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Toxicology Assessment of Matador in Heart Histology and Lipid Profile on edible fish *Cyprinus Carpio*

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Abstract

Aquatic ecosystems are continuously exposed to environmental pollutants due to rapid agricultural and industrial development; among these, pesticides are a major threat to water contamination and affect non-target aquatic organisms. The present study examined the acute toxicity of the pyrethroid pesticide Matador on the freshwater fish Cyprinus carpio. Sub-lethal concentrations of Matador were calculated for the freshwater fish Cyprinus carpio, which were 0.0018 ml/L after 24, 48, 72 and 96 hours. The calculated 1/10th sub-lethal concentration of matador was induced in different aquariums for the treated group against the control group for the evaluation of heart lipid panel, serum SGOT and observed alterations in fish heart histology at the intervals of 7, 14, 21 and 28 days. The treated group exhibited abnormal swimming, reduced feeding, bottom swimming, as well as erratic swimming behaviour. Heart lipid panel cholesterol, TG$_s$, LDL, VLDL and the enzyme SGOT of fish showed highly significant elevation (p<0.001), but HDL showed a highly significant decline(p<0.01). Histology of the heart revealed reduced compactness of cardiac muscle fibre, poor visibility of intercalated discs and nuclear damage in the acute study. Matador induced, caused an adverse effects on the fish's health, a hazardous impact on water bodies, non-target animals and human health.

Keywords: *Aquatic ecosystem, Enzyme, Edible fish, lipid panel, Pyrethroid toxicity.*

INTRODUCTION

Water is a fundamental unit that supports life and ecological stability. It acts as a source for chemical reactions, transport of nutrients and removal of waste materials in living organisms [1]. Freshwater ecosystems, such as ponds, lakes, rivers and other reservoirs, play an essential role in the aquatic ecological stability, which supports a vast range of biodiversity [2]. Besides this, it also plays a vital role in humans' daily lives. However, increasing urbanization and agricultural activities have led to contamination of the aquatic ecosystem [3].Water pollution not only harms aquatic life but also affects the environment and an adverse effect on the health of humans as well as other organism also [4].

Among the several pollutants, pesticides are emerging as a concerning issue due to its extensive usage in modern agriculture as well as chemical longevity [5]. Pesticides are persistently used in agriculture to improve crop productivity by controlling pests and diseases [6]. Such chemicals are commonly used for the management of various pests such as weeds, insects, pathogenic fungi, rodents, microorganisms, and so on [7]. Globally, an estimated 1/3 of crops are produced using pesticides [8]. From the year 2022-2023, approximately 299,000 metric tons of pesticides were produced by India [9]. A variety of pesticides are offered by markets, comprising both organic and inorganic chemicals. These are categorised as insecticides, fungicides, herbicides and rodenticides [10]. Based on chemical composition, pesticides are basically categorised into several groups, which include organochlorines, carbamates, organophosphates, pyrethroids, and neonicotinoids [9]. Pyrethroids are a class of synthetic pesticides that are structurally derived from pyrethrins extracted from C*hrysanthemum cinerariaefolium* flowers and some related species [11]. They are widely known for their effectiveness in controlling a broad range of pests. They are exclusively used in agriculture and known for their strong efficiency against insect pests [12]. According to the data given by Market Report Analytics (2026), the pyrethroid market in Pune, India, globally, is estimated to be approximately $2.5 billion in 2025, which is most likely to reach approximately $3.8 billion by 2033 at a Compound Annual Growth Rate (CAGR) of 5% [13]. Despite pyrethroids exhibiting lower toxicity than organophosphates, prolonged exposure may lead to a high risk of neurotoxic effects [14]. Pyrethroids exert their toxic effects on neuronal membranes by interfering with sodium ion channels, which causes continuous neuronal excitation, ultimately leading to paralysis and even death. [15]. Matador is a commercially available synthetic pyrethroid pesticide containing lambda-cyhalothrin as its active ingredient.

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It is frequently used alone or in combination with some other pesticides like imidacloprid, cypermethrin and deltamethrin to improve crop production [16] and pest management in crops such as paddy, maize, cotton and vegetables [17]. According to the report given by Credence Research, Pune, India, in 2024, the market value of Lambda Cyhalothrin was USD 1,654 million worldwide, in which the market value of Lambda Cyhalothrin in Asia was USD 608.7 million in 2024 and projected to reach USD 1,045.5 million by 2032 at a CAGR of 6.3% [18]. They have become popular because of their comparatively lower environmental persistence and faster degradation than other pesticides. According to the report of the Directorate of Agriculture, Assam, India, the target pests of matador are the yellow stem borer in paddy and bollworms in cotton, but it has a potential effect on non-target organisms [19]. It may enter water bodies through various ways, such as surface runoff, improper disposal practices, spray drift and leaching [20] and affect non-target aquatic organisms. Once matador is lipophilic in nature, it can easily bioaccumulate in the aquatic organisms, especially fish. As a result, it affects the physiological and biochemical functions of fish. Recent studies have shown that exposure to matador can effectively alter metabolic processes and cause toxic responses in fish, making this pesticide an ecological concern [21]. Lower concentrations of matador can influence enzymatic balance, oxidative stress and neurological dysfunction in aquatic organisms or humans [22].

Thus, analysing the toxicological impacts of matador on fish species is essential due to its increasing use in agriculture and high efficiency in contaminating water. Fish *Cyprinus crapio* (Common carp) is widely distributed in freshwater and a highly sensitive bioindicator for toxicity. Freshwater fish. *Cyprinus carpio* contains essential fatty acids, minerals, fat-soluble vitamins like A, D, and E and proteins [23]. It has considerable ecological and economic significance**.** The global carp market size was valued at USD 114.11 billion in 2024, according to the report given by Carp Market, Global headquarters, United States**.** The carp market in the Asia Pacific accounted for a share of 63.6% of the global revenue in 2024. The common carp market value is projected to grow at a CAGR of 5.6% from 2025 to 2030 [24]. It is highly adaptive to diverse environmental conditions, which makes it suitable for ecotoxicological investigations [25]. Toxicants present in water can enter the fish body through skin, gills and digestive tract [26]. Hence, *Cyprinus carpio* serves as a reliable bioindicator for analysing aquatic pollution [27]. The presence of matador in water bodies can cause changes in behavioral, physiological and biochemical parameters of *Cyprinus carpio* [28].

In fish, lipids serve as a primary source of energy storage and metabolic regulation and are crucial for maintaining membrane integrity and physiological balance. The heart is a highly metabolic active organ that uses lipid as its primary source of energy for proper functioning. This makes it particularly sensitive to any disturbances in lipid metabolism. In fish like *Cyprinus carpio*, changes in lipid levels due to stress or exposure to toxic substances can disturb normal heart activity. Hence, evaluation of the lipid panel of the heart helps detect any metabolic abnormalities. In addition, serum glutamate oxaloacetic transaminase (SGOT), also known as Aspartate aminotransferase (AST) serves as an important biochemical biomarker for the detection of any tissue damage and cellular disruptions. This enzyme is found in metabolic organs such as the liver, heart, kidney, muscles and other tissues.

When synthetic pyrethroids such as Matador (Lambda-cyhalothrin) accumulate in the vital organs of fish like *Cyprinus carpio*, this results in toxic effects in humans also after consumption. Therefore, the present study is designed to study the toxicological effect of Matador on heart histology, lipid panel, and serum SGOT levels in *Cyprinus carpio*.

Materials and Methods

Fish collection and sampling-For the evaluation of matador toxic effect, fifty-four freshwater fishes *Cyprinus carpio* (Common carp), both male and female, were captured due permission of IAEC-2004/GO/REBi/S/18/CCSEA with an average size of 18 to 20 cm and average weight 150 to 180 grams by the help of local fishermen using sieve nets (70 x 80 m) from the Johila river, Amarkantak in January 2026. Afterwards, fish were transferred into an oxygenated 15-litre plastic container with pores cap and were brought to the Aquatic Toxicology Laboratory, Department of Zoology, Indira Gandhi National Tribal University, Amarkantak, Madhya Pradesh. 24 hours prior to the collection of fish, eight well-ventilated aquariums (75x 35x 37.5 cm) were rinsed with 1% $KmnO_4$ and cleaned with water [29]. Each aquarium was filled with 40-50 litres of tap water. The level of water was marked. The temperature of water 26±2˚C was measured using a laboratory thermometer, and the pH of water ranged from 7 to 7.2, which was measured using litmus paper [30]. Each fish was dipped into 1% $KmnO_4$ solution to avoid any dermal infection [31]. Before adding fish to the aquariums, *Cyprinus carpio* was weighed using a digital hook weighing machine (GLUN), and 7 fish were transferred to each aquarium with the due permission of the IAEC IGNTU, CPCSEA guidelines.

Identification of fish-The fish *Cyprinus carpio* is easily available, ease of handling, is economically important, requires low maintenance and is ideal for a lab environment. Fish was recognized by its characteristics and morphometric features [23]. It has a brassy, greenish-brown on top with a yellowish-white belly. Fins are often dark with a reddish tint. The dorsal fin is usually long and has a serrated spine at the leading edge.

Fin formula of *Cyprinus carpio*: D. 3-4/14-19, P_1 1/7-8, P_2 1/7-8, A. 2-3/5 [32]
(D- Dorsal fin, P- Pectoral fin, A- Anal fin, C- Caudal fin)

Acclimatization and Maintenance- The fish were acclimatized in a viable environment one week before the experiment in the lab. During this period, the fish were fed with approximately 4 to 6 grains per fish of artificial food pellets, brand name "OPTIMUM", twice a day, in the morning (10.00 AM) & evening (5.00 pm), which was purchased from the local market of Pendra, Chhattisgarh. Uneaten food grains and faecal matter were removed using a siphon pipe to prevent foul smell and any kind of contamination in the aquarium. If any fish die, it was removed from the aquarium using a net to avoid infection to other fishes. pH and temperature were monitored daily using laboratory equipment. Proper aeration was provided in the aquariums using air pumps.

Test Compound: Matador (110 ml, Syngenta India Private Limited, Amar Paradigm) was selected as the experimental chemical for this study because of its high pesticidal efficiency and its described toxicity to the aquatic ecosystem.

It is easily accessible in Krishi Seva Kendra suppliers as well as online agricultural platforms. It is the most widely used synthetic pyrethroid insecticide in the field of agriculture. It contains Lambda-cyhalothrin as its active ingredient and is marketed as 4.9% emulsified concentrate. Exposure of matador can occur through dermal contact, inhalation and ingestion, which may cause irritation to the eyes and skin.

Physically, it usually appears as a pale yellow to light brown liquid with a mild odour and a density of approximately 1.2-1.3g/cm3. It is lipophilic in nature, therefore shows a high tendency for bioaccumulation in lipid-rich tissues. Because of the following properties, matador is easily absorbed in the soil as well as in sediment particles, resulting in less movement in water and is highly toxic towards aquatic organisms, particularly fish, because of its fast absorption across gill membranes as it is lipophilic in nature, which facilitates accumulation in tissues. These can lead to disturbances in physiological and biochemical processes, leading to structural and functional damage in vital organs [33,15].

Experimental design: The experiment was conducted following IAEC-2004/GO/REBi/S/18/CCSEA and according CEPSA in two phases

1. To determine the LC_{50} of Matador in freshwater fish *Cyprinus carpio*
2. To evaluate the sublethal effect of matador alternations in lipid panel, Serum SGOT and histology of the heart of *Cyprinus carpio.*

Experiment 1: For the determination of the LC_{50} of Matador in freshwater fish *Cyprinus carpio* [34].four aquariums(I, II, III and IV,) were filled with 30-liter tap water. From the acclimatized stock, six fish were randomly selected for each aquarium to determine the LC_{50} with different concentrations of Matador1.2, 1.4, 1.6, 1.8 µg added in separate aquariums for the duration 24, 48, 72, 96 hours [28]. At different intervals, mortality and survival percentages were recorded. The death of the fish was confirmed when the fish lied motionless on its back and showed no gill movement. Dead fish were removed using a net to avoid infection.

Experiment 2: To evaluate the sublethal effect of matador for 7, 14, 21, 28 days alternations in lipid panel, Serum SGOT and histology of the heart of *Cyprinus carpio*. For the experimental setup, 30 *Cyprinus carpio* were kept for 28 days in January 2026. Five aquariums were selected, labelled Control (I) and II, III, IV, and V labeled as the treated group with six fish in each aquarium. The control group stayed in its natural habitat, and the remaining four groups were exposed to a calculated 1/10th sublethal concentration (0.0018 ml/L) of Matador. Feeding was stopped 24 hours prior to the experiment to standardize the condition. Behavioural alteration was observed throughout the experiment.

At the interval of each exposure period of matador 7, 14, 21, 28 days, fish were drawn out carefully by the help of a net from the aquarium I, II, II, IV, V, respectively and weighed using a digital hook scale (GLUN), which was compared with the control. Euthanasia was performed by a gentle strike to the head while holding the caudal region. To study alterations in serum SGOT, a sterile needle was inserted on the ventral midline at an angle of 90̊ C and a blood sample was collected from the caudal vein of the *Cyprinus carpio* after an interval [35].

Dissection of Fish-Using a sterile dissection blade, an incision was done to open the body cavity from the anal opening anteriorly towards the pectoral fin. Using a fine scalpel and forceps, the heart was carefully removed from surrounding connective tissue to avoid structural damage after each interval. The collected heart sample was immediately kept on ice for further analysis of the lipid panel and for histology preserved in Bouin's solution.

Estimation of lipid panel: Observed by the following methods: Cholesterol by Liebermann-Burchard method, 1946[36], Triglycerides [37], High density lipoprotein Burstein Method , 1970[38] , Low density lipoprotein & VLDL by Friedwald, 1972[39] , Lipid extraction by Folch method 1957[40] , Serum SGOT alterations in *Cyprinus carpio* by Reitman & Frankel, 1957[41], Histology of the heart of *Cyprinus carpio* was performed using the standard method by Bancroft & Gamble, 2008[42] and slide was observed at 40X magnitude under light microscope (Magnus MLXi PLUS).

Statistical analysis: Lethal concentration (LC_{50}) of Matador was calculated by log dose probit regression analysis [34]. A Student's t-test is a statistical method used to compare the findings ($p < 0.05$) by applying GraphPad Prism 8.0.2.

Result and Discussion- This study aimed to find out of the 96-hour LC_{50} of matador in Cyprinus carpio and to investigate its effects on heart lipid panel through lipid extraction as Cholesterol, TGS, HDL, LGL, VLDL estimation, along with the evaluation of serum SGOT and examining histological changes in heart tissues after 7, 14, 21, and 28 days in treated group aquarium II, III, IV and V against the control group aquarium I.

To calculate the LC_{50} of pyrethroid pesticide Matador at different concentration *i.e.* 1.2, 1.4, 1.6, 1.8 µg were added in separate aquariums for the duration of 24, 48, 72, 96 hours and calculated by using the log dose/probit regression analysis [34], For this purpose twenty-four freshwater fish, *Cyprinus carpio*, were taken in four labelled aquariums (I, II, III, IV) and 6 fishes were put in each aquarium.

The test dose was converted into their logarithms values, and corresponding to the empirical probit values, the percentage of mortality was obtained from a standard probit table, graph and tabulated value obtained 0.0018 ml/l, its sublethal dose ($1/10^{th}$) was taken for experiment *i.e.* 0.00018 ml/L.

The toxicity of matador varies among different species. LC_{50} value of Lambda- cyhalothrin was 0.053µg/L in *Danio rerio* [43]. In *Clarias gariepinus,* the value of LC_{50} of lambda-cyhalothrin was found 0.325 mg/L [44]. The Lethal concentration value of Lambda-cyhalothrin was observed 0.09 µg/L for *Clarias batrachus* [45], whereas in *Labeo rohita,* the lethal concentration value 2.72 µg/L was calculated [46]. In *Clarias gariepinus,* the LC_{50} value of pyrethroid was calculated 1.80 µg/L [47], and in the juveniles of *Oreochromis niloticus,* the LC_{50} value of lambda-cyhalothrin was 2.9µg/L [48]. LC_{50} value of Lambda-cyhalothrin was noted 0.026 mg/L in *Ctenopharyngodon idella* [49]. In Guppy fish the value of LC_{50} was 81.83µg/L with the other pyrethroids[50]. The value of LC_{50} of lambda-cyhalothrin was calculated 2.04 µg/L in *Clarias gariepinus* [51], and in *Danio rerio* the sublethal concentration of lambda- cyhalothrin was evaluated 1.94µg/L [52]. The sublethal concentration of Lambda-cyhalothrin was 0.020 mg/20L in *Anabas tesudineus* [53].

The calculated values of LC_{50} of lambda-cyhalothrin in different species of fish were similar in the present study, but some were different; this may be due to differences in species of fish or environmental factors.

Behaviour alteration- The behavioural responses of *Cyprinus carpio* were carefully recorded after exposing 0.0054ml/L (0.00018 × 30L) concentration of matador for 28 days in different intervals, 7th, 14th, 21st, and 28th days, in the treated group of aquarium II, III, IV and V against the control group aquarium I.

In the aquarium I (control group), the fish displayed normal behavioural patterns and showed normal swimming patterns, gill movement, proper feeding, and regular operculum movement. While the fish exposed to matador in aquariums II, III, IV, and V exhibited noticeable behavioural response at the different intervals of 7, 14, 21, and 28 days. During the initial exposure period at the 7th day in aquarium II, the fish reflected occasional surfacing as compared to the control group. In aquarium III, by the 14th day, the fish showed reduced feeding and irregular swimming patterns. Further, till 20th day in aquarium IV, some fish were lethargic and revealed only bottom swimming in pairs. In aquarium V, as the exposure duration increased, till 25th day, the fish stopped feeding, they frequently remained near the bottom region as well as noticed living in pairs and in small groups.

In previous studies, similar behavioural changes have been observed in different species of fish exposed to lambda-cyhalothrin or other pyrethroid pesticides. The juveniles of *Clarias gariepinus* exhibited erratic movement when exposed to pyrethroid [47]. Reduced swimming activity, air gulping and vertical hanging were observed on *Clarias gariepinus* when exposed to lambda-cyhalothrin [44]. *Clarias batrachus* exposed to lambda-cyhalothrin showed loss of balance, erratic swimming, rapid swimming, as well as light discolouration [45]. Lambda-cyhalothrin caused hyperactivity and loss of equilibrium in *Oreochromis niloticus* [54]. Same behavioural responses, such as colour change and loss of balance, were observed in the juveniles of *Oreochromis niloticus* when exposed to lambda cyhalothrin [48]. Abnormal behaviour such as hyperactivity, jerky movements and repeated closing and opening of the mouth was observed in *Clarias garipinus* after exposure to lambda-cyhalothrin [55]. Behavioural alterations such as mucus secretion, loss of equilibrium and erratic swimming were observed in *Clarias gariepinus*. In *Clarias gariepinus* erratic swimming and mucus secretion were observed in response to lambda-cyhalothrin [56]. In Danio rerio, erratic swimming and loss of balance were noticed after exposure to lambda-cyhalothrin [21] *Nile tilapia* also revealed light discolouration and surface swimming after exposed of Lambda- cyhalothrin [10]. The exposure of lambda-cyhalothrin resulted in abnormal swimming patterns, such as erratic movements and irregular coordination in *Danio rerio* [57].

Lipid panel in fish heart is an important biochemical analysis used to examine the metabolic and physiological status of an organism. To evaluate the toxicological effect of a 0.0054ml/L concentration of Matador in the lipid panel and heart histology of *Cyprinus carpio* at the different intervals of 7th, 14th, 21st and 28th day for the treated group aquarium II, III, IV and V against the control group aquarium I.

Cholesterol: The cholesterol level in *Cyprinus carpio* showed a very highly significant increase at 7, 14, 21 and 28 days ($p< 0.001$) after exposure to the matador (Fig. 1). The increased level of cholesterol indicates an effect on lipid metabolism and impaired heart function caused by matador exposure. Pyrethroid pesticides Matador can induce reactive oxygen species (ROS), which causes disruption in the normal metabolism of lipid and might result in abnormal accumulation of cholesterol in heart tissue.

Triglycerides (TG_S): The increased TG level in *Cyprinus carpio* was found to be very highly significant ($p<0.001$) after exposure to matador (Fig 2). The increased level of TG_S might be from enhanced lipolysis and reduced lipid catabolism caused by matador exposure. Matador exposure can cause an imbalance in normal fat utilization leading to abnormal accumulation of TG_S in heart tissue.

High-Density Lipoprotein (HDL): The HDL level in *Cyprinus carpio* showed a highly significant ($p<0.01$) decline after exposure to the matador (Fig 3). A decreasing level of HDL might be possible due to ischemic damage to the myocardium, due to the exposure effect of the matador.

Low-Density Lipoprotein (LDL): In *Cyprinus carpio* the LDL level showed a very highly significant increase ($p< 0.001$) after exposure to the matador (Fig 4). Matador exposure may damage peripheral cells and disrupt LDL receptor function due to impaired protein synthesis. As a result, LDL was not properly removed from the bloodstream, leading to elevated serum LDL levels, which may increase the risk of cardiac damage and atherosclerotic changes.

Very Low Density Lipoprotein (VLDL): The increased TG levels in *Cyprinus carpio* were found very highly significant ($p<0.001$) after matador exposure at intervals (Fig 5). The elevated level of LDL might be due to damage to heart and liver cells because during toxic exposure, excessive VLDL is continuously converted into LDL, leading to altered lipid metabolism.

In previous studies, similar findings regarding the alterations in cholesterol, TGS, HDL, LDL and VLDL levels in heart, liver, and kidney, as well as in blood serum, during pesticide exposure in various species of fish have been observed. Exposure to organochlorine pesticides significantly increased cholesterol levels, while carbamate and organophosphates led to disturbances in cellular lipid metabolism. This might be because of impaired liver function and disturbances in lipid metabolism during pesticide exposure [58]. In *Ophiocephalus punctatus,* the exposure to cypermethrin resulted in alterations in the lipid profile [59]. Due to the exposure of nuvan in *Channa puncatatus*, a significant elevation in cholesterol level, but the level of TGs declined[60]. Exposure of malathion in *Oreochromis niloticus* resulted in an elevation in cholesterol and TGS level [61]. A significant decline in the HDL level but an increase in LDL & VLDL was observed *in Channa punctatus* due to exposure to Nuvan [62]. *In Clarias gariepinus,* the level of cholesterol and TG_S increased after exposure to aluminium chloride [47]. Exposure of imidacloprid in *Oreochromis niloticus* caued a significant elevation in LDL and VLDL but a decline in the level of HDL [48].

In *Clarias garipinus,* the lambda- cyhalothrin led to elevated levels of cholesterol and TG_S after exposure to lambda-cyhalothrin [63].

Exposure of cadmium in *Cyprinus carpio* resulted in cholesterol retention in the liver and slow metabolism of TG_s in the liver, which triggered the homeostasis of Cholesterol and TGS levels [64]. The comparative study of the total lipid of *Cyprinus carpio* resulted in an increase in the level of cholesterol, TG_s, HDL, LDL and VLDL, showing no significant difference in earthen ponds and wild fish [65]. Similarly, exposure to deltamethrin resulted in a significant increase in the cholesterol level in *Cyprinus carpio* [66]. *Clarias batrachus* reported a significant increase in LDL and VLDL, while a very highly significant reduction in HDL was recorded when exposed to Nuvan [67]. In *Nile tilapia* increase in cholesterol, TGS, LDL, and VLDL but a decline in HDL level due to exposure to Lambda-cyhalothrin [10]. An increase in the level of cholesterol, TG_s, LDL, and VLDL, but a decline in HDL level, was observed in *Danio rerio* after exposure to pyrethroid. These alterations were probably due to oxidative stress leading to lipid peroxidation, which affects the integrity and operation of cell membranes [29].

The effect of 0.0054/30ml/L concentration of matador on changes in serum SGOT in *Cyprinus carpio* was observed at the intervals of 7, 14, 21, 28 days in the treated group aquarium II, III, IV and V against the control group aquarium I. The level of serum SGOT in *Cyprinus carpio* showed a very highly significant increase ($p< 0.001$) after exposure to the matador (Fig 6). Disturbances in the lipid panel of *Cyprinus carpio* exposed to matador may lead to changes in membrane integrity and cellular damage in the heart. This might be due to the leakage of heart enzymes, including SGOT, into the bloodstream. An elevated level of SGOT is most common in myocardial damage.

In previous studies, similar findings have been observed in various species of fish after exposure to pesticides. Exposure of lambda-cyhalothrin caused damage to the tissue of liver and kidney which resulted inhibition of SGOT enzyme activities in *Clarias batrachus* [68]. Similarly, the level of SGOT remarkably increased after exposure of famfos in *Hetropneustes fossilis* [69]. The SGOT activity was increased in *Pontastacus leptadactylus* after exposure of chlorpyrifos [70]. The exposure of lambda-cyhalothrin exhibited a significant increase in SGOT in *Cyprinus carpio*. This indicates that the toxicant alters the enzymological parameters [28]. The exposure of lambda– cyhalothrin resulted in an increased level of AST in *Clarias garipinus*. It may be due to nephrotoxicity caused by the toxicant. A similar result was observed by the exposure of deltamethrin in *Cyprinus carpius* [71]. This may be because of damage caused to the hepatic tissue. In *Carassius auratus,* heavy metals such as cadmium and copper resulted in a prominent elevation in the SGOT concentration in the bloodstream [72].

Altered lipid profile and increased SGOT levels indicate disruption of cardiac lipid metabolism and leakage of intracellular enzymes due to toxicant-induced membrane damage. Oxidative stress and lipid peroxidation might impair heart tissue integrity, which was further confirmed by histological alterations observed in the cardiac tissue of exposed fish.

Histological alteration on heart tissue- To evaluate the toxicological effect of 0.0054ml/30L concentration of matador exposure in heart tissues of *Cyprinus carpio*, histological analysis was performed at 40X magnification for a duration of 7, 14, 21, and 28 days in the treated group aquarium II, III, IV and V against the control group aquarium I.

Control group heart histology of *Cyprinus carpio*: the control group of aquarium I heart tissue showed normal histological structure with densely packed and compactly arranged cardiac muscle fibres (CMF), which appeared uniformly arranged and closely associated with each other. Centrally placed oval nuclei were observed. In certain regions, intercalated discs (IC) were visible (Plates 1, 3, 5, 7, Fig.7).

Treated group heart histology of *Cyprinus carpio*: After 7th days, tissue appeared normal with intercalated discs (IC), centrally placed nuclei, and cardiac muscle fiber (CMF) was properly visible, with no major structural damage (Plate 2 Fig 7). But in 14th days, a slight decrease in the compactness of cardiac muscle fiber (CMF) was observed. Intercalated discs (IC) appeared affected in some regions (Plate 4 Fig 7). On the 21st day, further reduction in the density of cardiac muscle fiber (CMF), along with mild nuclear changes such as shrinkage and irregular appearance of nuclei and intercalated discs, appeared disrupted in certain regions (Plate 6 Fig 7). This might be due to the accumulation of reactive oxygen species (ROS) in the fish cardiac tissue. After extended exposure 28th days, the shrinkage of nuclei became prominent, intercalated discs were poorly visible and cardiac muscle fibers were distinct from each other (Plate 8 Fig 7). This might be due to changed membrane permeability and cellular injury.

Excess production of reactive oxygen species (ROS) causes lipid peroxidation, which might lead to injury of cardiac cell membranes and tissue degeneration. Changes in membrane permeability and ion balance may affect the structure and function of myocardial fibers.

In previous studies, the acute toxicity of other pesticides on the histological changes of the heart in fish has been observed. Exposure to imidacloprid caused no significant changes in the heart histology of *Labeo rohita* [73]. Different environmental toxicants in the form of nanoparticals, pesticides etc caused cardiac defects during embryonic development in zebrafish [74]. In *Danio rerio,* exposure to organochlorine caused histological changes such as impaired cardiomyocyte function and degeneration of cardiac muscle fibers [75]. Exposure of acetamiprid caused the congestion of the heart wall in *Nile tilapia* [48]. In fish species trout and tilapia, ROS-mediated oxidative stress was evaluated after inducing the pyrethroid pesticides, which might lead to lipid peroxidation and disrupt the genomic structure of fish cells [76]. Haemorrhage and congestion might be caused by a disturbance in blood circulation. In *Rita,* the exposure to agrochemicals caused distorted arterial walls [77]. The exposure of palm oil mill effluent to in *Clarias gariepinus* showed distorted muscle fibre and congestion of the heart wall [78]. This can be caused by oxidative stress–induced cellular degeneration. The exposure of nuvan caused degeneration of cardiac muscle fiber in *Clarias batrachus*. The exposure to pesticides activates apoptotic mechanisms and inflammatory pathways, which might cause myocardial degradation [67]. Accumulation of reactive oxygen species (ROS) caused degeneration in cardiac muscle fiber. In Clarias batrachus, exposure to lambda-cyhalothrin caused extensive fragmentation of myocardial muscle bundles and inflammation of leucocytes in the cardiac tissue [79]. Changes in oxygen supply and blood circulation weaken cardiac function in exposed fish.

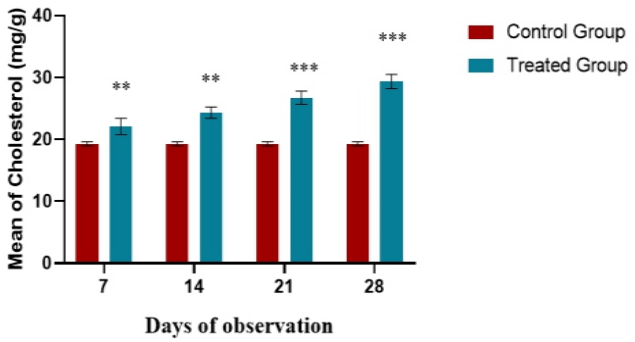


Fig 1: Cholesterol level in heart of Cyprinus carpio after matador exposure against control

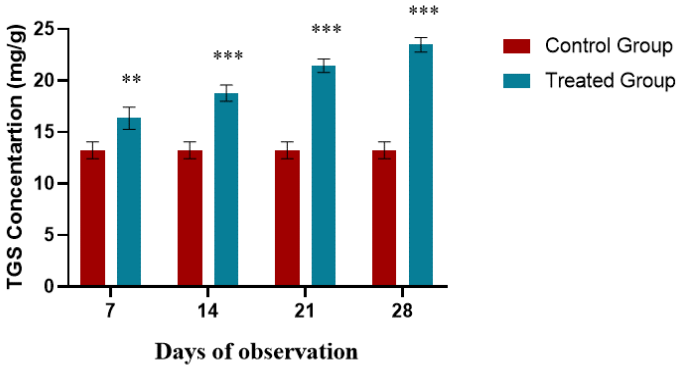


Fig 2: TGs level in heart of Cyprinus carpio after matador exposure against control

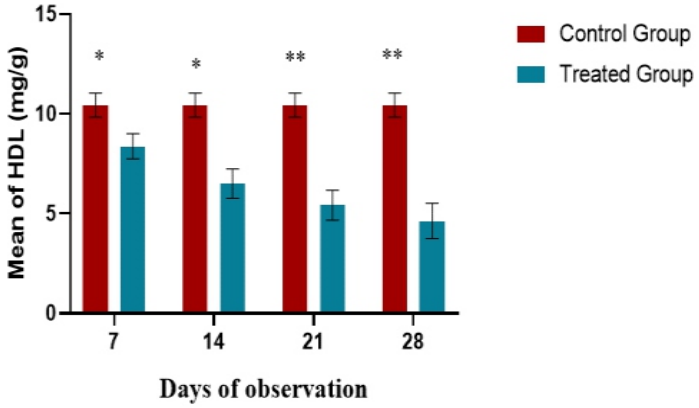


Fig 3: HDL level in heart of Cyprin carpio after matador exposure against control

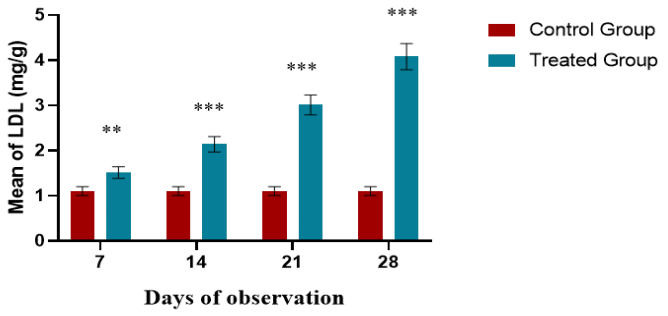


Fig 4: LDL level in heart of Cyprinus carpio after matador exposure against control

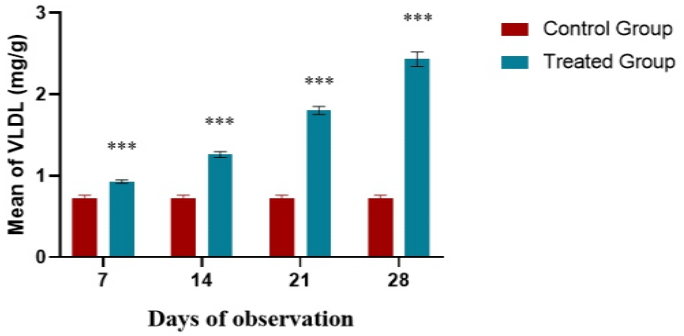


Fig 5: VLDL level in heart of Cyprinus carpio after matador exposure against control

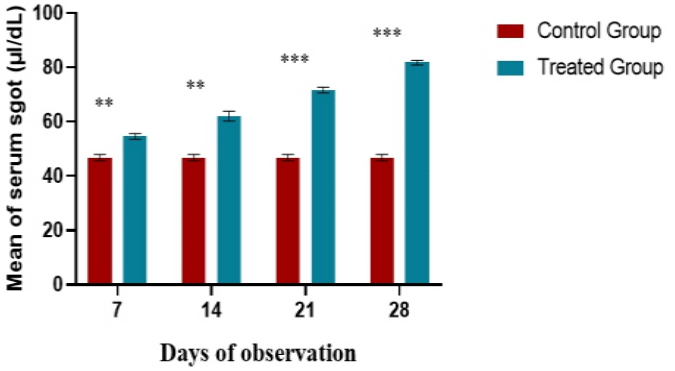


Fig 6: Level of serum SGOT of Cyprinus carpio after matador exposure against control

*Ns Not significant ($p > 0.05$), * Significant ($p < 0.05$)*
*** Highly significant ($p < 0.01$), *** Very highly significant ($p < 0.001$)*

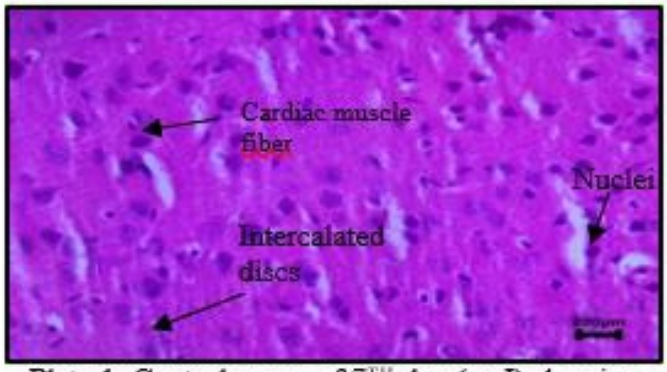


Plate 1: Control group of 7TH day (aq I) showing image of heart of *Cyprinus carpio* at 40X magnification

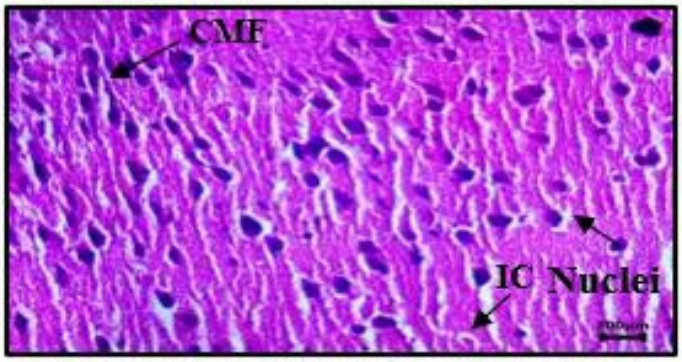


Plate 2: Treated group of 7th day (aq II) showing image of heart of *Cyprinus carpio* at 40X magnification

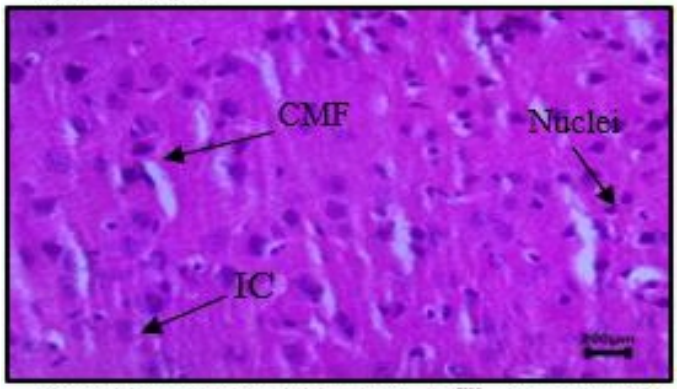


Plate 3: Control group of 14TH day (aq I) showing image of heart of *Cyprinus carpio* at 40X magnification

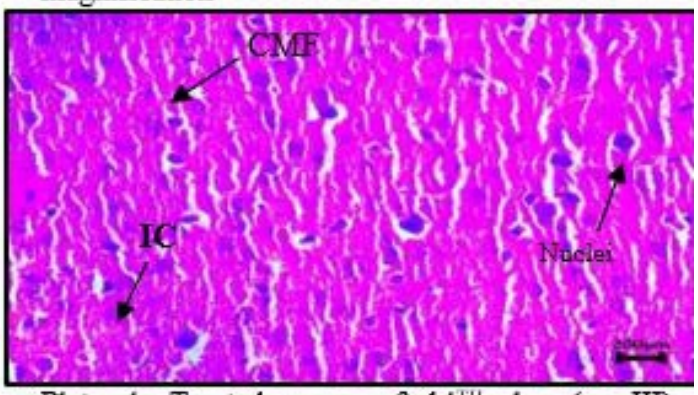


Plate 4: Treated group of 14TH day (aq III) showing image of heart of *Cyprinus carpio* at 40X magnification

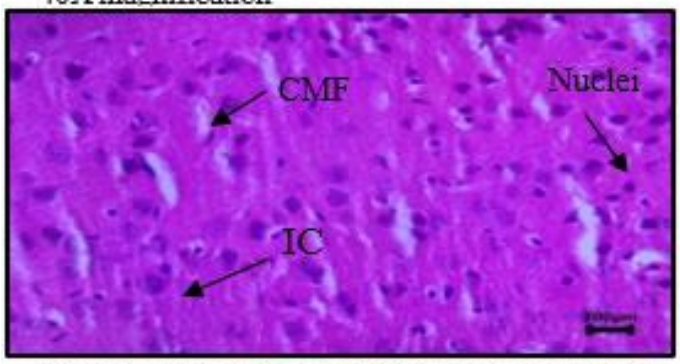


Plate 5: Control group of 21st day (aq I) showing image of heart of *Cyprinus carpio* at 40X magnification

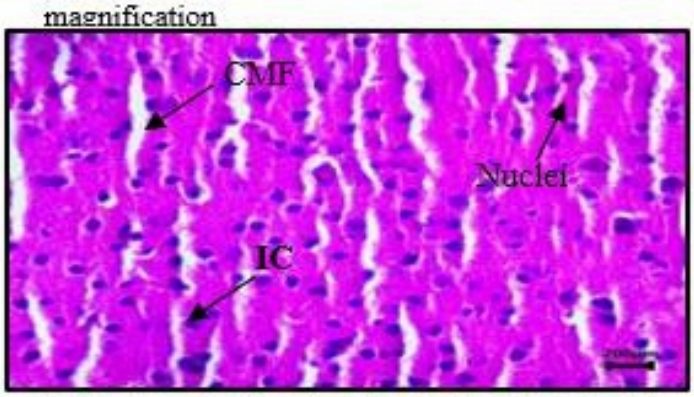


Plate 6: Treated group of 21ST day (aq IV) showing image of heart of *Cyprinus carpio* at 40X magnification

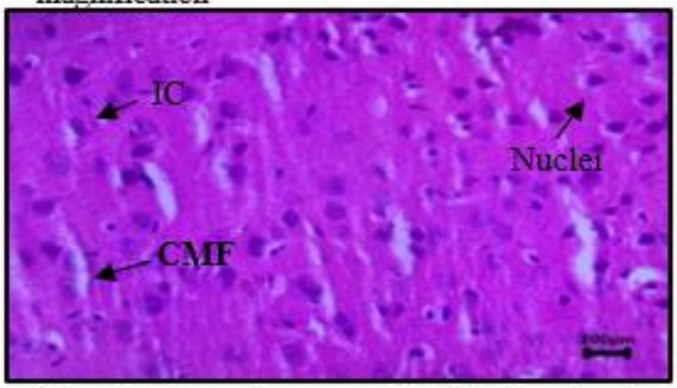


Plate 7: Control group of 28TH day (aq I) showing image of heart of *Cyprinus carpio* at 40X magnification

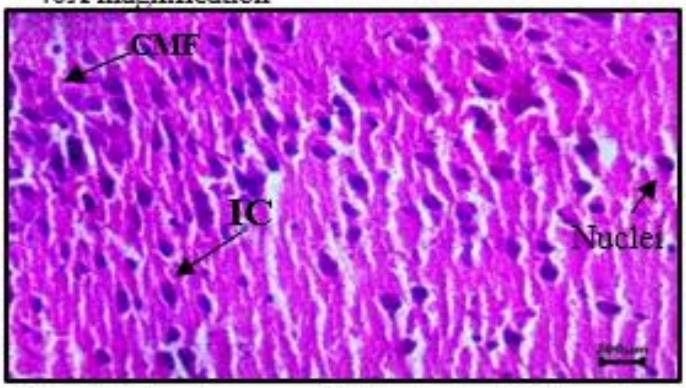


Plate 8: Treated group of 28TH day (aq V) showing image of heart of *Cyprinus carpio* at 40X magnification

Fig 7: Histology of the heart of Cyprinus carpio, Control and Matador treated groups of 7, 14, 21, and 28 days

Abbreviations: CMF- Cardiac muscle fiber, IC- Intercalated discs.

CONCLUSION

Present findings revealed that matador is causing toxicity even in very low concentration after 7, 14, 21 and 28 days, resulting in progressive alterations in heart lipid panel, serum SGOT and structural damage in the heart of *Cyprinus carpio.* The toxicity of matador caused elevation in Cholesterol, TG_s, LDL, VLDL and serum SGOT levels but a decline in HDL levels. The histological changes of the heart included reduced compactness of cardiac muscle fiber and degeneration of nuclei, all of which are indicative of cellular stress, metabolic imbalance and cardiac injury. Study highlights that exposure to matador caused physiological and structural damage in freshwater fishes. Although chronic studies are necessary for the evaluation of the effect of matador on water bodies, aquatic organisms, and humans.

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Data Availability Statement- Yes

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