

Original Article



Antioxidant activity of novel selena-diazole derivative against oxidative stress induced by dipyrone in female rats

Nadheerah F. Neamah^{1*} , Abdul-Razzak Naaem Khudair², Shaker.A.N.Al-Jadaan³

1. Pharmacology & Toxicology Department, College of Pharmacy, University of Basrah, Iraq
2. Physiological Department, College of Veterinary, University of Basrah, Iraq
3. Pharmaceutical Chemistry Department, College of Pharmacy, University of Basrah, Iraq

Abstract

Introduction: Selena-diazole has antioxidant, and antitumor activities. Also selena-diazol exhibited promising antifungal, antibacterial, viral infection and neurodegenerative disease. The aim of the study is to evaluate the antioxidant activity of a novel 4,4'-(4,5,6,7-tetrahydro- [1,2,3-] selenadiazolo [4,5 e] pyridine-4,6-diyl) bis(benzene-1,3-diol) (T) against dipyrone (Di) induced oxidative stress.

Methods: *In vitro* antioxidant using DPPH, concentrations of T and ascorbic acid (AA) at 10, 20, 30, 40 and 50µg was measured. *In vivo* study conducted using four groups, received 50mg/kg of T or/and Di and DW for 30 days. Antioxidant estimated *in vivo* by serum superoxide dismutase activity (SOD); Glutathione Peroxidase enzyme GPx measured by using Rat SOD1 kit and Rat GPX1 ELISA Kit respectively. Furthermore, Malondialdehyde (MDA) is reliable biomarkers to predict oxidative stress.

Results: The results indicate IC₅₀ rate using DPPH of T compound 48.888µg/ml. GPx of T and T&Di groups were significantly increased. SOD of T was significantly increased than other groups. MDA results presented essential reduction in T group value than Di group.

Conclusion: The study concluded that synthesized novel selena-diazole derivative T has a good effect as an anti-oxidant.

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Keywords:

Antioxidant;
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* Corresponding author:

N.F. Neamah

Email:

nadheerah.neamah@uobasrah.edu.iq

Tel: (+647) 801471701

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Introduction

Selena-diazole has antioxidant, and antitumor activities. Also selena-diazol exhibited promising antifungal, antibacterial, viral infection and neurodegenerative disease. In general, selenium

containing compounds restores antioxidant enzyme activity like glutathione peroxidase (GPx). Selenium is an oligo nutritional constituent with important biological roles. It acts as a prosthetic group in thioredoxin reductase enzyme and glutathione

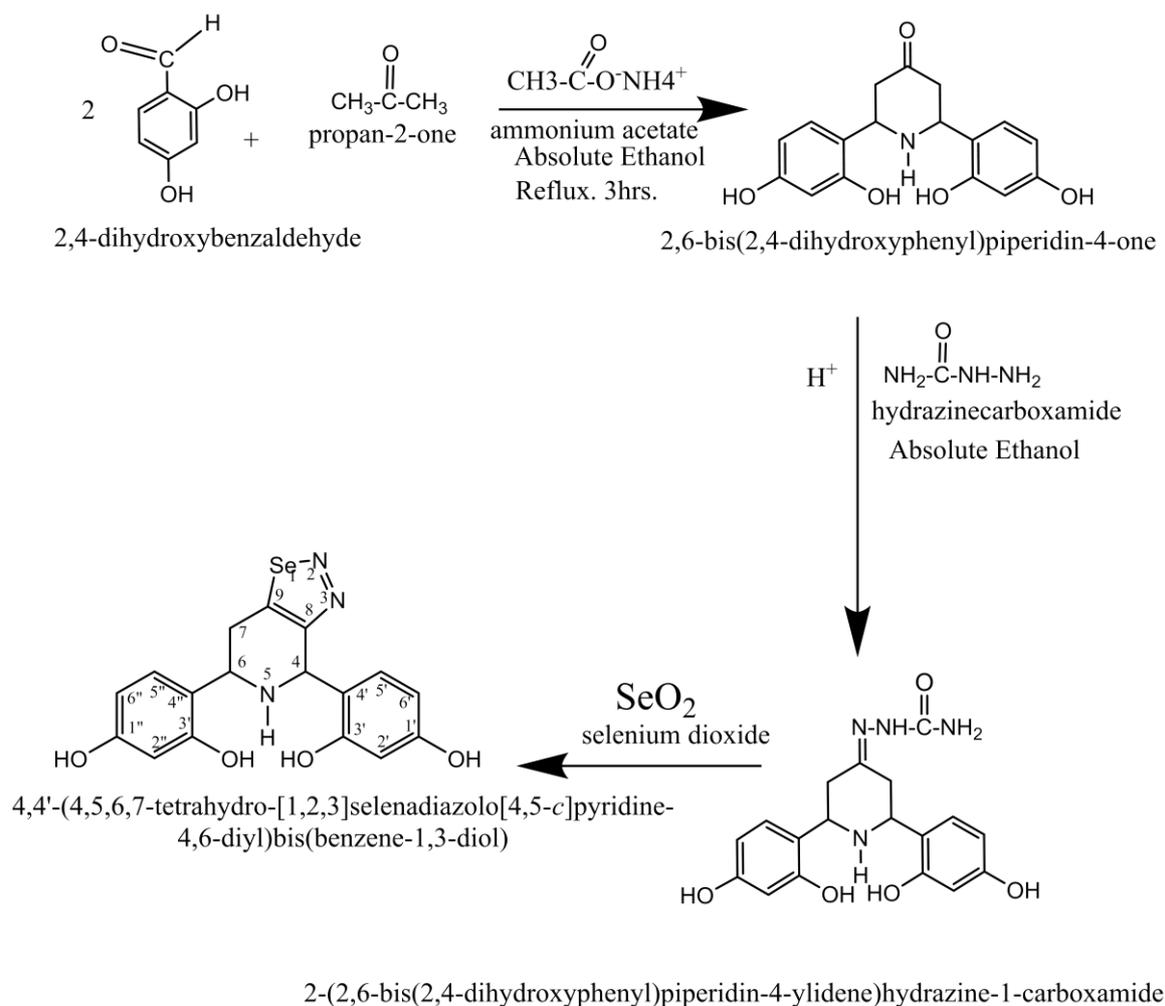


Fig.1. Schematic illustration of the synthesis path way for preparation of novel seleno-diazole derivative (Neamah et al., 2020)

peroxidase enzyme thus selenium considered as an effective free radicals scavenger (Ghorbel et al., 2017). Also, selenium has ability to oxidize thiol groups in both non- protein and protein as a consequence superoxide particle thus it can act as pro-oxidant. Selenium insufficiency is detected in numerous metabolic diseases, such as hyperlipidemia, hyper-glycemia and hyper-phenylalaninemia. Addition of selenium may recover hyper-cholesterolemia, type1 diabetes mellitus, atherosclerosis and phenylketonuria. Furthermore, selenium has detoxification activity to heavy metal intoxication, when selenium added to diet and its deficiency related with several diseases such as chronic degenerative disease (Ansar et al., 2017). Imbalance in homeostasis in pro-oxidant results in creation of highly reactive oxygen species (ROS)/reactive nitrogen species (RNS) which can be an essential mediator of destruction to cell components such as DNA and lipids. Oxidative

impairment acts as a vital role in health. ROS/RNS creation in low to moderate concentration induce molecular signals that manage a series of physiological actions specially regulates ventilation, preserves vascular tone and maintain redox homeostasis supporting (Kurutas, 2016). Malondialdehyde (MDA) is a naturally occurring product of lipid peroxidation. Lipid peroxidation is a well-established mechanism of cellular injury and assists as a reliable biomarker of oxidation; therefore MDA is mutagenic and carcinogenic. Organic selenium has larger bioavailability, with lower toxicity in comparison with inorganic compound. Firstly unstable compounds were synthesized like selenols. Various studies concentrated on development of more stables and easily purified organo-selenium compounds. Novel compounds have potential therapeutic effects towards several diseases, for example: cancer, microbial infections and neurodegenerative diseases. Seleno diazole

compound (T) compound was previously synthesized, characterized and identified. FT-IR spectra, melting point and TLC were measured in the department of Pharmaceutical Chemistry, College of Pharmacy/ University of Basrah/ Iraq. ¹H-NMR and ¹³C-NMR spectra of (T) compound was recorded using Bruker Ultra shield spectrophotometer (300 MHz), University of Al-al-Bayt, Jordan. Median lethal dose and antimicrobial activity also measured (Neamah et al., 2020). The pathway of the synthesis illustrated in Figure 1.

Dipyrrone (Di) or metamizole is a contentious drug, due to the hazard of its agranulocytosis side effect; therefore it's excluded for human use. The complete hazard of agranulocytosis related with the administration of pyrazolone drugs at an ordinary dose for short periods of time has been believed to be low. Nevertheless dipyrrone still accessible in some countries in Europe like Spain and Germany (Costa et al., 2006). Thus antioxidant enzyme like catalase (CAT), superoxide dismutase (SOD) and GPx are used as indexes to calculate the level of oxidative stress (Li et al., 2015). The current study aim to evaluate the antioxidant activity of a Novel 4,4'-(4,5,6,7-tetrahydro- [1,2,3-] selenadiazolo [4,5 e] pyridine-4,6-diyl) bis(benzene-1,3-diol) synthesized by authors against dipyrrone induced stress.

Materials and methods

Animal preparation

Forty female rats obtained from College of Veterinary Medicine/Basrah University. All procedures of this study were approved by Veterinary Medicine College/ University of Basrah (Approved No:7/18/2420 At Nov 2nd 2019), the animals kept in cages from polypropylene lined with sawdust (3-4rats/cage) and separated as groups. Rats were providing usual pellet diet and tap water. First, they were adapted to laboratory circumstance, natural day and night (12h day and 12h night). Room temperature was 21±4°C (Kumar et al., 2017). Body weight of all rats was measured. Each animal group consist 10 female rats, the rats were orally received through oral gavage 50mg/kg of body weight (BW) of T or/and Di, dissolved in 2ml distilled water (DW) for 30 days. Control group received only 2ml of DW. The rats after 30 days were sacrificed using chloroform anesthetic drug, the blood pull directly from the heart, blood sample kept in serum-separating tubes on room

temperature for 20-30 minutes. Serum collected using centrifuges for 10min at 4000 RPM.

Antioxidant

Radical scavenging assay using 2,2-diphenyl-1-picrylhydrazyl (DPPH)

The antioxidant capacity of any synthesized or natural compound detected according to its scavenging capacity of the stable DPPH free radical. Mixing DPPH, C₁₈H₁₂N₅O₆ (M=394.33) solution with the test material that can offer a hydrogen atom, increases the reduced form with change of the violet color. If DPPH radical representing by Z•, and the antioxidant or the donor molecule by AH, reaction is $Z^{\bullet}+AH=ZH+A^{\bullet}$ (1)

The free radical A• obviously reacts with an additional A• molecule.



DPPH conveys an intense absorption band at 517nm and solution appears a deep violet color (Rached et al., 2018). In each examination all concentrations of the test substance were measured for antioxidant activity at the same time and then the examination was repeated to all concentrations for the second time using new preparation materials. Each concentration repeated 10 times.

Preparation of DPPH

DPPH solution was prepared by adding 7.89mg of DPPH to 100ml of DMSO, the resultant 0.2mM DPPH solution was kept for 2h in a dark by casing the test tubes and flask with aluminum foil, at room temperature (23-25°C). The next step is adding 1ml of prepared DPPH to 3ml of DMSO, the absorbance was measured using 517nm, and recorded as control data (Mostafa et al., 2017).

Preparation of tested sample (T) and ascorbic acid (AA) concentrations

Five milligram of T and AA were weighted 3 times and then each dissolved in 10ml of DMSO. From this solution different concentrations of T and AA were prepared. First 1mg of each T and AA dissolved in 2ml of DMSO, each ml contain 500µg of T or AA. Only 400µl (50 µg/100µl) were added to 1600µl of DMSO, the resultant solution contain 200µg/2ml. T and AA concentrations at 10, 20, 30, 40 and 50µg was prepared by sequent dilution as mention in Table 1 (Sherikar and Mahanthesh, 2015).

Measurement assay

The spectrophotometric technique for measuring the antioxidant ability of T and AA are based on the reduction of the absorbance of the DPPH radical. From each concentration of T and AA, 3ml was added into separated test tube. One ml of 0.2mM DPPH was added to each T and AA test tube. The mixture was shaking and stands for 10min at room temperature. Then the absorbance measured via spectrophotometer at 517nm. AA first measured as reference standard material, inhibition of absorbance or DPPH scavenging activity was calculated by the equation:

Percent inhibition = $(A_0 - A_1 / A_0) * 100$ (S.D.Sanja et al., 2009).

A_0 refer to the absorbance of control reaction and A_1 the absorbance in presence of (T), or standard sample AA. The IC_{50} rate of the test sample was measured from concentration and inhibiting percentage curve. The IC_{50} of each diagnostic sample was measured according to the following formula:

IC_{50} for T: $y = 13.161x + 14.635$; IC_{50} for AA: $y = 5.8935x + 54.502$

Y are inhibition ratios, plotted against concentrations of the sample X, the regression line for each (T) and AA ($Y = aX + b$) is drawn. Basically all point that measured is on the regression line and at least 2 points around 50% do not have deviation from the line (Shimamura et al., 2014). The IC_{50} is the concentration of an antioxidant at which 50% inhibition of free radical activity is observed. The lower IC_{50} value indicates the greater overall effectiveness of the antioxidant. The IC_{50} of the compound was measured by spectrophotometric method (Hangun-Balkir and McKenney, 2012).

Serum MDA levels assay

Determination of MDA in different samples such as plasma, serum or tissue homogenates is one of the reliable biomarker to predict the oxidative stress levels (Singh et al., 2014). In the present study MDA measurement is carried out as reported by Yagi method (Yagi, 1998). The reaction achieved in acidic situations and at 95°C. The resultant substance was TBARS "thiobarbituric acid reactive substances". TBARS can be measured by either fluorimetry (excitation at 532nm and emission at 553nm) or colorimetry (532-535nm), (Atiba et al., 2016). The

results estimated by the following equation:

$$MDA (\mu\text{mol/l}) = (A_1 - A_0 / 1.56) * 10$$

Where A_1 is test sample absorbance and A_0 is control absorbance (Antolovich et al., 2002).

SOD activity

The serum SOD is measured by Rat SOD1 kit (Superoxide Dismutase 1, Soluble) from Elabascience Biotechnology Inc. China. Detection rate 0.16—10 ng/ml. Serum, plasma and other biological fluids can be used as a sample for SOD measurement.

Measurements of GPx

Serum GPx enzyme (pg/ml) measured by Rat GPX1 (Glutathione Peroxidase 1) ELISA Kit, Elabascience Biotechnology Inc. China. Serum, plasma and other biological fluids can be used for GPx measurement.

Results

DPPH radical scavenging assay (antioxidant action)

The results of significant antiradical activity were showed in Table 2. Both of tested samples (T and AA), in different concentration were evaluated for antioxidant effects. High scavenging effects observed up to (80.027 $\mu\text{g/ml} \pm 7.30$) for (T) compound and (82.74 $\mu\text{g/ml} \pm 4.19$) for standard antiradical AA. At low dose 10 $\mu\text{g/ml}$ there were significant differences between (T) 28.4362 \pm 7.28132 and AA 57.1962 $\mu\text{g/ml} \pm 10.18565$. The antioxidant effects increased with increased concentration. The regression line for each (T) and AA ($Y = aX + b$), and IC_{50} was calculated. Median antiradical inhibition rate IC_{50} of AA is 40.75 and 48.88 of T compound (Fig 2).

Serum SOD activity

Serum SOD concentrations numerically elevated in all treated groups. When compared with DW group, the mean SOD of T group (60.01pg/ml ± 9.08), was significantly greater than in DW group level (37.15pg/ml ± 2.18) and T&Di group. While in Di and T&Di groups, SOD values were (39.97 \pm 3.28) and (43.58 \pm 1.99) respectively, the concentration increments were statistically non-significant. The results are shown in Table3.

Serum MDA levels assay

Serum MDA of rats that received Di quantity was

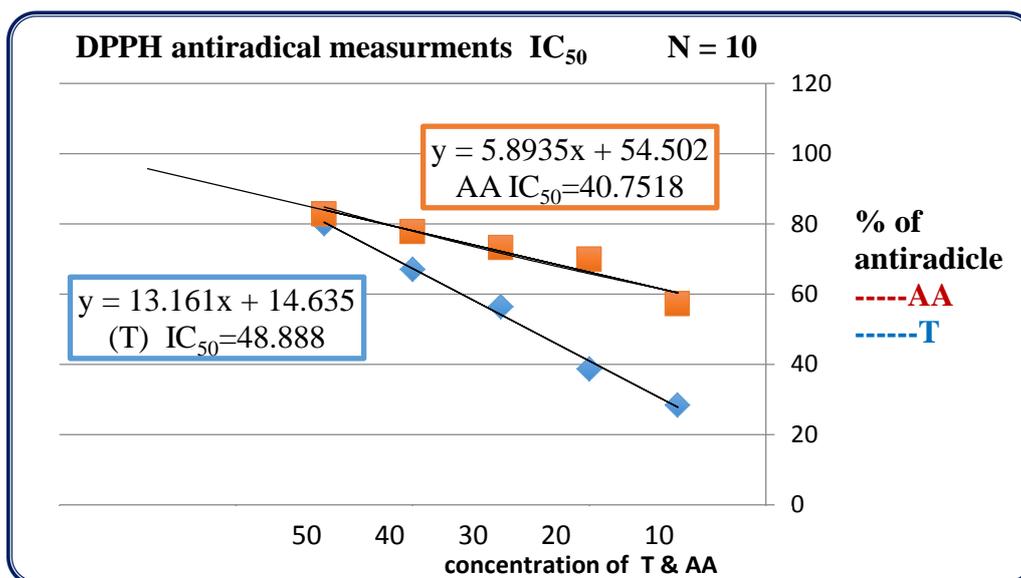


Fig.2. From the histogram median concentration inhibition (IC₅₀) calculated for both test selenadiazole derivative (T) and ascorbic acid (AA). N=times of examinations of each AA and each of T concentrations. The differences between T groups, P≤0.05 vs. AA at concentrations of 10, 20, 30 and 40 µg/ml.

Table 1: preparations of different concentrations of Test selenadiazole derivative (T) and ascorbic acid (AA)

500 µg/ml of T, and AA(1)	- 400µl of (1) added to 1600 µl DMSO	T, AA conc. are 100µg/ml(2)
	- 500 µL of(2) added to 500 µl	T, AA conc. are 50µg/ml
	- 400 µL of(2) added to 600 µl	T, AA conc. are 40µg/ml
	- 300µL of(2) added to 600 µl	T, AA conc. are 30 µg/ml
	- 200µL of(2) added to 800 µl	T, AA conc. are 20 µg/ml
	- 100µL of (2) added to 900 µl	T, AA conc. are 10 µg/ml

Table 2: Antiradical effects of (T) compound enhanced with increase its concentration compare with standard antiradical AA.

Treatment groups	Mean of Concentrations (µg/ml)± SEM				
	10µg/ml	20µg/ml	30µg/ml	40µg/ml	50µg/ml
(T) Compound	28.43± 7.8*	38.63± 14.63*	56.44± 6.4*	67.05± 7.8*	80.03± 7.31
Ascorbic acid (AA)	57.20± 10.19	69.94± 10.16	73.26± 8.50	77.77± 5.0	82.75± 4.20

*Significant differences at (P<0.05). Results are expressed as mean± SEM of the mean of the ten replicates.

statistically non-significant elevated to (3.35 µmol/l±1.87) than in DW group MDA (1.96 µmol/l±1.5). Also in rats received T&Di group, the concentration reduced to 1.69µmol/l ±0.41, but not statically significant. Only T group (0.61µmol/l±0.40) showed significant reduction than Di group, the results are shown in Table 3.

GPx levels

Administration of T, Di and T&Di compounds to female rats for 30days, then serum GPx was measured, after rats were sacrificed. It can be seen from the data in Table 3 that the results indicate significant enhancement in serum GPx concentration T group (4532.67pg/ml±444.94) and T&Di (3599.67±1058.63) GPx level compare to DW group

Table 3: illustrate the antioxidant activity of the experimental groups.

Groups	Parameters (mean±SEM)		
	GPx (pg/ml) N= 10	SOD (ng/ml) N= 10	MDA (µmol/l) N=10
Distilled water	1761.47±1055.02 A	37.15±2.18 A	1.96±1.57 A
Dipyron	1526.01±627.18 A	39.97±3.28 A	3.35±1.87 A
Test	4532.66±444.94 B	60.01±9.08 B	0.61±0.40 AB
Test and Dipyron	3599.66±1058.63 B	43.58±1.99 AC	1.69±0.41 A
LSD (Lesser Significant Differences)	1838.19	16.43	2.74

Means bearing different capital letters vertically differs significantly at 0.05 level ($P<0.050$). N refers to number of rats.

GPx level (1761.47pg/ml±1055.024). Di group GPx level was non-significantly reduced to (1526.01±627.18) than DW group.

Discussion

Numerous studies have been revealed that ROS generated the epithelial cells damage, to reduce or prevent cellular damage. There are two endogenously antioxidant systems; the first system is preventive the antioxidant system and the second is cleaning antioxidant enzyme system, e.g. vitamin E, C and GPx that eliminate produced ROS, so plasma membrane lipid. GPx (selenium-dependent glutathione peroxidase) is one of the chief anti-oxidative enzyme in the cells and it has been shown that Se is a structural component of GPx (Hasanvand et al., 2017).

Antioxidant activity is not determined based on a single test model. Several *in vitro* and *in vivo* test techniques carried out for assessing antioxidant activities of the studied samples. Another characteristic is that models of antioxidant test differ in different respects. Consequently, it is difficult to compare completely between any methods with the others (Alam et al., 2013). As, it is difficult to compare among different methods, therefore the present study attempts to involve a wide diversity of antiradical procedures including *in vitro* DPPH scavenging test and *in vivo* GP_x, SOD and MDA tests.

DPPH radical scavenging assay

DPPH *in vitro* technique considered to be the simplest methods in comparison with other antioxidant *in vitro* technique characterized with fewer steps and reagents and practically low-cost, requires

only a UV-V is spectrophotometer; therefore frequently used for *in vitro* antioxidant evaluation (Karadag et al., 2009).

The reduction ability of DPPH radical is measured by the decline in its absorbance at 517nm induced by antioxidants. The reduction in its absorbance caused by antiradical, due to the progresses of antioxidant molecules and radicle reaction; results in the radicle scavenging by hydrogen donation (Shekhar and Anju, 2014). This study indicates that synthesized (T) has a DPPH radicals scavenging in "dose dependent manner" due to its antioxidant capacity, compared with ascorbic acid (S.D.Sanja et al., 2009). The present findings by (Ruberte et al., 2018), seem to be consistent with other research which found selenadiazole derivatives" twenty-seven novel benzo [c][1,2,5]selena-diazole-5-carboxylic acid (BSCA) derivatives" have potent *in vitro* radical scavenging activity using DPPH antioxidant method. This series of compounds can serve as an excellent scaffold to achieve novel and potent antioxidant complexes beneficial for several diseases. Several studies have confirmed that a lot of novels selena-diazole derivatives have DPPH radicle scavenging effects (Zhang et al., 2010).

Glutathione peroxidase

GPx and selenoproteins, which are generated by selenium consumption, have been involved to enhance the ability of antioxidant activity in the animal tissues and cells, which breakdown H₂O₂ to water. In mitochondria, GPx converts lipid peroxidation to conforming alcohols. GPx enzyme has a vital inhibitory role of lipid peroxidation and protects cells from oxidative stress (Ighodaro and

Akinloye, 2019), also reduced ROS and RNS and protects lipids of DNA and protein. Furthermore, anti-inflammatory properties of selenium have involved in cyclooxygenase and lipoxygenase sequences (Karavelioglu et al., 2015). GPx enzyme low activity is one of the early consequences of a disorder of the prooxidant/antioxidant equilibrium (Alam et al., 2013). In recent years, a number of studies focused on antioxidant effects of selenium compounds. It was documented that a decrease in oxidation with higher activity of GPx by addition of selenium into the diets (Amirkolaie et al., 2014). Also, the antiradical activity of selenoneine was measured, the results that reported similar to those obtained by authors in the present study (Yamashita et al., 2010). The result of present study is also supported by a study which revealed that important elevation in both GPx actions after administration of many organic-selenium compounds (Stefanello et al., 2015). Many authors recently found comparable results of antioxidant action of selenium (Ansar et al., 2017); (Hasanvand et al., 2017). The Di anti-oxidant effects in the current study was consistent with other study showed that Di decreases endogenous glutathione levels and inhibits GPx action in dose dependent manner (Sa´nchez et al., 2002); however, the results were contradicted by the experiments of peroxy Radical ROO, that dipyrone has antioxidant activity (Costa et al., 2006).

Superoxide dismutase

SOD is the initial detoxification enzyme and more potent antioxidant enzyme that acts as a primary defense system in the cell. It activates the transformation of 2 molecules of superoxide anion (O_2^-) first to H_2O_2 and then molecular oxygen (O_2), changing the possibly destructive superoxide anion less (Ighodaro and Akinloye, 2019).

The results show that SOD of T group exert significant elevation with SOD level of DW group, as well as with T&Di group. These results might be due to hepato- protective special properties were evaluated by the capability to prevent lipid peroxidation, protein oxidation and to modify in the SOD (Schaffer et al., 2016). The results of current research support the idea that selenium containing compounds are more potent SOD inducer. Data from several sources have identified the increased SOD activity. The GPX and SOD plasma levels increased significantly in Se-supplemented-diet to diabetic rats

for one month (Ghaffari et al., 2011). Another study demonstrates that diphenyl diselenide (PhSe) active in contradiction of increased oxidative stress in kidney and liver (Sartori et al., 2017). Pre-treatment with diphenylmethyl selenocyanate found to be the most powerful SOD and CAT inducer (Jayanta Kumar Dasa et al., 2013). Also, it was reported that 1, 4-Anhydro-4-seleno-d-talitol (SeTal) has powerful antioxidant action *in vitro* and it's likely to stimulate wound healing in diabetic mice due to elevate SOD production and reduced NO formation (Ng et al., 2017). Similar results revealed that Se effectively elevated significantly the activities of SOD, GPx and CAT compared to the Ag nano-particles treated group (Ansar et al., 2017).

Serum MDA levels assay

Once lipid peroxides are unstable compounds, they tend to degrade rapidly in a variety of sub products. MDA is one of the most known secondary products of lipid peroxidation and it can be used as a marker of cell membrane injury (Grotto et al., 2009). Enhance level of MDA is considered as an indicator of change of cell function and tissue damage. This event appears in the liver or kidneys due to ROS formation or free radicals. It is common that natural antiradicals can diminish intracellular oxidative stress by prevent free radicals generation (Rjeibi et al., 2017).

In the present study MDA concentrations of all testing groups are measured and the results indicate the only significant difference was between T and Di groups. The result of the present study agrees comparatively with a study of the effects of selenium on oxidative stress of cadmium in bone tissue in rats, the results reported decreased in MDA when Se added to rats previously exposed to cadmium compare to control group (Ibrahim et al., 2014). The results also supported a study showed that Se decreased high-sensitivity C-reactive protein in serum and elevated GSH level, resulting in reduction of plasma MDA (Wang et al., 2017) which reveals that the marker of lipid peroxidation MDA had a negative association with serum level of selenium in both normal, and hyper cholesterolemic (specifically negative associated with low-density lipoprotein) patients. Furthermore (Hasanvand et al., 2017) showed that administration of Se remarkably decreased MDA. Recent study (Amraoui et al., 2018) has reported that rats treated concomitantly with

bisphenol A (BPA) and (Se + Vit E) displayed a significant decrease in MDA concentration as compared to BPA-treated group. Selenium could reduce the elevated MDA level by about 5-fold compared to the diabetic rats (Ghaffari et al., 2011). A study by (Orhan and Sahin, 2001) observed that Di at the high concentration exerted an inhibition which is statistically significant on H_2O_2 -forced erythrocytic membrane lipid peroxidation. The results agree with our data and explain the elevation in MDA. In contrast, (Costa et al., 2006) concluded that none of pyrazolones that studied including Di was able of scavenging O_2^- or $H_2O_2^-$. Pervious study by Batu and Erol (2007) found that elevated lipid peroxidation after Di administration, which confirms the results of current study. The study concluded that synthesized novel seleno-diazole derivative T has a good effect as an anti-oxidant.

Conclusion

which reveals that the marker of lipid peroxidation MDA had a negative association with serum level of selenium in both normal, and hyper cholesterolemic (specifically negative associated with low-density lipoprotein) patients.

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Conflict of interest

The authors declare that there is no conflict of interest.

References

- Alam MN, Bristi NJ, Rafiquzzaman M. Review on in vivo and in vitro methods evaluation of antioxidant activity. *Saudi Pharm J* 2013; 21: 143-152. <https://doi.org/10.1016/j.jsps.2012.05.002>
- Amirkolaie AK, Karimzadeh J, Kenari AA. The effects of organic selenium on performance and oxidative level in rainbow trout (*Oncorhynchus mykiss*, walbaum, 1792) fed a high-fat diet. *J Anim Feed Sci* 2014; 23: 90-96. <https://doi.org/10.22358/jafs/65721/2014>
- Amraoui W, Adjabi N, Bououza F, Boumendjel M, Taibi F, Boumendjel A, et al. Modulatory role of selenium and vitamin e, natural antioxidants, against bisphenol a-induced oxidative stress in wistar albinos rats. *Toxicol Res* 2018; 34: 231-239. <https://doi.org/10.5487/tr.2018.34.3.231>
- Ansar S, Alshehri SM, Abudawood M, Hamed SS, Ahamad T. Antioxidant and hepatoprotective role of selenium against silver nanoparticles. *Int J Nanomedicine* 2017; 12: 7789-7797. <https://doi.org/10.2147/ijn.s168974>
- Antolovich M, Prenzler PD, Patsalides E, McDonald S, Robards K. Methods for testing antioxidant activity. *Analyst*, 2002; 127: 183–198. <https://doi.org/10.1039/b009171p>
- Atiba AS, Abbiyesuku FM, Oparinde DP, A T, Niran-Atiba, Akindede RA. Plasma malondialdehyde (mda): An indication of liver damage in women with pre-eclampsia. *Ethiop J Health Sci* 2016; 26: 479-485. <https://doi.org/10.4314/ejhs.v26i5.10>
- Costa D, Marques AP, Reis RL, Lima JL, Fernandes E. Inhibition of human neutrophil oxidative burst by pyrazolone derivatives. *Free Radic Biol Med* 2006; 40: 632-40. <https://doi.org/10.1016/j.freeradbiomed.2005.09.017>
- Ghaffari T, Nouri M, Irannejad E, Rashidi aM-R. Effect of vitamin e and selenium supplement on paraoxonase-1 activity, oxidized low density lipoprotein and antioxidant defense in diabetic rats. *BiolImpacts* 2011; 1: 121-128. <https://doi.org/10.5681/bi.2011.016>
- Ghorbel I, Elwej A, Chaabane M, Jamoussi K, Mnif H, Boudawara T, et al. Selenium alleviates oxidative stress and lung damage induced by aluminum chloride in adult rats: biochemical and histological approach. *Biol Trace Elem Res* 2017; 176: 181-191. <https://doi.org/10.1007/s12011-016-0818-9>
- Grotto D, Maria LS, Valentini J, Paniz C, Schmitt G, Garcia SC. Importance of the lipid peroxidation biomarkers and methodological aspects for malondialdehyde quantification. *Quim Nova*, 2009; 32: 169-174. <https://doi.org/10.1590/S0100-40422009000100032>
- Hangun-Balkir Y, McKenney ML. Determination of antioxidant activities of berries and resveratrol. *Green Chem Lett Rev* 2012; 5: 147-153. <https://doi.org/10.1080/17518253.2011.603756>
- Hasanvand A, Abbaszadeh A, Darabi S, Nazari A, Gholami M, Kharazmkia A. Evaluation of selenium on kidney function following ischemic injury in rats; protective effects and antioxidant activity. *J Renal Inj Prev* 2017; 6: 93-98. <https://doi.org/10.15171/jrip.2017.18>
- Ibrahim TA, Tarboush HA, Aljada A, Mohanna MA. The effect of selenium and lycopene on oxidative stress in bone tissue in rats exposed to cadmium. *Food Nutr Sci* 2014; 05: 1420-1429. <http://dx.doi.org/10.4236/fns.2014.514155>
- Ighodaro OM, Akinloye OA. First line defence antioxidants-superoxide dismutase (sod), catalase (cat) and glutathione peroxidase (gpx): Their fundamental role in the entire antioxidant defence grid. *Alexandria J M* 2019; 54: 287-293. <https://doi.org/10.1016/j.ajme.2017.09.001>
- Jayanta Kumar Dasa, Sibani Sarkarb, Ugir Hossain Skc, Pramita Chakraborty, Das RK, Bhattacharya S. Diphenylmethyl selenocyanate attenuates malachite green induced oxidative injury through antioxidation & inhibition of DNA damage in mice. *Indian J Med Res*

- 2013; 137: 1163-1173.
- Karadag A, Ozcelik B, Saner S. Review of methods to determine antioxidant capacities. *Food Anal Methods* 2009; 2: 41-60.
- Karavelioglu E, Boyaci MG, Simsek N, Sonmez MA, Koc R, Karademir M, et al. Selenium protects cerebral cells by cisplatin induced neurotoxicity. *Acta Cir Bras* 2015; 30: 394-400. <https://doi.org/10.1590/s0102-86502015006000004>
- Kumar TS, Rani S, K S, B P, P N. Toxicity evaluation of ammonium sulfate to albino rat. *Asian J Pharm Clin Res* 2017; 10. <https://doi.org/10.22159/ajpcr.2017.v10i1.15355>
- Kurutas EB. The importance of antioxidants which play the role in cellular response against oxidative/nitrosative stress: Current state. *Kurutas Nutr J* 2016; 15. <https://doi.org/10.1186/s12937-016-0186-5>
- Li S, Tan H-Y, NingWang, Zhang Z-J, Lao L, Chi-WoonWong, et al. The role of oxidative stress and antioxidants in liver diseases. *Int J Mol Sci* 2015; 16: 26087-26124. <https://doi.org/10.3390/ijms161125942>
- Mostafa N, Eldahshan O, El-Beshbishy H, Singab AN. Hepatoprotective, antihyperglycemic and cytotoxic activities of jacaranda acutifolia leaf extract. *Med Aromat Plants* 2017; 13: 8. <https://doi.org/10.4172/2167-0412.1000297>
- Neamah NF, Khudair A-RN, Al-Jadaan SAN. Synthesis, characterization, antimicrobial activity and acute toxicity test of a novel 4,4' - (4, 5, 6, 7-tetrahydro- [1, 2, 3 -] selenadiazolo [4, 5 e] pyridine-4, 6-diyl) bis(benzene-1, 3-diol). *Egyptian J Chem* 2020; 63: 669-681. <https://dx.doi.org/10.21608/ejchem.2019.11702.1753>
- Ng HH, Leo CH, O'Sullivan K, Alexander SA, Davies MJ, Schiesser CH, et al. 1,4-anhydro-4-seleno-d-talitol (setal) protects endothelial function in the mouse aorta by scavenging superoxide radicals under conditions of acute oxidative stress. *Biochem Pharmacol* 2017; 128: 34-45. <https://doi.org/10.1016/j.bcp.2016.12.019>
- Orhan H, Sahin G. In vitro effects of NSAIDs and paracetamol on oxidative stress-related parameters of human erythrocytes. *Exp Toxicol Pathol* 2001; 53: 133-40. <https://doi.org/10.1078/0940-2993-00179>
- Rached W, Zeghada FZ, Bennaceur M, Barros L, Calheta RC, Heleno S, et al. Phytochemical analysis and assessment of antioxidant, antimicrobial, anti-inflammatory and cytotoxic properties of tetraclinis articulata (vahl) masters leaves. *Ind Crops Prod* 2018; 112: 460-466. <https://doi.org/10.1016/j.indcrop.2017.12.037>
- Rjeibi I, Feriani A, Ben Saad A, Ncib S, Sdayria J, Saidi I, et al. Phytochemical characterization and bioactivity of lycium europaeum: A focus on antioxidant, antinociceptive, hepatoprotective and nephroprotective effects. *Biomed Pharmacother* 2017; 95: 1441-1450. <https://doi.org/10.1016/j.biopha.2017.09.035>
- Ruberte AC, Plano D, Encío I, Aydillo C, Sharma AK, Sanmartín C. Novel selenadiazole derivatives as selective antitumor and radical scavenging agents. *European J Med Chem* 2018; 157: 14-27. <https://doi.org/10.1016/j.ejmech.2018.07.063>
- S.D.Sanja, N.R.Sheth, N.K.Patel, Patel D, Patel B. Characterization and evaluation of antioxidant activity of portulaca oleracea. *Int J Pharm Pharm Sci* 2009; 1.
- Sánchez S, Martí MJ, Ortiz P, Motilva V, Lastra Candel. Effects of dipyrone on inflammatory infiltration and oxidative metabolism in gastric mucosa comparison with acetaminophen and diclofenac. *Digest Dis Sci* 2002; 47: 1389-1398. <https://doi.org/10.1023/a:1015395103160>
- Sartori G, Jardim NS, Sari MH, Flores EF, Prigol M, Nogueira CW. Diphenyl diselenide reduces oxidative stress and toxicity caused by hsv-2 infection in mice. *J Cell Biochem* 2017; 118: 1028-1037. <https://doi.org/10.1002/jcb.25667>
- Schaffer TK, Wohlenberg MF, Medeiros N, Martins JB, Agostini F, Funchal C, et al. Evaluation of antioxidant activity of grapevine leaves extracts (vitis labrusca) in liver of wistar rats. *An Acad Bras Cienc* 2016; 88: 187-96. <https://doi.org/10.1590/0001-3765201620140658>
- Shekhar TC, Anju G. Antioxidant activity by DPPH radical scavenging method of Ageratum conyzoides Linn. Leaves. *Am J Ethnomed* 2014; 1: 244-149.
- Sherikar A, Mahanthesh M. Evaluation of aqueous and methanolic extract of leaves of epipremnum aureum for radical scavenging activity by DPPH method, total phenolic content, reducing capacity assay and FRAP assay. *J Pharmacogn Phytochem* 2015; 4: 36-40.
- Shimamura T, Sumikura Y, Yamazaki T, Tada A, Kashiwagi T, Ishikawa H, et al. Applicability of the DPPH assay for evaluating the antioxidant capacity of food additives - inter-laboratory evaluation study. *Anal Sci* 2014; 30: 717-21. <https://doi.org/10.2116/analsci.30.717>
- Singh Z, Karthigesu P, Singh P, Kaur R. Use of malondialdehyde as a biomarker for assessing oxidative stress in different disease pathologies: a review. *Iranian J Publ Health* 2014; 43: 7-16.
- Stefanello ST, Gubert P, Puntel B, Mizdal CR, Campos MMAd, Salman SM, et al. Protective effects of novel organic selenium compounds against oxidative stress in the nematode caenorhabditis elegans. *Toxicol Rep* 2015; 2: 961-967. <https://doi.org/10.1016/j.toxrep.2015.06.010>
- Wang N, Tan H-Y, Li S, Xu Y, Guo W, Feng Y. Supplementation of micronutrient selenium in metabolic diseases: Its role as an antioxidant. *Oxid Med Cell Longev* 2017; 2017: 13. <https://dx.doi.org/10.1155/2017/7478523>
- Yagi K. Serum malondialdehyde measurements. *Free Rad Antiox Prot* 1998; 108: 101-106.
- Yamashita Y, Yabu T, Yamashita M. Discovery of the strong antioxidant selenoneine in tuna and selenium redox metabolism. *World J Biol Chem* 2010; 1: 144-50.
- Zhang YB, Zheng WJ, Huang Z, Yang F, Liu J, Chen TF. [spectrometric investigation of the antioxidant activity of a novel synthetic selenadiazole derivative spo against DPPH and ABTS free radicals]. *Guang Pu Xue Yu Guang Pu Fen Xi* 2010; 30: 1866-71.