Ameliorative Effect of Basil Seeds *(Ocimum basilicum L.)* against Oxidative Stress Induced by Monosodium Glutamate in Rats

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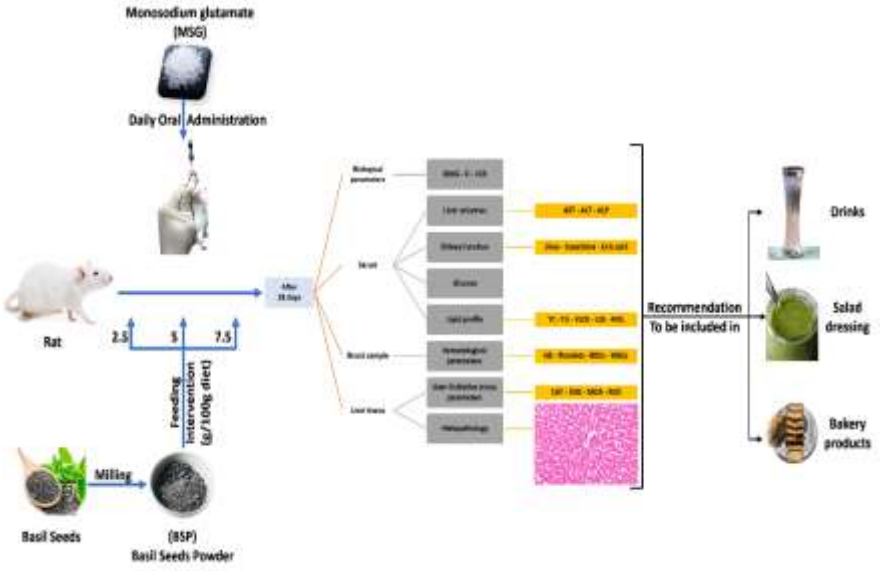
Abstract

Monosodium glutamate (MSG) is a silent excitotoxin that enhances flavor but poses major health risks to consumers. Therefore, this study was conducted to evaluate the modulatory effect of basil seeds powder (BSP) *(Ocimum basilicum L.)* on MSG-induced oxidative stress in rats. In this regard, thirty male adult albino rats weighing 150 ± 10.86 g were used for the study and separated into 5 groups of 6 rats each. Group 1(-): control negative group; group 2(+): MSG only as control positive group; groups 3, 4, and 5 were given MSG and treated with (2.5, 5, and 7.5 g/100 g diet) BSP, respectively. The MSG groups were given a 4 mg/kg b.wt. daily oral dose of MSG dissolved in distilled water by stomach tube throughout the experiment time. After completing 28 days, all animals were sacrificed; blood samples and liver tissue were collected and subjected to analysis. Exposure to MSG negatively impacted biological parameters such as body weight gain and feed intake, which increased by 100 and 169.57%, respectively, while the feed efficiency ratio significantly decreased by 25.61% compared to the normal group. These biological parameters were ameliorated by BSP intervention (2.5, 5, and 7.5 g/100 g diet). The use of BSP reversed the negative effects of MSG on liver oxidative stress parameters (CAT, SOD, MDA, and ROS), as BSG intervention increased CAT and SOD and decreased MDA and ROS. (7.5 g/100 g diet) The BSP-treated group recorded an improvement, reaching the point of no significant difference with the negative group in SOD, and recorded (320.86%) compared to the positive group. In addition, our results revealed that the MSG-treated group shows a significant change in deterioration in hematological parameters (Hb, platelets, RBCs, and WBCs), liver enzymes (AST, ALT, and ALP), some kidney function (urea, creatinine, and uric acid), serum glucose, and lipid profile (TC, TG, VLDL, HDL, and VLDL). Interestingly, BSP (2.5, 5, and 7.5 g/100 g diet) administration demonstrated the ability to significantly

($p \leq 0.05$) alleviate these toxic effects dose-dependently. Histological observations of liver tissue provided evidence for the ameliorative effect of BSP. The study noted the harmful effects of MSG and suggested BSP (2.5, 5, and 7.5 g/100 g diet) as a potential remedy for MSG oxidative stress, especially BSP (7.5 g/100 g diet), which achieved the best improvement results. These results bear the greatest significance for highlighting the use of BSP in the food industry and as a preventative measure against the oxidative stress caused by MSG.

Keywords: basil seeds, reactive oxygen species, flavor enhancer, linolenic acid

Graphic abstract



Introduction

Over the past years, most people prefer consuming fast food to unprocessed or natural foods due to its delicious flavor and changes in lifestyle (**Lee *et al.*, 2022)**. In order to improve the palatability of food, flavor enhancers and flavors are used to enhance the flavor of a variety of foods without adding their own flavor **(Al Saqqa, 2022)**. One of the most popular taste enhancers in the world is monosodium glutamate (MSG) **(Bayram *et al*., 2023)**. Along with sweet, sour, salty, and bitter, Kikunae Ikeda discovered MSG 100 years ago, making it the fifth basic taste. Apart from its fundamental uniqueness, the umami flavor can intensify overall flavors and increase food palatability **(Zanfirescu *et al*. 2019)**. With a global demand of about three million metric tons, valued at over $4.5 billion, it is highly sought after **(Kayode *et al*., 2023)**. MSG is a white, crystalline powder that seems like sugar or salt **(Airaodion *et al*., 2019)**. Its chemical composition consists mainly of up of glutamate (78%) which links to the umami taste receptor on the tongue to instantly trigger the flavor of food; the remaining components are sodium (21%), and water (1%), as reported by **Ikeda (2002)**. Consuming MSG led to a reduction in the mass of pancreatic beta cells, an increase in metabolic rates and oxidative stress, a decrease in the transport of glucose and insulin to skeletal muscles and adipose tissue, a reduction in insulin receptors, insulin insensitivity, and severe hyperinsulinemia. tumor formation, cytotoxicity induction in several cell types as cardiac myocyte, neuron, and hepatocyte, abnormal fetal development, fertility impairment, and hypertension (**Zanfirescu *et al*., 2019; Kayode *et al*.,2023, and Thongsepee *et al*.,2024)**. MSG is toxic to people and laboratory animals, especially in high dosages **(Iyeh *et al*., 2024)**. **Kesherwani *et al*. (2024)** added that MSG, even at low doses may affect oxidative stress. Oxidative stress has been shown to participate in a wide range of diseases **(Forman and Zhang, 2021)**. Consuming plant-based meals rich in various bioactive components may help in the reduction of oxidative stress **(Dixit *et al*., 2023)**. Among them having highly promising health benefits are basil seeds (*Ocimum basilicum* L.), which are incredible sources of bioactive substances like proteins, soluble and insoluble dietary fiber, essential minerals like potassium, calcium, and magnesium, and phenolic compounds

like rosmarinic acid, vicentine, and orientine. These substances are desirable to the food industry and consumers who are searching for foods with healthful qualities. It possesses amazing qualities that are useful for maintaining health and preventing illness **(Moghaddam and Mehdizadeh, 2015)** and **(Calderón Bravo *et al*., 2021)**. From a nutritional and functional perspective, the fat content of these seeds, ranging from 13 to 15% of the total weight, shows an extremely intriguing fatty acid profile because of the α-linolenic acid (ALA) **(Mostafavi *et al*., 2019)**. ALA, which makes up between 60 and 80% of the total fatty acid, is the major component of the lipid fraction. Because basil seeds have a high ALA concentration, they can be a helpful addition in nutraceutical formulations **(Martínez *et al*., 2022)**. According to **Ali and Setzer (2014),** there is a traditional belief that using basil seeds might enhance blood circulation, lower inflammation, lessen cholesterol oxidation, boost immunity, and regulate blood sugar levels. Additionally, studies on basil seeds have shown that they possess strong antibacterial, antioxidant, and anticancer properties, as well as antioxidant capacity that are very advantageous to human health **(Gajendiran *et al*., 2016 and Munir *et al*., 2017)**. Other pharmacological effects were noted by **Calderón Bravo *et al*. (2021)**, including antiviral, emmenagogue, analgesic, anticoagulant, and depressive qualities. Additionally, the gum found in basil seeds which has been extracted and extensively researched for its emulsifying, gelling, and foaming qualities, makes the seeds useful for biotechnological applications **(Naji-Tabasi and Razavi, 2017)**. Therefore, the present study was designed to investigate the ameliorative effect of basil seeds against MSG-induced oxidative stress in rats.

Materials and Methods

Materials

Basil seeds and monosodium glutamate were acquired from Harraz Company for Food Industry and Natural Products, Bab Alkhalq, Cairo, Egypt. The botanist from Menoufia University in Egypt's Department of Plant Protection and Production, Faculty of Agriculture, identified the plant materials as basil seeds *(Ocimum basilicum L.).*

From a local market in Shebin El-Kom, Menoufia, Egypt, we acquired corn oil, wheat bran, sucrose, and corn starch. Egypt's Cairo

Corporation for Chemical Trade provided the casein, vitamins, minerals, choline bitartrate, and L-cysteine.

Rats

A total of thirty adult male albino rats (Sprague Dawley strain) weighing 150 ± 10.86 g were procured from the Medical Analysis Department of the Research Institute of Ophthalmology in Cairo, Egypt. The ethical approval for this study was given by Menoufia University's Institutional Animal Care and Use Committee (IACUC) (**Reg. No., MUFHE /F/NFS/20/24)**.

Methods

Samples preparation

The basil seeds were ground into a powder using an electric grinder (Moulinex, France), and then stored in sterile bags at 4°C until used.

Diet

The components of the basal diet were produced in accordance with **Reeves *et al*. (1993)**. Treatment diets were prepared by incorporating 2.5, 5, and 7.5 g/100g diets.

Experimental design

This research was done at the biology lab of the Menoufia University of Egypt's Faculty of Home Economics. To prevent dispersal, the rats were given a conventional diet in designated food cups for seven days to allow for adaptation. They were housed in wire cages that were cylindrical and had wire bottoms. We also gave the rats water by projecting a glass tube through the wire cage. Following acclimation, thirty rats were separated into 5 groups, in which each group contains six rats. Group 1(-): fed only the basal diet and kept as control negative group. Group 2 (+): MSG rats fed a basal diet and used as positive control group. Group 3: MSG rats fed a basal diet supplemented with 2.5 g/100g diet of BSP. Group 4: MSG rats fed on basal diet supplemented with a 5 g/100g diet of BSP. And group 5: MSG rats fed on a basal diet supplemented with a 7 g/100g diet of BSP. The MSG groups were given 4mg/Kg b.wt. daily oral dose of MSG dissolved in distilled water, by stomach tube **(Doaa *et al*.,2019)** throughout the experiment, which lasted for 28 days.

Biological evaluation:

Body weight was measured every week and, the diet was followed daily during the experimental period. According to **Chapman *et al*. (1959),** the body weight gain, feed intake (FI), and

feed efficiency ratio (FER) were calculated using the following equations:

$$\boldsymbol{BWG = (Final\ weight - Initial\ weight)}$$

$$\boldsymbol{FER = \frac{Grams\ gain\ in\ body\ weight}{Grams\ feed\ consumed}}$$

Blood and liver tissue samples

After completion of 28 days' blood samples were collected after 12 h of fasting from the abdominal aorta after anesthetizing of rats with ether. Two blood samples were obtained from each rat, one of the two samples was received in a tube containing an anticoagulant for hematological parameters analysis and the other were taken into sterile, dry glass centrifuge tubes, and the serum was separated by centrifuging them for ten minutes at 4000 rpm. All serum samples were then frozen until analysis **(Stroev and Makarova,1989).** Liver specimens were divided into two sections. First, the samples were cleaned using a cooled saline solution and homogenized (10% w/v) in an Elvehjem-type homogenizer using ice-cold sodium and potassium phosphate buffer (0.01 M, pH 7.4) that contained 1.15% KCl. The homogenate was centrifuged at 860 g for 20 minutes at 4 ^{o} C. The supernatant that was obtained was stored for the **Noeman *et al.* (2011)** method of measuring SOD, CAT, MDA, and ROS. The second portion was soaked in 10% neutral buffered formalin for histological analysis.

Biological analysis

Liver tissues MDA, SOD, CAT and ROS levels were determined according to **Ohkawa *et al.* (1979), Wheeler *et al.* (1990), Sinha (1972) and Murphy *et al.* (2022)**. Following the methods of **Dacie (2006), Koda-Kimble *et al.* (2001), Lubsandorzhiev (2006), and Daly ,2011),** respectively, hemoglobin, WBCs, RBCs, and platelets were measured. The **Reitman and Frankel (1957**) approach was used to determine serum ALP, AST, and ALT quantitatively. Serum samples were used to calculate the concentrations of creatinine, urea, and uric acid in line with **Bartels *et al.* (1972), Patton and Crouch (1977), and Fossati *et al.* (1980)**, respectively. Serum glucose was calculated using **Lott and Turner's (1975)** methodology. According to **Richmond (1973), Lopes-Virella *et al.* (1977), and Fossati and Prencipe (1982),** the serum total cholesterol, triglycerides, and HDL were measured. The

technique described by **Lee and Nieman (1996)** was used to determine LDL and VLDL levels.

Statistical analysis

The data is shown as mean ± standard deviation (SD). A computerized costat program was used to statistically evaluate the data using one-way ANOVA. According to **Snedecor and Cochran (1967),** differences between treatments at $p < 0.05$ were considered statistically significant.

Results and Discussion

Effect of different levels of basil seeds powder (BSP) intervention on biological parameters of MSG rats

The data in Table (1) illustrate the impact of different levels of basil seeds powder (BSP) intervention on biological parameters (body weight gain (BWG), feed intake (FI), and feed efficiency ratio (FER)) of MSG rats. Such data indicated that utilization of MSG exhibited a significant ($p \leq 0.05$) increase in BWG and FI with percent of change 100 and 169.57, respectively. While, there was a significant decrease ($p \leq 0.05$) in FER with a percent of change 25.61% compared to the normal group. These findings supported the findings of **Rogers and Blundell (1990) and Savcheniuk *et al.* (2014)** that feeding animals MSG enhanced their consumption of feed and led them to gain weight. Studies showed that MSG has the ability to increase appetite and bioavailability of some micronutrients, and can also slow down the rate of metabolism, leading to weight gain in addition to elevated levels of insulin and leptin hormones (**Zanfirescu *et al.*, 2019; Ajayi *et al.*, 2020; and Hajihasani *et al.*, 2020)**. Similar results were obtained from **Hermanussen and Tresguerres (2003)** and **He *et al.* (2011)**, who provided the explanation for the link between MSG consumption and obesity. MSG affects energy balance by making food more palatable and by interfering with the hypothalamus signaling cascade that triggers leptin activation. Meanwhile, feeding MSG induced rats on a BSP- supplemented diet (2.5, 5, and 7.5 g/100g diet) recorded a significant decrease in the BWG with percent change of 20.92, 35.87, and 49.73, respectively. Similarly, a significant reduction in FI with percent of change 30.85, 47.18, and 60.50, respectively, when compared to MSG group. On the other side, there was a significant increase in FER by the rates of 13.33, 21.11 and 27.78% compared

to the positive group, respectively These findings agreed with the findings of other researchers who have noted that basil seeds are an excellent source of omega-3 fatty acids, which are vital for managing obesity (**Chaudhary *et al.*, 2016)**. According to the reported work of **Albracht-Schulte *et al*. (2018)** omega-3 fatty acids have an anti-obesity effect, they may improve body composition and reduce fat mass. Moreover, basil seeds are rich in dietary fiber, both soluble and insoluble **(Bravo *et al*., 2021)**. As well as , basil seeds after soaking in water, can form a considerable amount of mucilage around the seeds that can be used as a source of fiber with its beneficial effect on weight management **(Naji -Tabasi and Razavi, 2017**).

Table (1): Effect of different levels of basil seeds powder (BSP) intervention on biological parameters of MSG rats

Groups	BWG (g/ day)		FI(g/ day)		FER	
	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change
G1 (-)	1.84 ± 0.04^{d}	-----	15.15 ± 0.13^{e}	------	0.121±0.004^{a}	------
G2 (+) MSG	3.68 ± 0.06^{a}	100	40.84 ± 0.93^{a}	169.57	0.090 ± 0.001^{e}	-25.61
G3 (MSG+BSP 2.5%)	2.91 ± 0.09^{b}	-20.92	28.24 ± 0.13^{b}	-30.85	0.102± 0.003^{d}	13.33
G4 (MSG+BSP 5%)	2.37 ± 0.02^{c}	-35.87	21.57 ± 0.31^{c}	-47.18	0.109 ± 0.003^{c}	21.11
G5 (MSG+BSP 7%)	1.85 ± 0.01^{d}	-49.73	16.13 ± 0.36^{d}	-60.50	0.115 ±0.002^{b}	27.78
LSD	0.095		0.86		0.005	

Each value represents the mean value of three replicates ± SD. Means under the same column with different superscript letters exhibited significant at $P \leq 0.05$. MSG, monosodium glutamate; BSP, basil seeds powder; BWG, body weight gain; FI, feed intake; FER, feed efficiency ratio.

Effect of different levels of basil seeds powder(BSP) intervention on liver oxidative stress parameters (CAT, SOD, MDA and ROS) of MSG rats

As shown in Table (2) MSG administration resulted in CAT and SOD reduction with percent of change (79.18 and 76.48%),

respectively. Whereas, there was a significant elevation ($p \leq 0.05$) in MDA and ROS by 681.84 and 372.39%, respectively, compared to the normal group. Our results were supported by **Diniz *et al*. (2004); Onyema *et al.* (2006)** and **Chiaki (2009),** who noticed oxidative stress induction after MSG intake at high doses. Also, **Kumari *et al*. (2023)** found decreased levels of GSH, CAT, and SOD activity in livers of people who consumed MSG. Contrasting effects were noticed in BSP-supplemented groups (2.5, 5, and 7.5 g/100g diet). CAT was augmented by (134.62, 198.29, and 280.34 %), respectively. Similarly, increased SOD by 234.66, 286.67, and 320.86%, respectively as compared to the MSG group. Whereas, MDA and ROS were diminished by the rates of (60.11, 83.54, 85.89 and 58.55, 66.34 and 74.73%), respectively, compared to the MSG group. There was a dose-dependent line in the rates of CAT and SOD increase and MDA and ROS decline. In this context, various studies were conducted to evaluate the antioxidant activity of basil seeds. Their findings revealed that basil seeds possess antioxidant properties against oxidative stress, which results from cells producing excess free radicals or failing to remove them from cells **(Bashan *et al*., 2009).** This activity makes them perform a vital role in improving diseases like cancer and other oxidative stress related diseases **(Javanmardi *et al*., 2003; Safraz *et al*., 2011; Bucktowar *et al*.,2016, Khateib and Diab,2021, and Farouk *et al*.,2021)**. Similarly, **Mabood *et al*. (2017**) concluded that basil extracts protect against oxidative DNA damage and mutagenesis. Bioactive compounds of basil seeds, especially polyphenols and flavonoids, may be responsible for their antioxidant activity against oxidative stress **(Sifola and Barbieri, 2006; Sakr and Al-Amoudi, 2012; Moghaddam and Mehdizadeh, 2015 and Gajendiran *et al*.,2016)**. Moreover, basil seeds contain a high amount of micronutrients like minerals, beta-carotene, lutein, with their beneficial impact as antioxidants **(Tewari *et al*., 2012 and Munir *et al*.,2017)**. Several authors explained that the presence of ALA at high levels in basil seeds contributes to reducing blood glutathione (GSH) levels and lipid peroxidation with antioxidant potential **(Gupta *et al*.,2006 and Mostafavi et *al*.,2019**). Another study showed that the antioxidant activity of basil seeds is owed to peptides presence, that have

lowering behavior against oxidative stress and related diseases **(Nurul Hidayatul Afifah and Gan, 2016)**.

Table (2): Effect of different levels of basil seeds powder(BSP) intervention on liver oxidative stress parameters of MSG rats.

Groups	CAT(ng-mg)		SOD(U-mg)		MDA(nmol-mg)		ROS(Pg-mg)	
	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change
G1 (-)	11.24 ± 0.04[a]	------	173.48 ± 1.02[a]	------	0.848 ±0.01[d]	-------	111.72 ± 0.37[e]	-------
G2 (+) MSG	2.34 ± 0.01[e]	-79.18	40.80± 1.65[d]	-76.48	6.63± 0.20[a]	681.84	527.76 ± 4.68[a]	372.39
G3 (MSG+BSP 2.5%)	5.49± 0.07[d]	134.62	136.54 ± 0.98[c]	234.66	4.24± 0.06[b]	-60.11	218.71 ± 1.11[b]	-58.55
G4 (MSG+BSP 5%)	6.98 ± 0.05[c]	198.29	157.76 ± 1.02[b]	286.67	1.75± 0.26[c]	-83.54	177.65 ± 2.79[c]	-66.34
G5 (MSG+BSP 7%)	8.90± 0.06[b]	280.34	171.71 ± 0.62[a]	320.86	1.50± 0.06[c]	-85.89	133.37± 0.79[d]	-74.73
LSD	0.092		2.015		0.276		1.95	

Each value represents the mean value of three replicates ± SD. Means under the same column with different superscript letters exhibited significant at $P \leq 0.05$. MSG, monosodium glutamate; BSP, basil seeds powder; CAT, catalase; SOD, superoxide dismutase; MDA, malondialdehyde; ROS, reactive oxygen species.

Effect of different levels of basil seeds powder(BSP) intervention on hematological parameters of MSG rats

The impact of different levels of BSP intervention on the hematological parameters of MSG rats is shown by the data reported in Table 3. According to the results, the MSG-treated rats had a significant ($p \leq 0.05$) decrease in Hb, platelets, RBCs and WBCs by (33.33, 26.57 ,37.31, and 32.64 %) compared to the normal group, respectively. These results agreed with the findings of **Ahmed *et al.* (2021)**, who observed a statistically significant ($p < 0.05$) reduction in RBC count, Hb concentration, and PCV in MSG-treated animals when compared to the control group. Based on these findings, they concluded that MSG consumption negatively impacts blood parameters. Regarding the BSP-treated groups (2.5, 5, and 7.5 g/100g diet) there was a significant ($p \leq 0.05$) improvement in Hb, platelets, RBCs, and WBCs. (BSP) (7.5%) offered the best results. Such results confirmed the obtained results, **Oyedemi *et al.* (2011)** illustrated that aqueous extract of basil seeds contain some phytoconstituents that

can reverse erythropoietin deficient status; thus, these seeds are used traditionally to improve blood circulation **(Nurul Hidayatul Afifah and Gan, 2016)**. Additionally, **Chaudhary *et al*. (2016)** illustrated that aqueous extract of basil seeds has the ability to improve anemia, associated complications of diabetes mellitus-II, in STZ-effectuated diabetes in rats.

Table (3): Effect of different levels of basil seeds powder(BSP) intervention on hematological parameters of MSG rats.

Groups	Hb (g/dL)		Platelet (10^3 /µL)		RBCs (10^6 /µL)		WBCs (10^3 /µL)	
	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change
G1 (-)	12.84 ± 0.02[a]	-------	315.45 ± 2.07[a]	-------	5.52± 0.44[a]	-------	6.25± 0.04[a]	---------
G2 (+) MSG	8.56 ± 0.04[d]	-33.33	231.63 ± 2.01[e]	-26.57	3.46± 0.13[d]	-37.31	4.21± 0.03[e]	-32.64
G3 (MSG+BSP 2.5%)	8.64± 0.06[d]	.94	248.87 ± 1.76[d]	7.44	3.97± 0.12[c]	14.74	4.72± 0.02[d]	12.11
G4 (MSG+BSP 5%)	9.41± 0.05[c]	9.93	271.22 ± 1.08[c]	17.09	4.23± 0.08[c]	22.25	5.01± 0.03[c]	19.00
G5 (MSG+BSP 7%)	10.83± 0.18[b]	26.52	289.98 ± 1.41[b]	25.19	4.94± .08[b]	42.78	5.67± 0.05[b]	34.68
LSD	0.165		3.103		0.395		0.065	

Each value represents the mean value of three replicates ± SD. Means under the same column with different superscript letters exhibited significant at $P \leq 0.05$. MSG, monosodium glutamate; BSP, basil seeds powder; Hb, hemoglobin; RBCs, red blood cells; WBCs, white blood cells.

The influence of various levels of basil seeds powder(BSP) on liver enzymes of MSG rats.

As shown in Table 4 MSG consumption has an adverse effect on liver functions through increasing liver enzymes, compared to the normal group, ALT, ALP, and AST were significantly augmented ($p \leq 0.05$) in MSG rats by (274.95, 82.98, and 227.6%), respectively. In the same line, a significant increase in liver enzymes was observed in MSG treated animals due to its cytotoxic effects **(ALhamed *et al*., 2021)**. The detrimental impact of MSG on the liver can be attributed to damage in liver cells, MSG may result in degeneration and destruction of the liver cells and their cellular membranes, causing enzymes to release into the bloodstream (**El-Khayat *et al*.,2009 and Al-Asady and Ghaleb, 2020)**. Another study demonstrated that the elevated level of ALP in MSG- treated animals is due to intestine and gallbladder damage. This enzyme is found in the intestines and gallbladder in addition to hepatic cells **(OE *et al.*,2006)**. Such data are also supported by **Doaa *et al.* (2019)** who examined the liver histopathological changes of the MSG group; their findings demonstrated hepatic cell steatosis, enhanced vacuolation, severe fibrosis, and apoptosis. So they concluded that MSG has a hepatotoxic effect. On the other hand, feeding on BSP (2.5, 5, and 7.5 g/100g diet) significantly improved ($p \leq 0.05$) liver function through decreasing ALT, ALP and AST by the rates of 45.79, 47.31 and 50.98%, 28.06, 33.43 and41.19%, 33.93, 46.58 and -53.08%, respectively, compared to the MSG group. The rate of improving liver functions exhibited a dose-dependent manner. The obtained results were in agreement with **Kadhim (2016),** who summarized that basil seeds utilization may diminish inflammation and damage cells of liver incidence with a lowering effect on ALT, ALP, and AST levels; these effects may have contributed to the antioxidant activity of basil seeds based on its phytochemical content.

Table (4): The influence of various levels of basil seeds powder(BSP) on liver enzymes of MSG rats.

Groups	ALT(U-L)		ALP(U-L)		AST(U-L)	
	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change
G1 (-)	35.29± 1.04^{d}	-------	237.11 ± 1.07^{e}	-------	64.14 ±1.11^{e}	--------
G2 (+) MSG	132.32± 1.43^{a}	274.95	433.15± 2.08^{a}	82.68	210.12 ± 1.31^{a}	227.6
G3 (MSG+BSP 2.5%)	71.73± 1.16^{b}	-45.79	311.62 ± 1.04^{b}	-28.06	138.82 ± 1.12^{b}	-33.93
G4 (MSG+BSP 5%)	69.72 ± 1.09^{b}	-47.31	288.34 ± 1.22^{c}	-33.43	112.24 ± 1.48^{c}	-46.58
G5 (MSG+BSP 7%)	64.86± 0.97^{c}	-50.98	254.72 ± 1.51^{d}	-41.19	98.58 ±1.47^{d}	-53.08
LSD	2.09		2.61		2.38	

Each value represents the mean value of three replicates ± SD. Means under the same column with different superscript letters exhibited significant at $P \leq 0.05$. MSG, monosodium glutamate; BSP, basil seeds powder; AST, aspartate aminotransferase; ALT, alanine aminotransferase, ALP, a lkaline phosphatase.

The influence of various levels of basil seeds powder on some kidney functions and serum glucose of MSG rats.

Data presented in Table 5 show that the MSG-treated rats exhibited significantly ($p \leq 0.05$) increased levels of uric acid (112.12%), urea (173.08%), creatinine (95.16%), and serum glucose (189.12%) compared to the normal group, respectively. These data are also in line with the findings of **Ateya and Taha (2016),** who proposed that MSG led to a change in the tubular reabsorption threshold, as well as the glomerular filtration rate of the animal kidney with increased levels of serum urea and creatinine. Additionally, MSG-induced kidney damage is exacerbated by oxidative stress **(Sharma, 2015 and Koohpeyma *et al.*, 2021)**. Regarding the kidney functions and serum glucose of the BSP-treated groups (2.5, 5, and 7.5 g/100g diet) there was a significant decrease in the uric acid, urea, creatinine, and serum glucose with percent of change -16.37, -18.49, and -27.66%, -23.6, -36.37, and -48.53%, -

19.83, -37.19, and -42.98%, -61.04, -63.48, and -64.74%. The rate of decrease in uric acid, urea, creatinine, and serum glucose exhibited a dose-dependent manner. Our findings supported the conclusion stated by **Ben Mansour *et al*. (2024)** that methanol extract of basil seeds is effective in protecting renal functions from CCl_4 toxicity. As it was explained by **El-Wakeil *et al*, (2024),** basil seeds and their oil can potentially be preventive against ZnONPs-induced nephrotoxicity. Aqueous extract of basil seeds significantly reduced the blood glucose level and shown restoration of the pancreatic islets to their natural cellular state in diabetic rats **(Chaudhary *et al*., 2016)**. Beside this, different phytoconstituents of basil seeds should be considered responsible for the hypoglycemic effect **(Javed *et al*., 2021)**.

Table (5): The influence of various levels of basil seeds powder (BSP) on some kidney functions and serum glucose of MSG rats.

Groups	Uric acid (mg-dl)		Urea(mg-dl)		Creatinine (mg-dl)		Serum glucose (mg/dl)	
	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change
G1 (-)	2.88 ± 0.12^{d}	------	19.13 ± 0.72^{e}	-------	0.62± 0.02^{e}	---------	84.13 ± 1.05^{c}	--------
G2 (+) MSG	6.11 ± 0.09^{a}	112.12	52.24 ± 0.54^{a}	173.08	1.21 ± 0.03^{a}	95.16	243.24 ± 2.04^{a}	189.12
G3 (MSG+BSP 2.5%)	5.11 ± 0.08^{b}	-16.37	39.91 ± 0.83^{b}	-23.6	0.97 ± 0.03^{b}	-19.83	94.77 ± 2.05^{b}	-61.04
G4 (MSG+BSP 5%)	4.98 ± 0.03^{b}	-18.49	33.24 ± 0.21^{c}	-36.37	0.76 ± 0.04^{c}	-37.19	88.82 ± 3.82^{c}	-63.48
G5 (MSG+BSP 7%)	4.42 ± 0.07^{c}	-27.66	26.89 ± 0.35 ^{d}	-48.53	0.69 ±0.02^{d}	-42.98	85.76 ±1.06^{c}	-64.74
LSD	0.152		1.05		0.049		4.24	

Each value represents the mean value of three replicates ± SD. Means under the same column with different superscript letters exhibited significant at $P \leq 0.05$. MSG, monosodium glutamate; BSP, basil seeds powder.

The influence of various levels of basil seeds powder(BSP) on lipid profile of MSG rats.

Effects of various levels of BSP (2.5, 5, and 7.5%) on serum lipid fractions of MSG rats are shown in Table 6. The findings indicated that the oral administration of MSG caused TC, TG, VLDL, and LDL to rise significantly ($p \leq 0.05$) with percent of change (104.15, 93.77, 93.73, and 783.08%), respectively, while there was a significant reduction in HDL level with percent of change 70.22% compared to the normal group. These results agreed with **Singh and Ahluwalia (2012),** who illustrated that the consumption of MSG has been related to overall elevated levels of cholesterol in rats because of increasing levels of malondialdehyde in cardiac tissue. Also, these findings are supported by **El Malik and Sabahelkhier(2019**) **and Banerjee *et al,* (2021)** who observed that administration of MSG has a toxic impact on the cardiovascular system through increasing cardiac tissue oxidative stress and causing biochemical changes. On the other side, intake of BSP at different levels (2.5, 5, and 7.5 g/100g diet) caused serum TG, TC, VLDL, and LDL to reduce significantly ($p \leq 0.05$). While HDL level was significantly ($p \leq 0.05$) increased. The best effect was recorded in group 5 (BSP 7.5%); the rate of improvement was exhibited in a dose-dependent manner. These data are consistent with **Zeggwagh *et al*. (2007) and Munir *et al*. (2021)**, who proposed that basil seeds administration (400 mg/kg/day) showed a cholesterol-lowering effect due to the significant reduction in total plasma cholesterol, lipoproteins, and triacylglycerol levels. According to the reported work of **Idris *et al.* (2020) and Javed *et al*. (2021),** phytoconstituents of basil seeds are responsible for their hypolipidemic effect. Basil seeds are renowned for their high alpha linolenic acid (ALA) content Basil seeds can be a helpful component to reduce LDLc levels due to their high ALA content. So, basil seeds have a natural preventive role in cardiovascular disease (**Fitzpatrick, 2011; Mostafavi et *al*.,2019; Yu *et al*., 2020; and Martínez *et al*., 2022)**.

Table (6): The influence of various levels of basil seeds powder (BSP) on lipid profile of MSG rats.

Groups	TC (mg-dl)		TG (mg-dl)		HDL (mg-dl)		VLDL (mg-dl)		LDL (mg-dl)	
	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change	Mean ± SD	% of change
G1 (-)	81.18 ± 1.23^{e}	------	78.89 ± 0.64^{e}	-----	51.81 ±0.73^{a}	-------	15.78± 0.13^{e}	-------- -	13.59 ± 1.09^{e}	-----
G2 (+) MSG	166.02 ± 1.33^{a}	104.51	152.87 ± 1.73^{a}	93.77	15.43± 0.73^{d}	- 70.218	30.57± 0.38^{a}	93.73	120.01 ± 0.27^{a}	783.08
G3 (MSG+BSP 2.5%)	90.63 ± 0.97^{b}	-45.41	90.01 ± 0.65^{b}	-41.12	46.69± 0.81^{c}	202.59	18.00± 0.11^{b}	-41.12	26.24 ± 1.23^{b}	-78.14
G4 (MSG+BSP 5%)	86.72± 0.68^{c}	-47.77	87.52 ± 0.91^{c}	-42.74	48.29± 0.67^{b}	212.96	17.50± 0.19^{c}	-42.75	20.92± 0.72^{c}	-82.56
G5 (MSG+BSP 7%)	83.12± 0.74^{d}	-49.93	82.32 ± 0.53^{d}	-46.15	50.83 ±0.81^{a}	229.42	16.46 ±0.11^{d}	-46.16	15.82± 1.44^{d}	-86.82
LSD	1.86		1.79		1.37		0.36		1.88	

Each value represents the mean value of three replicates ± SD. Means under the same column with different superscript letters exhibited significant at $P \leq 0.05$. MSG, monosodium glutamate; BSP, basil seeds powder; TG, triglycerides, TC, total cholesterol; HDL, high-density lipoproteins, LDL, low-density lipoproteins. VLDL, very low-density lipoproteins.

Liver histopathological examination:

Histopathological examination of liver sections of Group 1 rats showed a normal hepatic parenchyma histoarchitecture (Figs. 1 & 2). In contrast, the liver of rats from group 2 MSG exhibited histopathological lesions characterized by hepatocellular vacuolar degeneration (Figs. 3 & 4), Kupffer cells proliferation (Figs. 3, 5 & 6), infiltration of the portal triad with inflammatory cells (Fig. 4), and localized hepatocellular necrosis accompanied by an influx of inflammatory cells (Figs. 5 & 6). Moreover, the liver of rats from group 3 (MSG+BSP 2.5%) revealed hepatocellular vacuolar degeneration and Kupffer cells proliferation (Fig. 7), Figures 8 and 9 show focal hepatocellular necrosis with infiltration of inflammatory cells, while Figure 8 shows a little infiltration of inflammatory cells in the portal triad. Kupffer cells proliferation is laden with golden

brown hemosiderin pigments (Fig. 9). Otherwise, the liver of the rats in group 4 (MSG+BSP 5%) improved significantly; sections that were looked at revealed sporadic hepatocyte necrosis (Fig. 10), and Kupffer cells proliferation (Figs. 11, 12 & 13). Likewise, some examined sections from group 5 (MSG+BSP 7.5%) described no changes except Kupffer cells proliferation (Figs. 14 & 15) and mild central venous congestion (Fig. 16), while other sections displayed centrilobular hepatocyte vacuolar degeneration (Fig. 17).

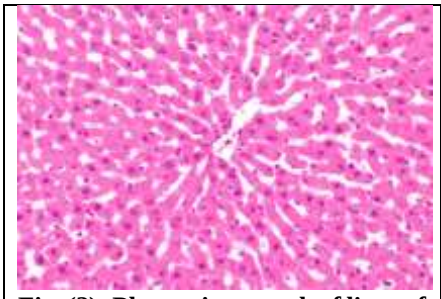


Fig. (2): Photomicrograph of liver of rat from group 1 (normal rats) showing the normal histoarchitecture of hepatic parenchyma (H & E X 400).

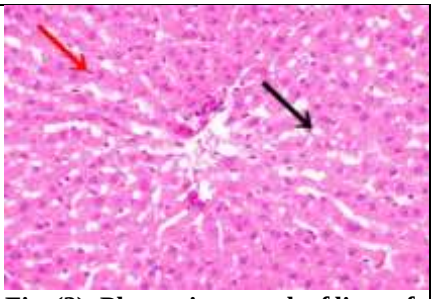


Fig. (3): Photomicrograph of liver of rat from group 2(MSG) showing hepatocellular vacuolar degeneration (black arrow) and Kupffer cells proliferation (red arrow) (H & E X 400).

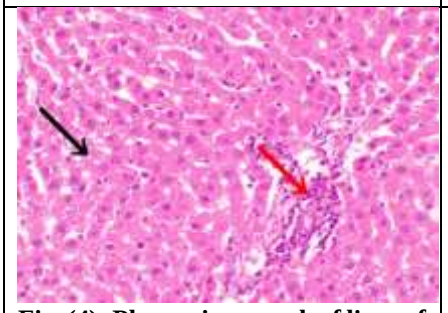


Fig. (4): Photomicrograph of liver of rat from group 2 (MSG) showing hepatocellular vacuolar degeneration (black arrow) and inflammatory cell infiltration of the portal triad (red arrow) (H & E X 400).

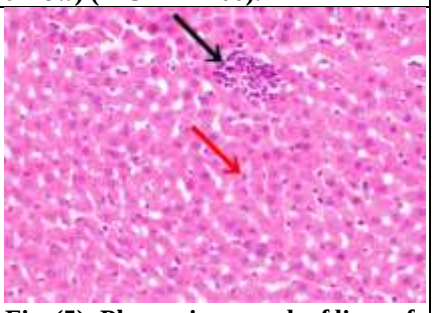


Fig. (5): Photomicrograph of liver of rat from group 2 (MSG)showing focal hepatocellular necrosis with inflammatory cells infiltration (black arrow) and Kupffer cells proliferation (red arrow) (H & E X 400).

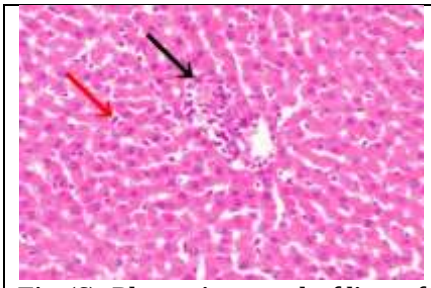


Fig. (6): Photomicrograph of liver of rat from group 2(MSG) showing focal hepatocellular necrosis with inflammatory cells infiltration (black arrow) and Kupffer cells proliferation (red arrow) (H & E X 400).

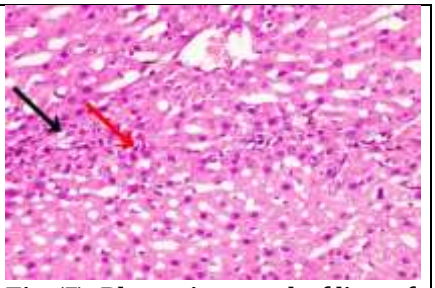


Fig. (7): Photomicrograph of liver of rat from group 3 (MSG+BSP 2.5%) showing hepatocellular vacuolar degeneration (black arrow) and Kupffer cells proliferation (red arrow) (H & E X 400).

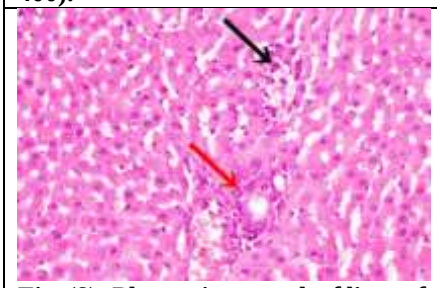


Fig. (8): Photomicrograph of liver of rat from group 3(MSG+BSP 2.5%) showing focal hepatocellular necrosis with inflammatory cells infiltration (black arrow) and few inflammatory cells infiltration in the portal triad (red arrow) (H & E X 400).

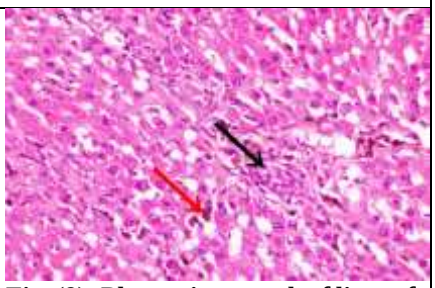


Fig. (9): Photomicrograph of liver of rat from group 3(MSG+BSP 2.5%) showing focal hepatocellular necrosis with inflammatory cells infiltration (black arrow) and Kupffer cells proliferation laden with golden brown hemosiderin pigments (red arrow) (H & E X 400).

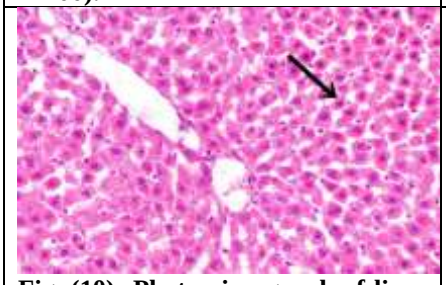


Fig. (10): Photomicrograph of liver of rat from group 4(MSG+BSP 5%) showing necrosis of sporadic hepatocytes (black arrow) (H & E X 400).

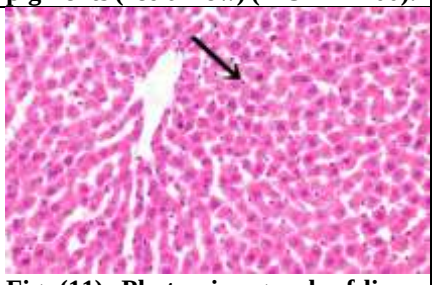


Fig. (11): Photomicrograph of liver of rat from group 4 (MSG+BSP 5%) showing Kupffer cells proliferation (black arrow) (H & E X 400).

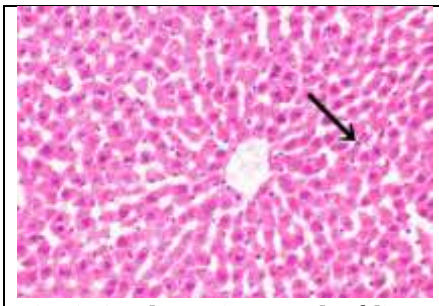


Fig. (12): Photomicrograph of liver of rat from group 4 (MSG+BSP 5%)showing Kupffer cells proliferation (black arrow) (H & E X 400).

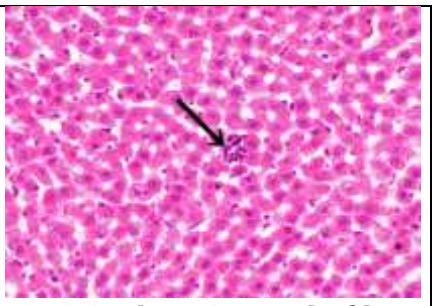


Fig. (13): Photomicrograph of liver of rat from group 4 (MSG+BSP 5%) showing Kupffer cells proliferation (black arrow) (H & E X 400).

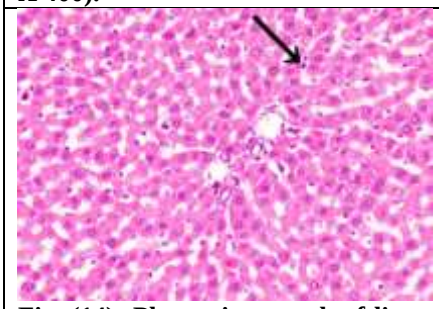


Fig. (14): Photomicrograph of liver of rat from group 5 (MSG+BSP 7.5%) showing Kupffer cells proliferation (black arrow) (H & E X 400).

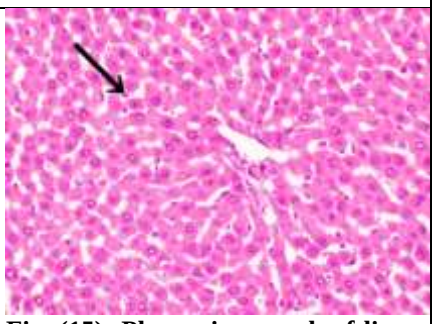


Fig. (15): Photomicrograph of liver of rat from group 5 (MSG+BSP 7.5%)showing Kupffer cells proliferation (black arrow) (H & E X 400).

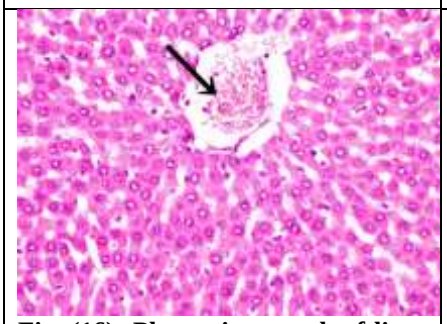


Fig. (16): Photomicrograph of liver of rat from group 5 (MSG+BSP 7.5%)showing slight congestion of central vein (black arrow) (H & E X 400).

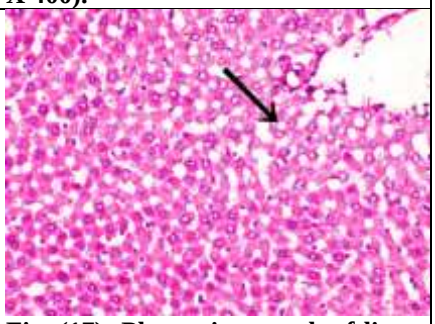


Fig. (17): Photomicrograph of liver of rat from group 5(MSG+BSP 7.5%) showing vacuolar degeneration of centrilobular hepatocytes (black arrow) (H & E X 400).

These outcomes corroborated those of **Eweka *et al*. (2016)**, who noted that histological observations revealed alterations such as atrophic and degenerative changes on the liver of the animals that received feed infused with monosodium glutamate, cyto-architectural distortions of the hepatocytes, and dilatation of the central vein, which contained lysed red blood cells. Moreover, MSG has oxidant and hepatotoxic effects. In the hepatic cells, particularly the centrilobular ones in the MSG group, the histological and immunohistochemical data revealed steatosis; enhanced vacuolation; severe fibrosis; and apoptosis **(Doaa *et al*., 2019)**. Histopathology staining and microscopy showed a normal pattern of cellular structure in hepatic cells of basil seed extract-treated mice. No sign of hepatotoxicity was observed **(Munir *et al*.,2021)**.

Conclusion:

Our results highlighted harmful effects of MSG and, for the first time, suggested BSP as a potential remedy for MSG oxidative stress in rats. This is due to the role of BSP in improving biological parameters, liver oxidative stress parameters, hematological parameters, liver enzymes, some kidney function, serum glucose, and the lipid profile of rats, which recorded satisfactory levels as a result of MSG oral administration (4mg/Kg b.wt.). Our histological analysis revealed supportive evidence for BSP. The study recommended the inclusion of BSP in the diet daily routine (drinks, salad sauces and bakery products), and more clinical research needed to be conducted.

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التأثير المحسن لبذور الريحان ضد الإجهاد التأكسدي الناجم عن أحادي جلوتامات الصوديوم في الفئران

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أحادي جلوتامات الصوديوم هي مادة سامة صامتة تعزز النكهة ولكنها تشكل مخاطر صحية كبيرة للمستهلكين. لذلك، أجريت هذه الدراسة لتقييم التأثير التعديلي لمسحوق بذور الريحان على الإجهاد التأكسدي الناجم عن أحادي جلوتامات الصوديوم في الفئران. وفي هذا الصدد، تم استخدام ثلاثين فأرًا أبيضًا بالغًا من الذكور يزنون ١٥٠ ± ١٠,٨٦ جرام للدراسة وتم تقسيمهم إلى ٥ مجموعات ٦ فئران لكل منها. المجموعة ١ (-): المجموعة الضابطة السالبة، المجموعة ٢ (+): مجموعة أحادي جلوتامات الصوديوم فقط كمجموعة ضابطة موجبة، المجموعات ٣ ،٤ و٥ أعطيت أحادي جلوتامات الصوديوم وعولجت بـ (٢,٥ ،٥ و٧,٥ جم / ١٠٠ جم من النظام الغذائي) من مسحوق بذور الريحان، على التوالي. تم إعطاء مجموعات أحادي جلوتامات الصوديوم جرعة يومية عن طريق الفم من أحادي جلوتامات الصوديوم ٤ ملغ / كجم من وزن الجسم مذابة في الماء المقطر عن طريق أنبوب المعدة طوال فترة التجربة. بعد إكمال ٢٨ يومًا، تم تشريح الفئران؛ ثم جمع عينات الدم وأنسجة الكبد، وإخضاعها للتحاليل. أثر التعرض لـ أحادي جلوتامات الصوديوم سلبًا على المعايير البيولوجية مثل زيادة وزن الجسم وتناول االغذاء، والتي زادت بنسبة ١٠٠ و١٦٩,٥٧٪ على التوالي، بينما انخفضت نسبة كفاءة التغذية بشكل كبير بنسبة ٢٥,٦١٪ مقارنة بالمجموعة الطبيعية. تم تحسين هذه المعايير البيولوجية من خلال التدخل بمسحوق بذور الريحان (٢,٥ ،٥، ٧,٥ جم / ١٠٠ جم من النظام الغذائي). عكس استخدام مسحوق بذور الريحان التأثيرات السلبية لأحادي جلوتامات الصوديوم على مؤشرات الإجهاد التأكسدي للكبد (CAT، SOD، MDA وROS)، حيث أدى تدخل مسحوق بذور الريحان إلى زيادة CAT وSOD وتقليل MDA و ROS. سجلت المجموعة المعالجة بـ مسحوق بذور الريحان (٧,٥ جم / ١٠٠ جم من النظام الغذائي) تحسنًا، ووصلت إلى عدم وجود فرق معنوي مع المجموعة الضابطة السالبة في SOD، وسجلت (٣٢٠,٨٦٪) مقارنة بالمجموعة الضابطة الموجبة. بالإضافة إلى ذلك، كشفت نتائجنا أن المجموعة المصابة بـ أحادي جلوتامات الصوديوم أظهرت تغييرًا معنويا في التدهور في المعايير الدموية (الهيموجلوبين، الصفائح الدموية، خلايا الدم الحمراء، وخلايا الدم البيضاء)، إنزيمات الكبد (AST، ALT وALP)، بعض وظائف الكلى (اليوريا، الكرياتينين وحمض البوليك)، سيرم جلوكوز وصورة دهون الدم (TC، TG، VLDL، HDL، وVLDL). ومن المثير للاهتمام أن تناول مسحوق بذور الريحان (٢,٥، ٥ و٧,٥ جم / ١٠٠ جم من النظام الغذائي) أظهر القدرة على التخفيف بشكل معنوي ($p \leq 0.05$) من هذه التأثيرات السامة اعتمادًا على الجرعة. قدمت الملاحظات النسيجية لأنسجة الكبد دليلاً على التأثير المحسن لـ مسحوق بذور الريحان. أشارت الدراسة إلى التأثيرات الضارة لمادة أحادي جلوتامات الصوديوم واقترحت استخدام مسحوق بذور الريحان (٢,٥ ،٥ و٧,٥ جم/١٠٠ جم من النظام الغذائي) كعلاج محتمل للإجهاد التأكسدي الناتج عن أحادي جلوتامات الصوديوم، وخاصة مسحوق بذور الريحان (٧,٥ جم/١٠٠ جم من النظام الغذائي) الذي حقق أفضل نتائج التحسن. تحمل هذه النتائج أهمية كبيرة لتسليط الضوء على استخدام مسحوق بذور الريحان في صناعة الأغذية وكإجراء وقائي ضد الإجهاد التأكسدي الناتج عن أحادي جلوتامات الصوديوم.

الكلمات المفتاحية: بذور الريحان، الشوارد الحرة، محسن النكهة، حمض اللينولينك.