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Studies on Fenaxoprop-P-Ethyl Induced Antioxidant Response in *Cyprinus carpio* L.

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ABSTRACT

The occurrence of pollutants in the aquatic environment can produce severe toxic effects on non-target organisms, including fish. These sources of contamination are numerous and include herbicides, which represent a large group of toxic chemicals. The present study was undertaken to investigate the oxidative stress of the herbicide Fenaxoprop-P-Ethyl in a common freshwater fish, *Cyprinus carpio*. These fish were exposed to environmentally relevant concentrations of Fenaxoprop-P-Ethyl (37.5µg/L 1/8th of LC_{50} 300µg/) for 15, 30 and 45 days. Antioxidant parameters MDA Levels, glutathione peroxidase (GPx), Glutathione S-transferase activity (GST) glutathione reductase (GR), reduced glutathione (GSH) were measured in the gill, liver and muscle, together with levels of oxidative damage that occurred. After day's exposure, significant increases in activity content were observed in all three tissues at the highest concentration of exposure (37.5µg/L). The highest concentration of Fenaxoprop-P-Ethyl induced oxidative stress to different tissues in the common carp, especially the gills, liver and muscles after chronic exposure occurred. These results provide evidence that the oxidant-antioxidant could be integrated into monitoring programs determining the toxicity of water pollutants.

***Key words*:** *Cyprinus carpio* fish, Fenoxaprop-P-Ethyl FEP herbicide, MDA, GPx, GST, GR, GSH, Gills, Muscle, Liver

In agricultural production, the use of pesticides is an as often as possible embraced practice for keeping up and improving harvest yield. Be that as it may, expanded utilization of pesticides can bring about natural contamination and oftentimes enter close by aquatic environments by means of shower float, overflow or soil filtering, possibly creating adverse consequences on non-target organisms [1-3]. Fish are oftentimes utilized as pointers of the effect of destructive xenobiotics, including pesticides, in view of their wide utility in giving information identified with exposure to conceivably harmful substances and extrapolating to make forecasts relating to impacts to human wellbeing [4-5].

Biochemical reactions in fish give significant information on ecological and aquatic toxicology and are every now and again utilized as early cautious biomarkers of natural contamination [6-8]. Under ordinary conditions, the disposal of receptive oxygen species (ROS) keep a powerful equilibrium in living beings including fish; moreover, some antioxidant enzymes like catalase (CAT), glutathione peroxidase (GPx) and glutathione reductase (GR) can attempt the role in searching ROS [9-11]. In any case, when this equilibrium is hindered by synthetics, including a few pesticides, the overproduction of ROS can modify the antioxidant system in organisms, prompting oxidative pressure, lipid peroxidation, DNA harm and even demise [12]. In testing of macromolecules, malondialdehyde (MDA), a result of lipid peroxidation, is regularly used to measure the harm of toxins to membranes in organisms [13].

Herbicides are known as a sort of pesticide used to execute undesirable weeds and plants. Since the last part of the 1940s with the presentation of the main herbicide (2, 4-D) 2,4-dichlorophenoxyacetic acid, it has been generally utilized. Notwithstanding, herbicides have both positive and unfriendly impact on the natural ecosystem. Fish, as quite possibly the most agent organic entity in freshwater, is frequently on the highest point of the trophic level. Because of bioaccumulation of herbicides, the concentration of herbicide in fishes may turn out to be sufficiently high to incite poisonous reactions in fishes and furthermore in people that may utilize the fish for food. Fish may likewise be a decent bioindicator for environmental safety [14-15].

Aryloxyphenoxypropionate herbicides (AOPPs) repress the initial step of unsaturated fat combination by impeding the protein acetyl coenzyme-A carboxylase (ACCase) and are high strong herbicides for the control of *A. myosuroides* [16]. The current investigation primarily tended to towards the similar evaluation on oxidative stress

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and antioxidant activities in gills, muscles and liver of *Cyprinus carpio*, in laboratory condition and lastly to decide the toxicity of Fenoxaprop-P-Ethyl herbicide under aquatic environment.

Oxidative stress in aquatic life forms, primarily fish, has incredible significance for natural and aquatic toxicology. Since oxidative pressure is instigated by numerous synthetic compounds, including a few pesticides, these pollutants may stimulate responsive oxygen species and modification in antioxidant activities. Perhaps the main early occurrence in cell degeneration is lipid peroxidative effect, which happens mainly in the cell membrane. Furthermore, lipid peroxidation leads to a continuous response to free radical effect on organs and tissues [17]. The beginning of oxidative stress in fish is additionally influenced by pesticide biodegradation [18]. This investigation tends to whether and how, low concentrations of Fenaxoprop-P-Ethyl influence the physiology of *Cyprinus carpio*. In spite of the acute and sub- lethal impacts of intense and exposures of fish to atrazine, another s-triazine herbicide, have been all around recorded, there is a lack of literature and information on the exposure to Fenaxoprop-P-Ethyl at ecologically sensible fixations regarding oxidative stress and antioxidant reactions in *Cyprinus carpio*. The point of this investigation was to assess oxidative stress and antioxidant reaction of *Cyprinus carpio* exposed to Fenaxoprop-P-Ethyl.

MATERIALS AND METHODS

Experimental animal

Healthy and active *Cyprinus carpio* were procured from the Bhadra Fish Seed Farm, Shimoga, Karnataka. Fishes were maintained in large cement tanks (1000 litres) which were duly aerated. Water in the tanks was treated with 1% KCl solution prior to the introduction of the fish into the tank. Fish were fed with balanced nutritious food pellets (Nova, Aquatic P. Feed) and allowed to acclimatize for a period of 14 days at 24°C temperature and 12-14 hours of photoperiod. Water in the tanks was renewed daily and the physicochemical parameters of water were examined according to the guidelines of American Public Health Association.

Selection of sublethal concentration and grouping of experimental fish

Previously determined median lethal concentration value of 300 µg/L [19] was taken into consideration for the present investigation in order to minimize the animal kill. A single sublethal concentration of $1/8^{th}$ (37.5µg/L) of LC_{50} was selected as test concentration for the present experimentation. The fish were divided into four groups, namely: control (C), 15 (E_1), 30 (E_2) and 45 days of exposure (E_3). Each group was maintained in triplicate and consisted of ten individual fishes each. During the experiment, both control and exposed *Cyprinus carpio* showed normal feeding behavior. There were no signs of respiratory distress such as rapid ventilation, increased rate of gill opercular movements, or floating at the surface of water. There were no mortalities during the experiment. Water was renewed daily, whose physico-chemical characteristics were analyzed following the methods mentioned in APHA (2005).

Preparation of stock and exposure of fishes

Fenoxaprop-P-Ethyl of 6.9% w/v E.C was procured from Bayer house, Central Avenue, Hiranandani estate (west), India. Stock solution was prepared by serial dilution method from the selected sublethal concentrations of the herbicide (37.5µg/L). The replacement of the water medium was followed by the addition of the desired dose of the test compound at an interval of every 24 h until completion of the exposure (E_1, E_2 and E_3). The study was conducted under OECD Guidelines for static-renewal test conditions (OECD 1992). At the ends of 15, 30 and 45 days (E_1, E_2 and E_3), the requisite organs were isolated by sacrificing the fish and were processed for further investigations.

Antioxidant enzyme assay and MDA levels

The antioxidant enzymes, Glutathione reductase, glutathione peroxidase, Lipid peroxidation levels/MDA levels, Glutathione S-transferase activity GST and reduced glutathione which served as an indicator of oxidative damage for the present investigation and were assayed using a spectrophotometer (Secomam, Anthelie advanced 2).

Glutathione Reductase (GR) Glutathione reductase activity was determined by the method of Carlberg and Mannervik, [20], as described by Iqbal *et al*. [21]. Reduced Glutathione the assay for reduced glutathione was determined by the method of Ellman [22], modified by Jollow *et al*. [23]. Glutathione peroxidase activity was measured by the method of Paglia and Valentine [24]. Glutathione S-transferase activity (GST) activity was assayed by the method of Habig *et al*. [25].

Lipid peroxidation (LPO) level was performed according to the method of Buege and Aust [26] and estimated by thiobarbituric acid reactive substance (TBARS) assay performed by an optically measured malondialdehyde (MDA) reaction with TBA.

Ethical statement

All the experiments performed in the present study abide by the guidelines of the Institutional Animal Ethics Committee (IAEC). The experimental animals used in the study were handled with care according to the guidelines provided by the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA), New Delhi, India.

Statistical analysis

The antioxidant activities are reported as the Mean ±Standard error of the mean (SEM) obtained from triplicates. The data were subjected to one-way analysis of variance and further subjected to Tukey's test for post hoc analysis by defining the significance level at $p \leq 0.05$.

RESULTS AND DISCUSSION

The antioxidant enzyme status in the fish exposed to 37.5µg/L (1/8th of LC_{50}) of FEP for 15 days (E_1), 30 days (E_2) 45 days (E_3) and control (C). In the experimental groups, the activity of all the investigated antioxidant enzymes, CAT, SOD, GPx, and GST, was found to significant different ($P<0.05$) in a constant pattern following exposure to 37.5µg/L ($1/8^{th}$ of LC_{50}) of FEP. Changes in GPx activity under FEP stress varied significantly (p) with percent decrease of –gills -1.9964, -3.1318, -3.5972% and Muscles -10.0769, -9.5927, -5.3016 and Liver -2.3229, -1.4951, -5.5871% for E_1, E_2 and E_3, respectively. Changes in the activity of Gultathione reductase were noted for

exposure and durations. The changes in activity of Gultathione reductase noticed were in the Gills -7.5243, -50678, -1.4251 % for E_1, E_2 and E_3 respectively, indicating the highest decline of enzymatic threshold at E_3 in gills. In muscles -8.6822, -4.1563, -1.3185% for E_1, E_2 and E_3 respectively. In Liver -3.2968, -2.0689, -80.0407% for E_1, E_2 and E_3 respectively.

Changes in the Glutathione-S-Transferase activity in gills were -6.9492, -5.8145, -2.2647% for E_1, E_2 and E_3respectively. Muscles were -4.0516, -3.3036, -1.1077% for E1, E2 and E3 respectively and in liver were -3, 4682, -2.0752, -3.0354% for E_1, E_2 and E_3 respectively. Reduced Glutathione level activity in gills was -2.9886, -1.8393, -1.4845% for E_1, E_2 and E_3 respectively. In muscles -4.9180, -2.1642, -2.0470% for E_1, E_2 and E_3 respectively. Liver was -2.5885, -1.9527 and -1.2610 for E_1, E_2 and E_3 respectively.

Lipid peroxidation/ MDA levels in the gills were -35.9882, -29.2532, -20.4685% for E_1, E_2 and E_3 respectively. In muscles was -54.5448, -66.8096, -21.8817% for E_1, E_2 and E_3 respectively. Liver was -42.7866, -28.1952, -20.3949% for E_1, E_2 and E_3 respectively.

Increased amount of damage was noticed for GPx, GR, GST and Reduced Glutathione as well under the influence of FEP. The highest damage was recognized by maximum decrease. A significant change (p) in the activities was also recorded at all the experimental durations, while highest loss of its activity was recognized at signifying the maximum damage following constant exposure. This was followed with activity at a percent change% conceded by the fish's mechanism. The oxidative damage determined through LPO levels indicated significant (p) elevation in levels of LPO as compared with group C. Cellular damage was, on the other hand, found to be dependent on the duration of exposure to FEP. However, based on the LPO level for it was clear that the fish upon subjecting, nevertheless indicating the requirement of further duration for total reclamation from oxidative damage.

Familiarity with remaining pesticides, particularly FEP, in the aquatic climate is developing as examinations of these contaminations increase and identification methods improve. Fish exposed to ecological toxins display an assortment of physiological reactions, including oxidative response lopsided characteristics [27]. The outcomes from the current investigation show varieties in biochemical reactions viewpoints in fish exposed to 37.5µg/L (1/8th of LC_{50}) of FEP.

Table 1 Glutathione peroxidase (n moles of NADPH oxidized/min/mg protein) activity in gills, brain and liver in control and Fenoxaprop-P-Ethyl treated *Cyprinus carpio*

Indices	Control	Test groups		
		15 days (E_1)	30 days (E_2)	45 days (E_3)
Gills	11.6256^{A}	11.3935^{B}	11.2615^{C}	11.2074^{D}
SD±	0.0032	0.0003	0.0003	0.0003
% Change	-	-1.9964	-3.1318	-3.5972
Muscles	18.7641^{A}	16.8733^{D}	16.9641^{C}	17.7693^{B}
SD±	0.0034	0.0003	0.0034	0.0003
% Change	-	-10.0769	-9.5927	-5.3016
Liver	21.2614^{A}	20.7675^{D}	20.9435^{B}	20.0735^{C}
SD±	0.0003	0.0003	0.0003	0.0003
% Change	-	-2.3229	-1.4951	-5.5871

Data are means ± SD., *Significant differences compared with control value, <0.05

GPx protein is mainly associated with the utilization of hydrogen peroxide [28-29]. It catalyzes the glutathione decrease of hydroperoxides and of hydrogen peroxide. Along these lines, this compound may secure tissues against oxidative stress because of lipid peroxidation [30]. GPx in gills, brain, and liver homogenates in control and FEP treated fish are shown in the (Table 1). Antioxidant enzyme GPx in gills, brain and liver tissues showed increased levels E_1 and E_2 and decreases in group E_3 as on compared to control of gills. In brain group E_1 and E_2 increased and group E_3 decreased. In liver group E_1 and E_2 increased were as group E_3 decreased shown in (Fig 1).

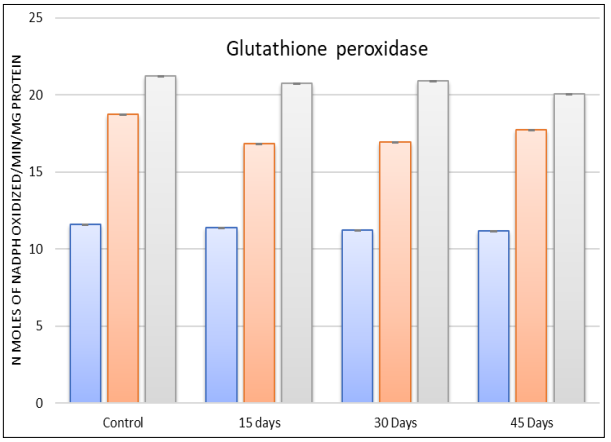

Fig 1 Changes in gills, muscles and liver Glutathione peroxidase activity of fish *Cyprinus carpio* exposed to sublethal concentration (37.5µg/L mg/L) of Fenaxoprop-P-Ethyl

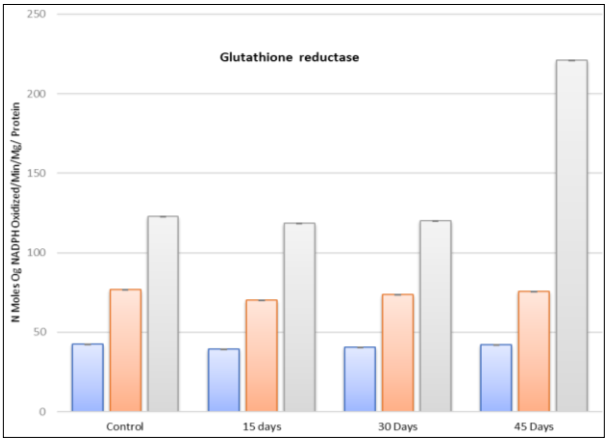

Fig 2 Changes in gills, muscles and liver Glutathione reductase activity of fish *Cyprinus carpio* exposed to sublethal concentration (37.5µg/L mg/L) of Fenaxoprop-P-Ethyl

The increased action of GPx in gills, brain and liver of each Group under toxic condition might be because of its role in eliminating toxic H_2O_2 or the natural H_2O_2 formed during the exposure of FEP to fishes. Present investigation indicated the decrease in GPx activity in gills, brain and liver of each groups because of more accumulation of herbicide which is as per the experiment performed by [31] who found the decrease in GPx action under the impact of 2,4-d pesticide in *Channa striatus*. Our results are in resembles with [32] who detailed the reduction in GPx activities in rodents treated with fenthion an organo phosphorous pesticide. The decrease in GPx could be negative criticism from overabundance of substrate or toxic effect by oxidative change [33]. A decrease in GPx action may show that its antioxidants were by the measure of hydrogen peroxide, the results of lipidoxidation [34].

Glutathione reductase assumes a significant part in recovery of decreased GSH from its oxidized structure with the oxidation of + NADPH to NADP [35]. GR is significant for keeping up GSH homeostasis under oxidative pressure conditions [36]. GR activities in gills, brain and liver tissue in control group and treated groups with sublethal 37.5µg/L concentrations of FEP are shown in the (Table 2). GR activities in gills E_1 group it is decreased and increased in E_2 and E_3. In group E_1 of brain it is decreased and group E_2 and E_3 are increased. In liver group E_1 and E_2 decreased and increased in group E_3 organs when compared with control shown in (Fig 2).

Table 2 Glutathione reductase (n moles of NADPH oxidized/min/mg protein) activity in gills, muscles and liver of control and Fenoxaprop-P-Ethyl treated *Cyprinus carpio*

Indices	Control	Test groups		
		15 days (E_1)	30 days (E_2)	45 days (E_3)
Gills	42.6215^{A}	39.4145^{D}	40.4615^{B}	42.0141^{C}
SD±	0.0003	0.0003	0.0003	0.0034
% Change	-	-7.5243	-5.0678	-1.4251
Muscles	76.8143^{A}	70.1451^{D}	73.6216^{C}	75.8015^{B}
SD±	0.0033	0.0034	0.0003	0.0003
% Change	-	-8.6822	-4.1563	-1.3185
Liver	122.7614^{B}	118.7142^{D}	120.2215^{C}	221.0206^{A}
SD±	0.0003	0.0034	0.0003	0.0003
% Change	-	-3.2968	-2.0689	-80.0407

Data are means ± SD., *Significant differences compared with control value, <0.05

GR action in the tissues exposed to Fenaxoprop-P-Ethyl, groups appeared to be a sign of the indications made by the cells to reestablish the equilibrium of GSH. A general decreasing in GR was found in groups that may be because of GSH exhaustion effect by the fish. Consumption in GR action in gills, kidney and liver of carp because of Butachlor has been accounted for by [37] which compare our current investigation.

Glutathione-S-transferases (GST) are a group of proteins that are associated with the detoxification of both responsive intermediates and oxygen extremists [38]. Rise in Glutathione-S-transferases (GST) in fish exposed to Roundup pesticide is informed by [39]. The activities of Glutathione-S-transferases (GST) protein in various organs in herbicide Fenaxoprop-P-Ethyl treated and control fish are appeared in (Table 3). Raised levels of GST were seen in gills, brain and liver tissues in group E_1 of gills it is decreased and group E_2 and E_3 it is increased because of high impact of exposures times of FEP, in brain tissue group E_1 and E_2 decreased and E_3 marginally increased and in liver E_1, E_3 decreased E_2 increased when compared with control group shown in (Fig 3).

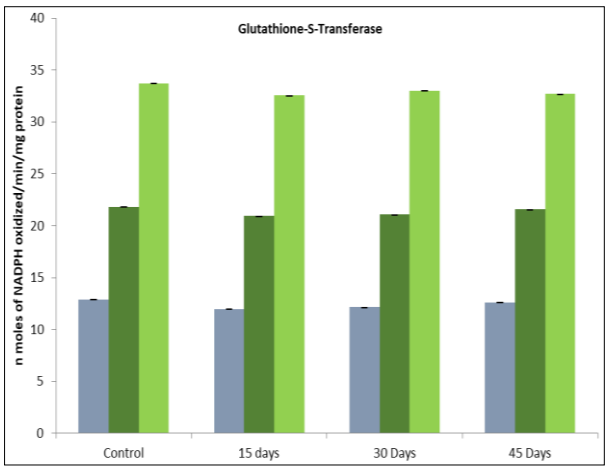

Fig 3 Changes in gills, muscles and liver Glutathione-S--Transferase activity of fish *Cyprinus carpio* exposed to sub lethal concentration (37.5µg/L mg/L) of Fenaxoprop-P-Ethyl

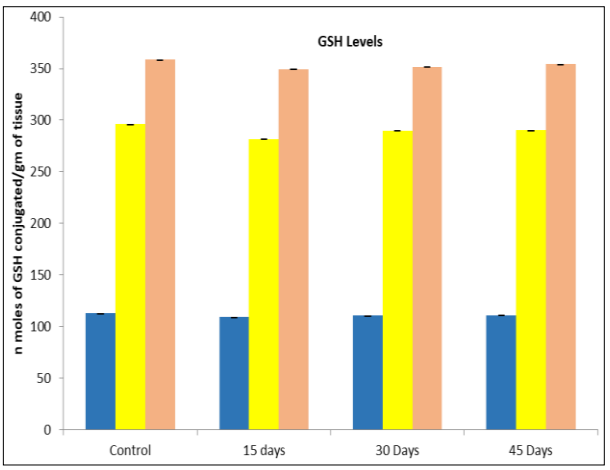

Fig 4 Changes in gills, muscles and liver Reduced Glutathione Level activity of fish *Cyprinus carpio* exposed to sublethal concentration (37.5µg/L mg/L) of Fenaxoprop-P-Ethyl

GST in groups compared with control proposes dynamic association of this protein in detoxification of Fenaxoprop-P-Ethyl [40]. Present investigation shows the upgrade in the GST action in groups that might be a versatile reaction to decrease ROS impact [41] and may show toxic impacts of pesticide [42]. The decrease in the

action of GST in fish of Group exposed to the herbicide might be because of the presence of oxidants that results in inactivation of the enzymatic action [43]. The slowdown of GST was seen in the liver of goldfish after 96 h introduction to Roundup unique [44]. Decrease in GST level was specified in chlorpyrifos on milkfish *chanos* [45]. Reduction in GST detailed by [46] in *Channa striatus* treated with 2,4-d pesticide.

Table 3 Glutathione-S-Transferase activity (nmol CDNB conjugates/min/mg protein) in gills, muscles and liver in control and Fenaxoprop-P-Ethyl treated *Cyprinus carpio*

Indices	Control	Test groups		
		15 days (E_1)	30 days (E_2)	45 days (E_3)
Gills	12.8935^{A}	11.9975^{D}	12.1438^{C}	12.6015^{B}
SD±	0.0003	0.0003	0.0014	0.0003
% Change	-	-6.9492	-5.8145	-2.2647
Muscles	21.8181^{A}	20.9341^{C}	21.0973^{D}	21.5764^{B}
SD±	0.0084	0.0034	0.0003	0.0026
% Change	-	-4.0516	-3.3036	-1.1077
Liver	33.7314^{A}	32.5615^{D}	33.0314^{B}	32.7075^{C}
SD±	0.0003	0.0003	0.0003	0.0003
% Change	-	-3.4682	-2.0752	

Data are means ± SD., *Significant differences compared with control value, <0.05

Table 4 Reduced Glutathione level activity (n moles of GSH conjugated/gm of tissue) level in gills, muscles and liver of control and Fenaxoprop-P-Ethyl treated *Cyprinus carpio*

Indices	Control	Test groups		
		15 days (E_1)	30 days (E_2)	45 days (E_3)
Gills	112.6945^{A}	109.3265^{D}	110.6217^{C}	111.0215^{B}
SD±	0.0004	0.0003	0.0004	0.0003
% Change	-	-2.9886	-1.8393	-1.4845
Muscles	296.1734^{A}	281.6075^{D}	289.7635^{C}	290.1107^{B}
SD±	0.0003	0.0003	0.0003	0.0003
% Change	-	-4.9180	-2.1642	-2.0470
Liver	358.6245^{A}	349.3415^{D}	351.6215^{C}	354.102^{B}
SD±	0.0003	0.0220	0.0003	0.0010
% Change	-	-2.5885	-1.9527	-1.2610

Data are means ± SD., *Significant differences compared with control value, <0.05

Glutathione-S-transferases (GST) in gills, muscles and liver tissues of Fenaxoprop-P-Ethyl treated fish and control is shown in (Table 4). GSH level decreased in E_1 of gills and E_2, E_3 increased. In muscles group E_1 decreased and group E_2, E_3 increased [47]. Liver E_1 decreased and group E_2, E_3 increased comparing with separate control group (Fig 4).

Increased in the level of GSH might be because of oxidative stress states; in any case, intense oxidative stress in pesticide treated fish may exhaust GSH levels because of loss of versatile systems joined with oxidation to GSSG [48]. Decrease in GSH level under the impact of Fenaxoprop-P-Ethyl was additionally seen by [49] in the gills, kidneys and liver of *Cyprinus carpio* (L) which resembles our outcomes. A decrease in GSH level in gills, muscles and liver of the pesticide treated fish in the current investigation might be because of its usage to neutralize the impact of oxidative stress affected by Fenaxoprop-P-Ethyl.

Table 5 Lipid peroxidation (n moles of TBARS formed/h/gm tissue) in gills, muscles and liver in Fenaxoprop-P-Ethyl treated *Cyprinus carpio*

Indices	Control	Test groups		
		15 days (E_1)	30 days (E_2)	45 days (E_3)
Gills	0.3415^{D}	0.4644^{A}	0.4414^{B}	0.4114^{C}
SD±	0.0003	0.0003	0.0003	0.0003
% Change	-	-35.9882	-29.2532	-20.4685
Muscles	1.6315^{D}	2.5214^{B}	2.7215^{A}	1.9885^{C}
SD±	0.0003	0.0003	0.0003	0.0003
% Change	-	-54.5448	-66.8096	-21.8817
Liver	0.9115^{D}	1.3015^{A}	1.0685^{C}	1.0974^{B}
SD±	0.0003	0.0003	0.0003	0.0003
% Change	-	-42.7866	-28.1952	-20.3949

Data are means ± SD., *Significant differences compared with control value, <0.05

Lipid peroxidation level has been distinguished as one of the fundamental deteriorative responses in cell system of the pesticide incited oxidative stress in fresh water fishes. Lipid peroxidation levels in all the treated organs in FEP treated groups and control group are shown in (Table 5). Increase in the levels of TBARS or elevation in lipid

peroxidation was seen in the FEP treated fishes. High levels of lipid peroxidation in gills was found in E_1 and E_2 Groups and least in E_3 group, the low centralization of the cell mechanism seen in gills, muscles and liver of fish in groups in this investigation may be the explanation behind raised convergence of lipid peroxidation found in the tissues of exposed fish [50]. In muscles most extreme level was found in group E_2 and least in group E_1 and E_3. Liver of group E_1 was most extreme were as least in E_2 and E_3 when compared with individual control groups shown in (Fig 5).

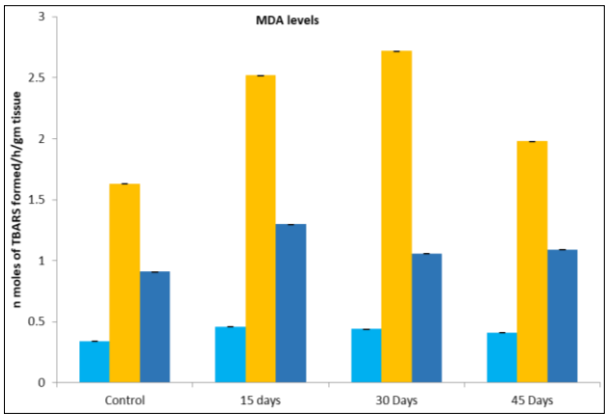

Fig 5 Changes in gills, muscles and liver Lipid peroxidation levels in fish *Cyprinus carpio* exposed to sublethal concentration (37.5µg/L mg/L) of Fenaxoprop-P-Ethyl

Lipid peroxidation in various tissues was additionally detailed by [51] in *Cyprinius carpio* (L). The huge acceptance of LPO in the gill, kidney and liver of *Labeo rohita* treated with endosulfan and fenvalerate which might be because of ROS [52]. Increased LPO in fish exposed to butachlor is the consequence of oxidative stress because of collection of free extremists that brought about cell damage [53]. Height in the levels of lipid peroxidation was seen in Cyhalothrin-effected fish when compared with control [54].

CONCLUSION

The present study apparently shows that fish *C. carpio* under Fenaxoprop-P-Ethyl stress undergoes partial abolition of functional regulation in gills, muscles and liver organs through an imbalance in enzymes in exposed fish. The process clearly indicates the effort of regulatory mechanism of fish to compensate the loss in harmonic manner and in turn rescue and reimburse the imbalance caused by toxic impact. It is thus an intrinsic oscillatory ability of fish which is viewed as a nutshell in the present investigation. Further direct analysis under molecular evaluation methodologies may certainly throw light on the principles behind the cascadic changes in biochemical activities of liver. The study may contribute in the course of regulatory surveillance and monitoring of aquatic bodies with its applications to aquaculture practices as well, but needs more detailed investigation before these findings can be used to monitor the aquatic environment for pesticide pollution. Responses varied among organs, with muscles and liver being the most sensitive tissue. Potentially could be fish liver used as indicators for monitoring residual Fenaxoprop-P-Ethyl present in the aquatic environment. Mechanisms of these physiological responses in fish are not clear, and need to be further studied.

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Conflicts of Interest

Author claims no conflict of interest.

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