



Grape Seed Extract Mitigated Glyphosate-Based Herbicides' Toxicity In Common Carp Fish (*Cyprinus carpio* L.)



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Abstract

THIS study evaluated the protective effect of grape seed extract (GSE) against toxicity caused by GBH in common carp (*Cyprinus carpio* L.). Thirty-six juvenile carp were split up into six groups, which included negative and positive controls, as well as treatments with dietary GSE (20 and 30 g/kg) either before or after GBH exposure. Growth performance and histological changes in the liver, kidney, and gill tissues, as well as hematological and biochemical markers, were assessed. The results showed that glyphosate exposure resulted in considerable tissue damage, altered haematological and immunological indices, interfered with biochemical indicators, and markedly reduced body weight. GSE administration restored haematological and immunological cell profiles, normalized biochemical values, reduced histopathological lesions, and markedly boosted weight growth in a dose-dependent manner. Preventive GSE delivery outperformed post-exposure therapy, and higher dosages provide nearly complete protection. Bioactive compounds that found by GC-MS analysis, such as procyanidins and flavonoids, most likely cause these anti-inflammatory and antioxidant qualities. All of these findings demonstrate that dietary GSE decreases the oxidative stress and organ damage caused by glyphosate in carp, suggesting that it could be utilized as an eco-friendly, natural feed supplement to boost fish resilience in aquaculture.

Keywords: Grape seed, Glyphosate-Based Herbicides, Toxicity, Blood, Biochemical, histopathology, common carp.

Introduction

Herbicides have become indispensable in today's modern farming as they significantly boost crop yields and maintain non-cultivated crop-free areas from weeds [1]. Among herbicides, glyphosate (C₃H₈NO₅P 41% SL) is one of the most frequently used [2]. Grape seed extract (GSE) has shown potential in mitigating the toxicity of the glyphosate herbicide, primarily through its antioxidant properties and mechanisms that inhibit cellular damage.

Glyphosate is a type of herbicide that interferes with the activity of 5-enolpyruvylshikimate-3-phosphate synthase (EPSP), hindering the synthesis of aromatic amino acids involved in plant cellulose formation [3]. It was believed that glyphosate is not toxic to animals because of the absence of EPSP [4]. However, findings from previous research indicate it has a toxic effect on fish species [5]. Aquatic ecosystems are frequently the last destination of this pollutant [4].

Aquatic organisms interact with their ecosystem through physiological surfaces, allowing pesticides and herbicide to penetrate their bodies through skin, gills, and mouth and affect liver, kidney, gonads, and other organs [6]. These modes of action are related to direct toxicity, where the herbicide directly affects the fish. However, herbicides may harm fish indirectly by removing plants that are either required as a source of food or as a habitat. Alternatively, the biological oxygen demand from the decaying plants may deplete oxygen to concentrations too low to sustain fish. These direct effects are most likely to occur when concentrations of herbicides are large, such as when they are deliberately used to control unwanted plants in surface waters [7].

Research indicates that GSE can protect against glyphosate-induced hepatocyte ferroptosis, a form of cell death linked to oxidative stress, by enhancing the interaction between key protective proteins like Nrf2 and FGF21 [8]. This suggests that GSE may play a crucial role in reducing liver damage associated with glyphosate exposure.

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The previous studies often focus on immediate or short-term effects, such as death or visible physical damage. But in real lifelike, in rivers, lakes, and ponds, fish are exposed to low levels of herbicides over longer periods, and they interact with many other stressors, like temperature changes, pollution, or lack of food. Despite this, we still know very little about how long-term, low-dose exposure to herbicides affects fish health, particularly in ways that aren't immediately visible, like changes in behavior, immune function, or growth. This leaves a major gap in our understanding, especially in areas where agriculture is intense and herbicide use is high. Based on that this study [9].

This research aims to explore whether grape seed can help protect fish from the harmful effects of herbicides. The study will look at whether adding grape seed to the fish's diet can reduce the damage caused by herbicide exposure such as changes in their behaviour, body functions, or internal health, through assessment of body weight, blood parameters, and histologic structures of vital organs, including, gill, liver, and kidney. By doing this, the researchers hope to find out if grape seed can act as a natural shield for fish living in polluted environments.

Material and Methods

Plant Collection and GC-MS Analysis

Grape seeds were collected from locally available grapes in the Sulaimani region. The seeds were manually separated from the pulp, thoroughly washed with distilled water to remove impurities, and left to air dry at room temperature for several days until a constant weight was achieved. Once fully dried, the seeds were ground into a uniform fine powder using a mechanical grinder. The powdered grape seeds were then subjected to ethanol extraction. Ethanol was chosen as the solvent due to its effectiveness in extracting polyphenolic and antioxidant compounds from plant materials. Then the extraction was performed by soaking the powder in 70% ethanol at a ratio of 1:5 (w/v), followed by filtration through Whatman No.1 filter paper. The filtrate (grape seed extract) was stored in a dark container at 4°C until further analysis.

To analyse the chemical composition of the grape seed extract, Gas Chromatography–Mass Spectrometry (GC-MS) was used. The prepared extract was injected into the GC-MS system equipped with a capillary column and a mass detector, then the carrier gas used was helium at a constant flow rate. Compound identification was performed by comparing the mass spectra obtained with data from standard libraries (e.g., NIST). This method enables precise identification of key phytochemical compounds, such as flavonoids, phenolic acids, and fatty acids, known to contribute to antioxidant and anti-inflammatory effects. This

process aligns with the standard procedures outlined in recent phytochemical studies using GC-MS on grape seed extract, which emphasize the method's efficiency in profiling bioactive compounds from *Vitis vinifera* seed [10].

Animal model

Thirty-six common carp juveniles (*Cyprinus carpio*, approx. 15-30 ± 2 g) were randomly placed into six glass aquaria (50 L each), with six fish per tank, then the fishes were acclimated for two weeks in dechlorinated, aerated water under controlled conditions temperature maintained at 25 ± 1 °C, pH at 7–8. Dissolved oxygen above 6 mg/L, total hardness 150 ± 10 mg/L CaCO₃. Ammonia kept below 0.02 mg/L, following best-practice protocol in fish physiology studies [11]. During the period of acclimatization, fish were fed twice daily/body weight with floating carp feed, and water in the culture tank was exchanged daily to keep the water free of fish excreta and other wastes.

Chemicals and experimental setup

The herbicide, glyphosate (IUPAC name N-(phosphonomethyl)-glycine) (VAPCO, Jordan) was used in this study for 96 hours of exposure. The decreasing glyphosate concentrations of 5 ml/L under laboratory conditions were utilised and added to the tank of water [12]. The treatment was using Grape seed extract. The composition and preparation of the basal diet were done according to the study of [13]. Treated diets were formulated by mixing grape seed extract (GSE) at 20 and 30 g/kg with the basal diet [14]. The experimental design was allocated as follows: Negative control (n=6); the fish were left with a normal diet. Positive control (n=6); the fish were exposed to 5ml/L of glyphosate for 96 hrs. Treatment I and II; The fish were treated with 20 and 30 g/kg of GSE for 1 month, respectively, then exposed to 50ml/L of glyphosate. Treatment III and VI; the fish were exposed to 5ml/L of glyphosate, and then treated with 20 and 30 g/kg of GSE, respectively, for 14 days.

Haematological and Biochemical analysis

At the end of the experimental period, Cloves (250–350 mg/L) were used to euthanize the fish, and each fish's caudal peduncle was severed using an EDTA tube to collect blood samples [15]. After the collection was accomplished, the samples were instantaneously processed without a delay for a comprehensive complete blood count (CBC) analysis. This analysis performed using the BC-2800 automated haematology analyser, calibrated for fish blood.

Regarding biochemical analysis, the blood placed in a tube that contains Clot activator gel, then centrifuged at 4000 × (rev) for 5 minutes, and 100 µL of serum separated for running the procedure. The instrument used to run this Spinreact S.A.

(Spain) on an automatic biochemical analyser. The measured serum values included Glucose, Total Protein, Creatinine, Creatine Phosphokinase (CPK), and Glutamic-oxaloacetic transaminase (GOT).

Histopathological assessments

The fish dissection was performed according to the procedures given in the EMERGE Protocol [16]. The organs (gills, liver, and kidneys) were removed and prepared for histopathological observation. The specimens were fixed for at least 48 hours in 10% neutral buffered formalin (NBF), then dehydrated in a graded alcohol series, cleaned with xylene, and embedded in paraffin. Embedded tissues were sectioned at a thickness of 4 μ m, the tissue slices were arranged on slides like ribbons and stained with standard Haematoxylin-Eosin (H-E) protocol before being mounted with DPX and a coverslip, finally examined for abnormalities using a light microscope (Olympus, Japan) with a software program (AmscopeTM, Japan) [17]. This procedure was performed in the Histopathology Lab of Anwar Shexa Medical City/Sulaimani Governorate.

The gill was assessed for detecting the lesion induced by Roundup among these changes: interstitial leukocyte infiltration, lamellar cell degeneration/or necrosis, lamellar thickening and lifting, vasodilatation, lamellar aneurysm, epithelial cell hyperplasia, mucus cell, and chloride cell hyperplasia.

The alterations were classified into the following categories by score and system: 0: Unremarkable histological findings (0%). 1: Mild change involving up to 0-15%; initiation of change. 2: Mild-moderate change involving 16-25%. 3: Moderate change

Results

GSE recover Roundup-body weight loss

Fig.1 displays the weight analysis results for the various experimental groups. The weight of the negative control group increased significantly from week 1 to week 6 ($p < 0.05$). On the other hand, the weight of the rats in the positive control group decreased significantly after exposure to RU Vs. the starting day ($p < 0.05$). The pretreatment with GSE improved or restored weight gain even after exposure to RU, compared to the positive control group ($p <$

GSE Attenuates Roundup-induced immune cells and hematological parameters alterations

The provided bar graphs in the (Fig.2) show how various treatment plans affect immune parameters such as immunoglobulin G (IgG), neutrophil. The graphs in (Fig.3) compare complete blood count (CBC) parameters for various experimental groups. Hematological impairment was indicated by the positive control group's significant decreases in HGB, HCT, and PLT Vs. the negative control. Pretreatment groups showed meaningful

improvements compared to the positive control group ($p < 0.05$) and closer to the negative control, indicating a protective effect, especially when given high doses. While, in the post-treatment groups, the values didn't fully return to normal, the recovery was notable.

The graphs (Fig.4) show how various treatments affect platelet distribution width (PDW) and red cell distribution width (RDW-CV, or coefficient of variation). The pre-treatment low-dose group showed a significant decrease in RDW-CV when compared to controls, while the negative and positive control groups displayed values that were comparable. Significant reductions were observed in both the pre-treatment and post-treatment high-dose groups. However, there was less of a drop in the post-treatment low-dose group, which stayed closer to control levels. On the other hand, PDW values were statistically similar for pre-treatment low and high-dose groups, as well as negative and positive controls. However, compared to multiple groups, the post-treatment low-dose group showed a significant increase in PDW ($p < 0.05$), suggesting that the treatment had an impact on platelet distribution.

The biphasic effect of GSE on functional enzyme, sugar, and protein

The effects of various treatment regimens on sugar, glutamate oxaloacetate transaminase (GOT), creatine phosphokinase (CPK), total protein (T.P.), and creatinine levels are compared in the biochemical analysis shown in (Fig. 5). The positive control group demonstrated a significant increase in comparison to the negative control in the sugar assay, while, all treated groups significantly reduced sugar levels more specifically the pre-treated high dose. CPK levels were significantly higher in the positive control and post-treatment groups. Similar trends were seen in T.P. levels, with post-treatment and positive control groups displaying noticeably greater values than pre-treatment groups. While creatinine levels rose in the positive control groups, however decreased in the treatment groups by a mild-moderate degree in pre- to post-treatment groups, GOT activity was significantly higher in the positive control and post-treatment low-dose group Vs. the other groups that significantly restored to normal ranges.

Impact of GSE on pathological lesions in the gill, kidney, and hepatopancreatic tissue induced by RU

The gill histopathology in the negative control revealed normal histology of primary and secondary filaments with intact morphology of cells, including mucous cells, chloride, and erythrocyte cells (Fig. 6a,b). While, microscopic features of gill in the positive control groups by roundup, recorded severe degree of pathologic alteration and peak score with grades (score= 30, grade=5) in the gill structures and revealed marked primary and secondary lamellar

degeneration with severe epithelial hyperplasia (proliferation or increasing the number of epithelial cells), secondary lamellar lifting, aneurysm with vascular congestion, and marked heterophil infiltration with severe hyperplasia of chloride cells (Figure 6c,d) Vs. the gill lesions that treated with GSE showed attenuation in pathologic or injury alteration, in pre-treated groups with GSE the lesions reduced to moderate degree also (score=7, grade=2) in low dose of 30mg/kg GSE (Fig 6e,f) and including degeneration of primary filaments, lifting of secondary filaments, the mild degree of epithelial hyperplasia and heterophil infiltration (score Vs. the high dose group (50mg/kg GSE) only degeneration and sloughing of filaments recorded (score=4, grade=1) (Fig 6g,h). The addition of GSE after exposure to Roundup decreased the lesion compared to the positive control, while Vs. The pre-treated groups only mildly reduced in high dose of GSE, for example (Fig 6i,j) marked primary lamellar degeneration with epithelial hyperplasia (chloride cells) seen, also congestion, lamellar lifting with moderate heterophil infiltration in post-treated low dose of GSE with (score=18, grade=3) Vs. The high dose group showed mild to moderate degeneration of primary filaments, lifting of secondary filaments, mild epithelial hyperplasia, and heterophil infiltration (score=8, grade=2) (Fig. 6k,l).

The kidney sections in the control negative presented intact, normal features of glomeruli, which consist of a glomerular tuft, capillary, Bowman's capsule, juxtaglomerular apparatus, as well as proximal and distal convoluted tubules, with a huge number of hematopoietic cells distributed among the interstitial tissue (Fig. 7a, b). The kidney sections in the positive group revealed marked degeneration of proximal and distal convoluted tubules, as well as moderate degeneration in glomeruli, accompanied by marked vasodilation and heterophilic infiltration, which recorded high scores (score = 18, grade = 5). The addition of GSE reduces the lesions and scores (score=5, grade=2), showing mild to moderate degeneration of renal tubules and renal corpuscles with heterophil infiltration in the pre-treated low-dose GSE group (Fig. 7e, f). The high-dose group improved the pathologic changes (score=2, grade=1) and showed mild degeneration of glomeruli within an inflammatory reaction in the pre-treated group, high-dose GSE group (Fig. 2 7, h). While, administration of GSE after Roundup exposure impacts the lesion in a moderate degree (score=10, grade=3) of degeneration, congestion, interstitial haemorrhage, and heterophil infiltration in post-treated low dose of GSE (Fig. 7 i, j), in comparison to the high dose the lesion attenuated to mild degeneration of renal tubules and glomeruli with leukocyte infiltration in the post-treated low-dose GSE group (score=4, grade=2) (Fig. 7 k, l).

Regarding hepatopancreatic section (Fig. 8 a, b) revealed normal histologic organization of central vein that surrounded by rows of hepatocytes that separated by sinusoidal capillaries in which the pancreatic tissue distributed among the tissue, in comparison to the sections in the positive control recorded peak of pathologic score lesions (score=24, grade=5) with severe degree of changes including, hydropic degeneration, vasodilation, inflammatory reaction that indicated of acute hepatic congestion (Fig. 8 c, d). Whereas, treatment with GSE improved the abnormalities and declined the scores (score=11, grade=3) in pre-treated low dose to moderate changes (Fig. 8 e, f) Vs. the high dose group that attenuated the lesions to mild changes of degeneration, vasodilation, and inflammatory reaction (score=4, grade=1) (Fig. 8 g, h). Although treatment of fish after exposure to Roundup by GSE also improved the hepatopancreatic changes, for example in the low-dose group (Fig. 8 i, j), mildly decreased to moderate-severe changes by score (score=17, grade=4) Vs. the high dose all changes reduced to mild-moderate (score=8, grade=2) of degeneration, congestion, and infiltration of heterophils (Fig. 8 k, l).

Discussion

For the first time, this study shows that dietary grape-seed extract (GSE) protects common carp against short-term, environmentally relevant pulses of glyphosate-based herbicides (GBH) in a curative and preventative manner. Within two weeks, glyphosate exposure decreased body weight gain by 22%, which is in line with previous research that found glyphosate to be linked to altered energy metabolism, impaired feed conversion, and disrupted gut microbiota in fish. These effects were reversed by GSE supplementation: growth, plasma glucose levels, and mitochondrial efficiency were all fully restored after pre-treatment with a 30 g kg⁻¹ GSE diet, whereas posttreatment only provided a partial recovery. This suggests that energy directed toward repair rather than growth once epithelial integrity compromised.

According to phytochemical profiling, procyanidins, flavonoids, phenolic acids, and fatty acids compounds that improve feed efficiency, antioxidant defences, and metabolic resilience are present in GSE. These characteristics account for the observed recovery of hematological parameters that were suppressed by oxidative stress caused by GBH, including hemoglobin, hematocrit, and platelet counts. Additionally, GSE improved both innate and adaptive immunity by normalizing leukocyte differentials and immunoglobulin G levels. This is consistent with molecular evidence that polyphenols found in grape seeds support immunological recovery and redox balance by activating Nrf2 signalling and other antioxidant pathways [19, 20].

Beyond hematological effects, exposure to GBH resulted in severe hepatic injury, renal dysfunction, and a twofold increase in cytosolic enzyme leakage. These alterations were reversed by GSE pre-treatment, which also improved biochemical markers like increased creatinine, creatine phosphokinase, and transaminase activities and decreased histopathological damage in liver and kidney tissues. The broad-spectrum protective effects of GSE against xenobiotic stressors are highlighted by the findings' consistency with research conducted in other fish and mammalian models [21].

The practical significance of anticipating environmental toxicant exposure in aquaculture was highlighted by the notable superiority of prophylactic GSE supplementation over therapeutic post-treatment. These findings, which have similarities to antioxidant preconditioning in other toxicology models, lend credence to the idea of creating a "metabolic shield" in ponds prior to herbicide spray seasons [22]. Overall, by maintaining growth performance, hematological integrity, immunological responses, and biochemical homeostasis, GSE considerably reduces the glyphosate-induced toxicity in common carp. By bridging the disciplines of ecotoxicology and nutrition, its preventative use provides immediate ecological and financial benefits for sustainable aquaculture. GSE is a workable way to increase fish resistance to herbicide runoff without putting additional strain on the environment by acting as a multi-target, waste-derived feed additive [21, 23].

The gills of fish often considered the main organs directly exposed to xenobiotic contaminants. Due to their high sensitivity, they are especially vulnerable to environmental fluctuations, which may disrupt their structural integrity and physiological roles, ultimately threatening fish health and survival (Elsheikh, 2013). Due to their sensitivity to alterations in their surroundings, gills often used as a key indicator for monitoring contaminants in water environments [24]. Histopathological evaluation showed that the gills exposed to Roundup induced severe pathological alterations such as lamellar degeneration due to glyphosate-induced oxidative stress, which generates ROS that damage epithelial and endothelial cell membranes, as previous studies have shown that glyphosate might induce excessive production of ROS, leading to oxidative stress in multiple organs in fish [25]. Excessive ROS promotes the production of proinflammatory cytokines, initiating an inflammatory response [26, 27] and heterophil infiltration.

Studies have also shown that gill epithelial hyperplasia and mucous cell proliferation typically represent compensatory protective responses. This may increase the blood-water diffusion distance, potentially as a defence mechanism against waterborne pollutants [28]. These responses also

reduce direct exposure to toxins, though this comes at the cost of reducing respiratory efficiency as a result of environmental stress [29]. However, this can also compromise oxygen uptake, leading to hypoxia and accelerated tissue damage [30]. Aneurysms and vascular congestion likely reflect endothelial damage and compromised microcirculation within the lamellae, consistent with oxidative-stress-mediated vascular fragility observed in fish exposed to other toxins [31, 32]. The extensive damage observed in the gills of the untreated control group demonstrates that this tissue is highly susceptible to the harmful inflammatory and oxidative effects of glyphosate.

Pre-treatment with grape seed extract (GSE) significantly reduced gill damage in a dose-dependent manner. A moderate dose (30 mg/kg) lessened the injuries, and a higher dose (50 mg/kg) provided almost complete protection, with only minor damage observed. This indicates that GSE prophylaxis boosts the antioxidant system and strengthens gill tissue before exposure to the toxin. Consistent with these findings, Mousavi et al. (33) showed that dietary pre-treatment with grape seed extract in rainbow trout significantly reduced levels of malondialdehyde, a marker of oxidative damage, and enhanced antioxidant-related gene expression, indicating improved oxidative defence prior to any toxic insult.

Post-treatment with GSE also alleviated Roundup-induced gill damage, though the protective effects were less pronounced compared to pre-treatment, particularly at the lower dose. These findings indicate that GSE is more effective in preventing glyphosate toxicity than in reversing established tissue injury. The observed protective effects of GSE can attributed to its high content of polyphenols, particularly proanthocyanidins, as shown in recent studies [34, 35, 36]. These compounds known for their potent free radical-scavenging [37] and anti-inflammatory properties [38]. Additional in vitro evidence shows GSE restores mitochondrial membrane potential and reinforces tight junction proteins under inflammatory stress [39]. Altogether, the broader pharmacological profile of GSE underscores its antioxidant, anti-inflammatory, and membrane-protective capabilities [35].

The liver is one of the most vital organs in fish, playing a key role in metabolism, detoxification, bile secretion, energy storage, and immune regulation. Because of its central role in filtering and processing substances from the bloodstream, the liver is highly vulnerable to damage caused by environmental pollutants, particularly glyphosate-based herbicides like Roundup. In this study, exposure to Roundup resulted in severe structural damage to liver tissues. The kidneys of fish are essential organs responsible for osmoregulation, excretion of metabolic waste, acid-base balance, and immune function, making

them highly sensitive to environmental pollutants. Because the kidneys continuously filter blood and regulate water and electrolyte balance, they are among the first organs to be affected by waterborne toxins, including glyphosate-based herbicides. In this study, fish exposed to Roundup showed severe structural damage in kidney tissues [40, 41]. Similar patterns have been reported in other studies where glyphosate exposure caused oxidative stress, liver inflammation, and cellular injury in species such as *Oreochromis niloticus* and *Cyprinus carpio* [42, 43].

Interestingly, GSE showed a remarkable protective effect on the liver and kidney [33]. Fish that received GSE before exposure to Roundup displayed much healthier liver and renal structures, with only mild changes. A moderate dose (30 mg/kg) provided noticeable protection, while a higher dose (50 mg/kg) offered near-complete repair of liver and renal architecture. The previous findings suggest that GSE enhances the antioxidant defence system and prepares the liver and kidney to better withstand toxic stress. Mousavi *et al.* [33] similarly reported that GSE supplementation in rainbow trout reduced oxidative damage by decreasing lipid peroxidation and boosting antioxidant gene expression.

Post-treatment with GSE also improved liver and kidney morphologic features but was less effective compared to pre-treatment, especially at lower doses. This indicates that GSE works best as a preventive agent, helping protect the liver and kidney before damage occurs. The strong hepatoprotective and renal protective effects of GSE are linked to its high content of polyphenolic compounds, especially proanthocyanidins, which are powerful free radical

scavengers [33, 37] and also help reduce inflammation (44). Furthermore, studies show that GSE supports mitochondrial stability, strengthens cell membranes, and prevents cell death under oxidative stress conditions [44].

Conclusion

The research indicates that grape seed extract can protect common carp from the harmful effects of herbicides, such as glyphosate. GSE, especially at higher doses, restores growth performance, improves hematological and immunological parameters, normalizes biochemical markers, and reduces tissue damage. GSE has a lot of polyphenols, which make it anti-inflammatory, antioxidant, and membrane stabilizing. This means that GSE is a natural, eco-friendly, and effective feed supplement that encourages sustainable aquaculture practices.

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This study didn't receive any funding support

Declaration of Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical of approval

This study follows the ethics guidelines of the College of Veterinary Medicine, University of Sulaimani, Iraq (ethics approval number; VMUS.E.C. Doc 22-2025/ May 2025).

TABLE 1. Evaluation score of histopathological characteristics in the gill [18].

LOCATIONS	HISTOPATHOLOGIC ABNORMALITIES	SCORES	INTERPRETATION
PRIMARY AND SECONDARY FILAMENTS	Degeneration	0	Absence of change
		1	Mild
		2	Mild-Moderate
		3	Moderate
		4	Severe
SECONDARY FILAMENTS	Aneurysm Lifting	0	Absence of change
		1	Mild
		2	Moderate
		3	Moderate-Severe
		4	Severe
CELLS	Hyperplasia	0	Absence of change
		1	Mild
		2	Mild-moderate
		3	Moderate
		4	Severe
INTERSTITIAL COMPARTMENT	Congestion and Hemorrhage	0	Absence of change
		1	Mild
		2	Mild-moderate
		3	Moderate
		4	Moderate-Severe
	Inflammation	5	Severe
		0	Absence of change
		1	Mild
		2	Mild-moderate
		3	Moderate
		4	Moderate-Severe
		5	Severe

TABLE 2. Evaluation score of histopathological characteristics in the liver and kidneys [18].

LOCATIONS	HISTOPATHOLOGIC ABNORMALITIES	SCORES	INTERPRETATION
GLOMERULI	Degeneration	0	Absence of change
		1	Mild
		2	Mild-moderate
		3	Moderate
		4	Moderate-severe
		5	Severe
TUBULAR COMPARTMENT	Degeneration and cast formation	0	Absence of change
		1	Mild
		2	Mild-moderate
		3	Moderate
		4	Moderate-severe
		5	Severe
HEPATIC AND PANCREAS VASCULATURE	Congestion and Haemorrhage	0	Absence of change
		1	Mild
		2	Mild-moderate
		3	Moderate
		4	Moderate-severe
		5	Severe
HEPATOCYTES	Swelling and Hydropic degeneration	0	Absence of change
		1	Mild
		2	Mild-moderate
		3	Moderate
		4	Moderate-severe
		5	Severe
INTERSTITIAL COMPARTMENT	Congestion and Haemorrhage	0	Absence of change
		1	Mild
		2	Mild-moderate
		3	Moderate
		4	Moderate-severe
		5	Severe
	Inflammation	0	Absence of change
		1	Mild
		2	Mild-moderate
		3	Moderate
		4	Moderate-severe
		5	Severe

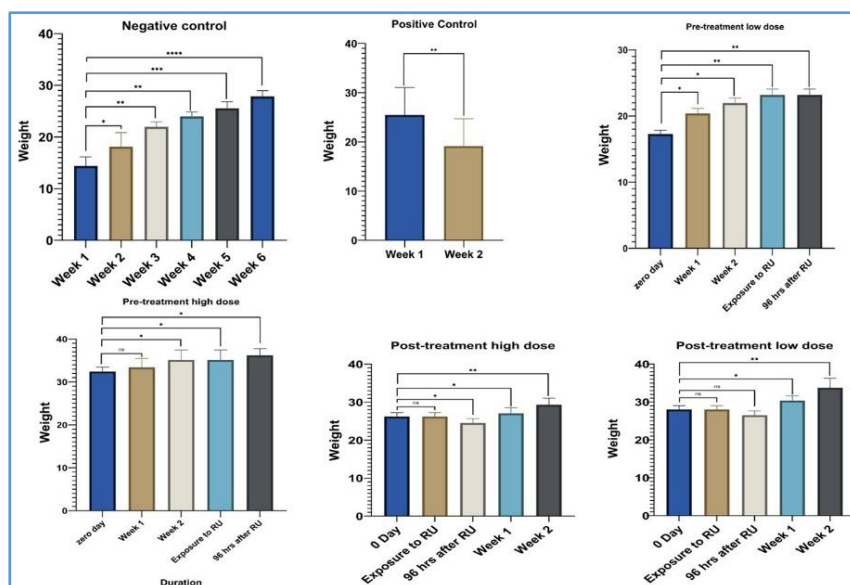


Fig. 1. Weight assessment across five groups: Data are mean $\pm$ SE; statistical analysis via one-way ANOVA with Dunnett's test vs. control. Significance: ($p > 0.05$), * ($p \leq 0.0332$), ** ($p \leq 0.0021$), *** ($p \leq 0.0002$), **** ($p < 0.0001$).

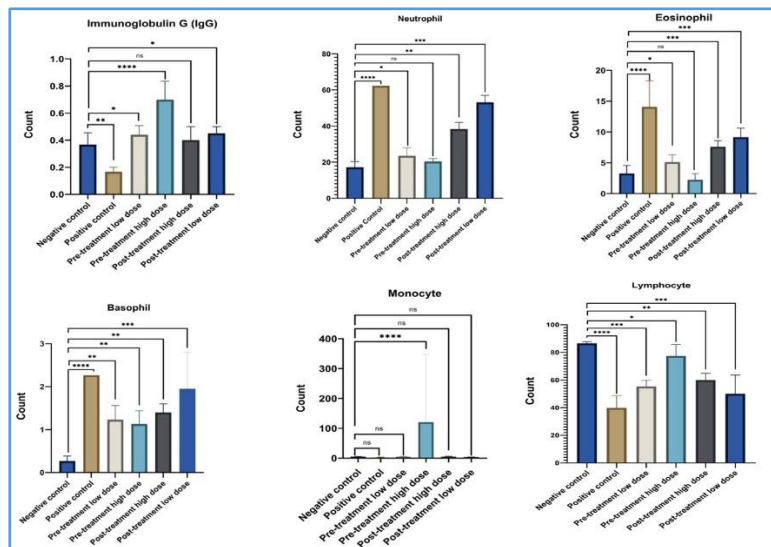


Fig. 2. Differential leukocyte counts in rats across five groups: Data are mean $\pm$ SE; statistical analysis via one-way ANOVA with Dunnett's test vs. control. Significance: ($p > 0.05$), * ($p \leq 0.0332$), ** ($p \leq 0.0021$), *** ($p \leq 0.0002$), **** ($p < 0.0001$).

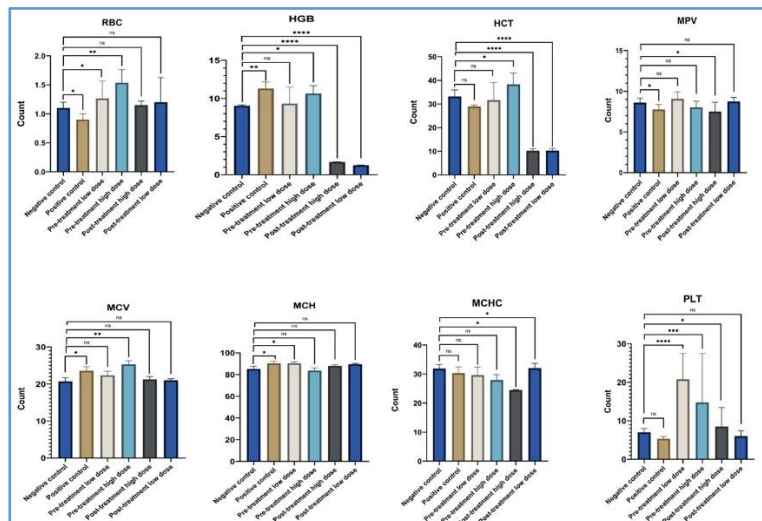


Fig. 3. Erythrocyte indices in fish: Data are mean $\pm$ SE; one-way ANOVA with Dunnett's test was used. Significance: ($p > 0.05$), * ($p \leq 0.0332$), ** ($p \leq 0.0021$), *** ($p \leq 0.0002$).

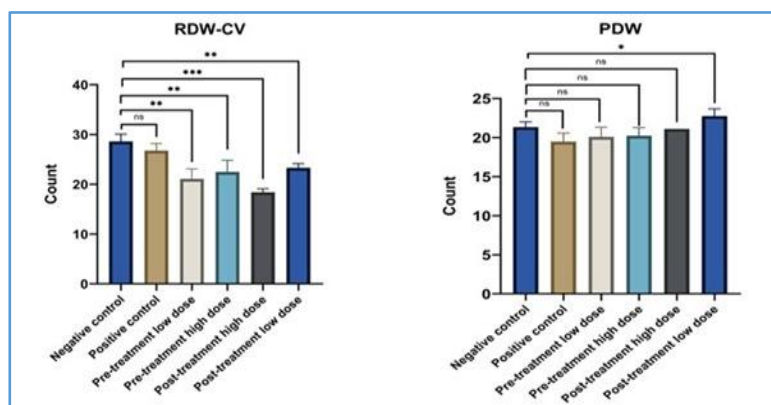


Fig. 4. Differential thrombocyte indices in fish across five groups: Data are presented as mean $\pm$ SE; statistical analysis was conducted using one-way ANOVA with Dunnett's post hoc test vs. control. Significance: ($p > 0.05$), * ($p \leq 0.0332$), ** ($p \leq 0.0021$), *** ($p \leq 0.0002$).

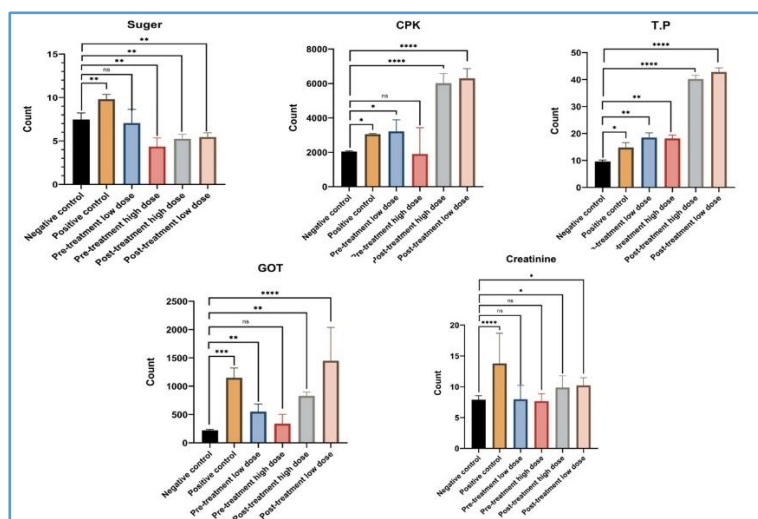


Fig. 5. Different sugar and biochemical markers: Data are presented as mean $\pm$ SE; statistical analysis was conducted using one-way ANOVA with Dunnett's post hoc test vs. control. Significance: ($p > 0.05$), * ($p \leq 0.0332$), ** ($p \leq 0.0021$), *** ($p \leq 0.0002$).

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تخفيف مستخلص بذور العنب لسمية مبيدات الأعشاب القائمة على الجليفوسات في أسماك الكارب الشائع

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الملخص

قيمت هذه الدراسة التأثير الوقائي لمستخلص بذور العنب (GSE) ضد السمية الناجمة عن مبيدات الأعشاب القائمة على الجليفوسات (GBH) في أسماك الكارب الشائع (*Cyprinus carpio* L.). تم تقسيم 36 من صغار الكارب إلى ست مجموعات، شملت مجموعتي التحكم السلبي والإيجابي، بالإضافة إلى مجموعات المعالجة بمستخلص بذور العنب الغذائي (20 و 30 غرام/كيلوغرام) إما قبل أو بعد التعرض لمبيدات الأعشاب القائمة على الجليفوسات. تم تقييم أداء النمو والتغيرات النسيجية في أنسجة الكبد والكلى والخياشيم، بالإضافة إلى المؤشرات الدموية والكيميائية الحيوية. أظهرت النتائج أن التعرض للجليفوسات أدى إلى تلف نسيجي كبير، وتغير في المؤشرات الدموية والمناعية، وتداخل مع المؤشرات الكيميائية الحيوية، وانخفاض ملحوظ في وزن الجسم. أعادت إدارة مستخلص بذور العنب التوازن لملفات الخلايا الدموية والمناعية، وعادت بالقيم الكيميائية الحيوية إلى طبيعتها، وقللت من الأفات النسيجية المرضية، وعززت بشكل ملحوظ نمو الوزن بشكل يعتمد على الجرعة. تفوقت إعطاء مستخلص بذور العنب الوقائي على العلاج بعد التعرض، وقدمت الجرعات الأعلى حماية شبه كاملة. يُعزى هذه الخصائص المضادة للالتهابات ومضادة للأكسدة على الأرجح إلى المركبات النشطة بيولوجيًا التي تم اكتشافها بواسطة تحليل GC-MS، مثل البروسيانيدينات والفلافونويدات. تُظهر كل هذه النتائج أن مستخلص بذور العنب الغذائي يقلل من الإجهاد التأكسدي وتلف الأعضاء الناجم عن الجليفوسات في أسماك الكارب، مما يشير إلى إمكانية استخدامه كمكمل غذائي طبيعي صديق للبيئة لتعزيز مقاومة الأسماك في استزراع الأحياء المائية.

الكلمات الدالة: بذور العنب، مبيدات الأعشاب-الجليفوسات، السمية، الدم، الصفات الكيموحياتية، التغيرات النسيجية. الكارب.