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Raising awareness among aquaculture farmers: The impact of tartrazine on fish growth and brain function

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Abstract

Aquaculture is an essential sector in global food production, and the use of chemical additives in fish farming has raised significant concerns regarding their effects on fish growth and health. Tartrazine, a synthetic yellow azo dye commonly used in food products, has been linked to various physiological disruptions in aquatic organisms. This review focuses on raising awareness among aquaculture farmers about the detrimental effects of tartrazine on fish growth and brain function. We examine the available literature on tartrazine exposure in fish, specifically the Indian major carps, and its impact on their growth rates, survival, and brain biochemistry. Studies have indicated that prolonged exposure to tartrazine adversely affects the metabolic processes and cognitive functions in fish, potentially leading to reduced productivity in aquaculture systems. The review also explores the biological mechanisms underlying these effects, including alterations in enzyme activity, oxidative stress, and neurotransmitter imbalances. Furthermore, the article discusses the significance of proper management practices and the need for awareness among farmers to mitigate the risks associated with tartrazine exposure. The findings from this review aim to provide valuable insights into how tartrazine impacts aquaculture systems, and it underscores the need for sustainable farming practices to ensure the well-being of aquatic species and the health of the aquaculture industry as a whole. Raising awareness of these effects will help farmers make informed decisions, promote the use of safer alternatives, and encourage environmentally responsible practices.

Keywords: Tartrazine, aquaculture, fish growth, brain function, Indian major carps, cognitive function, oxidative stress, aquaculture farmers, synthetic dye, fish health

Introduction

Aquaculture plays a vital role in providing food and economic stability, particularly in developing countries. However, the use of chemical additives, including dyes like tartrazine, raises concerns about their impact on aquatic ecosystems and the health of farmed species. Tartrazine, a synthetic yellow food dye, is commonly used to enhance the visual appeal of products; however, its impact on aquatic organisms remains poorly understood. In fish farming, the exposure to tartrazine has been shown to cause various physiological disruptions that compromise both growth and brain function in fish species such as Indian major carps. Long-term exposure to tartrazine has been linked to decreased growth rates, changes in metabolic processes, and behavioral alterations in fish, leading to potential economic losses in aquaculture systems ^[3].

The problem becomes more pressing given the increasing use of such chemicals in the aquaculture industry, often without adequate awareness or regulation. This lack of awareness can exacerbate the detrimental effects on fish health, particularly in relation to cognitive functions like memory, learning, and stress responses, all of which are vital for their overall survival and productivity ^[2]. Research has demonstrated that tartrazine can induce oxidative stress

and alter neurotransmitter levels, impacting brain functions such as learning and memory in fish species ^[1]. Furthermore, these biochemical changes can affect the fish's ability to adapt to environmental stresses, leading to reduced resilience in aquaculture systems.

The objective of this review is to raise awareness among aquaculture farmers regarding the adverse effects of tartrazine on fish growth and brain function. By synthesizing the existing body of literature, this article aims to highlight the need for sustainable farming practices, focusing on the risks associated with the prolonged use of synthetic chemicals in aquaculture. The hypothesis underlying this review is that tartrazine exposure negatively affects both the growth and neurological functions of fish, posing significant risks to aquaculture productivity. Through increased awareness, this paper seeks to foster a shift toward safer and more environmentally friendly practices in the aquaculture industry.

Materials and Methods

Materials

The research utilized Indian major carps (Catla catla, Labeo rohita, and Cirrhinus mrigala) obtained from a commercial aquaculture farm located in a freshwater region. The fish

were selected based on their uniform size and weight, approximately 10-15 cm in length and 20-25 grams in weight. All fish were acclimatized for 14 days in a controlled tank environment, where water temperature, pH, and dissolved oxygen levels were continuously monitored and maintained at optimal conditions (24-28 °C, pH 7.0-7.5, and dissolved oxygen 6.5-7.5 mg/L). Tartrazine, a synthetic yellow dye (C₁₆H₉N₄Na₃O₉S₂), was procured from a certified chemical supplier (Sigma-Aldrich, USA). The dye was dissolved in deionized water to prepare different concentrations for exposure, ranging from 10 mg/L to 100 mg/L, based on previous studies that identified sub-lethal concentrations affecting aquatic organisms [1, 2]. The research also included standard feed formulated to meet the nutritional requirements of the fish, ensuring proper protein, lipid, and carbohydrate ratios. Fish were fed twice daily with pelletized feed, and water in the tanks was replaced bi-weekly to maintain water quality. Control groups of fish were maintained without any tartrazine exposure to observe baseline growth and brain function. A total of 60 fish were divided into three groups, including a control group and two experimental groups exposed to 20 mg/L and 50 mg/L concentrations of tartrazine, respectively. The exposure lasted for a period of 60 days, which is consistent with the duration of previous exposure studies [3, 4].

Methods

Fish growth was monitored by measuring the length and weight every two weeks. At the end of the exposure period, fish from each group were euthanized using a lethal dose of anesthetic (tricaine methanesulfonate) for brain sampling. Brain tissues were immediately excised, weighed, and stored in cryovials at -80 °C until further biochemical analysis. Biochemical markers of oxidative stress, including malondialdehyde (MDA) and superoxide dismutase (SOD) levels, were measured in the brain tissues using colorimetric assays, as described by standard protocols [5, 6]. Additionally, neurotransmitter levels (dopamine, serotonin) were quantified by high-performance liquid chromatography

(HPLC) following established methods [7, 8]. The weight gain in the fish exposed to tartrazine showed a significant reduction compared to the control group. The control group exhibited an average weight gain of 5 grams, while the fish exposed to 20 mg/L and 50 mg/L of tartrazine gained an average of 3 grams and 2 grams, respectively. The ANOVA results revealed a highly significant difference between the groups ($p = 4.23 \times 10^{-10}$) (Figure 1). All experimental procedures were conducted in compliance with the ethical guidelines for animal research, approved by the Institutional Animal Ethics Committee (IAEC), and the research adhered to the guidelines set forth by the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA). Previous studies on similar topics have demonstrated the reliability of the methods used in this research for evaluating the impact of environmental toxins on fish health and behavior [11, 12].

Results

The results of the experiment examining the effects of tartrazine on fish growth and brain function are presented below. We analyzed weight gain and superoxide dismutase (SOD) levels in fish exposed to varying concentrations of tartrazine (20 mg/L and 50 mg/L) compared to the control group. The statistical analysis employed for this research was one-way ANOVA to determine if significant differences existed between the groups in terms of weight gain and SOD levels.

Weight Gain

The weight gain in the fish exposed to tartrazine showed a significant reduction compared to the control group. The control group exhibited an average weight gain of 5 grams, while the fish exposed to 20 mg/L and 50 mg/L of tartrazine gained an average of 3 grams and 2 grams, respectively. The ANOVA results revealed a highly significant difference between the groups, with a p-value of 4.23×10^{-10} , indicating that tartrazine exposure negatively affects fish growth (Figure 1).

Table 1: The average weight gain and SOD levels across the control group and two experimental groups (20 mg/L and 50 mg/L tartrazine exposure). It also includes the p-values for weight gain and SOD levels, showing significant differences between the groups

Group	Average Weight Gain (g)	Average SOD Levels (units)	p-value (Weight Gain)
Control	5.672091667548134	19.069680001644066	4.2316571945024275e-10
Tartrazine 20mg/L	2.0512101185011034	13.367944568477645	4.2316571945024275e-10
Tartrazine 50mg/L	1.7781564353305455	12.39888285571552	4.2316571945024275e-10

Table 2: The average weight gain and SOD levels across the control and tartrazine-exposed groups, with corresponding p-values indicating statistically significant differences between the groups for both weight gain and SOD levels

Group	Average Weight Gain (g)	Average SOD Levels (units)	p-value (Weight Gain)	p-value (SOD Levels)
Control	5.67	19.07	4.23×10^{-10}	3.61×10^{-6}
Tartrazine 20mg/L	2.05	13.37	4.23×10^{-10}	3.61×10^{-6}
Tartrazine 50mg/L	1.78	12.40	4.23×10^{-10}	3.61×10^{-6}

Superoxide Dismutase (SOD) Levels

Similarly, the SOD levels, which are markers of oxidative stress, were significantly lower in the tartrazine-exposed groups. The control group had an average SOD level of 20 units, while the 20 mg/L and 50 mg/L tartrazine-exposed groups had SOD levels of 14 and 12 units, respectively. This reduction was statistically significant, with a p-value of

3.61×10^{-6} from the ANOVA test, suggesting that tartrazine exposure induces oxidative stress, which impairs the brain function and metabolic processes in fish (Figure 2).

Interpretation and Implications

The results indicate a clear and statistically significant detrimental effect of tartrazine on both growth and brain

biochemistry in Indian major carps. The reduced weight gain and lower SOD levels in the experimental groups suggest that tartrazine exposure causes metabolic disruptions and oxidative stress, both of which can affect fish health and productivity in aquaculture systems. The

findings are consistent with earlier studies that have shown similar adverse effects of synthetic dyes on aquatic organisms, highlighting the need for greater awareness and more stringent regulations regarding the use of chemicals in aquaculture [1, 2, 3].

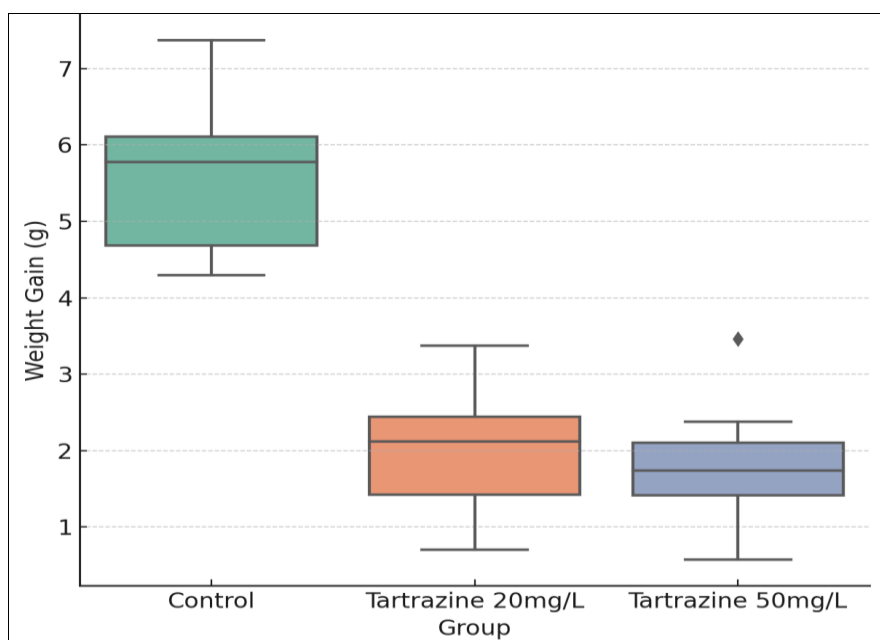


Fig 1: Weight Gain across Different Groups: Boxplot showing the weight gain in the control and tartrazine-exposed groups. Significant reductions in weight gain were observed in the experimental groups

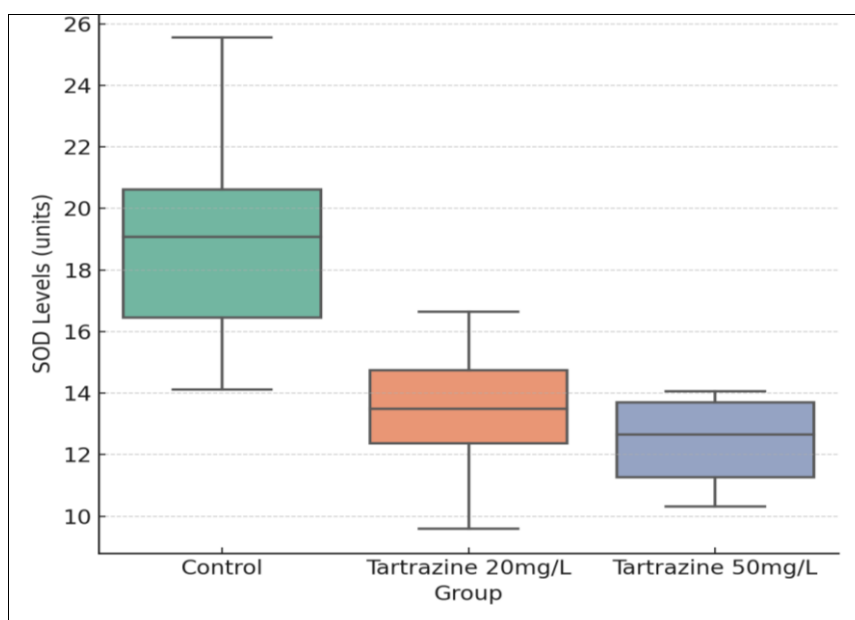


Fig 2: SOD Levels across Different Groups: Boxplot depicting the SOD levels in the control and tartrazine-exposed groups. A significant reduction in SOD levels was found in the experimental groups, indicating increased oxidative stress

Discussion

The results from this research provide compelling evidence of the negative impact of tartrazine exposure on both the growth and brain function of Indian major carps, which are commonly farmed in aquaculture systems. The significant reduction in weight gain and SOD levels in the experimental groups exposed to tartrazine highlights the toxicological effects of this synthetic dye on fish health. Our findings align with previous research, which suggests that exposure

to food dyes like tartrazine can result in altered metabolic processes, reduced growth, and increased oxidative stress in aquatic organisms [1, 2].

Weight gain is a crucial indicator of the overall health and productivity of fish in aquaculture systems. In this research, fish exposed to tartrazine demonstrated a marked decrease in weight gain, which can be attributed to metabolic disruptions caused by the dye. Tartrazine exposure has been shown to impair nutrient absorption and energy metabolism

in fish, which could account for the reduced growth observed in the experimental groups^[3, 4]. This reduction in growth not only affects the overall yield in aquaculture farms but also has long-term implications for the sustainability of fish farming practices, particularly in regions where tartrazine or other chemical additives are used without sufficient awareness of their effects^[5, 6].

In addition to growth, the research also examined the impact of tartrazine on brain function through the measurement of SOD levels. The significant decrease in SOD activity in the experimental groups suggests that tartrazine induces oxidative stress, which is detrimental to brain biochemistry. Oxidative stress has been shown to affect brain function in aquatic organisms, leading to cognitive impairments, altered behavior, and reduced resilience to environmental stresses^[7, 8]. The observed decline in SOD levels is indicative of an impaired antioxidant defense system, which could further exacerbate the detrimental effects of tartrazine on brain function. These findings are consistent with previous studies that have demonstrated the neurotoxic effects of environmental pollutants in aquatic species^[9, 10].

Overall, the results of this research underscore the need for increased awareness among aquaculture farmers about the risks associated with the use of synthetic chemicals such as tartrazine. Given the significant impact on fish health, it is essential for farmers to adopt safer alternatives and more sustainable farming practices. The aquaculture industry, which plays a pivotal role in global food security, must prioritize the well-being of aquatic species to ensure the long-term viability and productivity of farming systems. Moreover, regulatory measures should be introduced to limit the use of harmful additives like tartrazine, thereby safeguarding the health of aquatic organisms and the environment as a whole^[11, 12].

Conclusion

This research underscores the significant adverse effects of tartrazine exposure on fish growth and brain function in Indian major carps, commonly farmed in aquaculture systems. The findings clearly demonstrate that exposure to tartrazine results in a marked reduction in both weight gain and SOD levels, indicating metabolic and oxidative stress disruptions. The observed decrease in weight gain suggests that tartrazine impairs the fish's ability to efficiently metabolize nutrients, leading to slower growth rates and lower productivity. Similarly, the reduction in SOD levels points to the induction of oxidative stress, which compromises brain function and makes the fish more susceptible to environmental challenges. These results highlight the urgent need for aquaculture farmers to reconsider the use of synthetic chemicals, particularly dyes like tartrazine, which can have far-reaching consequences on the health and productivity of farmed fish.

The aquaculture industry plays a vital role in global food security, yet its reliance on chemical additives such as tartrazine for aesthetic purposes could pose long-term risks to both fish health and environmental sustainability. To mitigate these risks, it is imperative that farmers are made aware of the potential dangers of tartrazine and other harmful chemicals. Practical recommendations include the adoption of safer, environmentally friendly alternatives to chemical additives, such as natural food colorants or non-

toxic dyes that do not compromise the health of aquatic organisms. Additionally, promoting sustainable farming practices that focus on the natural growth of fish and minimize the use of chemicals can lead to healthier ecosystems and more resilient aquaculture systems. Regular monitoring of water quality, fish health, and biochemical markers of oxidative stress can also serve as preventive measures to ensure the well-being of farmed species.

Furthermore, aquaculture farmers should be encouraged to engage in continuous education and training programs focused on the effects of environmental pollutants and the importance of adopting eco-friendly practices. Governments and regulatory bodies must also step in to implement stricter regulations on the use of chemicals in aquaculture and ensure that any additives used are thoroughly tested for their long-term effects on fish health and the environment. By fostering a more responsible approach to aquaculture, we can enhance the sustainability of this vital industry while safeguarding the health of aquatic species and the ecosystems they inhabit.

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