors have been studied (Nasibova *et al*., 2016, 2021, 2023; Khalilov *et al*., 2011). During our study, we examined the structural and functional changes induced by ionizing gamma radiation in various living systems (Hasanzadeh *et al*., 2017; Nasibova *et al*., 2024). Different biological systems plants and some animal organisms were studied using Electron Paramagnetic Resonance Spectroscopy (Khomutov *et al*., 2014; Mammadova *et al*., 2022; Aliyeva *et al*., 2023; Nasibova *et al*., 2015). In recent years, certain studies involving laboratory rats have been conducted, focusing on the EPR spectra recorded under the influence of stress factors (Nasibova *et al*., 2024; Khalilov *et al*., 2022).

2. Materials and Methods

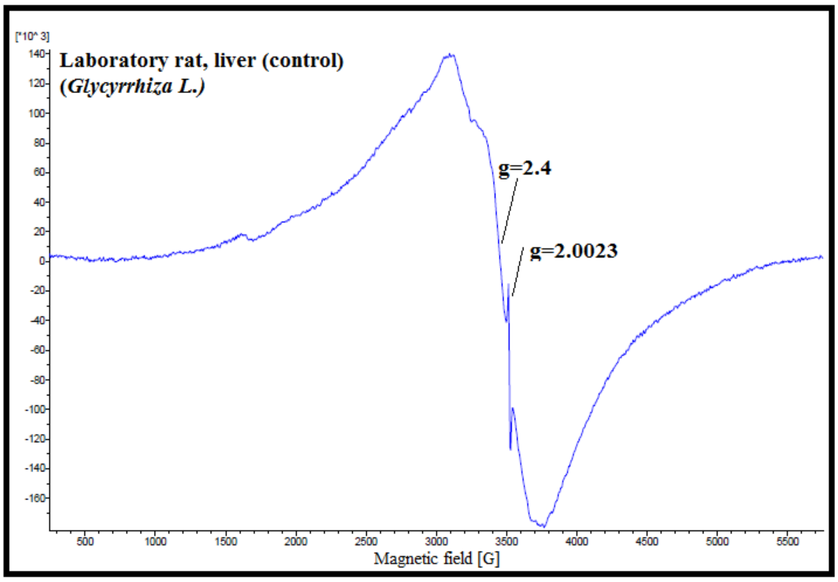
Experiments were conducted using 3-month-old laboratory rats (*Wistar Albino*). These rats are commonly used in medical, pharmacological, genetic and toxicological research, as well as in neurology. The rats were divided into 4 groups, each containing 6 individuals: control - fed with syrup made from licorice root and not irradiated; rats irradiated with a dose of 3 Gy gamma radiation (1) and rats irradiated with a dose of 3 Gy gamma radiation and at the same time fed with licorice syrup (2); rats irradiated with a dose of 6 Gy gamma radiation and fed with licorice syrup; rats irradiated with a dose of 8 Gy gamma radiation and fed with licorice syrup.

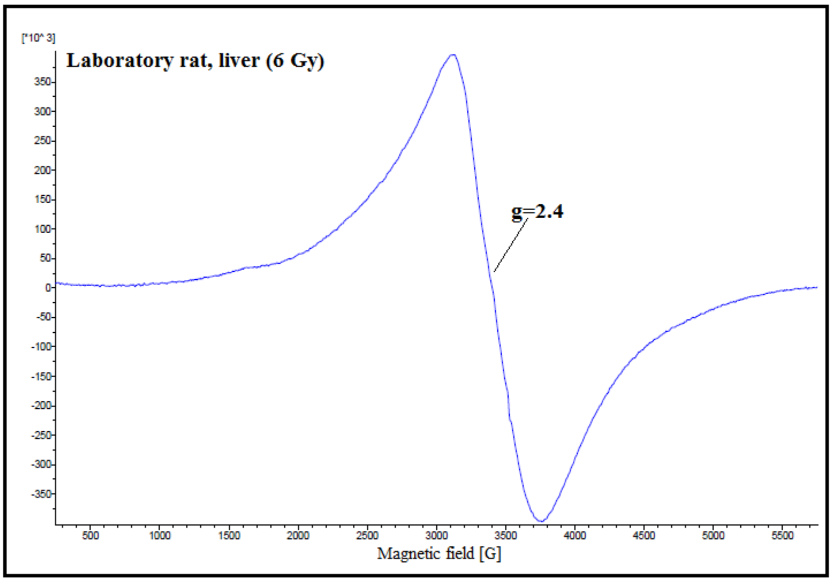
After being kept in the laboratory for 90 days in accordance with bioethical guidelines, the internal organs of the rats (liver, lungs, heart, kidneys and brain) were studied using the Electron Paramagnetic Resonance (EPR) spectroscopy method.

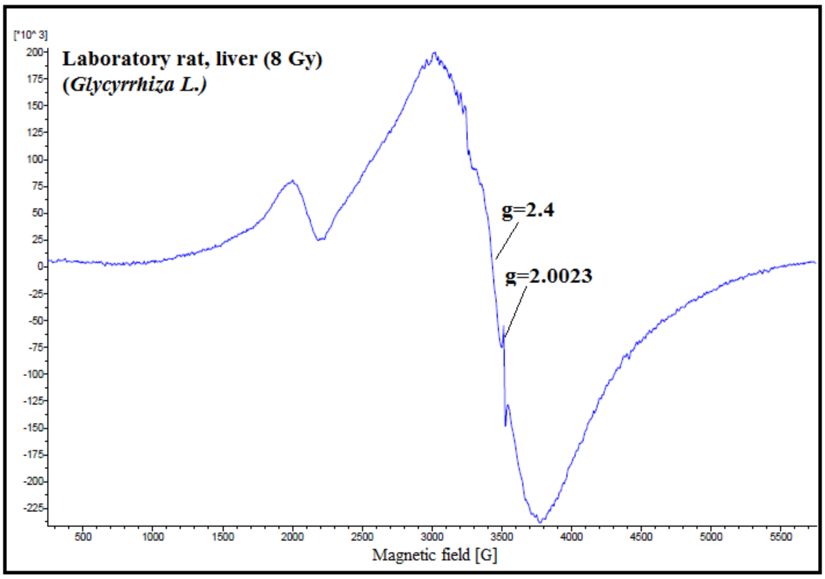
EPR spectra were then analyzed. The Electron Paramagnetic Resonance (EPR) method is a sensitive spectroscopic technique used to study the response of electrons in free radicals or paramagnetic ions to a magnetic field. In the studies, the levels of SOD, CAT and MDA in the rat's erythrocytes were also measured using spectrophotometric methods.

3. Results and Discussion

The EPR spectra of the internal organs of control, irradiated and licorice syrup-fed laboratory rats were recorded. The signals observed in liver and brain samples are shown in the figures below (Figures 1 and 2). Free radical signals (g=2.0023) and signals from iron oxide magnetic nanoparticles (g=2.4) were identified (Figure 1).


Laboratory rat, liver (control)
(Glycyrrhiza L.)
g=2.4
g=2.0023
Magnetic field [G]


Laboratory rat, liver (6 Gy)
g=2.4
Magnetic field [G]


Laboratory rat, liver (8 Gy)
(Glycyrrhiza L.)
g=2.4
g=2.0023
Magnetic field [G]

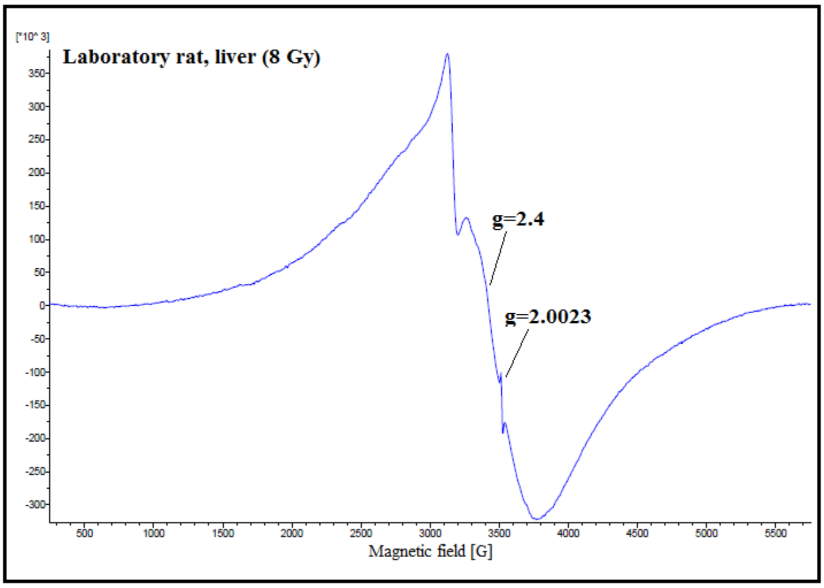
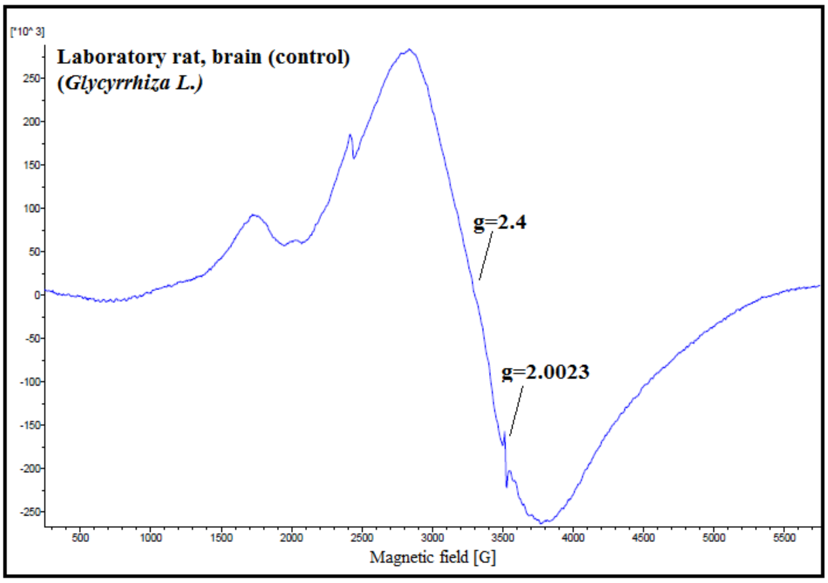


Figure 1. EPR spectra obtained from the liver organs of the laboratory rats

Experiments conducted with the EPR method showed that biomineralization processes are more active in the liver tissues of irradiated rats fed with juice made from licorice root, resulting in the formation of more magnetic nanoparticles. In analyses conducted on the brain, the formation of paramagnetic centers in the brain tissues of rats fed with licorice juice was observed under the influence of free radicals. These changes were also evident in the EPR spectra at angles of 90°C and 180°C. The results indicate that licorice juice has a radioprotective effect on living systems (Figure 2).



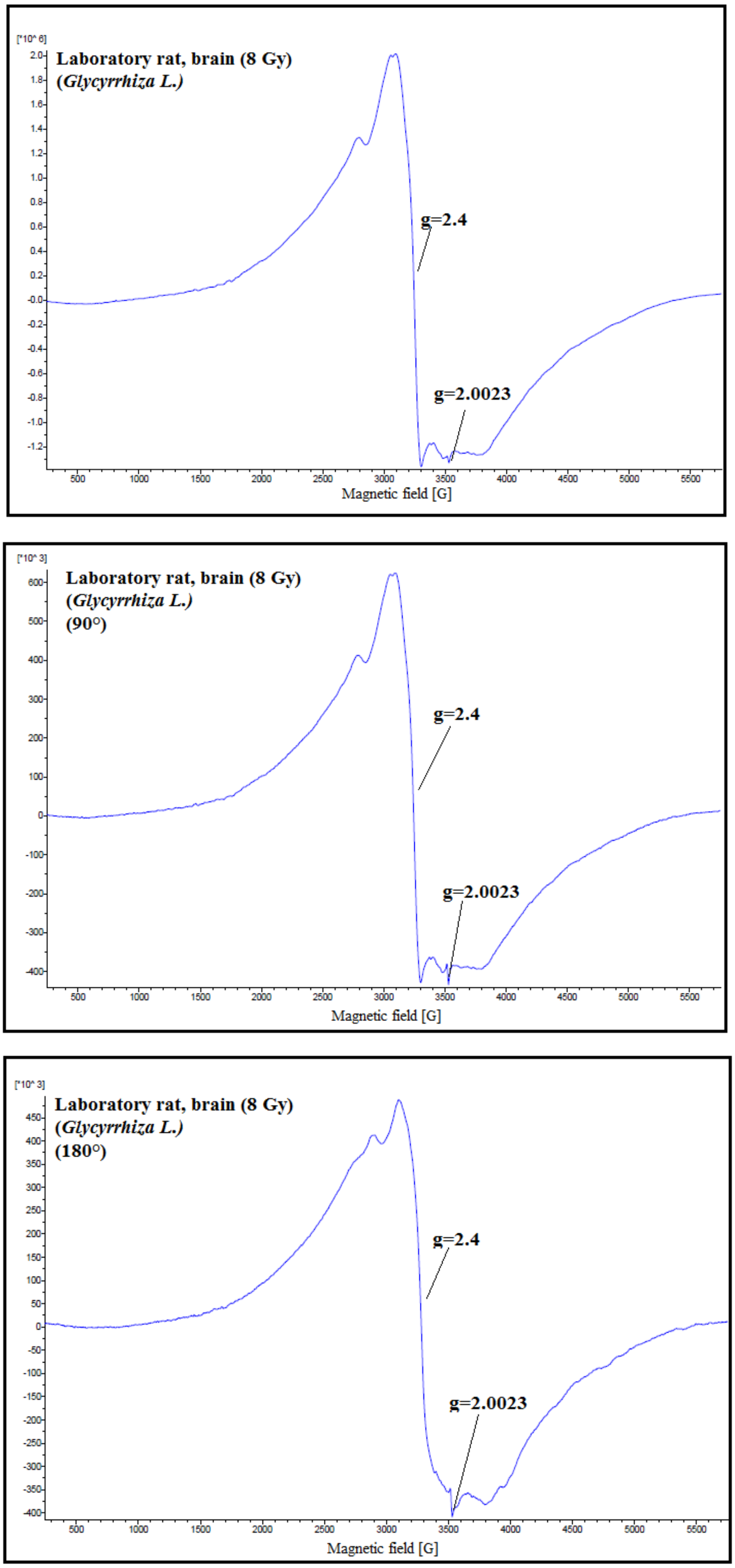


Figure 2. EPR spectra of the brain organs of laboratory rats

As a continuation of the experiments, the levels of antioxidant enzymes in the rat's erythrocytes were measured using various methods.

Table 1. MDA Biochemical Indicator
3 Gy (1) - rats irradiated with a dose of 3 Gy gamma radiation;
3 Gy(2) - rats irradiated with a dose of 3 Gy gamma radiation and at the same time fed with licorice syrup

Samples	MDA Biochemical Indicator
Control	3,49 µmol/l
3 Gy (1)	4,96 µmol/l
3 Gy (2)	5,42 µmol/l
6 Gy	6,77 µmol/l
8 Gy	4,22 µmol/l

Table 2. SOD Biochemical Indicator

Samples	SOD Biochemical Indicator
Control	20,1 µmol/l
3 Gy (1)	3,65 µmol/l
3 Gy (2)	11,45 µmol/l
6 Gy	4,83 µmol/l
8 Gy	0,266 µmol/l

Table 3. CAT Biochemical Indicator

Samples	CAT Biochemical Indicator
Control	13,79 µmol/l
3 Gy (1)	16,59 µmol/l
3 Gy (2)	18,45 µmol/l
6 Gy	69,61 µmol/l
8 Gy	38,86 µmol/l

The MDA level was determined based on the "Suplova" method, the SOD enzyme was measured according to the "Dubinina" method and catalase was determined based on the "Korolyuk" method. The biochemical indicators of catalase were measured at a wavelength of 410 nm on a spectrophotometer, while MDA and SOD were measured at wavelengths of 540 nm.

4. Conclusion

Biochemical analyses conducted on the erythrocytes of the rats indicated positive effects of licorice syrup on the levels of SOD, CAT and MDA (Tables 1, 2 and 3). In irradiated rats fed with licorice syrup, oxidative stress induced by free radicals was reduced, while the levels of antioxidant enzymes increased.

The results of the study indicate that licorice root juice plays a significant role in reducing oxidative stress in rats exposed to ionizing gamma radiation. Licorice juice possesses radioprotective properties and has the ability to prevent damage caused by free radicals. The biomineralization and formation of paramagnetic centers detected in liver and brain tissues may demonstrate the specific protective effect of licorice juice on these tissues (Ahmadkhani *et al*., 2017; Hosainzadegan *et al*., 2020; Montazersaheb *et al*., 2023; Maleki Dizaj *et al*., 2021).

The findings of this research prove that licorice root is an effective radioprotector against oxidative stress caused by gamma radiation. Licorice syrup can be considered a potential natural agent for preventing cellular damage and protecting the body from the harmful effects of radiation.

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