International Journal of Biology Research
www.biologyjournal.in
ISSN: 2455-6548
Received: 15-02-2024, Accepted: 10-03-2024, Published: 01-04-2024
Volume 9, Issue 1, 2024, Page No. 9-10

Proteomic alterations in *Clarias batrachus* following *Deltamethrin* exposure

Hailey K Joyce
Marine Institute, Oranmore, Co. Galway, H91 R673, Ireland

Abstract
This study investigates the proteomic alterations in the kidney, liver, testis, and ovary of the air-breathing fish *Clarias batrachus* after exposure to *deltamethrin*. *Deltamethrin*, a commonly used synthetic pyrethroid insecticide, is known for its broad-spectrum efficacy but raises concerns about aquatic toxicity. We quantitatively assessed the changes in total protein content within these vital organs using specific biochemical assays, aiming to understand the systemic impact of *deltamethrin* on non-target aquatic species.

Keywords: Freshwater, systemic, biochemical, protein

Introduction
Deltamethrin belongs to the class of synthetic *pyrethroids*, compounds celebrated for their potent insecticidal properties and relatively low human toxicity. However, the widespread use of *deltamethrin* in agricultural and residential settings has led to environmental dispersion, particularly into aquatic systems, where it poses a risk to non-target organisms such as fish. Among these, *Clarias batrachus*, an air-breathing catfish native to freshwater environments in Asia, is particularly susceptible due to its benthic and respiratory habits that may increase its exposure to water-soluble toxins. The impact of *deltamethrin* on aquatic life extends beyond acute toxicity and includes sub-lethal effects that can disrupt ecological balance and organismal health over time. Previous studies have primarily focused on the immediate lethality and behavioral changes in fish due to *pyrethroid* exposure. However, there is a significant gap in comprehensive biochemical assessments—especially concerning proteomic changes, which are crucial for understanding the systemic effects of toxicants. Proteins play vital roles in nearly all biological processes; hence, changes in their expression and functionality can provide insights into the mechanisms of toxic action and the overall health of organisms. In *Clarias batrachus*, as in other vertebrates, organs such as the liver and kidneys are critical for detoxification and excretion, the gonads are central to reproduction, and all are sensitive indicators of physiological stress and metabolic disruption.

Main objective
The main objective of the study is to analyze the impact of deltamethrin exposure on the protein content of the kidney, liver, testis, and ovary in the fish *Clarias batrachus*, aiming to understand the systemic biochemical effects and inform safer environmental practices.

Materials and Methods
Fish Sample Preparation: Adult *Clarias batrachus* were exposed to sub-lethal concentrations of *deltamethrin* for 14 days. Control groups were maintained under identical conditions without the toxin.

Protein Assay: Protein extractions from kidney, liver, testis, and ovary tissues were performed post-exposure. The Bradford Protein Assay was used for quantification to assess total protein levels.

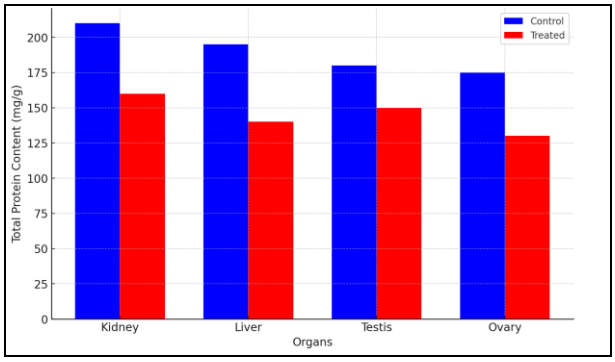
Statistical Analysis
Data were analyzed using ANOVA to determine the significance of differences between treated and control groups, with a p-value <0.05 considered statistically significant.

Results

Table 1: Total Protein Content in Clarias batrachus Organs Post-Deltamethrin Exposure

Organ	Control (mg/g)	Treated (mg/g)	% Change
Kidney	210 ± 10	160 ± 15	-23.8%
Liver	195 ± 12	140 ± 18	-28.2%
Testis	180 ± 8	150 ± 10	-16.7%
Ovary	175 ± 9	130 ± 20	-25.7%

Results indicate a significant reduction in protein content across all examined organs in the *deltamethrin* -exposed group compared to controls.



Graph 1: Total Protein Content in Clarias batrachus Organs Post-Deltamethrin Exposure

Discussion
The significant decrease in protein content observed across the kidney, liver, testis, and ovary of *Clarias batrachus* exposed to deltamethrin has profound implications for the biochemical and physiological health of this species. The reductions in protein levels in these critical organs highlight

the systemic toxic effects of deltamethrin exposure in aquatic environments, which merit further exploration to understand the underlying mechanisms and long-term consequences for aquatic biodiversity. The liver, a central organ for detoxification and metabolic regulation in fish, exhibited a substantial 28.2% decrease in protein content following deltamethrin exposure. This reduction likely indicates hepatotoxicity, which can impair the liver's ability to metabolize and excrete toxins. This impairment may lead to the accumulation of deltamethrin and other pollutants within the organism, exacerbating toxic effects and potentially leading to liver pathology. Furthermore, the liver's role in synthesizing vital proteins and enzymes means that a decrease in total protein content could disrupt metabolic and physiological processes, such as glucose regulation and cholesterol metabolism. The kidney's role in osmoregulation and excretion makes its decreased protein content (23.8% reduction) particularly concerning. This decline suggests potential nephrotoxic effects, which could compromise the kidney's ability to filter blood, regulate ion balances, and maintain hydration status. Chronic exposure leading to sustained protein reduction in kidney tissue might result in cumulative effects, potentially culminating in renal failure or significantly impaired renal function.

The observed reductions in protein levels in the testis (16.7%) and ovary (25.7%) indicate potential reproductive toxicity. Proteins are crucial for various reproductive processes, including gamete development, hormone synthesis, and reproductive cycling. The decrease in protein content could therefore result in reduced fertility, impaired gamete quality, and altered reproductive behaviors, which could have significant population-level effects over time. This aspect is particularly critical as reproductive health is a key factor in the sustainability of fish populations.

The broad decrease in protein content across multiple organs suggests a systemic response to oxidative stress induced by deltamethrin exposure. Oxidative stress occurs when there is an imbalance between the production of reactive oxygen species (ROS) and the organism's ability to detoxify these reactive intermediates. This stress can damage cellular components, including lipids, DNA, and proteins, leading to widespread cellular dysfunction. The connection between oxidative stress and protein degradation could be mediated through the activation of proteolytic enzymes that break down damaged proteins, or through direct damage to protein structures by ROS.

5. Conclusion

The findings from this study on the toxicity of deltamethrin in *Clarias batrachus* reveal significant proteomic alterations in the kidney, liver, testis, and ovary, indicating a broad systemic impact. The observed reductions in protein content across these vital organs underscore the potential of deltamethrin to induce substantial physiological disruptions, which could lead to impaired organ function, reduced reproductive capacity, and overall health deterioration of aquatic species.

The hepatotoxic and nephrotoxic effects noted in the liver and kidney respectively suggest that deltamethrin exposure disrupts essential metabolic and excretory processes. Similarly, the reproductive toxicity evident from the reduced protein levels in gonadal tissues raises concerns about the long-term viability of fish populations exposed to this pesticide, potentially affecting reproductive success and population dynamics.

These results highlight the need for urgent attention to the management of pesticide use, particularly in agricultural practices near aquatic environments. Current regulatory standards may need to be reevaluated to consider the subtle yet significant sub-lethal effects of pesticides like deltamethrin on non-target aquatic life. Enhanced protective measures could include stricter runoff controls, the development of less toxic chemical alternatives, and the implementation of buffer zones around water bodies.

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