UNDER PEER REVIEW

Monosodium Glutamate induced hepatotoxicity and the possible mitigatingeffect of Vitamin C and Propolis

Abstract

Monosodium Glutamate has been recognized as flavor enhancer that adversely affects liver function's parameters. The aim of this study was to evaluate the effects of Monosodium Glutamate on the liver enzyme functions, lipid profile and antioxidant system and also assessed the ameliorating effects of Vitamin E and propolis in the rat liver tissues. Mature male wistar rats (weighing 150-200 g and each group of seven animals) were given Monosodium Glutamate (60 mg/Kg bw) and/or Vitamin C (200 mg/Kg) and/or Propolis (200 mg/Kg) extract daily via gavage for 4 weeks. In the present study, Monosodium Glutamate exposure resulted in an increase in the TBARS level and a decrease in the SOD, CAT, GPX activities in liver homogenates, with respect to the control. Supplementations of Vitamin E and/or propolis to Monosodium Glutamate-induced groups declined lipid peroxidation, increased SOD, CAT, GPX activities. As a result, Monosodium Glutamate induced hepatic toxicity is reduced by Vitamin E and/or selenium to a great extent by the entire restoration of the liver function markers and the antioxidant status.

Key words: Monosdium Glutamate, Vitamin C, propolis, Oxidative stress, Liver functions.

Abbreviations: MSG: Monosodium Glutamate, Vit.E: Vitamin E, SOD: Superoxide dismutase, CAT: Catalase, MDA: Malondialdhyde , GPX: Glutathione peroxidase.

1-Introduction

Eating behavior plays a vital role in metabolis and diet-related disorders. Some mechanisms for food cravings may benefit mammals from nutrient deficiency, otherwise overfeeding of palatable food may cause an imbalanced intake of nutrients . Monosodium glutamate (MSG) is one of the most abundant naturally occurring non-essential amino acids and MSG-treatment is able to produce metabolic changes, which can further result in severe bodily disturbances [1].

Glutamate is one of the most abundant amino acids in nature. Glutamate which is a derivative of l-glutamic acid is reported to be a natural nutrient in many foods. Today it is increasingly used (in the form of its salt MSG (monosodium glutamate) in food process singand home cooking all over the world aims to improve food palatability for humans. It gives a particular taste named “umami” is now recognized as the fifth basic taste. Recently it was recognized as an excitatory neurotransmitter in mammalian nervous system [2].

During intestinal absorption, a large amount of glutamic acid is transaminated and consequently alanine levels in portal blood are elevated. If large amounts of glutamate are ingested, portal glutamate levels will increase, this elevation results in an increase hepatic

UNDER PEER REVIEW

metabolism of glutamate, leading to the release of glucose, lactate, glutamine, and other amino acids, into systemic circulation [3].

Antioxidants have been reported to play a significant rolein the protection against lipid peroxidation **[4]**. Some investigators reported that antioxidantsinhibit chemical carcinogenesis when the antioxidants are administeredeither prior or during carcinogenic changes **[5]**.

Antioxidants as vitamins, can prevent the uncontrolled formation Of free radicals, or inhibit their reaction with biological sites, also the destruction of most free radicals rely on the oxidation of endogenous antioxidants mainly by scavenging and reducing molecules [6]. Vitamin C, as a water soluble antioxidant is reported to neutralize ROS and reduce oxidative DNA damage and hence genetic mutations [7].

Propolis hasattractedtheattentionofresearchersbecauseof its variousbiologicalactivitiesandtherapeuticproperties.Propolis is asticky,resinousproductthatisproducedbyhoneybeesforthe construction andmaintenanceoftheirhives.Itismadebymixing the honeybees ownwaxeswiththeresinsthatarecollectedfrom variousplants.Propoliscontainsavarietyofchemicalcompounds, such aspolyphenols(flavonoidaglycones,phenolicacidsandtheir esters, andphenolicaldehydes),alcoholsandketones,sesquiter-penequinones,coumarins,steroids,aminoacids,andinorganic compounds **[8]**.

One ofthebiologicalactivitiesof propolis, itsantibacterialandantifungalactivitiesofpropolis is the mostextensively investigated **[9]**. Its pharmacological activities, suchas anticancer **[10]**, anti-inflammatory **[11]**, antibiotic **[12]**, antioxidative**[13]**, antiviral **[14]** anaestheticand immunostimulant**[13]**havebeen described totheethanolicextractsofpropolis.

In the last few years, fear had increased due to the adverse reactions and toxicity of MSG, with few and limited literature regarding the biochemical and histological studies of the damage in liver treatment of animals with MSG.So, the present study was designed to investigate the effects of MSG on the testicular tissue of mature male rats. In addition, to the best of our knowledge, no comprehensive study concerning the protective effect of vit C and propolis on MSG-induced hepatic dysfunction. The main objective of the present work is to study the effect of propolis or vit C and their role in the amelioration of the hepatic toxicity induced by MSG.

2-Material and methods:

2.1. Chemicals:

Monosodium glutamate ($C_5H_9NO_4$.-Na) Purity 99% NT, it was sold in most open market under the license of Ajinomoto Co.INC.Tokyo, Japan. A stock solution was prepared by dissolving 60 g of MSG crystals in 1000 ml of distilled water. The dose schedule was so adjusted that the amount of MSG administration per animal was as per their respective weight. The applied doses were selected according to **[15]**.Vitamin (C) was supplied by

UNDER PEER REVIEW

Merck (Germany) and it was dissolved in dist.water and administered orally for 30 successive days at a dose 200 mg/Kg [**16**].
Commercially available diagnostic UV kits were used to determine alanine transferase (ALT), lactate dehydrogenase (LDH) and total proteins (Human diagnostic worldwide,Germany). Moreover, total cholesterol, high density lipoprotein-cholesterol (HDL-c) and ascorbic acid (AA), were bought from Bio-diagnostic, Egypt (Stanbio Co.,Spain).

2.2. Propolis preparation:

Fifty grams of the resinous material of Egyptian propolis were cut into small pieces and extracted with 600 ml of 80% (v/v) ethanol at 60˚C for 30 min. After extraction, the mixture was centrifuged and the supernatant was evaporated to complete dryness under vacuum at 40˚C [**17**]. It was kept at 4 ˚C for further use. An aqueous suspension of propolis was prepared in 1% gum acacia suspension, and orally administered to the animals for 3 weeks at a dose of 200 mg/kg [**18**].

2.1.Animals and experimental design:

Seventy male Wistar rats (Weighing 220-250 g), were used in all experiments of this study. They were obtained from the Animal House of the National Research Center (Dokki, Giza, Egypt). The animals were maintained on solid-bottom shoe box, type polycarbonate cages with stainless steel wire-bar lids, using a wooden dust free litter as a bedding material. Animals were allowed free access to diet and water in good air conditioned room and were allowed free access and tap water for two weeks before starting the experiment. We have followed the European community Directive (86/609/EEC) and national rules on animal care. One group served as control.Animals were weighed and randomly allocated into 7 groups (10 rats each) as following:
Group 1 – control rats treated with 1 mg/kgBW corn oil per day; Group 2 – MSG–treatedrats (60 mg/Kg BW per day in distilled water) [**15**]; Group 3– vit C treated rats (200 mg/kg BW per day in corn oil)[16]; Group Group 4 – Propolis treated rats (200 mg/kg BW per day in distilled water) [18]; Group5– MSG plus Vit.C-treated rats. Group 6 – MSG plus propolis.Group 7 – MSG treatedrats followed by MSG and propolis daily for successive 30 days.The doses were administered in the morning (between 9.30 and 10.30 h) to non-fasted rats.The first day, when the animals were treated was considered experimental day 0. At the end of the 30 days of treatment, all animals were scarified and dissected. The testis tissues were quickly processed for light microscopeinvestigations and biochemical examinations.

2.4. Biochemical Analyses

2.4.1. Lipid profile

Triglycerides, cholesterol and high density lipoprotein-cholesterol (HDL-c) were determined using the commercial kits. Low density lipoprotein-cholesterol (LDL-c) levels were calculated by using the following formula of Muruganandan et al.[19] LDL-c = total cholesterol—(HDL-c + triglycerides)/5. Volatile low density lipoprotein-cholesterol (VLDL-c) levels were calculated by using the following formula :VLDL-c = triglyceride/5.

UNDER PEER REVIEW

2.4.2. Hepatic markers

Serum aspartate transaminase (AST), alanine transaminase (ALT) and lactate dehydrogenase (LDH) enzyme activities were determined with kits from Human diagnostic worldwide, Germany.

2.5. Tissue homogenates preparation and estimation ofantioxidant capacities parameters:

The excised liver tissue was washed with distilled water for the removal of blood, and later thefatty parts were removed. Tissues were homogenized inice-cold 50 mM sodium phosphate buffer (pH 7.4) containing 0.1 mM ethylenediaminetetraacetic acid (EDTA). Thesupernatant was separated by means of centrifugation at5000 rpm for 20 min at 4◦C. The supernatant was used forthe analyses of all biochemical parameters.

2.5.1. Lipid peroxidation assay

TBARS content was evaluated by using the thiobarbituric acid (TBA) test as described by Ohkawa et al. [20]. Afterincubation of testis homogenates with TBA at 95◦C, TBARSreacts to form a colored complex. Absorbance was measured spectrophotometrically at 532 nm to determine theTBARS content. The level is expressed as nmol/mg protein.

2.5.2. Measurement of superoxide dismutase (SOD)

SOD activity was measured according to the methoddescribed according to Misra and Fridovich [21] byassaying the auto oxidation of pyrogallol at 440 nm for3 min. One unit of SOD activity was calculated as theamount of protein that caused 50% pyrogallol autooxidation inhibition. A blank without homogenate was usedas a control for non-enzymatic oxidation of pyrogallol inTris–EDTA buffer (50 mM Tris, 10 mM EDTA, pH 8.2). TheSOD activity is expressed as U/mg protein.

2.5.3. Measurement of catalase (CAT)

CAT activity was measured according to the methoddescribed by Aebi [22] by assaying the hydrolysis of $H_2O_2$and the resulting decrease in absorbance at 240 nm overa 3 min period at 25◦C. Before determination of the CATactivity, samples were diluted 1:9 with 1% (v/v) Triton X-100. CAT activity is expressed as mmol/mg protein.

2.5.4. Measurement of glutathione peroxidase (GPx)

GPx activity was measured using H_2O_2as substrateaccording to the method described by Paglia and Valentinen [23]. The reaction was monitored indirectly as the oxidation rate of NADPH at 240 nm for 3 min. A blank withouthomogenate was used as a control for non-enzymatic oxidation of NADPH upon addition of hydrogen peroxide in0.1 M Tris buffer, pH 8.0. Enzyme activity was expressed asnmol/mg protein.

2.6. Statistical analysis:

Data were collected, arranged and reported asmean ± standard error of mean (SEM) of twelve groups, andthen analyzed using the computer program (SPSS/version15.0). The statistical method was one way analyzes of variance ANOVA test, and if significant differences betweenmeans were found, Duncan's multiple range test (Whosesignificant level was defined as $P < 0.05$) according to [24]to estimate the effect of different treated groups.

UNDER PEER REVIEW

3. Results:

3.1.Biomarkers of liver and lipogram assessment:

All the parameters of the lipid profile (TG, TC, LDL-c and VLDL-c) were increased except the HDL-c was decreased when the rats exposed to the dose of MSG (Table.1). Administration of Vit C or/and propolis to the MSG-treated group restored most normal values of the parameters cited above (Fig. 1).Serum ALT activity of Vit C and propolis groups elicited non-significant changes when compared with the control group. In the MSG-treated group, the ALT was increased by 78 fold when compared to control (Fig. 2). Treatingthe rats with 60 mg/Kg of MSG with the combination of Vit C and propolis decreased the activity of ALT more than combination with each compound separately.The same observation has been noticed in the AST activity that increased by administration the dose of MSG and decreased by thetreatment of each antioxidant separately and the most increment was recorded in the combination of both antioxidants (Vit.C and propolis) with MSG (Fig. 2). LDH enzymehighly increased in MSG-treated group by 1890 fold when compared with the control group , but increased by 543 and 545 fold in the groups treated with the MSG and Vit C or MSG and propolis, respectively (Fig. 2).The best combination group that highly decreased LDH value was recorded in the group treated with a combination of Vit.C and propolis with MSGas LDH was increased by 340 fold as compared to a normal control group.

3.2.Assessment of enzymatic antioxidantsand non-enzymatic lipid peroxidation as oxidative biomarkers:

As shown in Table 3, the data showed that treatment with MSG caused a significant ($p < 0.05$) decrease in the activity of SOD level in MSG treated group as compared to control group. Meanwhile the administration of Vit.C alone and propolis alone to rats elicited non-significant changes as compared to normal control group.Administration of Vit.Cin combination with propolis exhibited slight significant decrease in SOD activity with respect to control group by 27.35 % .In addition, a significant recovery relating to CAT and GPX was observed in response to the presence of Vit.C with propolis in treated rats with MSG. Treatmentof the rats with MSG alone decreased the CAT and GPX activities. However, Co administration of Vit.C and propolis with MSG increased the CAT and GPX activities as compared with the MSG group.

The treatment of the rats with MSG alone induced a highly significant increase in MDA level (non-enzymatic antioxidant) as MDA is the final product marker of lipid peroxidation.The treatment of rats with Vit.C and propolis in combination with MSG afforded asignificant increase in MDA but with the significant reduction in MDA as compared to SG treated group only by 53.2%.

4. Discussion:

The present study was conducted to elucidate the protective role of Vit.C or propolis separately or in combination against MSG-induced hepatic damage and oxidative stress

UNDER PEER REVIEW

in liver tissues of rats. There is no literature report available on the efficacy of Vit.C and propolis in combination in cases of MSG exposure in rats. In this respect, the present study bears originality.

Variation in total cholesterol levels were significantly within the groups; however, Group treated with MSG had shown elevated cholesterol levels more than groups treated with a combination of MSG and VitC and propolis, which suggest a direct correlation between MSG administration and the increment of cholesterol level and affecting on fat metabolism. Inuwa et al.[25] found that the potential explanation for MSG – obesity link lies in the alteration of regulatory mechanisms that affect fat metabolism.Also, another explanation in this study related to increased levels of TG, LDL-c and vLDL-c and decreasing HDL-c level suggests that MSG could be a risk factor or coronary heart disease [26].

According to our previous results recorded by Hamza et al.,[27] as they reported the role of propolis in decreasing blood glucose levels in diabetic rats and thus enhancing lipid metabolism as it is known that liver is organ involved in glycogenesis, glycogenolysis, gluconeogenesis, and glycolysis and thus affecting by direct way on lipid metabolism and this confirmed our obtained results by decreased the levels of TC,TG,LDL-c and vLDL-c in groups treated by either propolis or combination between propolis and MSG.
Results of Elmazoudy et al [28] supported our results as they clearly indicated that previous administration of the propolis induced marked change in lipoproteinsand elicited marked fall in the total cholesterol and LDL-c levels in rats induced by CPF in the rat blood serum.

The elevated levels of ALT and AST levels could be an indication of hepatocellular damage induced by MSG [25].Our findings are greatly supported by our previous results obtained by Diab et al.,2012 as they showed that the AST activity determined to be higher in the group that was administered Chlorpyrifos and AST was demonstrated to be decreased in the groups that were administered Propolis in combination with Chlorpyrifos.
Ramadan et al., [29] reported that oral administration of Propolis for 70 days; decreased the activities of AST and ALT in plasma. Also, Sforcin et al., [30] reported that treatment of rats with Propolis does not induce any alteration in AST level. Moreover, Mani et al., [31] found no alteration in AST value in the serum of Propolis treated rats for (30 or 90 or 150 days) at doses of (1, 3 and 6 mg/kg/day) and so all these findings supported our obtained results that propolis protect against hepatotoxicity induced by MSG administration.
It has been generally accepted that the leakage of LDH enzyme correlates well with cellular viability, thus being a useful indicator of plasmatic membrane damage and/or necrosis of hepatocytes [26].

UNDER PEER REVIEW

The present significant change in liver enzymes AST and ALT in MSG treated group and , thus, may confirm that the hepatocytes are more affected by MSG exposure.

Oxidative stress refers to disrupted redox equilibrium between the production of freeradicals and the ability of cells to protect against damage caused by these species. Defense against oxidative stress are maintained by using several mechanisms which include antioxidant machinery. The main cellular components susceptible to damage by free radicals are lipids (peroxidation of unsaturated fatty acids in cell membranes), proteins (denaturation), carbohydrates and nucleic acids; this in turn can impair cellular structure and function [32].

It has been indicated that the LPO is one of the molecular mechanisms involved in pesticide-induced cytotoxicity [33]. These findings support the occurrence of oxidative stress in the present study induced by CPF. The results showed that the LPO level was significantly increased in rat testicular tissue treated with CPF. The toxic manifestations induced by the tested

pesticide may be associated with the enhanced production of ROS or the increase in MDA levels which is induced by the pesticide itself (degradation of phospholipids and ultimately result in

cellular deterioration) or by a possible increase in free radicals caused by CPF [34].

Among the antioxidant enzymes, SOD, CAT and GPx are the first line of defense against oxidative injury. SOD is the primary step of the defense mechanism in the antioxidant system against oxidative stress by catalyzing the dismutation of superoxide radicals (O_2^-) into molecular oxygen (O_2) and hydrogen peroxide (H_2O_2) [35]. H_2O_2 is neutralized by the combined action of CAT and GPx in all vertebrates [36]. These enzymes act in coordination and the cells may be pushed to oxidative stress state if any changeoccurs in the levels of enzymes.

Our obtained data confirmed by the results obtained by Hamza et al.,2014b who reported that MSG caused an elevation in lipid peroxidation level parallel with significant decline in SOD, CAT as well as GPx activities in testis tissues.

The current data displayed MSG-induced reduction in the activities of the antioxidant enzymes (SOD, CAT and GPx) and the content of non-enzymatic antioxidant (MDA). This effect might be due to increased H_2O_2production and ROS generation which in turn induces oxidative stress.

In the present study, a significant decrease in the specific activity of SOD in liver tissues was observed in MSG-treated livertissue, suggests an increased superoxide radical production and other ROS thereby induce oxidative damage [37]. CAT activity of hepatic tissue was decreased in MSG-treated rat.

GPx is the general name of an enzyme family with peroxidase activity whose main biological role is to protect the organism from oxidative damage. The biological function of GPx is to reduce lipid hydroperoxides conversion to their corresponding alcohols and to reduce free H_2O_2 reaction [38].

In our present study, a significant fall in GPx activity was observed in MSG-treated animals. This observation may be due to enhanced free radical production (as evidence

UNDER PEER REVIEW

by increase LPO) and apart from CAT also involved in the removalof H_2O_2. H_2O_2 generated due to MSG toxicity,
.Hence, the GPx level decreases on MSGadministration.

It was found that the administration of vit C and/or propolis to MSG-injected rats restored SOD , CAT and GPx activity to nearly control level. However, MDA level was decreased significantly after Vit C administration as compared to MSG. Therefore, the present decrease in GPx activity and restoration of SOD activity to nearly control level, inaddition to the decrease in MDA content in the liver tissues, could indicate the antioxidant properties of Vit C. It also increased the antioxidant enzymatic activity.
In accordance with our results, the mild oxidative state observed in the hippocampus due to MSG administration may be due to the inherent high content of Vit C in this brain area. The consumption of vit C is useful for the antioxidant effect as it offers an effective and safe way of increasing body immune system against free radicals and, at the same time, keeps the oxidative stress in a state of balance [39].

The results indicate the protective effect of vit C and/or propolis in combating oxidative stress undergone by the rat. In addition, thehigh antioxidant activity was found in the rat treated with vit C alone and incombination with propolis as reported before by Hashim [40] and Diab etl.2012 [41]. This result indicates that vit C and propolis are a strong scavenger of free radicals.
In conclusion, the present findings strongly indicate that hepatic damage , hyperlipidemia and oxidative stress resulting from MSG in dose dependent manner is involved in toxicity mechanisms of liver of rat. MSG increased the enzymes leakage of LDH due to increase of the generation of free radicals as hepatic LPO increased. MSG decreased the enzymatic and non-enzymatic antioxidants. These results suggest that these MSG-induced metabolic disorders associated with oxidative stress while,Vit.C and propolis exhibited strong antioxidant activities. The results emphasize the importance of reassessment of MSG toxicity, a substance widely used in food industry. Protection can be derived from treatment of the rats with antioxidant
vit C and propolis that increased the stability of membrane and decreased the liberation of cellular enzymes. Treatment with vit C and propolis after treatment with the MSG restored the same efficiency of the antioxidant enzymes, and they plays a preventive role against MSG-induced cellular oxidative stress.

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UNDER PEER REVIEW

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UNDER PEER REVIEW

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UNDER PEER REVIEW

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UNDER PEER REVIEW

Tables

Table (1): Effects of treatment of Monosodium Glutamate, Vitamin C, Propolis and their combinations with MSG on Lipid profile parameters.

Groups	Cholesterol (mg/dl)	Triglycerides (mg/dl)	HDL-c (mg/dl)	LDL-c (mg/dl)	VLDL-c (mg/dl)
1- control group	67.22±4.57^{g}	98.99±4.77^{f}	36.78±3.62^{ab}	33.24±2.52^{f}	6.64±2.45^{e}
2-Mono sodium Glutamate (MSG)	255.14±22.1^{a}	193.62±9.54^{a}	7.25±2.42^{g}	210.23±12.45^{a}	42.04±4.21^{a}
3-Vitamin C	70.11±2.15^{ef}	100.25±10.25^{ef}	31.20±5.24^{c}	37.20±5.42^{ef}	7.44±3.52^{de}
4-Propolis	69.11±2.15^{fg}	101.63±8.65^{ef}	33.25±3.24^{bc}	36.52±3.52^{ef}	7.30±5.75^{de}
5-MSG+Vit.C group	99.41±6.75^{bc}	135.74±6.48^{c}	20.34±3.21^{e}	115.32±4.36^{c}	23.06±6.75^{b}
6-MSG+Propolis	97.52±3.54^{c}	142.03±7.25^{bc}	17.28±3.21^{f}	128.98±6.38^{b}	25.79±3.68^{b}
7- MSG+Vit.C + Propolis	81.08±4.12^{d}	129.24±9.45^{d}	27.36±2.75^{d}	69.21±4.12^{d}	13.84±3.96^{c}

Means within the same column in each category carrying different litters are significant at ($P \leq 0.05$) using Duncan's multiple range tests, where the highest mean value has symbol (a) and decreasing in value were assigned alphabetically.

Table (2): Effects of treatment of Monosodium Glutamate, Vitamin C, Propolis and theircombinations with MSG on Liver function parameters.

Groups	ALT (U/L)	AST (U/L)	LDH(U/L)
1- control group	13.00±0.56^{ef}	12.20±0.54^{de}	310.66±20.63^{d}
2-Mono sodium Glutamate (MSG)	91.00±1.18^{a}	177.80±7.39^{a}	2200.40±25.37^{a}
3-Vitamin C	12.35±1.42^{f}	11.98±0.23^{e}	341.30±23.10^{cd}
4-Propolis	13.01±1.35^{ef}	12.24±1.01^{de}	345.69±17.33^{cd}
5-MSG+Vit.C group	70.45±1.18^{c}	109.36±5.36^{b}	853.12±23.04
6-MSG+Propolis	78.80±1.82^{bc}	107.80±6.02^{b}	855.40±25.37^{b}
7- MSG+Vit.C + Propolis	20.40±0.30^{d}	55.40±1.12^{c}	650.21±18.23

Means within the same column in each category carrying different litters are significant at ($P \leq 0.05$) using Duncan's multiple range tests, where the highest mean value has symbol (a) and decreasing in value were assigned alphabetically.

Table (3):Effects of treatment of Monosodium Glutamate, Vitamin C, Propolis and their combinations with MSG on antioxidant parameters capacities in liver homogenates.

Groups	MDA (nmol/mg protein)	CAT (nmol/mg protein)	SOD (U/mg protein)	GPx (nmol/mg protein)
1- control group	0.24±0.01^{b}	0.86±0.12^{a}	9.65±0.36^{ab}	6.67±0.63^{ab}
2-Mono sodium Glutamate (MSG)	0.92±0.03^{a}	0.25±0.10^{e}	2.63±0.45^{e}	1.10±0.85^{f}
3-Vitamin C	0.25±0.02^{b}	0.85±0.23^{a}	9.30±0.96^{b}	6.55±0.74^{b}
4-Propolis	0.26±0.02^{b}	0.87±0.15^{a}	9.38±0.42^{b}	6.50±0.36^{b}
5-MSG+Vit.C group	0.63±0.01^{d}	0.43±0.18^{d}	5.55±0.36^{d}	3.79±0.10^{cd}
6-MSG+Propolis	0.76±0.04^{d}	0.49±0.20^{cd}	5.58±1.20^{d}	3.87±0.57^{c}
7- MSG+Vit.C+ Propolis	0.43±0.03^{c}	0.65±0.35^{b}	7.01±1.11c	4.36±0.85^{e}

UNDER PEER REVIEW

Means within the same column in each category carrying different litters are significant at ($P \leq 0.05$) using Duncan's multiple range tests, where the highest mean value has symbol (a) and decreasing in value were assigned alphabetically.

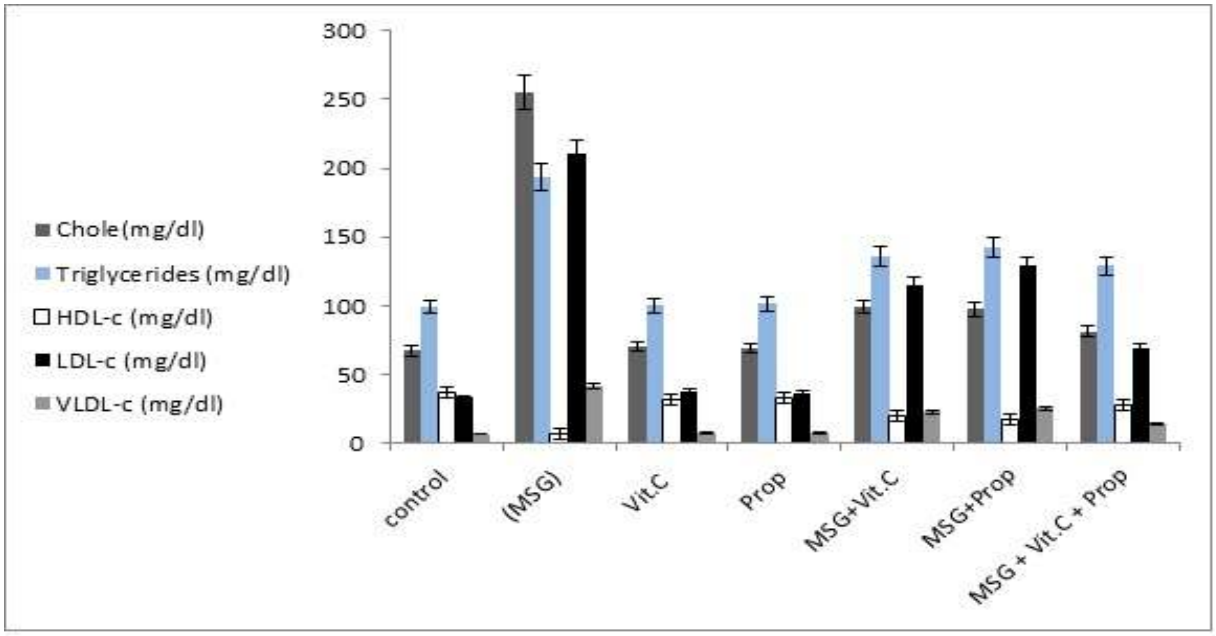
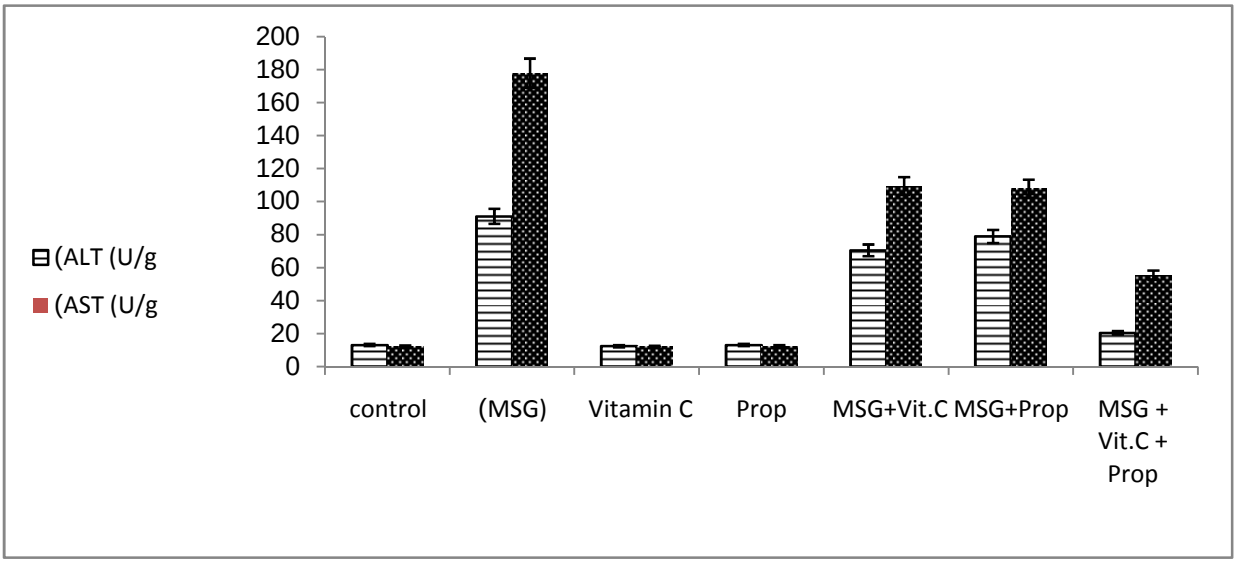


Fig (1):Effects of treatment of Monosodium Glutamate, Vitamin C, Propolis and their combinations with MSG on Lipid profile parameters.



Fig(2):Effects of treatment of Monosodium Glutamate, Vitamin C, Propolis and theircombinations with MSG on Liver function biomarkers.

UNDER PEER REVIEW

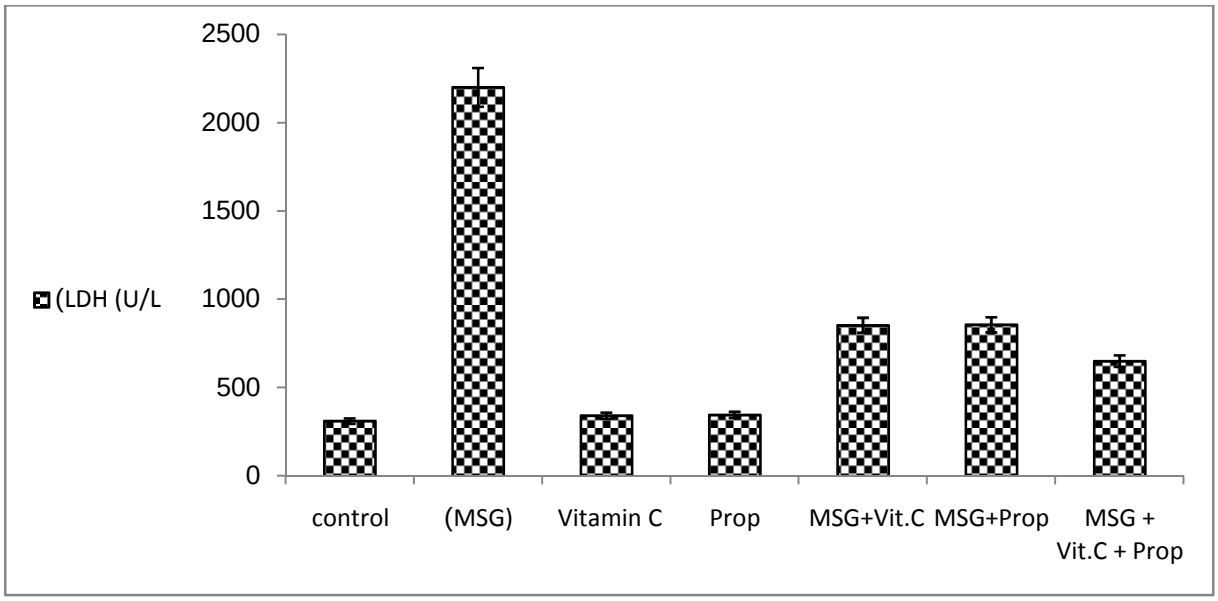


Fig (3):Effects of treatment of Monosodium Glutamate, Vitamin C, Propolis and theircombinations with MSG on LDH enzyme level.

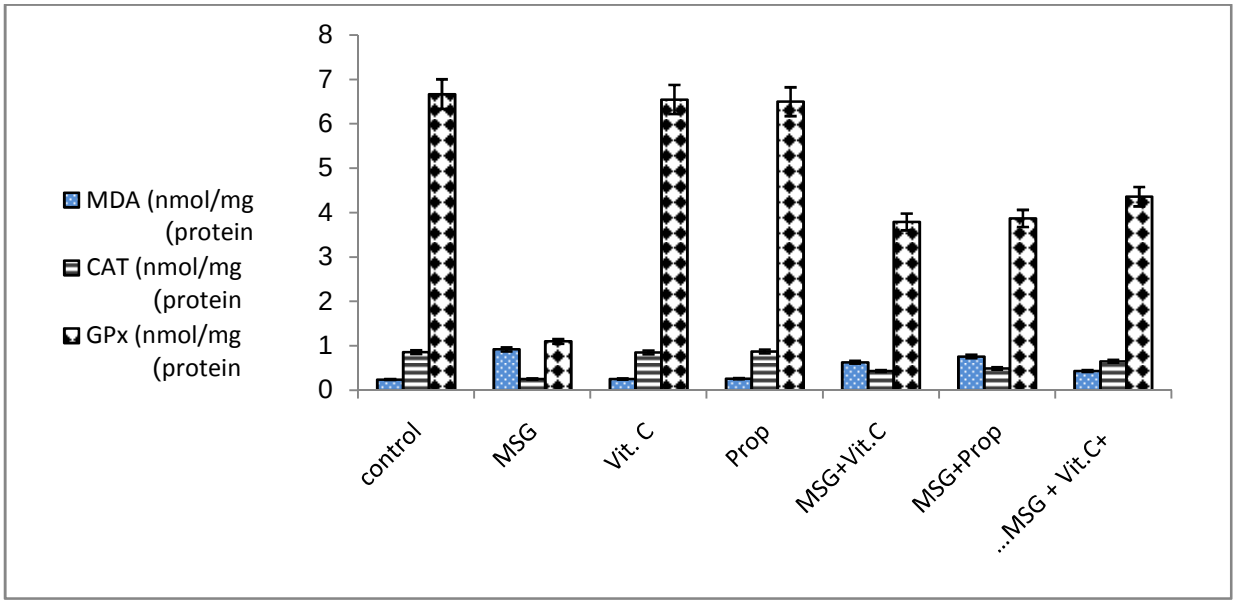


Fig (4):Effects of treatment of Monosodium Glutamate, Vitamin C, Propolis and their combinations with MSG on antioxidant parameters capacities in liver homogenates.