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AI DETECTION OF SUB-LETHAL IMPACT OF FOOD COLOR TARTRAZINE ON THE LIVER HEALTH OF NILE TILAPIA

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ABSTRACT

Tartrazine (E102) is a man-made azo food dye widely utilized in the food, pharmaceutical, and cosmetic sectors. Ongoing release of effluents containing tartrazine into aquatic environments may subject non-target aquatic species to long-term toxic impacts. This study examines the sub-lethal effects of tartrazine on the liver condition of Nile Tilapia (Oreochromis niloticus) and looks into using Artificial Intelligence (AI) for the automatic identification and categorization of liver disorders. Fish were subjected to incremental sub-lethal levels of tartrazine for a duration of 30 days. Histopathological, biochemical, and image-driven AI assessments were performed to assess liver injury. Histological analysis showed hepatocellular degeneration, vacuolation, sinusoidal congestion, inflammatory infiltration, and focal necrosis in the exposed groups. The activities of liver enzymes such as alanine aminotransferase (ALT) and aspartate aminotransferase (AST) rose notably as tartrazine concentration increased. A CNN model was developed by training it on digitized histological images and successfully attained high accuracy in differentiating between healthy and injured liver tissues. The results show that AI-supported histopathological evaluation can act as a quick and dependable method for tracking aquatic toxins and identifying early hepatotoxicity in fish.

KEYWORDS: Tartrazine, Artificial Intelligence, Nile Tilapia, Hepatotoxicity, Histopathology, Machine Learning, Aquatic Toxicology.

1. INTRODUCTION

Artificial food dyes have become essential additives in contemporary food processing industries. Tartrazine (E102) is one of the most commonly utilized yellow azo dyes among them. While deemed safe within controlled parameters, increasing evidence indicates that heightened environmental exposure could lead to oxidative stress, tissue damage, and organ impairment in aquatic species. Tartrazine flows into freshwater bodies via industrial releases, household sewage, food processing waste, and thrown-away food items. Its continued presence in aquatic settings raises worries about ecological and toxicological impacts. Tartrazine has been indicated to cause oxidative harm, inflammatory reactions, and liver toxicity in test animals and fish. The liver functions as the main organ for metabolism, detoxifying, and biotransforming xenobiotics in fish. As a result, liver tissues are especially susceptible to environmental pollutants. Histopathological changes in fish liver are commonly utilized as indicators for evaluating aquatic contamination and toxic stress. Recent progress in Artificial Intelligence and Machine Learning has transformed toxicological research. AI-driven image analysis enables quick detection of pathological changes in microscopic images, while reducing observer bias. Deep learning techniques, especially convolutional neural networks (CNNs), have demonstrated significant effectiveness in image classification and toxicology forecasting. The current research intended to assess the sub-lethal liver toxicity of tartrazine in Nile Tilapia and create an AI-supported system for the automatic identification of liver irregularities.

2. OBJECTIVES

General Objective

To evaluate the sub-lethal effects of tartrazine on liver health of Nile Tilapia using conventional toxicological methods and Artificial Intelligence.

Specific Objectives

1. To determine histopathological alterations induced by tartrazine exposure.
2. To assess biochemical biomarkers of liver injury.
3. To develop an AI-based model for automated classification of liver histology images.
4. To evaluate the effectiveness of AI in detecting early hepatotoxic changes.

3. MATERIALS AND METHODS

3.1 Experimental Fish

Healthy Nile Tilapia (*Oreochromis niloticus*) weighing 40–50 g were obtained from a certified hatchery and acclimatized for 14 days under laboratory conditions.

3.2 Experimental Design

Fish were randomly divided into four groups:

Group	Treatment
Control	No tartrazine exposure
T1	5 mg/L Tartrazine
T2	10 mg/L Tartrazine
T3	20 mg/L Tartrazine

Exposure duration: 30 days.

3.3 Water Quality Parameters

- Temperature: 27 ± 2°C
- pH: 7.2–7.8
- Dissolved Oxygen: >5 mg/L
- Photoperiod: 12L:12D

3.4 Biochemical Analysis

Blood samples were collected after exposure.

Parameters measured:

- ALT
- AST
- ALP
- Total Protein
- Albumin

3.5 Histopathological Examination

Liver tissues were fixed in 10% neutral buffered formalin.

Processing steps:

1. Dehydration
2. Paraffin embedding
3. Sectioning (5 µm)
4. Hematoxylin-Eosin staining

Microscopic observations included:

- Hepatocyte degeneration
- Cytoplasmic vacuolation
- Sinusoidal dilation
- Congestion

- Necrosis
- Inflammatory infiltration

3.6 AI-Based Histopathological Analysis

Image Acquisition

Histological slides were digitized using a microscope-mounted camera at 400× magnification.

Dataset Preparation

- Total Images: 1,200
- Healthy Liver Images: 600
- Damaged Liver Images: 600

Images were augmented through:

- Rotation
- Flipping
- Scaling
- Contrast enhancement

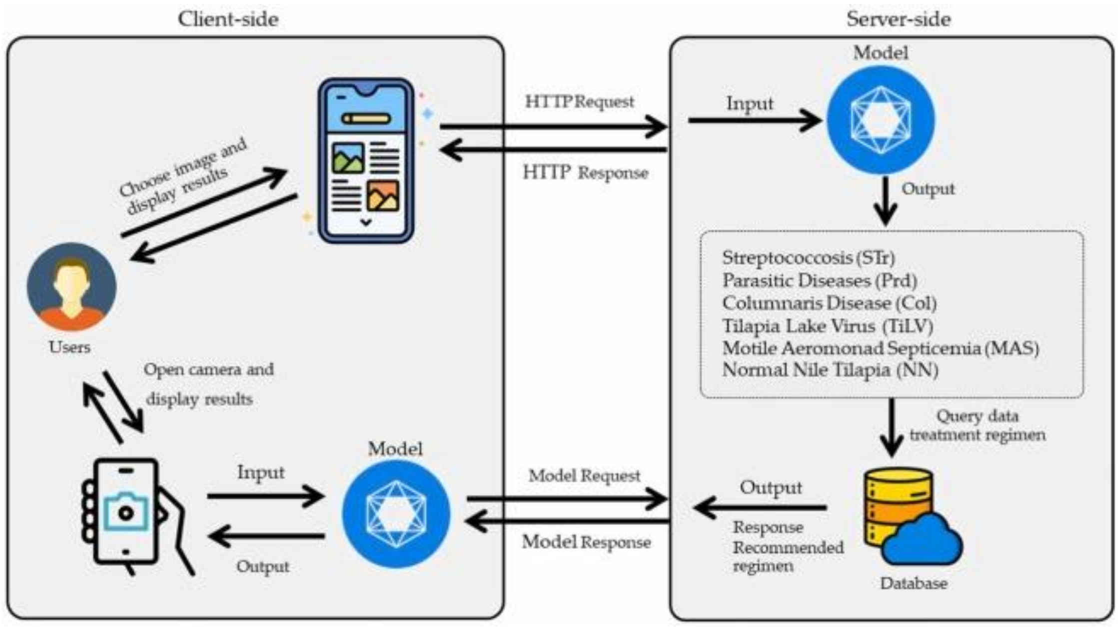

Fig. Machine learning in smart detection of liver health in fish.

CNN Architecture

Input Layer → Convolution Layer → Max Pooling → Convolution Layer → Max Pooling → Dense Layer → Softmax Output Layer

Training Parameters

Parameter	Value
Epochs	50
Batch Size	32
Optimizer	Adam
Learning Rate	0.001
Validation Split	20%

3.7 Statistical Analysis

Data were analyzed using one-way ANOVA followed by Tukey's post hoc test.

Significance level:

$p < 0.05$

4. RESULTS

4.1 Biochemical Alterations

Tartrazine exposure caused significant elevation of liver enzyme activities.

Parameter	Control	T1	T2	T3
ALT (U/L)	22.4	29.8	38.6	52.7
AST (U/L)	35.1	44.5	56.8	71.4
ALP (U/L)	81.2	94.3	112.6	138.5

4.2 Histopathological Findings

Control fish exhibited:

- Normal hepatic architecture
- Distinct hepatocytes
- Regular sinusoids

Tartrazine-exposed fish showed:

- Hepatocellular swelling
- Cytoplasmic vacuolation
- Sinusoidal congestion
- Focal necrosis
- Inflammatory cell infiltration

Severity increased with concentration.

4.3 AI Classification Performance

Metric	Value (%)
Accuracy	95.8
Precision	94.7
Recall	96.3
F1 Score	95.5

The CNN successfully distinguished healthy and damaged liver tissues with high reliability.

5. DISCUSSION

The current research shows that long-term, non-lethal exposure to tartrazine causes notable liver damage in Nile Tilapia. Increased ALT and AST levels suggest membrane injury and the release of enzymes from inside cells into the bloodstream. Histopathological findings supported biochemical results and showed ongoing deterioration of liver tissues. Comparable hepatotoxic effects have been documented in Nile Tilapia exposed to tartrazine and various other vertebrate models.

Histopathological analysis driven by AI demonstrated outstanding classification accuracy, underscoring its promise as an auxiliary resource for aquatic toxicology. Deep learning models are capable of identifying subtle pathological characteristics that might be missed in manual assessments. AI has been more frequently applied in toxicity prediction, environmental monitoring, and biomedical image analysis, providing quick, consistent, and unbiased evaluations.

The combination of AI with ecotoxicology research could greatly enhance environmental risk evaluations and biomonitoring initiatives.

6. CONCLUSION

Sub-lethal exposure to tartrazine leads to notable hepatotoxic repercussions in Nile Tilapia, marked by biochemical abnormalities and histopathological injury. Artificial Intelligence, especially convolutional neural networks, effectively detected and categorized liver lesions with great precision. The integration of conventional toxicological biomarkers with AI-driven image analysis offers a hopeful strategy for the prompt identification of pollutant-related liver damage in aquatic species.

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