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Effect of Acute Toxicity of Formalin on *Oreochromis niloticus* (Linnaeus, 1758)

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Abstract

The objective of this study is to investigate the effect of the toxicity of formalin on Oreochromis niloticus in Wudil, Kano State, Nigeria. An experimental design was adopted for this study which involves two sets of experiments: determining the acute toxicity of formalin and the therapeutic effect of formalin. The method for the acute toxicity test as recommended by Yadav and Singh (2009) was also employed. The research was conducted at the fish laboratory of the Biological Science Department, Nigeria Police Academy, Wudil, Kano. The Nigerian Police Academy is located in Wudil, Kano State, Nigeria. A total number of 36 tilapia juveniles (*Oreochromis niloticus*) were collected alive from River Wudil. Formalin was obtained as 40% formaldehyde. The following concentrations were administered to each of them: 0.5, 0.1, and 1.5 mg/l and a control with 0.00 mg/l. Each concentration had 4 treatments. 3 juveniles of the specimen were randomly selected and stocked in each of the 12 plastic bowls, and the experiment was set randomly. A static bioassay was then used to determine the toxicity test of formalin for *Oreochromis niloticus* juveniles. Another set of fish infested with Cichlidogyrus spp. in aquaculture habitual conditions was exposed to different concentrations of formalin, and then observation was done to find the concentration range that effectively treats the disease or parasite while minimising the harm to the fish. Changes in appearance and mortality were also recorded. All data obtained were subjected to one-way analysis of variance (ANOVA) using the Statistical Package for Social Sciences (SPSS), version 23 for Windows. Differences in means were separated using Duncan's new multiple range test (DMRT). The level of significance was determined at the P = 0.05 level of probability. The significant difference was established at a 5% probability level ($P < 0.05$), while the results generated were expressed as mean ± standard deviation (SD). The results showed that at the concentration of 0.5 mg/l, the mean values of the fish mortality were 0.00, 0.00, 0.00, 0.33, 0.33 and 0.67 mg/l. While at concentration 1.0, mean values of fish mortality were 0.00, 0.33, 0.33, 0.00, 0.67 and 0.33, and at a concentration of 1.5 mg/l, mean values are 0.00, 0.67, 0.33, 1.00, 1.00 and 1.33. At 0.00 concentration, there was no fish mortality at all. The study showed that formalin has a therapeutic effect on fish infested with Cichlidogyn spp. It was therefore concluded that the use of formalin in a lesser concentration based on this study is safe for tilapia (*Oreochromis niloticus*). Also, if the period of exposure of the fish does not exceed 6 hours, it is not going to be toxic to *Oreochromis niloticus. Moreover*, there is effectiveness in using formalin to reduce the infestation of fish by parasites. The study recommended that indiscriminate use of formalin in water impoundments should be avoided, especially when the concentration is high to preserve fish diversity, among others.

Keywords: Acute Toxicity, Formalin, Oreochromis Niloticus, Juvenile, Aquaculture.

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INTRODUCTION

Fish such as oreochromis niloticus are sensitive to the impact of a complex mixture of chemicals in a specific aquatic ecosystem, integrating the environmental load over time and space. Tilapia farming provides an alternative to cheap animal protein and a source of employment. Tilapia culture has increased worldwide in the last decade, with a production of about 3 million tonnes, which equals approximately US$5,000 million (FAO, 2014). This fish is also the most cultivated in Nigeria, with an increasing value market of US$475 million (Fagbenro, 2012). Oreochromis niloticus (tilapia) is a common fish in tropical freshwater, where it is well suited for pond culture. Hence, its choice for this investigation. Fish farmers, particularly in the northern region, culture tilapia, one of the largest species. This choice is because of the robustness of tilapia and its lower feeding frequency compared to other fish species (Fafioye, 2012). Tilapia farming provides an alternative to cheap animal protein and a source of employment. Tilapia culture has increased worldwide in the last decade, with a production of about 3 million tonnes, which equals approximately US$5,000,000 (FAO, 2014). This fish is also the most cultivated in Nigeria, with an increasing value market of US$475 million (Fagbenro, 2012). Fish have been one of the main sources of protein and are essential for human health worldwide. Hence, it is critical to guarantee sustainable fish production through artificial means, such as aquaculture. Sustainable aquaculture can play a significant role in achieving a more environmentally and economically viable fish production (Cressey, 2009). Fish such as Oreochromis niloticus are sensitive to the impact of a complex mixture of chemicals in a specific aquatic ecosystem, integrating the environmental load over time and space.

Oreochromis niloticus (tilapia) is a common fish in the tropical freshwater, where it is well suited for pond culture. Hence its choice for this investigation. Fish farmers, particularly in the northern region, culture tilapia, one of the largest species. This choice is because of the robustness of tilapia and its lower feeding frequency compared to other fish species (Fafioye, 2012). Tilapia farming provides an alternative to cheap animal protein and a source of employment. Tilapia culture has increased worldwide in the last decade, with a production of about 3 million tonnes, which equals approximately US$5,000 million (FAO, 2014). This fish is also the most cultivated in Nigeria, with an increasing value market of US$475 million (Fagbenro, 2012). However, the increase in fish mortality could be a concern.

Fish mortalities can be caused by monogenean parasites, which produce external abrasions that contribute to secondary infections, leading to a significant reduction in production profitability due to associated mortalities (Vidal-Martínez et al., 2002; Babatunde & Oladimeji, 2014).

Therefore, the ongoing losses from fish mortalities may lead to either the closure of fish farms or a change in the productive activities of their owners (Syngai, Dey, & Bharali, 2016). Therefore, it is necessary to improve the routine sanitary procedures with the objective of preventing pathologies. Fish mortalities can be caused by monogenean parasites, which create external abrasions on the fish, leading to secondary infections that severely reduce production profitability due to associated mortalities (Vidal-Martínez et al., 2002; Babatunde & Oladimeji, 2014). These parasites can be controlled with formaldehyde (formalin).

Formaldehyde (formalin) is a chemical compound (CHO) that can be used as antiparasitic control in fish culture (Leal *et al*., 2016). It is one of the most effective and widely used compounds in fish culture for the therapeutic and prophylactic treatment of fungal infections and external parasites in fish and fish eggs. The use of formaldehyde as a means of increasing agricultural productivity can pose a serious threat and have significant consequences for the water bodies. Formaldehyde (formalin) is a chemical compound (CHO) that can be used as antiparasitic control in fish culture (Leal *et al*., 2016). It is one of the most effective and widely used compounds in fish culture for the therapeutic and prophylactic treatment of fungal infections and external parasites in fish and fish eggs. The use of formaldehyde as a means of increasing agricultural productivity can pose a serious threat and have significant consequences for the water bodies. The application of formalin to fishponds to kill bacteria, fungi and other harmful micro-organisms can also pose a great problem to humans after the consumption of the affected fishes. Increased concentrations of formalin in aquatic environments can reduce the amount of oxygen available, leading to respiratory distress in fish, which may manifest as loss of balance, gulping for air, vertical movement, excessive mucus accumulation, and ultimately death. Hence, treatment for ectoparasitic diseases of freshwater fish with formalin appears to be ineffective. For this reason, using formalin is clearly an unnecessary expense. In addition, formalin possibly leaves toxic residues in fish flesh and in the environment, which are eventually harmful to consumers.

Owing to the increasing demand for fish, the world market farmers continue to use formalin and other chemicals to maximise the harvest efficiency of the fish, although this may be detrimental to human health.

Hence, studying the potential risks posed by formalin exposure to Nile tilapia is crucial for ensuring the sustainability and safety of aquaculture practices. Therefore, the findings from this study can inform regulatory agencies and policymakers about the potential hazards associated with formalin use in aquaculture and guide the development of regulations aimed at protecting aquatic environments and promoting sustainable aquaculture practices. Conclusively, this study will contribute to safeguarding fish welfare, environmental sustainability, and human health in the context of aquaculture activities involving formalin use. Ayuba *et al*. (2013) showed that an increased concentration of formalin in aquatic water reduces the amount of oxygen circulated and causes respiratory distress among the fishes, loss of balance, gulping for air, vertical movement of fishes, excessive accumulation of mucus and death. In view of these findings, the need to carry out a study to determine the effect of acute toxicity of formalin on tilapia becomes imperative. Moreover, no published work has been done in this regard, especially in this part of the country. This study, therefore, investigated the effect of acute toxicity of formalin on Oreochromis niloticus in the Wudil River, Kano State.

AIMS AND SPECIFIC OBJECTIVES

The objective of this study was to investigate the effect of the toxicity of formalin on Oreochromis niloticus in Wudil, Kano State, Nigeria. Specifically, it determined the effect of the following:

1. Acute toxicity of formalin on *Oreochromis niloticus*
2. Therapeutic doses of formalin on *Oreochromis niloticus*

RESEARCH METHODOLOGY

An experimental design was adopted for this study which involves two sets of experiments: determining the acute toxicity of formalin and the therapeutic effect of formalin. The method for the acute toxicity test as recommended by Yadav and Singh (2009) was employed.

The research was conducted at the fish laboratory of the Biological Science Department, Nigeria Police Academy, Wudil, Kano. The Nigerian Police Academy is located in Wudil, Kano State, Nigeria. Wudil is a local government area in Kano State in the northern part of Nigeria. It is approximately 35 kilometres southeast of Kano City, the capital of Kano State, Nigeria. Wudil is known for its agricultural activities, including farming and livestock rearing, which are vital to the local economy. The location of the Nigeria Police Academy provides a conducive environment for the academic and research activities with access to facilities and resources that support learning, training and research endeavours.

A total number of 36 tilapia juveniles (*Oreochromis niloticus*) were collected alive from River Wudil. The fish were then transported to the Department of Biological Science, Nigeria Police Academy, using plastic bowls. The fish (of average weight 11.7 g) will be acclimatised for 14 days in the Department of Biological Sciences' outdoor pond in the Biological Garden.

The experimental fish species used in this study, Oreochromis niloticus (Nile tilapia), is presented in Plate I

Plate I: Oreochromis niloticus (Nile tilapia)

During the acclimatisation period, the fish were fed twice daily (8.00 am and 4.00 pm) at 3% of their body weight with commercial feed (Coppens). No mortality is assumed to be recorded during the period of acclimatisation. Fish were not fed for 24 hours before and during the exposure period, which lasted for 6 hours.

Formalin was obtained as 40% formaldehyde. Acclimatisation test runs will be done for 6 hours to determine the concentration use for the experiment. The following concentrations were administered to each of them: 0.5, 0.1, and 1.5 mg/l and a control with 0.00 mg/l. Each concentration had 4 treatments. 3 juveniles of the specimen were randomly selected and stocked in each of the 12 plastic bowls and set for the experiment randomly. A static bioassay was then used to determine the toxicity test of formalin for *Oreochromis niloticus* juveniles.

The arrangement of the experimental tanks used for rearing Oreochromis niloticus during the bioassay is shown in Plate II.

Plate II: Experimental Tanks Used for Rearing Oreochromis niloticus

Another set of fish infested with Cichlidogyrus spp. in aquaculture habitual conditions was exposed to different concentrations of formalin, as in the first experimental setup. Observation was done to determine the concentration range that effectively treats the disease or parasite while minimising harm to the fish. Changes in appearance and mortality were recorded. The span of the research lasted 10 months. From Feb 2025 to December 2025.

All data obtained were subjected to one-way analysis of variance (ANOVA) using the Statistical Package for Social Sciences (SPSS), version 23 for Windows. Differences in means were separated using Duncan's new multiple range test (DMRT). The level of significance was determined at the P = 0.05 level of probability. The significant difference was established at a 5% probability level ($P < 0.05$), while the results generated were expressed as mean ± standard deviation (SD).

RESULTS

Mean Mortality of *Oreochromis niloticus* Exposed to Varying Concentration of Formalin.

The mean mortality of *Oreochromis niloticus* subjected to 0.5 to 1.5 concentration of formalin for the period of 1 to 6 hours were presented in table 4.1

Table 4.1: Mean mortality of *Oreochromis niloticus*

Concentration Mg/l	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours
0.0	0.00	0.00	0.00	0.00	0.00	0.00
0.5	0.00	0.00	0.00	0.33	0.33	0.67
1.0	0.00	0.33	0.33	0.00	0.67	0.33
1.5	0.00	0.67	0.33	1.00	1.00	1.33

The mean mortality of *Oreochromis niloticus* subjected to 0.5 to 1.5 concentration of formalin for the period of 1 to 6 hours shows a significant difference in the mortality of those exposed.

Table 4.2: Mean Separation of Mortality of *Oreochromis niloticus* Exposed to Different Concentrations of Formalin

Concentration (mg/L)	1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	6 Hours
0.00	0.00	-	-	-	-	-
0.50	0.00	0.33^{a}	0.00^{a}	0.66^{a}	0.66^{a}	0.66^{a}
1.00	0.00	0.00^{a}	0.33^{a}	0.33^{a}	0.66^{a}	0.33^{a}
1.50	0.00	0.66^{a}	0.33^{a}	0.33^{a}	0.66^{a}	0.00^{a}
SE	0.00	0.235	0.235	0.288	0.288	0.235
LSD	0.00	0.768	0.768	0.941	0.941	0.768

Mean values within the same column bearing the same superscript are not significantly different at $P \leq 0.05$.

Table 4.3: Physicochemical Parameters of the Experimental Setup during the 6-Hour Exposure Period

Concentration (mg/L)	pH	Temperature (°C)
0.00	6.38^{b}	26.90^{a}
0.50	6.30^{b}	26.80^{a}
1.00	6.30^{b}	26.80^{a}
1.50	6.15^{b}	26.81^{a}
SEM	0.06	0.02

Mean values within the same column bearing the same superscript are not significantly different at $P < 0.05$.

Table 4.4 Mean values of prevalence, and mean abundance of Cichlidogyrus spp. in Oreochromis niloticus for different concentrations of formalin after of the bioassay of effectiveness against prevalence (P%) and abundance

Concentration(mL L^{-1}	Prevalence (after)	Abundance After ±SD	P%	A
2.0	0	0	100	100
1.5	0	0	100	100
1.0	3.33	0.33±0.56	93.75	96.87
0.5	33.3	0.26±0.46	37.55	72.91
0.0	78.1	0.99±0.84	------	----

Table 4.4 showed that at 0.00 concentration, the prevalence and abundance rate were 78.1 and 0.99±0.84, respectively; at 0.5 concentration, the prevalence and abundance rate were 33.3 and 0.26±0.46, respectively; at 1.0, the prevalence and mortality rate were 3.33 and 0.33±0.56, respectively; and at 1.5 and 2.0, the prevalence and abundance rate were 0 and 100% effective, respectively.

DISCUSSION

The results showed that at the concentration of 0.5 mg/l, the mean values of the fish mortality were 0.00, 0.00, 0.00, 0.33, 0.33 and 0.67 mg/l. While at a concentration of 1.0, mean values of fish mortality were 0.00, 0.33, 0.33, 0.00, 0.67 and 0.33, and at a concentration of 1.5 mg/l, mean values are 0.00, 0.67, 0.33, 1.00, 1.00 and 1.33. At 0.00 concentration, there was no fish mortality at all. Formalin application at concentrations of 0.5 to 1.5 mg/l caused few fish mortalities, and all concentrations had similar effects over 1 to 6 hours. When the mean values of the mortality were subjected to the least significant difference (LSD) analysis for the mean separation, there were no statistical differences at $p < 0.05$. This implies that at the application of formalin for the concentration of 0.5 to 1.5 for the period of one to six hours, the mortality is negligible. This may be associated with the closer range of the concentration of the formalin, and the numbers of fish used for the experiment were few. These results were similar to the work carried out by Sandoval-Gio et al. (2008), which found that the effective therapeutic concentration (ETC) of formalin for treating cichlido-gyriasis in tilapia was 1.5 mg/l for 1 hour, achieving 100% effectiveness against the prevalence and abundance of the parasite. This study established an optimal margin with high sensitivity due to the closer concentration range and the small number of fish used in the experiment. Additionally, my results were similar to those reported by Fafioye (2012), which observed that the effects of formalin on fish (Oreochromis niloticus) led to changes in behaviour, causing them to become either more aggressive or more passive than usual, exhibiting erratic movement, moribundity, and gasping for air before succumbing to death. These were rapid behavioural changes.

However, my result was contrary to the work carried out. Warren (1977), who earlier reported that the introduction of a toxicant into an aquatic system may decrease the dissolved oxygen concentration no matter the concentration of the toxicant.

Findings on the therapeutic effect of formalin on fish infested with ciclidogyn spp. showed that at 0.00 concentration, the prevalence and abundance rate were 78.1% and 0.99±0.84, respectively; at 0.5 concentration, the prevalence and abundance rate were 33.3% and 0.26±0.46, respectively; at 1.0, the prevalence and mortality rate were 3.33% and 0.33±0.56, respectively; and at 1.5 and 2.0, the prevalence and abundance rate were 0 and 100% effective, respectively. The study showed that formalin has a therapeutic effect on fish infested with Cichlidogyn spp. This finding corresponds with the findings of Sandoval-Gio *et al*. (2013), who carried out research using the same concentration of formalin and discovered that there was a 100% effect of formalin on fish exposed to the same parasites. The study of Garcia-Magaria et al. (2019) on the effectiveness of sodium chloride and formalin on infected fish. Valparaíso, 47(1), 164-174. Doi:10.3856/vol47-issue1. validates the present study for discovering that formalin was also effective in controlling fish infestation.

CONCLUSION

It was therefore concluded that the use of formalin in a lesser concentration based on this study is safe for tilapia (*Oreochromis niloticus*). If the fish are exposed for 6 hours or less, it will not be toxic to Oreochromis niloticus. *Moreover*, there is effectiveness in using formalin to reduce the infestation of fish by parasites.

RECOMMENDATIONS

i. Indiscriminate use of formalin in water impoundments should be avoided, especially when the concentration is high, to preserve fish diversity.
ii. A little concentration of formalin can be used in the external treatment of fish.

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