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Original Article

Lipophilic Vitamins (D and E) and Flavonoids (Quercetin and Naringin) Attenuate the Effects of Dichlorvos Toxicity on Catalase Activity

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Abstract

[Dichlorvos (2,2-dichlorovinyl dimethyl phosphate) is an organophosphate pesticide and insecticide used all over the world. Catalase is an enzyme that is responsible for degrading hydrogen peroxides present in organs or blood cells and tissue to prevent oxidative damage to these respected organs. The flavonoids (naringin and quercetin) and vitamin D and E have been found to reduce oxidative stress in the body. The study was carried out to detect the effect of specific lipophilic vitamins, naringin, and quercetin on catalase activity in the presence of a dichlorvos induced system. 112 male rats were divided into 14 groups of 8 rats each grouped as positive and negative control groups, dichlorvos only induced groups (2 groups), vitamins only induced groups (vitamin D and vitamin E), flavonoids only induced groups (quercetin and naringin), dichlorvos + vitamins administered groups (2 group each containing a different vitamin administration), and dichlorvos + flavonoids administered groups, baseline group and

$DMSO_4$ group. They were administered the dichlorvos for two weeks, and subsequent administration of vitamin D and E with naringin and quercetin respectively two weeks after. The animals were weighed every three days and were sacrificed immediately after administration, plasma and RBC along with the organs (liver and brain) were used to assess the effects of the vitamins and phytochemicals antioxidant capacity on catalase activity of the animals. Results showed that specific vitamin D, naringin, and quercetin were most important in their antioxidant capacity and helped improved catalase activity of initially treated dichlorvos group in some organs and compartments with the brain and red blood cells mostly benefitting from it with dichlorvos + vitamin D group, and vitamin D group having an SEM of 0.141±0.0044 and 0.150±0.00069, respectively, in the red blood cells. Meanwhile, the phytochemicals (naringin and quercetin) were more prominent in attenuating catalase activity in the brain with dichlorvos + naringin group and naringin group recording an SEM of 2.216±0.067 and 2.302±0.076, respectively, and dichlorvos + quercetin group and quercetin group recorded an SEM of 0.670±0.009 and 1.276±0.060, respectively. As a result, the fat-soluble vitamins, and phytochemicals reduced dichlorvos toxicity, but could not offer complete and absolute protection against the hydrogen peroxides and oxidative stress produced.

Keywords: Dichlorvos, Naringin, Quercetin, Catalase and phytochemicals.

Introduction

Dichlorvos (2,2-dichlorovinyl dimethyl phosphate; DDVP) is an organophosphate compound and is one of the most widely used pesticides for the control of household pests, public health pests, and stored product insect infestations [1]. Exposure of the general public to dichlorvos may occur via air, water, or food because it is readily absorbed through all routes of exposure. [2]. Dichlorvos exposure has been linked to substantial adverse health effects on several organ systems, including the respiratory system [3] and reproductive system [4,5]. The acute effects of dichlorvos are well documented and are mediated through the inhibition of acetylcholinesterase, an enzyme vital for cholinergic transmission. [6].

Vitamins are generally defined as organic substances required in a small amount for the maintenance and growth of living organisms. Their deficiency may lead to certain specific diseases or symptoms which can be cured by the administration of that specific vitamin only. In the early 20th century, the discovery of vitamins began. In 1906, the British Biochemist Sir Frederick Hopkins demonstrated that foods contain accessory factors in addition to proteins, carbohydrates, fats, minerals, and water [7]. The term vitamin was first discovered by Funk. Funk identified that the anti-beriberi substance in unpolished rice was an amine which is a type of nitrogen-containing compound. He coined the term "vitamin" a combination word from vita and amine, meaning amine of life, and considered that amines are vital for life. However, it was later found that all vitamins are either “nitrogen” or “amines”, particularly in vitamin A [8]. In 1912, Hopkins and Funk made a hypothesis according to which the absence of some vitamins could cause diseases such as beriberi and scurvy [8,7]. Vitamins are highly essential to the human body except for vitamins D, K, and biotin as they cannot be synthesized in the body. [9]

Many plants and microorganisms except humans and some other animals synthesize vitamins. Hence, they need to be supplied through diet to the human body. Most of the vitamins are present in required quantities in the fresh and natural foods available in both plants and animal sources. Vitamins are required in tiny amounts because of their inactivation in the body they play a catalytic role in many metabolic reactions of the cells and act as coenzymes or part of coenzymes and enzyme systems. Certain vitamins act as hormones and exert their action at intracellular receptor sites like Vitamin A and D. [9]

Catalase is a key enzyme in the metabolism of H_2O_2 and reactive nitrogen species, and its expression and localization are markedly altered in tumors, because generally in toxicity of a system, catalase decomposes hydrogen peroxide into oxygen and water since hydrogen peroxide can be toxic in large quantities [10]. Protective antioxidant enzymes such as catalase are the line first line of defense against reactive oxygen species-ROS. Many normal biological processes that occur in eukaryotes involve the generation of a controlled amount of reactive oxygen species which mostly serves as a self-defense mechanism against antigenic substances. These reactive species are normally removed from the system by specialized antioxidant defensive mechanisms which work in a concerted manner to prevent oxidative damage to cells and tissues [11]. Naringin is an important water-soluble flavonoid isolated from citrus fruits [12] and is the major flavanone in grapefruits (it is regarded as the compound responsible for the clinically important interactions of grapefruit).

Quercetin is the most widely distributed and extensively studied flavonoid found in various food sources, including fruits, vegetables, nuts, wine, and seeds [13]. Quercetin has various biological properties, including antioxidant, anti-inflammatory, antibacterial, antiviral, radical-scavenging, gastroprotective, and immune-modulatory activities [14, 15].

Accordingly, the current preliminary study was designed to carry out the investigation and evaluation of lipophilic vitamins (D and E) and flavonoids (naringin and quercetin) in the attenuation of effects of dichlorvos toxicity on catalase activity.

Methodology

Experimental Animals

112 male albino Wistar rats were purchased from Covenant University, Ota, Ogun State, Nigeria. The animals were housed in the Animal house belonging to the Department of Biochemistry. The rats were placed in wired plastic cages and were separated according to their weights. They were fed twice daily.

Chemicals and Reagents

Dichlorvos (Sniper), Vitamin D, and E were purchased from Twins Faja Supermarket, Lagos. Coconut oil and $DMSO_4$ were donated by the supervisor. Naringin and Quercetin were purchased and gotten from Covenant University, Ota, Ogun State. Catalase kits were also gotten from Covenant University, Ota, Ogun State.

Experimental Design

The rats were allowed to acclimatize for 2 weeks and were fed with a grain feed that was rich in protein to speed up their increase in size. The animals were weighed and grouped initially into 14 groups of 8 rats each by weights during the acclimatization weeks but were later grouped randomly for administration

and they were correctly labeled. Their weights were taken and noted at 3 days intervals across the administration period. They were grouped as follows:

Control Groups

There are 3 different groups in the control group and are the positive control group (coconut oil), the negative control group (distilled water), and the $DMSO_4$ control group. The positive and negative control group were administered a dose of 4 mg/kg body weight of distilled water and coconut oil respectively per day via oral gavage. The $DMSO_4$ group was administered 0.2 ml of $DMSO_4$ to each rat per day via oral gavage.

(1) Dichlorvos-treated groups:

There are 2 different groups which are Dichlorvos only and Dichlorvos recovery group. The rats in these groups were administered a dose of 4 mg/kg body weight of the dichlorvos once daily.

(2) Vitamins-treated group:

There are 2 different groups which are vitamin D and vitamin E groups. The vitamin E group received a vitamin E dosage of 150 mg/kg body weight once daily. The vitamin D group was administered a vitamin D dose of 0.0179 mg/kg body weight once daily.

(3) Phytochemicals-treated groups:

There are 2 different groups which Naringin and Quercetin groups. The rats of the naringin group were administered 100mg/kg body weight of the naringin mixture once daily. The rats of the quercetin group were administered 75 mg/kg body weight of the quercetin mixture once daily.

(4) Dichlorvos and vitamin treatment group:

There are 2 groups here which are dichlorvos with vitamin D group and dichlorvos with vitamin E treated group. Dichlorvos (4 mg/kg) was initially administered to all rats in these groups for 2 weeks and then 150 mg/kg of vitamin E was administered for 2 weeks to the Dichlorvos with vitamin E group and 0.0179 mg/kg of vitamin D was administered for 2 weeks to the Dichlorvos with vitamin D group.

- Dichlorvos and phytochemicals treatment group:

There are 2 groups here which are dichlorvos with the naringin group and dichlorvos with the quercetin treated group. Dichlorvos (4 mg/kg) was first administered to all rats in these groups for 2 weeks and then 100 mg/kg of naringin and 75 mg/kg of quercetin were administered to their respective groups for 2 weeks.

Sample Collection

The Wistar rats were killed by suffocation with chloroform and organs which included the brain, and liver was carefully collected, sterilized surgical tools were used to sacrifice the rats. The organs were immediately placed in normal saline which mainly consists of NaCl which helps to remove the blood stain present in an organ. The organs were removed from the normal saline and placed on a sanitary pad to absorb any moisture present in them and their weights were recorded. 0.1 g of each organ was cut and weighed and each weighed organ was later placed in ice.

The blood gotten from the heart of each rat were centrifuged at 4000 rpm for 10 minutes within 24 hours of sacrifice to obtain the best separation. After centrifuging, the plasma was carefully collected and placed in Eppendorf tubes while the red blood cells were left in the heparin tubes after which enzyme analysis took place in them.

Preparation of Phosphate Buffer Saline (PBS)

800 ml of distilled water was prepared in a suitable container. 16.282 g of K_2HPO_4 was prepared and added to the distilled water, and then 0.888 g of KH_2PO_4 was added. Then the mixture was allowed to dissolve before adding more distilled water to get a quantity of 1 L mixture.

Preparation of Tissue Homogenate

Homogenization of 0.1 g of each organ (brain and liver) was carried out by adding 1ml of phosphate buffer, after which the homogenates were centrifuged at 4000 rpm for 5 minutes. The supernatant was removed by using a micropipette and was kept in a clean Eppendorf tube before enzyme analysis.

Biochemical Analysis

The catalase kit was used on the plasma, RBC, brain, and liver. The buffered peroxide was prepared by diluting 184 uL of H_2O_2 with 20 ml of Catalase buffer. The distilled water of 380 uL was pipetted into the cuvette followed by 200 uL of the buffered H_2O_2 into the same cuvette. The mixture was allowed to incubate for 5 minutes to achieve temperature equilibrium, and then 20 uL of the sample was added and the absorbance at 240 nm was recorded for 2 minutes.

Statistical Analysis

Values are expressed as mean ± SEM. All statistical tests were performed using GraphPad Prism version 8. Nonparametric one-way ANOVA and multiple comparisons (to compare to controls) were used to evaluate catalase parameters between multiple groups.

Results

Evaluation of Body Weights, Organ Weights, Relative Weights, and Average Weights

Evaluation of Dichlorvos Effect and Vitamins and Phytochemical Effect on Body Weights

The body weight of animals exposed to dichlorvos followed by treatment with fat-soluble vitamins (Vit D and Vit E) is shown in figure 1 (below). The result of Figure 1 shows that the baseline rats, negative control group slowly and steadily increased in their body weights while the positive control group maintained constant body weight. The administration of dichlorvos reduced the body weights of the rats and subsequently, the dichlorvos recovery group had also an initial decrease in body weights for the first 14 days and then steadily increased in body weights in the following days.

The body weights of rats administered vitamin D also increased in body weights, but the vitamin E group had a decreased body weight. The dichlorvos + Vit D and dichlorvos + Vit E both recorded a decrease in the body weight of the rat after the initial exposure to dichlorvos.

The body weight of animals exposed to dichlorvos followed by treatment with phytochemicals (Naringin and Quercetin) is shown in Figure 2. In Figure 2, the baseline group had a slow and steady body weight increase while the negative control group had an initial decrease in body weight and finally had an increase in body weight. The positive control group also maintained their body weight. The administration of dichlorvos reduced the body weights of the rats, and the dichlorvos recovery group maintained their initial body weights for the first 14 days and then steadily increased in body weights in the following days. The body

weight of the naringin group increased steadily, but the quercetin group had a decrease in their body weight. The dichlorvos + naringin group had an increased body weight but the dichlorvos + quercetin group had an initial increase then later maintained body weight at the end of the experimental week. Evaluation of the effects of dichlorvos and vitamins and phytochemicals on catalase activity in plasma.

Evaluation of the Effects of Dichlorvos and Vitamins on Catalase Activity in Plasma

Figures 3 and 4 depict the concentration and comparison of catalase activity in all vitamins treated groups, dichlorvos treated groups, control groups to the baseline group, and positive control, group. There was an increase in catalase activity of the dichlorvos group compared to the baseline, and the vitamin D group had an increased catalase activity and was significant to the baseline while the vitamin E group had the same range as the baseline group and was not significant from it. The dichlorvos with vitamin D treated group had a similar catalase activity range with the baseline group and was not significant from it. The dichlorvos with vitamin E treated group had the highest level of catalase activity with its increased range in the plasma.

In Figure 4, the dichlorvos group had an increased catalase activity compared to the positive control group and was significant from it. The vitamin D group also recorded an increase in catalase activity to the positive control and was shown to be significant to the positive control while the vitamin E group showed no significant difference to the positive control and had the same range in catalase activity as the positive control.

Meanwhile, the dichlorvos with vitamin E group showed a massive increase in catalase concentrations in comparison to the positive control and was also significant but the dichlorvos and vitamin D group showed no significance to the positive control and had the same catalase range as the positive control.

Dichlorvos recorded a major percentage decrease of 15% in the plasma when compared to the negative control with an SEM of 0.044±0.0010.

The vitamin D and E group also recorded a percentage decrease of 15% and 32% catalase activity respectively in comparison to the negative control group with an SEM of 0.047±0.0007, and 0.035±0.0002 respectively. Meanwhile, the dichlorvos + vitamin E group recorded a positive and percentage increase of 108% catalase activity in the plasma with an SEM of 0.107±0.0011, but the dichlorvos + vitamin D group recorded the same negative and percentage decrease of 34% catalase activity with an SEM of 0.034±0.0017 in the plasma.

Evaluation of the Effects of Dichlorvos and Phytochemicals on Catalase Activity in Plasma

Figures 5 and 6 illustrate the concentration and comparison of catalase activity in all vitamins treated groups, dichlorvos treated groups, control groups to the baseline group, and positive control, group. In Figure 5, the dichlorvos group was not significant from the baseline group of the plasma but had a little increase in the catalase concentrations.

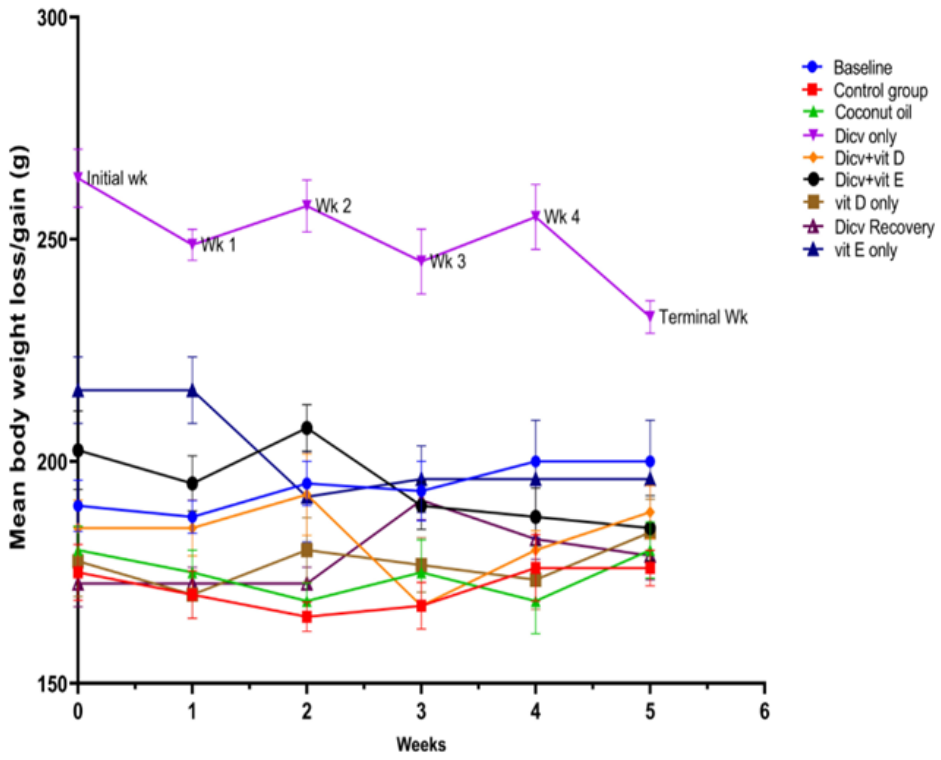

Figure 1 Mean body weights of male rats treated with fat-soluble vitamins (Vit D and Vit E) after orally exposed to dichlorvos (dicv) for 14 days

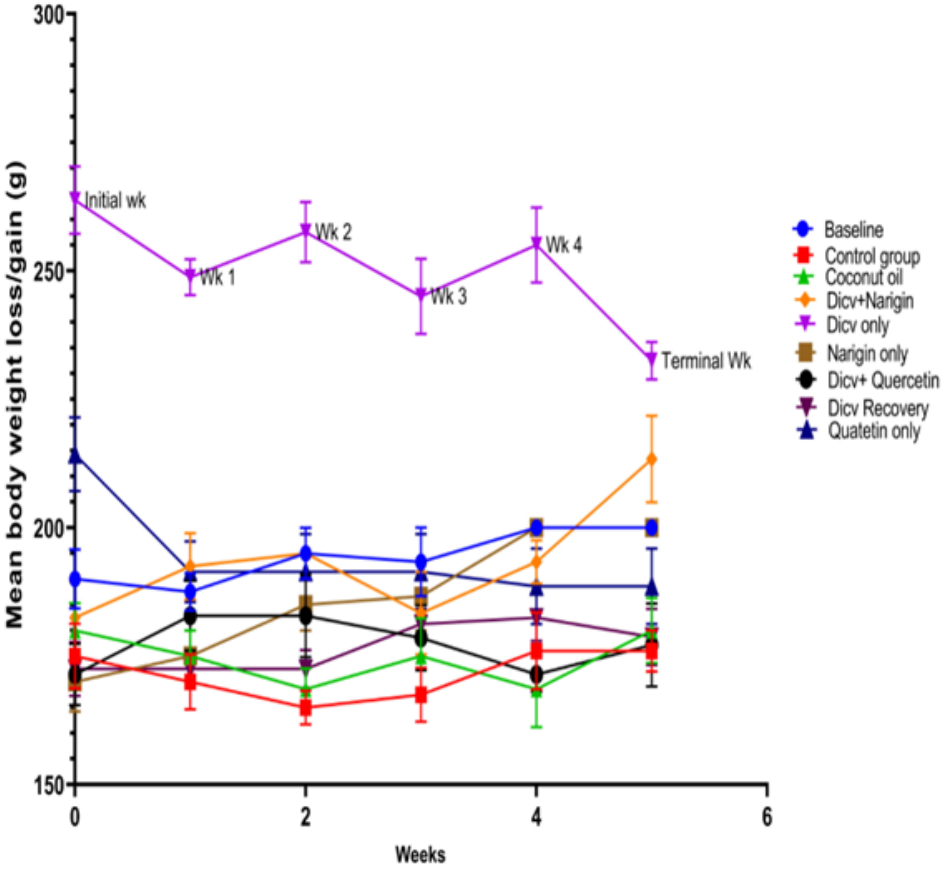

Figure 2 Mean body weights of male rats treated with phytochemicals (Naringin and Quercetin) after orally exposed to dichlorvos (dicv) for 14 days

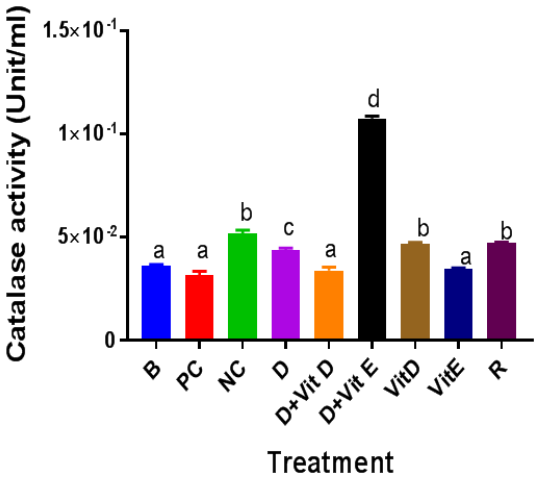

Figure 3 Effect of dichlorvos and vitamins doses on plasma catalase levels in comparison to the baseline group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the baseline group

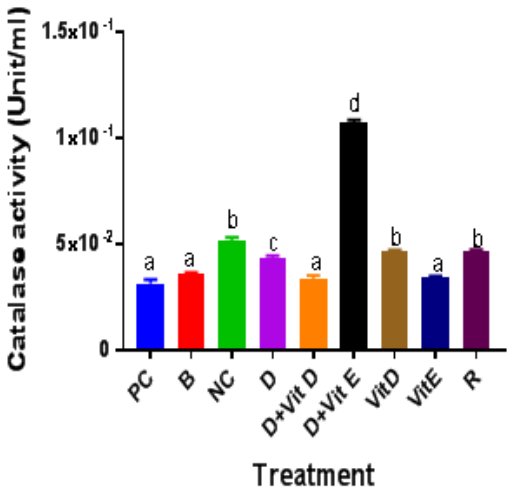

Figure 4 Effect of dichlorvos and vitamins doses on plasma catalase levels in comparison to the positive control group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the positive control group

The naringin group was significant from the baseline group and had the highest catalase concentrations in comparison to the baseline group and the quercetin group was also significant to the baseline group but recorded the lowest catalase concentrations, even lower than the baseline. The dichlorvos with the naringin group recorded a low catalase concentration and proved to be significant to the baseline group, but the dichlorvos with quercetin group was significant and had increased concentrations of catalase in the plasma in comparison to the baseline group.

In Figure 6, the dichlorvos group had increased catalase concentrations to the positive control group and was shown to be significant. The naringin group was also significant to the positive control and also had increased catalase concentrations but the quercetin group had a low catalase concentration and was not significant to the positive control

group. The dichlorvos with the naringin group had low catalase concentrations and was also significant in comparison to the positive control. Meanwhile, the dichlorvos with quercetin recorded an increased catalase concentration and was significantly different from the positive control group.

In comparison to the negative control, dichlorvos recorded a negative percentage decrease of 15% with an SEM of 0.044±0.0010, likewise did the quercetin group recording a negative percentage decrease of 5% catalase activity with an SEM of 0.024±0.0006 in the plasma, but the naringin group recorded a slight positive percentage increase of 6% catalase activity in comparison to the negative control with an SEM of 0.055±0.0029. The dichlorvos + quercetin group recorded a small percentage increase of 4% catalase activity with an SEM of 0.054±0.0010 in the plasma while the dichlorvos + naringin group recorded a p'ercentage decrease of 52% catalase activity with an 'SEM of 0.025±0.0010 in the plasma.

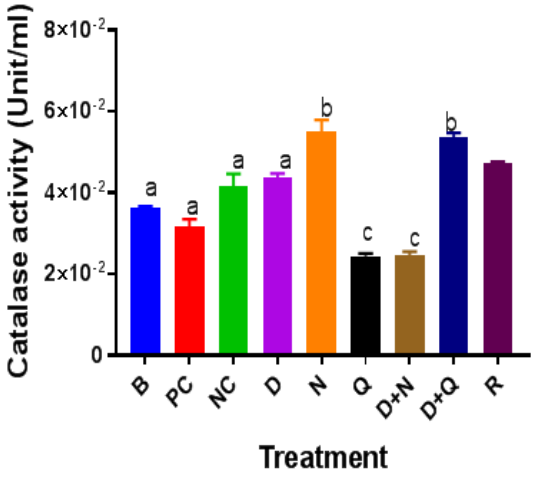

Figure 5 Effect of dichlorvos and phytochemicals doses on plasma catalase levels in comparison to the baseline group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the baseline group

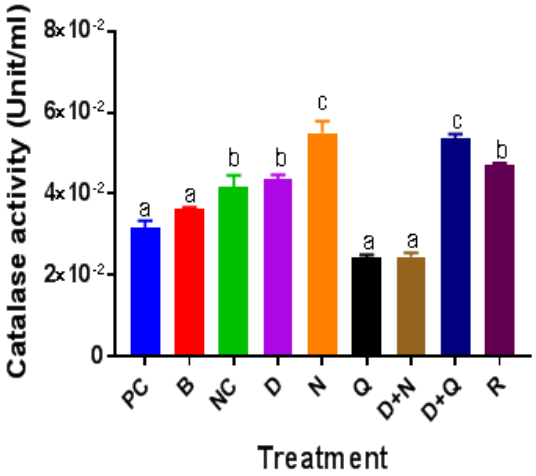

Figure 6 Effect of dichlorvos and phytochemicals doses on plasma catalase levels in comparison to the positive control group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the positive control group

Evaluation of the Effects of Dichlorvos and Vitamins and Phytochemicals on Catalase Activity in Red Blood Cells

Evaluation of the Effects of Dichlorvos and Vitamins on Catalase Activity in Red Blood Cells

Figures 7 and 8 depict the concentration and comparison of catalase activity in all vitamins treated groups, dichlorvos treated groups, control groups to the baseline group, and positive control, group. In Figure 7, the catalase concentrations of the dichlorvos group were similar and very low to the baseline group and were not significantly different from the baseline. The vitamin E group was also similar to the baseline group in catalase concentrations and wasn't significantly different from the baseline group while the vitamin D group was significantly different from the baseline group and had a high concentration in respect to the baseline group. The dichlorvos with vitamin E group was not significant to the baseline and had similar catalase concentrations to the baseline group in the red blood cells. The dichlorvos with vitamin D had a high concentration of catalase in comparison to the baseline in the red blood cell and was also shown to be significantly different from the baseline group.

In Figure 8, the dichlorvos group was not significant to the positive control and also possessed a similar catalase concentration range to the positive control group. The vitamin E group had increased catalase concentrations to the positive control and was also significant to the positive control group and the vitamin D group was also significant to the positive group and had a high range of catalase concentrations when compared to the positive group. The dichlorvos with vitamin E group was not significant to the positive group and also had a similar catalase concentration to the positive control group in the red blood cell. Meanwhile, the dichlorvos with vitamin D group was significantly different from the positive control group and had high catalase concentrations in comparison to the positive control group in the red blood cell.

Dichlorvos group recorded a negative percentage decrease of 31% catalase activity with an SEM of 0.046±0.0007 in the red blood cell in comparison to the negative control. Vitamin E group recorded a negative percentage decrease of 20% catalase activity with an SEM of 0.053±0.0020 while the vitamin D group recorded a positive percentage increase of 123% catalase activity with an SEM of 0.150±0.0006 in the red blood cell. The dichlorvos + vitamin D also recorded a positive percentage increase of 110% catalase activity with an SEM of 0.141±0.0044 in the red blood cell in comparison to the negative control. Meanwhile, the dichlorvos + vitamin E group recorded a negative percentage decrease of 32% catalase activity with an SEM of 0.045±0.0002 in the red blood cell to the negative control group.

Evaluation of the Effects of Dichlorvos and Phytochemicals on Catalase Activity in Red Blood Cells

Figures 9 and 10 depict the concentration and comparison of catalase activity in all vitamins treated groups, dichlorvos treated groups, control groups to the baseline group, and positive control, group. In Figure 9, the dichlorvos group had similar ranges of catalase concentrations to the baseline group and was not significant to the baseline group. The naringin group had a lower catalase concentration from the baseline group and was significantly different from the baseline group in red blood cells and the quercetin group had increased catalase concentrations and

was significantly different from the baseline group in the red blood cell. Dichlorvos with the naringin group had an increased catalase concentration to the baseline group and was also significantly different from the baseline group, but the dichlorvos with quercetin group was not significantly different from the baseline group and had similar catalase concentrations with the baseline group.

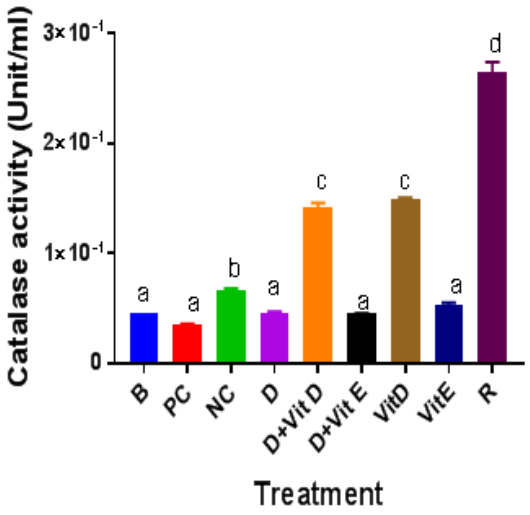

Figure 7 Effect of dichlorvos and vitamins doses on red blood cells catalase levels in comparison to the baseline group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the baseline group

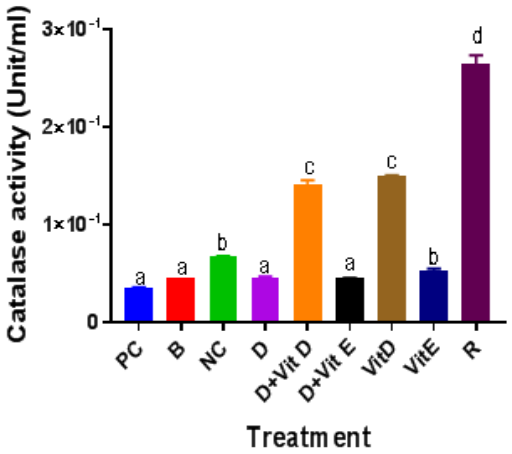

Figure 8 Effect of dichlorvos and vitamins doses on red blood cell catalase levels in comparison to the positive control group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the positive control group

In Figure 10, the dichlorvos group was not significantly different from the positive control group and also had similar catalase concentrations with the positive control group, likewise the naringin group which was not significantly different from the positive control group, but the naringin group had lower catalase concentrations than the positive control group. The quercetin

group had increased catalase concentrations and was also significantly different from the positive control group. The dichlorvos with the naringin group and dichlorvos with quercetin group both had higher catalase concentrations in comparison to the positive control group and both were also significantly different from the positive control group in the red blood cell.

In comparison to the negative control group, dichlorvos recorded a negative percentage decrease of 31% catalase activity with an SEM of 0.046±0.0007 and the naringin group also recorded a negative percentage decrease of 64% catalase activity with an SEM of 0.024±0.0005, while the quercetin group recorded a positive percentage increase of 15% catalase activity with an SEM of 0.077±0.0004 in the red blood cell in comparison to the negative control group. Dichlorvos + naringin group had a positive percentage increase of 5% catalase activity with an SEM of 0.071±0.0009, but dichlorvos + quercetin had a negative percentage decrease of 15% catalase activity with an SEM of 0.056±0.0004 in the red blood cell.

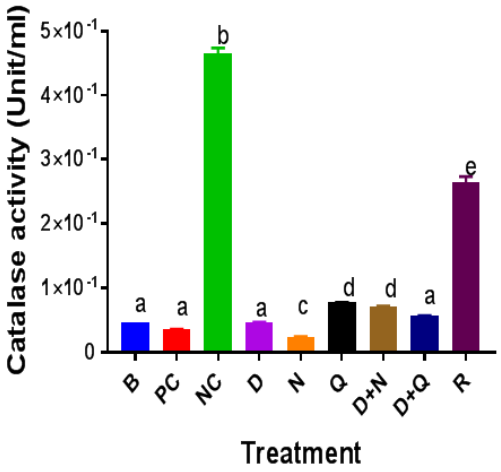

Figure 9 Effect of dichlorvos and phytochemicals doses on red blood cell catalase levels in comparison to the baseline group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the baseline group

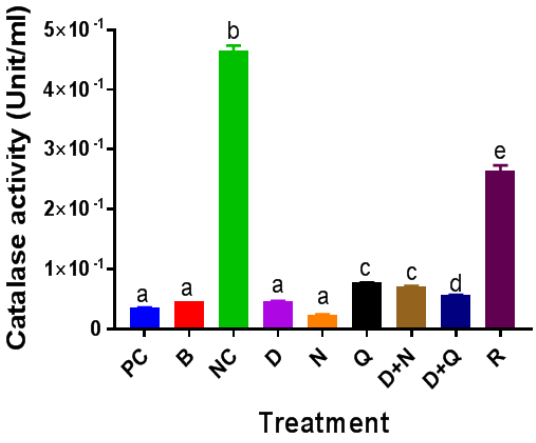

Figure 10 Effect of dichlorvos and phytochemicals doses on red blood cell catalase levels in comparison to the positive control group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the positive control group

Evaluation of the Effects of Dichlorvos and Vitamins and Phytochemicals on Catalase Activity in the Brain

Evaluation of the Effects of Dichlorvos and Vitamins on Catalase Activity in the Brain

Figures 11 and 12 depict the concentration and comparison of catalase activity in all vitamins treated groups, dichlorvos treated groups, control groups to the baseline group, and positive control, group. In Figure 11, the catalase concentration of the dichlorvos group was relatively low in comparison to the baseline group and was also significantly different in the brain. Vitamin D and vitamin E both had decreased catalase concentrations in the baseline group and were both significantly different from the baseline group in the brain. Dichlorvos with vitamin D and dichlorvos with vitamin E also had decreased concentrations of catalase in the brain in comparison to the baseline group and were both significantly different from the baseline group in the brain.

In Figure 12, the dichlorvos group, vitamin D group, vitamin E group had similar catalase concentrations to the positive control group, and they were not significantly different from the positive control group in the brain. Dichlorvos with vitamin D group and dichlorvos with vitamin E group also had similar concentrations to the positive control group and were not significantly different from the positive group.

Dichlorvos group recorded a negative percentage decrease of 24% catalase activity with an SEM of 0.344±0.007 in the brain. The percentage of brain catalase activity of the vitamin E group and the dichlorvos + vitamin E group were both negatively decreased by 2.7 x 10^{-5} % and 0.4% respectively with an SEM of 0.459±0.003, and 0.457±0.003 respectively. Meanwhile, vitamin D and dichlorvos + vitamin D groups both recorded a positive percentage increase of 22% and 20% respectively of catalase levels with a respective SEM of 0.564±0.006 and 0.552±0.004 in the brain in comparison to the negative control.

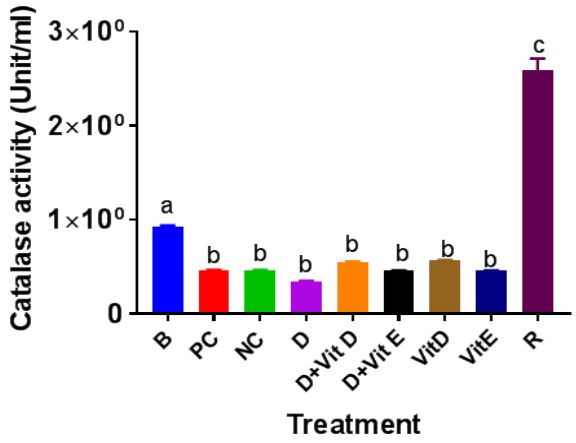

Figure 11 Effect of dichlorvos and vitamins doses on brain catalase levels in comparison to the baseline group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the baseline group

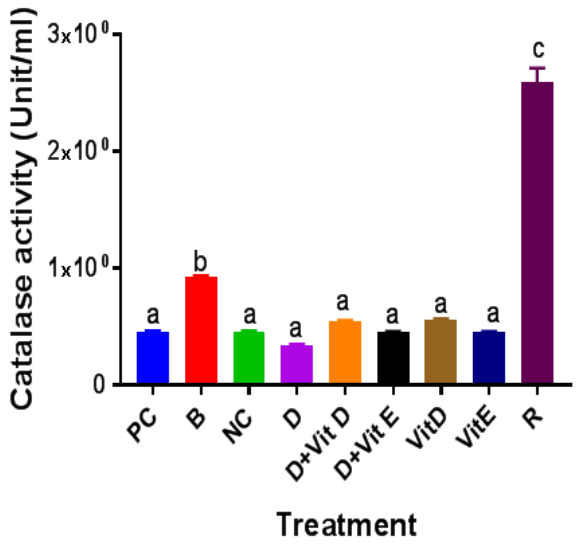

Figure 12 Effect of dichlorvos and vitamins doses on brain catalase levels in comparison to the positive control group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the positive control group

Evaluation of the Effects of Dichlorvos and Phytochemicals on Catalase Activity in the Brain

Figures 13 and 14 depict the concentration and 'comparison of catalase activity in all vitamins treated groups, dichlorvos treated groups, control groups to the baseline group, and positive control group. In Figure 13, it was shown that the dichlorvos group had a relatively low catalase concentration when compared to the baseline group and it was also found to be statistically significant to the baseline group. The quercetin group and dichlorvos + quercetin group were also not significantly different from the baseline group, but the quercetin group showed an increase in the catalase concentrations when compared with the baseline group, and also, dichlorvos + quercetin group had a similar but little catalase concentration in comparison to the baseline group in the brain. The naringin group and dichlorvos + naringin group both had higher catalase concentrations in the brain than the baseline group and were found to be statistically significant to the baseline group.

In Figure 14, the catalase concentrations of the dichlorvos group were small but similar to the baseline group and it was not significant to the baseline group. The naringin group and dichlorvos + naringin group had high catalase concentrations and were both statistically significant to the baseline group in the brain. The quercetin group was found to be high in catalase concentration compared to the baseline and was also significant to the baseline group while the dichlorvos + quercetin group was not found to be statistically significant from the baseline group, but it had a little bit high catalase concentration to the baseline group.

In contrast to the negative group, the dichlorvos group recorded a negative percentage decrease of 24% in catalase activity with an SEM of 0.344±0.007 in the brain. The naringin group and dichlorvos + naringin group both recorded a positive increase of 401% and 383% respectively of catalase activity, and recording an SEM of 2.302±0.076, and 2.216±0.067, respectively, in the

brain and the quercetin group and dichlorvos + quercetin group also recorded a positive percentage increase of 178% and 46% respectively of catalase activity, and an SEM of 1.276±0.060, and 0.670±0.009 respectively in the brain in contrast to the negative control group.

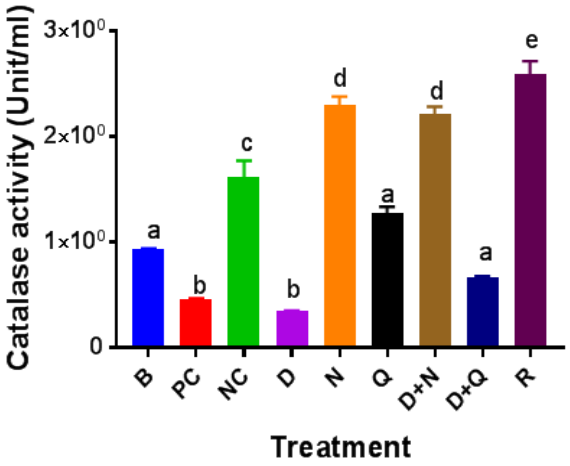

Figure 13 Effect of dichlorvos and phytochemicals doses on brain catalase levels in comparison to the baseline group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the baseline group

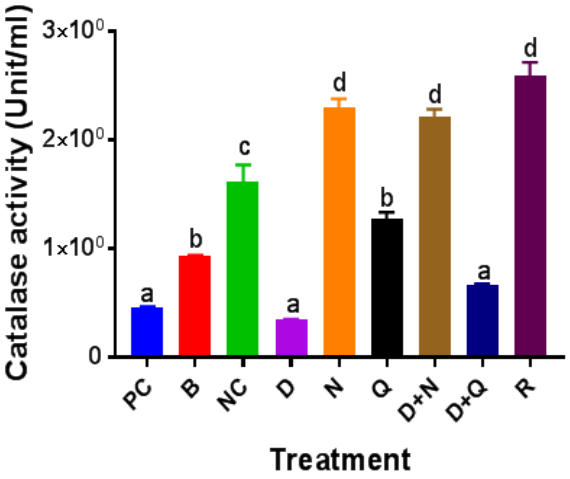

Figure 14 Effect of dichlorvos and phytochemicals doses on brain catalase levels in comparison to the positive control group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the positive control group

Evaluation of the Effects of Dichlorvos and Vitamins and Phytochemicals on Catalase Activity in the Liver

Evaluation of the Effects of Dichlorvos and Vitamins on Catalase Activity in the Liver

Figures 15 and 16 illustrate the concentration and comparison of catalase activity in all vitamins treated groups, dichlorvos treated groups, control groups to the baseline group, and positive control, group. In Figure 15, the dichlorvos group had a high catalase concentration compared to the baseline in the liver and it was also statistically significant from the baseline group. The vitamin D group was similar to the

baseline group in catalase concentration and was not statistically significant from the baseline group in the liver, but the vitamin E group had a little increase in catalase concentration compared to the baseline group and was further found to be statistically significant to the baseline group. The dichlorvos + vitamin D group had a high increase in catalase concentrations in comparison to the baseline group and was significant from the baseline group. The dichlorvos + vitamin E group, therefore showed a similar but little increase in catalase concentrations when compared to the baseline group, but it was not statistically different from the baseline group in the liver.

In Figure 16, the dichlorvos group had an increased catalase concentration in contrast to the positive control group and was significant from the positive control group. The vitamin D and vitamin E groups were not significant to the positive control group and the vitamin D was similar to the positive catalase concentration in the liver but the vitamin E group had an increase in the catalase concentrations in the liver. The dichlorvos + vitamin D had an increased catalase concentration and was also found to be significant to the positive control group, but the dichlorvos + vitamin E group had a similar but little increase in the catalase concentration when compared to the positive control group. Furthermore, the dichlorvos + vitamin E group was not significant from the positive control group.

In the liver, the dichlorvos group, vitamin D and vitamin E group, dichlorvos + vitamin D, and dichlorvos + vitamin E group were all found to record a negative percentage decrease of 50%, 72%, 62%, 46%, and 65% respectively of the catalase activity with an SEM of 1.194±0.023, 0.670±0.008, 0.919±0.005, 1.311±0.049, and 0.850±0.009, respectively, when compared to the negative control group in the liver.

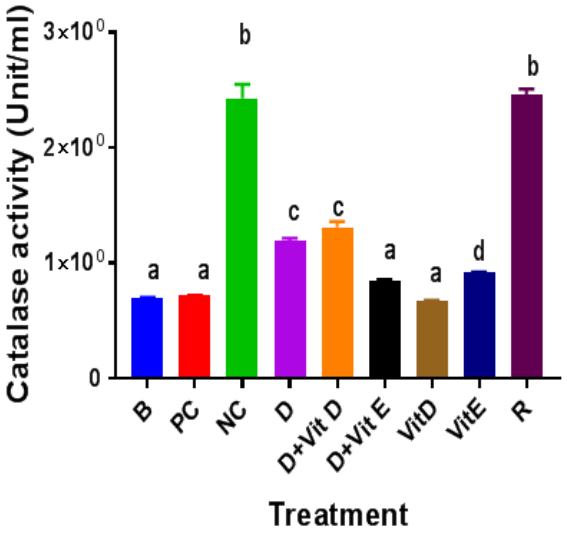

Figure 15 Effect of dichlorvos and vitamins doses on liver catalase levels in comparison to the baseline group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the baseline group

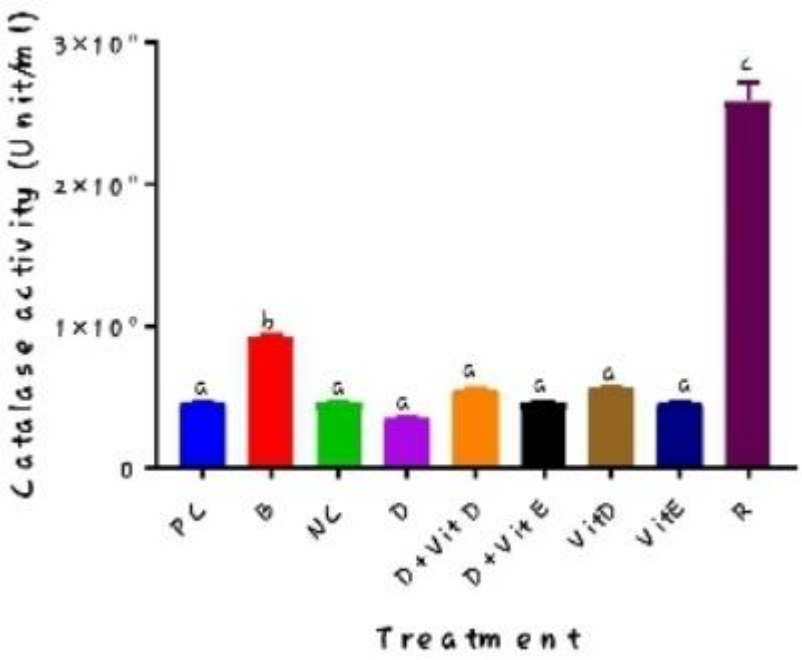

Figure 16 Effect of dichlorvos and vitamins doses on liver catalase levels in comparison to the positive control group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the positive control group

Evaluation of the Effects of Dichlorvos and Phytochemicals on Catalase Activity in the Liver

Figures 17 and 18 depict the concentration and comparison of catalase activity in all vitamins treated groups, dichlorvos treated groups, control groups to the baseline group, and positive control, group. In Figure 17, the catalase concentration of the dichlorvos group was higher than the baseline group and was also significantly different from the baseline group in the liver. The naringin group had the highest catalase activity in the liver when compared to the baseline and is statistically significant from the baseline group in the liver and the quercetin group also had a high catalase concentration to the baseline group and was also significantly different from the baseline group. The dichlorvos + naringin group had a relative but slightly similar catalase concentration but was found to be significant to the baseline group while the dichlorvos + quercetin group had a high catalase concentration in contrast to the baseline group and was also statistically significant to the baseline group in the liver.

In Figure 18, the dichlorvos group had a high catalase concentration to the positive control group and was statistically significant to the positive control group. The naringin group had the highest catalase concentrations in the liver in comparison to the positive control group and was also significant to the positive control group and the quercetin group also had a high catalase concentration and was significantly different from the positive control group. The dichlorvos + naringin group had a relatively high catalase concentration to the positive control group and was also significantly different in the liver while the dichlorvos + quercetin group also had a high catalase concentration and was

also statistically significant to the positive group in the liver.

In the liver, the dichlorvos group had a negative percentage decrease of 50% catalase activity with an SEM of 1.194±0.023. Also, the quercetin group, dichlorvos + quercetin, and dichlorvos + naringin recorded a negative percentage decrease of 49%, 25%, 56% respectively of catalase activity with an SEM of 1.233±0.055, 1.822±0.023, 1.060±0.014 in the liver to the negative control group. Meanwhile, the naringin group recorded a positive percentage increase of 71% catalase activity, and also recorded an SEM of 4.177±0.042 in the liver when compared to the negative control group.

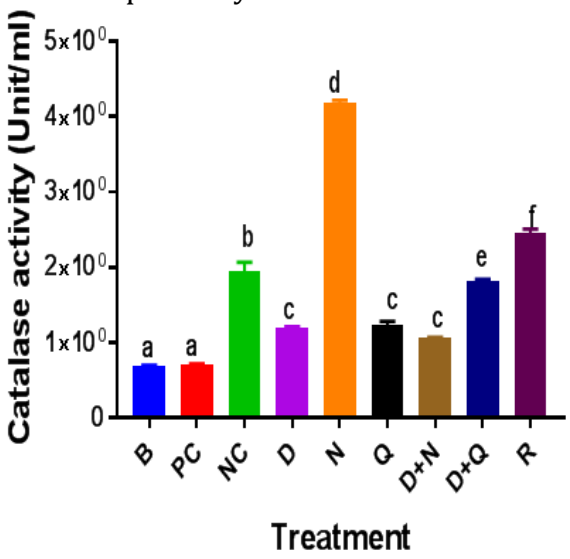

Figure 17 Effect of dichlorvos and phytochemicals doses on liver catalase levels in comparison to the baseline group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the baseline group

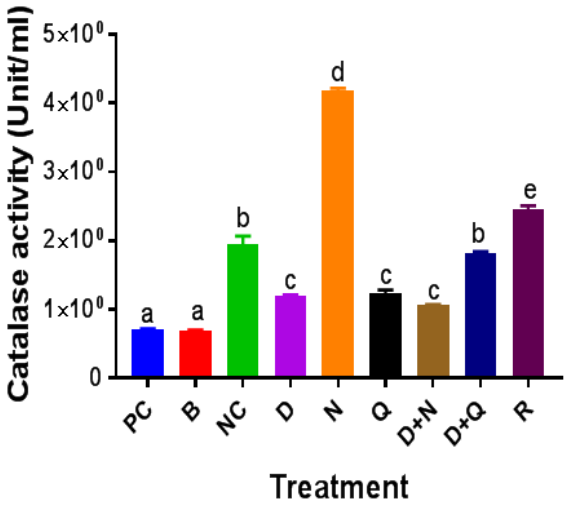

Figure 18 Effect of dichlorvos and phytochemicals doses on liver catalase levels in comparison to the positive control group. Each bar represents the Mean±SEM of 8 rats. Bars with different alphabets are significantly different from each other and a significant difference of mean ($p<0.05$) between each treatment group to the positive control group

Histology

The Liver

In Figure 19, groups 1, 2, 5, and 9-10 showed normal central venules without congestion, the morphology of the liver cells (hepatocytes) appear normal, the sinusoids appear normal and not infiltrated, no significant observable pathological lesion was seen. This confers that the baseline group, control groups, and treatment groups had normal hepatocyte morphology and no damage incurred due to a normal feeding schedule and only vitamins or bioflavonoids treatment. Group 6-8 shows mild infiltration of congestion, the hepatocytes morphology appears normal, the sinusoids appear normal and mildly infiltrated (arrow). These groups are the initial dichlorvos administered group and were later administered vitamins (D and E), and naringin. It was indicative in these groups, that treatment with vitamins alleviated the dichlorvos effect in the liver. Groups 3 and 4 show central venules with congestion, the morphology of the hepatocytes appear pyknotic and distorted, the sinusoids appear congested and infiltrated, observable signs of hemorrhagic cells, red inflammatory cells, and signs of fibrosis are characteristic features of these groups (yellow arrows). This is the major indication that the administration of dichlorvos is damaging to the liver organ.

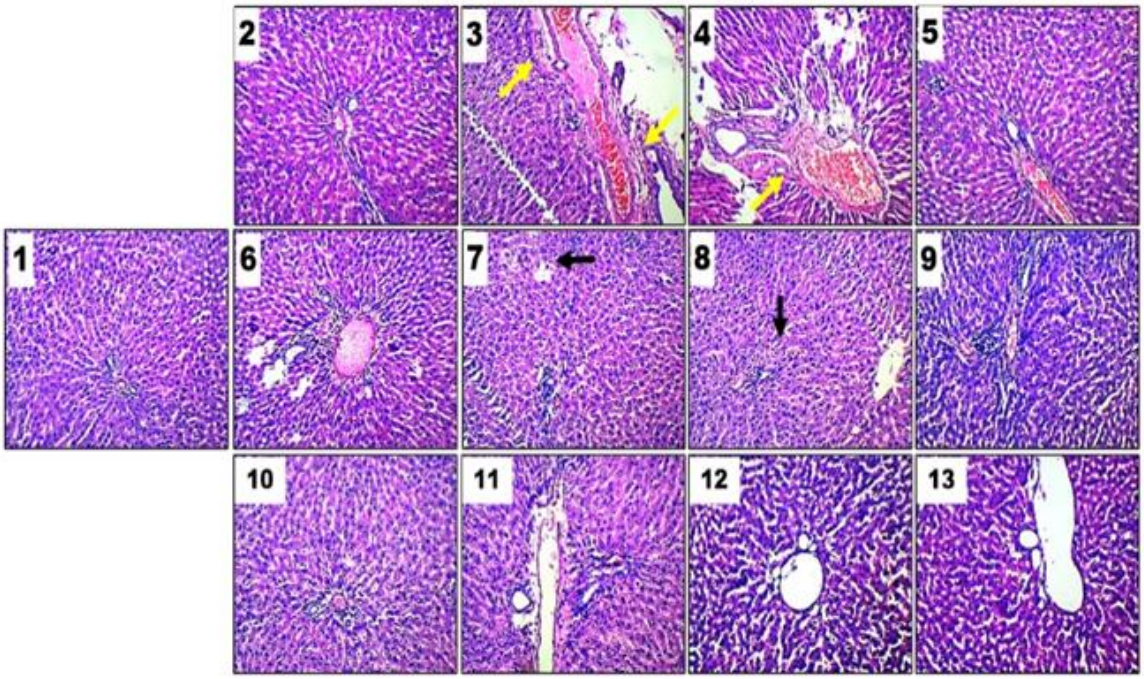

Figure 19 Panoramic views of a liver micromorphologic'al section demonstrated by hematoxylin and 'eosin staining at low magnification (x400). The h'"epatocytes, sinusoids, portal triad (hepatic vein, ''hepatic artery, and bile duct) are all visible across 'the various groups

The Brain

Figure 20 demonstrates representative micrographs of H&E staining showing the general and magnified cytoarchitecture of the brain (cortex) in Wistar rats. (Magnification: X100 and X400 respectively). Groups 1, 2, 5, and 9-13 treatment depicted normal histological features of the brain (cortex); this is characterized by large pyramidal as well as granule neurons, the pyramidal cells are characterized with long axons that extend well from the soma to adjacent neurons within the neuropil.

Apical and basal dendrites extend from the well-delineated soma of the pyramidal neurons in this group. Perineural space surrounding these cells appears intact, with intact nuclear and cytoplasmic content; both pyramidal and granular cells appear darkly stained with no signs of diffused content with distinct layering. This is evidenced in'' the figures above that these groups had no damage incurred and possessed normal brain structures.

Groups 3 and 4 treatment had conspicuous degenerative changes in the brain (cortex) that was characterized by peripheral and central degenerative changes, scattered pyknotic pyramidal and granule neurons that appear with fragmented cytoplasm and condensed nuclei. Wide Perineural spaces can be seen surrounding degenerating neurons, axons, and dendrites are scarcely appreciable around neurons in this group, neuronal population appears scarcely appreciable in this group (yellow arrow). This is indicative of the damage caused by the dichlorvos administration.

Groups 6-8 treatment showed mild degenerative changes in the brain (cortex) but largely presents similar to group 10-13 (black arrow).

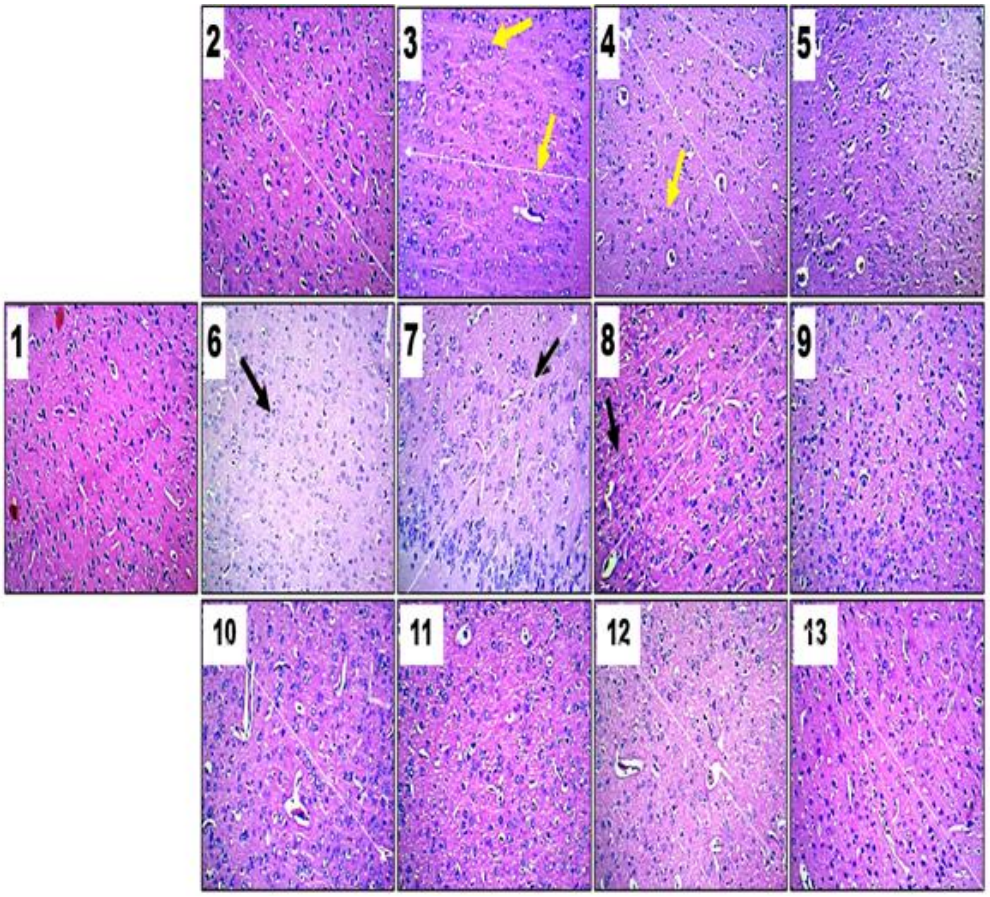

Figure 20 Photomicrographs showing panoramic views of the brain (cortex) general micromorphological presentations in Wistar rats across the study groups. H&E stain (magnification x100). The molecular layer (I), external granular layer (II), external pyramidal layer (III), internal granular layer (IV), internal pyramidal layer (V), and the multiform layer (V) are demonstrated across study groups (white thin arrow direction)

Discussion

Pesticides may induce oxidative stress, leading to the generation of free radicals and alteration in antioxidants, oxygen-free radicals, the scavenging enzyme system, and lipid peroxidation. The most prominent clinical effects of poisoning with OPs result from their inhibition of acetylcholinesterase (AchE). Several studies have demonstrated oxidative stress induced by OPs in rats and humans [16].

Dichlorvos (2,2-dichlorovinyl dimethyl phosphate) is an organophosphate pesticide and insecticide used all over the world. It has known hepatotoxic, neurotoxic, and other toxic effects in the body [17, 18]. Catalase is an enzyme that is responsible for degrading hydrogen peroxides present in organs or blood cells and tissue to prevent oxidative damage to these respected organs [19]. The flavonoids (naringin and quercetin) and vitamin D and E have been found to reduce oxidative stress in the body.

Protective antioxidant enzymes such as catalase are the line first line of defense against reactive oxygen species-ROS. Many normal biological processes that occur in eukaryotes involve generating a controlled amount of reactive oxygen species which mostly serves as a self-defense mechanism against antigenic substances. These reactive species are normally removed from the system by specialized antioxidant defensive mechanisms which work in a concerted manner to prevent oxidative damage to cells and tissues [20].

However, when the levels of these radicals exceed the capacity of antioxidant molecules, oxidative stress results. Therefore mostly, in a toxic compromised system, it is expected to have a decrease in antioxidants level which was generalized by the percentage decrease of catalase in the plasma, RBC, brain, and liver. Consequently, the dichlorvos administered group had a decrease in the antioxidant level in the liver, brain, plasma, red blood cells. All these are correspondent with the fact there was a decreased level of antioxidant in an exposed system of toxicity.

The histological results clearly show that dichlorvos indeed caused damage to the organs and liver thereby expressing higher levels of antioxidants enzymes to counteract its effects. In the brain, catalase was found to be in action, thereby reducing the effects of the toxicity caused by the dichlorvos.

The low level of catalase in the brain of dichlorvos-induced rats showed the enzyme expression in that group. Meanwhile, the flavonoids and vitamins were found to alleviate the levels of catalase in the brain and reduce the toxic effects of the dichlorvos. Naringin and quercetin attenuated the effects of dichlorvos toxicity on the catalase level by increasing the effect on them. Naringin showed an increase in catalase levels similar to the dichlorvos + naringin-treated group which accounted for low or eradicated levels of toxicity in the system of those rats. Likewise, quercetin, and dichlorvos + quercetin-treated groups accounted for increasing catalase concentrations but were not as high as the catalase levels depicted by the naringin family, and so little or no oxidative stress would have been observed in the rats. Vitamin D is also another attenuator in the brain because vitamin D had a slight increase in catalase activity in the brain of the dichlorvos + vitamin D treated group, and the dichlorvos + vitamin D group still experienced oxidative stress in the brain of the animals due to the small increase in catalase activity which meant that there wera still high hydrogen peroxide levels in the brain.

Catalase enzyme activity in the tissues of organs may be in response to H_2O_2 produced by the catalytic activity of SOD [21, 22]. In the liver, catalase levels in the dichlorvos group were found to be low but not as low as compared to the control and vitamin with flavonoids treated group. The increased level depicted the lesser activity of catalase in the liver organ. The liver is an organ that is supposed to have higher levels of catalase normally, but when induced with dichlorvos, the catalase activity dropped. In the flavonoids and vitamins treated group, it was not to be concluded that the high levels observed in the dichlorvos + vitamin D treated group was beneficial or not as the group recorded an increase in catalase concentrations in the liver and naringin had the highest catalase concentrations in the liver of naringin treated group but recorded a decrease in catalase concentrations in dichlorvos + naringin administered group which is evident that naringin did not attenuate dichlorvos effect in the liver. The histology report also corresponds to this observation which showed major damage in dichlorvos induced groups, and slight damage in the dichlorvos + naringin group.

The red blood cell is a compartment of body fluids that also has enough and high levels of catalase enzymes. The catalase activity in the dichlorvos treated group was found to be higher because catalase levels were very low. This study is in correlation with [23], which states that exposure to organophosphate pesticides was associated with increased levels of catalase in erythrocytes. Vitamin D is a major attenuator because it was found to increase catalase efficiency in the dichlorvos + vitamin D treated group compared to other attenuators. The vitamin D treated group also had increased catalase concentrations depicting a decrease in hydrogen peroxide levels in the red blood cells, which was similar to the dichlorvos + vitamin D treated group. Vitamin E and the bioflavonoids had little efficiency in raising the catalase levels of the red blood cells, and they had their antioxidant level getting depleted [24].

In the plasma, the catalase levels of the dichlorvos induced group were found to be low as expected. Vitamin E was found to be a potent attenuator of catalase by increasing the fold of catalase efficiency in initially dichlorvos treated groups. The dichlorvos + vitamin E treated group recorded an increased catalase concentration which depicted the efficiency of vitamin E in a toxic system in the plasma which was the highest of any other attenuator in the plasma catalase concentrations because it increased catalase concentrations, but it cannot be concluded if it did offer absolute protection by just increasing catalase concentrations in the plasma. The increased level of naringin meant increased catalase concentrations and low hydrogen peroxide levels in the plasma of the naringin-treated group.

The histology report backs up all the observations found in the organs and it was found out that dichlorvos did damage organs and depletes oxidative markers thereby increasing oxidative stress. But with certain and potent attenuators, catalase activity was found to be more efficient in alleviating oxidative stress caused by the induction of dichlorvos.

Conclusion

To sum up, the bioflavonoids were found to be great and potent attenuators of dichlorvos effect on catalase activity majorly in the plasma, brain, and liver as they showed a great increase of catalase activity in the dichlorvos with phytochemical treated groups. They also increased the catalase efficiency and levels in normal phytochemical treated

groups. Vitamin D is also a potent attenuator as its effect was greatly displayed in the RBC and brain. Vitamin D increased catalase effects in both the vitamin D treated groups of brain and RBC and dichlorvos with vitamin D treated groups of brain and RBC. Vitamin E is also an active attenuator of dichlorvos effects as it was not efficient in increasing catalase activity at all in all dichlorvos and vitamin E treated groups across brain, liver, RBC except in the plasma where it increased the plasma catalase activity of dichlorvos and vitamin E treated group, but it was found to possess antioxidant capacities because it depicted depleted catalase levels across all compartments (brain, liver and red blood cells) which shows its potency at trying to ameliorate the effects of dichlorvos in a system. But across all vitamin E treated groups of organs and plasma and RBC it showed no active effect.

Nevertheless, despite the antioxidant capacities portrayed by these bioflavonoids (naringin and quercetin), and vitamins (vitamin D and vitamin E), they do not offer complete and absolute amelioration of dichlorvos in a toxic system, hence they do not offer complete protection against the administration of dichlorvos [17].

Conflict of Interest

None.

Consent for Publication

Not applicable.

Availability of Data and Materials

All supporting data are available on request.

Authors' Contributions

All co-authors participated in all stages of this study while preparing the final version. All authors read and approved the final manuscript.

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Ethical consent

The authors declare that ethics committee approval was not required for this study as no animals were sacrificed or used in the study. The work contains plants study with data collection from online resources freely available in the public domain that does not collect or store identifiable data. All related laws, rules and regulations necessary for the execution of the study have been followed.

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References

1. Celik I, Yilmaz Z, Turkoglu V. Hematotoxic and hepatotoxic effects of dichlorvos at sublethal dosages in rats. Environmental Toxicology: An International Journal. 2009 Apr;24(2):128-32. [Crossref], [Google Scholar], [Publisher]
2. Raheja G, Gill KD. Calcium homeostasis and dichlorvos induced neurotoxicity in rat brain. Molecular and cellular biochemistry. 2002 Mar;232:13-8. [Crossref], [Google Scholar], [Publisher]
3. Atiş S, Çömelekoğlu Ü, Coşkun B, Özge A, Ersöz G, Talas D. Electrophysiological and histopathological evaluation of respiratory tract, diaphragm, and phrenic nerve after dichlorvos inhalation in rats. Inhalation Toxicology. 2002 Jan 1;14(2):199-215. [Crossref], [Google Scholar], [Publisher]
4. Okamura A, Kamijima M, Shibata E, Ohtani K, Takagi K, Ueyama J, Watanabe Y, Omura M, Wang H, Ichihara G, Kondo T. A comprehensive evaluation of the testicular toxicity of dichlorvos in Wistar rats. Toxicology. 2005 Sep 15; 213(1-2):129-37. [Crossref], [Google Scholar], [Publisher]
5. Oral B, Guney M, Demirin H, Ozguner M, Giray SG, Take G, Mungan T, Altuntas I. Endometrial damage and apoptosis in rats induced by dichlorvos and ameliorating effect of antioxidant vitamins E and C. Reproductive toxicology. 2006 Nov 1;22(4):783-90. [Crossref], [Google Scholar], [Publisher]
6. Sarin S, Gill KD. Dichlorvos induced alterations in glucose homeostasis: possible implications on the state of neuronal function in rats. Molecular and cellular biochemistry. 1999 Sep;199:87-92. [Crossref], [Google Scholar], [Publisher]
7. GowlandáHopkins F. The analyst and the medical man. Analyst. 1906;31(369):385b-404. [Crossref], [Google Scholar], [Publisher]
8. Funk C. On the chemical nature of the substance which cures polyneuritis in birds induced by a diet of polished rice. The Journal of physiology. 1911 Dec 12;43(5):395. [Crossref], [Google Scholar], [Publisher]
9. Ravisankar P, Reddy AA, Nagalakshmi B, Koushik OS, Kumar BV, Anvith PS. The comprehensive review on fat soluble vitamins. IOSR Journal of Pharmacy. 2015 Nov; 5(11):12-28. [Google Scholar], [Publisher]
10. Glorieux C, Calderon PB. Catalase, a remarkable enzyme: targeting the oldest antioxidant enzyme to find a new cancer treatment approach. Biological chemistry. 2017 Sep 26;398(10):1095-108. [Crossref], [Google Scholar], [Publisher]
11. 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 journal of medicine. 2018;54(4):287-93. [Crossref], [Google Scholar], [Publisher]
12. Sharma P, Kumar V, Guleria P. Naringin: Biosynthesis and Pharmaceutical Applications. Indian Journal of Pharmaceutical Sciences. 2019 Nov 1;81(6). [Crossref], [Google Scholar], [Publisher]
13. Oboh G, Ademosun AO, Ogunsuyi OB. Quercetin and its role in chronic diseases. Drug discovery from mother nature. 2016:377-87. [Crossref], [Google Scholar], [Publisher]
14. David AV, Arulmoli R, Parasuraman S. Overviews of biological importance of quercetin: A bioactive flavonoid. Pharmacognosy reviews. 2016

Jul;10(20):84. [Crossref], [Google Scholar], [Publisher]
15. Massi A, Bortolini O, Ragno D, Bernardi T, Sacchetti G, Tacchini M, De Risi C. Research progress in the modification of quercetin leading to anticancer agents. Molecules. 2017 Jul 29;22(8):1270. [Crossref], [Google Scholar], [Publisher]
16. Yarsan E, Cakir O. Effects of dichlorvos on lipid peroxidation in mice on subacute and subchronic periods. Pesticide biochemistry and physiology. 2006 Oct 1;86(2):106-9. [Crossref], [Google Scholar], [Publisher]
17. Ogutcu A, Suludere Z, Kalender Y. Dichlorvos-induced hepatotoxicity in rats and the protective effects of vitamins C and E. Environmental Toxicology and Pharmacology. 2008 Nov 1; 26(3):355-61. [Crossref], [Google Scholar], [Publisher]
18. Charles OO, Damilare YM, Damian OC, Eriuroro JP, Precious I, Dolapo IA, Iyanu OF, Hannah A. Phytochemical Profile and Antioxidant Properties of Extracts from Sargassum flutans. International Journal of Advanced Biological and Biomedical Research, 11(4), pp. 261-276. [Crossref], [Google Scholar], [Publisher]
19. Kavitha KV. *Effect of Courouptia Guianensis on N-Diethylnitrosamine Induced Oxidative Stress in Wistar Rats* (Doctoral dissertation, JKK Nattraja College of Pharmacy, Komarapalayam). [Google Scholar],
20. Ji LL, Yeo D. Oxidative stress: an evolving definition. Faculty Reviews. 2021;10.
21. Rossi SC, Dreyer da Silva M, Piancini LD, Oliveira Ribeiro CA, Cestari MM, Silva de Assis HC. Sublethal effects of waterborne herbicides in tropical freshwater fish. Bulletin of environmental contamination and toxicology. 2011 Dec;87:603-7. [Crossref], [Google Scholar], [Publisher]
22. Toni C, Ferreira D, Kreutz LC, Loro VL, Barcellos LJ. Assessment of oxidative stress and metabolic changes in common carp (Cyprinus carpio) acutely exposed to different concentrations of the fungicide tebuconazole. Chemosphere. 2011 Apr 1;83(4):579-84. [Crossref], [Google Scholar], [Publisher]
23. Shadnia S, Azizi E, Hosseini R, Khoei S, Fouladdel S, Pajoumand A, Jalali N, Abdollahi M. Evaluation of oxidative stress and genotoxicity in organophosphorus insecticide formulators. Human & experimental toxicology. 2005 Sep;24(9):439-45. [Crossref], [Google Scholar], [Publisher]
24. Hamid NA, Hasrul MA, Ruzanna RJ, Ibrahim IA, Baruah PS, Mazlan M, Yusof YA, Ngah WZ. Effect of vitamin E (Tri E®) on antioxidant enzymes and DNA damage in rats following eight weeks exercise. Nutrition journal. 2011 Dec;10(1):1-7. [Crossref], [Google Scholar], [Publisher]

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