

# Efficacy of Copper Sulphate as a Prophylactic Agent for Fungal Infection on Egg, and its Effect on Hatching and Early Growth of *Clarias gariepinus* (Burchell 1822)

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## Abstract

This study was undertaken to determine the efficacy of prophylactic treatment of North African catfish, *Clarias gariepinus* (Burchell 1822) eggs with copper sulphate ( $\text{CuSO}_4$ ) and its effect on hatch rate, survival to first feeding and growth of fry. Copper sulphate concentrations were: 2 mg L<sup>-1</sup>, 4 mg L<sup>-1</sup>, 6 mg L<sup>-1</sup>, 8 mg L<sup>-1</sup> and 10 mg L<sup>-1</sup>. The study employed two treatment methods termed “dip treatment” and “continuous treatment”. A homogeneous mass of eggs (2.4 g) from the same fertilized batch treated with either the dip or continuous method were used to determine the hatching success of the eggs. With a mean fertilization rate of 63.2% in all treatments, significant differences in the hatchability between treated eggs and the control was observed. However an increase in concentration did not affect hatch rate significantly for both methods. Eggs subjected to the dip treatment at all concentration had *Saprolegnia* growth compared to those incubated in the continuous treatment. Survival rates were significantly higher in eggs treated with concentrations above 6 mg L<sup>-1</sup> compared to the control and lower concentrations. The use of the continuous treatment for rearing fry beyond first feeding is recommended at 2 mg L<sup>-1</sup>  $\text{CuSO}_4$ ; this concentration exhibited the best growth performance and survival.

## Introduction

The North African catfish *Clarias gariepinus* (Burchell 1822) is highly appreciated as a good aquaculture species because of its resistance to disease, ability to tolerate a wide range of environmental parameters and relative fast growth rate (Goos and Richter 1996). In many parts of the world, *C. gariepinus* is firmly entrenched as one of the most important aquaculture species. With increased emphasis on fish culture in Nigeria and the advent of modern techniques, *C. gariepinus* has become even more valuable to man (AIFP 2005). It is among the most widespread freshwater fishes in Africa (Nguyen and Janssen 2002). Fingerling production and availability of quality fish feeds have been bottlenecks for development of fish farming in Nigeria for over 40 years (NSPFS 2006). Over the past several years, private sector fingerling production has increased from 3 million fingerlings per year in 2001 to more than 30 million per annum in 2006 with several large producers delivering more than 300,000 fingerlings monthly (NSPFS 2006). However, the Federal Ministry of Agriculture plans to increase fingerling production to 1.25 billion fingerlings annually beginning

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from 2013 (Nigerian Tribune 2013). Farming of the species in Nigeria is limited by problems of high mortality in fingerlings and the resulting fry scarcity. Despite the high fecundity, the hatch rates of eggs in many hatcheries in Africa are erratic, ranging from 8-70% depending on the degree of sophistication of management in the hatcheries (Macharia et al. 2005). One probable cause of erratic hatching is the parasitization of eggs. In the United States, it has been shown that unfertilized channel catfish, *Ictalurus punctatus* (Rafinesque 1818) eggs contribute to egg mortality because these eggs are easily colonized by fungus (USDA 2003). The common practice in hatcheries is to routinely control fungal infection by using anti-fungal agents (Barnes and Gaikowski 2004).

In Nigeria's aquaculture industry, fungicides used include malachite green, formalin and sodium chloride (Adeyemo et al. 2011). They are used together or separately as anti-parasite treatments against ectoparasites such as *Gyrodactylus*, *Dactylogyrus*, *Ichthyobodo*, *Trichodina*, *Chilodonella* and *Ichthyophthirius* (Adeyemo et al. 2011). Malachite green is effective for the control of ichthyophthiriasis and other protozoan parasites, but is prohibited for the treatment of eggs of herbivorous fish and tench; in some countries around the world, this prohibition generally covers food fish (Citek et al. 1998) because eggs of these fish species are very sensitive to malachite green and treatments leave the residual leucomalachite in flesh. Hence efforts are being made to find alternative chemicals for treating fish diseases. Considerable research has been undertaken on the suitability of copper sulphate ( $\text{CuSO}_4$ ) in aquaculture operations. The effectiveness of  $\text{CuSO}_4$  in controlling ichthyophthiriasis and saprolegniasis in channel catfish and other temperate fish species has been demonstrated (Straus and Tucker 1993, Schlenk et al. 1998, Straus et al. 2008a; Straus et al. 2009a). However, little is known about its use in the control of fungus in *C. gariepinus* hatcheries. Today,  $\text{CuSO}_4$  is approved as an algicide and molluscicide by the U.S. Environmental Protection Agency (EPA) but not approved by the FDA for therapeutic use in aquaculture (Straus et al. 2009b). Regulatory action on  $\text{CuSO}_4$  has been deferred pending the outcome of ongoing research at the Harry K. Dupree–Stuttgart National Aquaculture Research Center (SNARC) (Straus et al. 2009b). In light of the need to find a suitable substitute for conventionally prophylactic use in aquaculture, the present study was designed to determine the effectiveness of  $\text{CuSO}_4$  to control fungus infection in *C. gariepinus*.

## Materials and Methods

The broodstock (400-500 g) used for the present study were obtained from the research farm at the University of Agriculture in Makurdi (Benue State, Nigeria) and transferred to the north core hatchery of the University of Agriculture Makurdi where the experiment was conducted. Copper sulphate (Sigma-Aldrich Corporation, Saint Louis, Missouri, USA) solutions were prepared in five concentrations. A stock solution of  $\text{CuSO}_4$  was aliquoted into 10 L of water to give 2, 4, 6, 8 and 10  $\text{mg} \cdot \text{L}^{-1}$ . Alkalinity of the water source was determined and found to be 37  $\text{mg} \cdot \text{L}^{-1}$ , which was above the minimum of 20  $\text{mg} \cdot \text{L}^{-1}$  recommended by Masser and Jensen (1991) for the administration of  $\text{CuSO}_4$  as therapeutic agent on fish. Two treatment methods were applied: "dip treatment" which

involved spreading the eggs on an incubating raft and dipping in the appropriate water solution with each concentration for 20 sec and “continuous treatment” where the eggs were left to incubate in the CuSO<sub>4</sub> solution until hatching. The study had three replications. Fertilization of eggs was determined using the methods of Ella (1987) after which percentage fertilization was calculated.

The hatch rate was determined using a simple proportion and assuming a normal distribution of fry in water. The bowl containing the fry was stirred to create an even spread and triplicate sample of 200 mL water was collected in a conical flask. The number of fry in 200 mL was counted three times. From this, total number of fry in a litre of water was calculated.

Percent survival was determined by counting the number of live fry at first feeding and after 2 weeks of feeding, this was expressed as percent of the initially hatched fry.

Fungal infestation was not induced but it occurred naturally. Fungi infestation was verified by visual examination of the eggs for a fungal mass, after which samples were examined under a microscope for the typical mycelia and hyphal development (presumptive identification). Fungus samples from the control treatment were morphologically identified to genus via reproductive structures. After the absorption of the endogenous food, the second experiment was set up to determine the growth rate of *C. gariepinus* fry exposed to various concentrations of CuSO<sub>4</sub> for 12 days after hatching using the same concentrations. The routine weighing and cleaning of the bowls were done every 3 days; water in each bowl was renewed with the appropriate concentration of CuSO<sub>4</sub> accordingly. Three hundred fry were stocked for each concentration of CuSO<sub>4</sub> used. Fish were bulk weighed on a balance and mean weights were obtained after counting.

Growth parameters of fry were determined using the relation shown below:

- Final mean weight (mg)
- Weight gain:  $W_1 - W_0$  (mg)
- Growth rate:  $\frac{W_1 - W_0}{t}$  and
- Specific growth rate (SGR) :  $\frac{\ln W_1 - \ln W_0}{t} \times 100$

Water quality parameters (dissolved oxygen, temperature, hardness, free CO<sub>2</sub>, ammonia, sulphide and pH) were analysed using the methods of APHA (1998).

Descriptive statistics for all the treatment means was done with Minitab 14 software (Minitab Inc., State College, Pennsylvania, USA). Students t-test was used to determine differences in hatch rate and survival to first feeding between each treatment methods (dip and continuous treatments) using GraphPad Prism 5 software (GraphPad Software Inc., San Diego, California, USA). Hatch rate, survival, and growth parameters were subjected to one-way ANOVA to determine significant differences between the means in the various concentrations for the dip and continuous treatment, as well as the growth experiment.

## Results

Eggs were infested with fungi between 9-24 h of incubation in the control and in all the dip treatments. There were no visible fungi growth on dead eggs incubated in continuous treatments while those in dip treatments had observable growth (Fig. 1). Fungi were identified as *Saprolegnia spp.* Species-level determination could not be made because of lack of oogonial development. The study revealed that hatch rate was statistically similar between dip and continuous treatments across all concentrations (Table 1), but significantly higher than the control. Survival to first feeding between dip and continuous treatments was higher ( $P < 0.05$ ) in the continuous treatment for  $4 \text{ mg}\cdot\text{L}^{-1}$   $\text{CuSO}_4$  and higher when compared to the dip treatment. Dip treatments had the highest survival in the  $8 \text{ mg}\cdot\text{L}^{-1}$  (74.7%) and  $10 \text{ mg}\cdot\text{L}^{-1}$  (82.64%)  $\text{CuSO}_4$  concentrations while the lowest survival was observed in the  $0 \text{ mg}\cdot\text{L}^{-1}$  (33.3%) treatment. Continuous treatments with concentrations above  $4 \text{ mg}\cdot\text{L}^{-1}$   $\text{CuSO}_4$  had similar survival, but differed from the values observed for the  $0 \text{ mg}\cdot\text{L}^{-1}$  and  $2 \text{ mg}\cdot\text{L}^{-1}$  ( $P < 0.05$ )  $\text{CuSO}_4$  treatments (Table 2). Ranges of water quality parameters in the dip treatment during incubation and rearing to first feeding include: free  $\text{CO}_2$ :  $3.5 \text{ mg}\cdot\text{L}^{-1}$  to  $6.5 \text{ mg}\cdot\text{L}^{-1}$ , pH: 6.7 to 7.4,  $\text{NH}_3$ :  $0.3 \text{ mg}\cdot\text{L}^{-1}$  to  $0.7 \text{ mg}\cdot\text{L}^{-1}$ , hardness:  $53.0 \text{ mg}\cdot\text{L}^{-1}$  to  $59.5 \text{ mg}\cdot\text{L}^{-1}$ ,  $\text{SO}_3$ :  $0.04 \text{ mg}\cdot\text{L}^{-1}$  to  $0.12 \text{ mg}\cdot\text{L}^{-1}$ , dissolved oxygen:  $5.5 \text{ mg}\cdot\text{L}^{-1}$  to  $6.2 \text{ mg}\cdot\text{L}^{-1}$  and temperature:  $25.7^\circ\text{C}$  to  $26.5^\circ\text{C}$ . In the continuous treatment during egg incubation and rearing to first feeding, water quality parameter ranges were: free  $\text{CO}_2$ :  $4.3 \text{ mg}\cdot\text{L}^{-1}$  to  $5.2 \text{ mg}\cdot\text{L}^{-1}$ , pH: 6.4 to 7.2,  $\text{NH}_3$ :  $0.2 \text{ mg}\cdot\text{L}^{-1}$  to  $0.4 \text{ mg}\cdot\text{L}^{-1}$ , hardness:  $46.5 \text{ mg}\cdot\text{L}^{-1}$  to  $53.5 \text{ mg}\cdot\text{L}^{-1}$ ,  $\text{SO}_3$ :  $0.005 \text{ mg}\cdot\text{L}^{-1}$  to  $0.15 \text{ mg}\cdot\text{L}^{-1}$ , dissolved oxygen:  $5.4 \text{ mg}\cdot\text{L}^{-1}$  to  $6.0 \text{ mg}\cdot\text{L}^{-1}$  and temperature:  $25.5^\circ\text{C}$  to  $25.95^\circ\text{C}$ . Growth and survival of *C. gariepinus* fry raised for 12 days in the continuous treatment at different concentrations are presented in Table 3 and reveals that mean final weight (MFW) ranged from  $23.0 \pm 0.1 \text{ mg}$  ( $10 \text{ mg}\cdot\text{L}^{-1}$ ) to  $38.4 \pm 0.6 \text{ mg}$  ( $2 \text{ mg}\cdot\text{L}^{-1}$ ) with significant differences between the concentrations ( $P < 0.05$ ). The general trend in growth reveals that fry raised in the control ( $0 \text{ mg}\cdot\text{L}^{-1}$ ) were significantly larger than those exposed to  $8 \text{ mg}\cdot\text{L}^{-1}$  and  $10 \text{ mg}\cdot\text{L}^{-1}$  and were statistically similar with those exposed to  $4 \text{ mg}\cdot\text{L}^{-1}$  and  $6 \text{ mg}\cdot\text{L}^{-1}$ . However, fry raised in  $2 \text{ mg}\cdot\text{L}^{-1}$  had the best growth. Percent survival decreased as the level of concentration of  $\text{CuSO}_4$  increased and the highest value of 60.1% was observed at the lowest concentration of  $\text{CuSO}_4$  ( $2 \text{ mg}\cdot\text{L}^{-1}$ ) while the lowest survival recorded was 19.8% for the control. Water quality was also monitored and ranges were: free  $\text{CO}_2$ :  $3.7 \text{ mg}\cdot\text{L}^{-1}$  to  $4.2 \text{ mg}\cdot\text{L}^{-1}$ , pH: 6.6 to 7.3,  $\text{NH}_3$ :  $0.4 \text{ mg}\cdot\text{L}^{-1}$  to  $0.8 \text{ mg}\cdot\text{L}^{-1}$ , hardness:  $46.0 \text{ mg}\cdot\text{L}^{-1}$  to  $51.0 \text{ mg}\cdot\text{L}^{-1}$ ,  $\text{SO}_3$ :  $0.015 \text{ mg}\cdot\text{L}^{-1}$  to  $0.11 \text{ mg}\cdot\text{L}^{-1}$ , dissolved oxygen:  $5.5 \text{ mg}\cdot\text{L}^{-1}$  to  $6.7 \text{ mg}\cdot\text{L}^{-1}$  and temperature:  $25.8^\circ\text{C}$  to  $26.5^\circ\text{C}$ .

**Table 1.** Hatch rate and survival to first feeding (comparison between dip and continuous treatments).

Treatment	% Hatch			% Survival to 1 <sup>st</sup> feeding		
	Dip	Continuous	P-Value	Dip	Continuous	P-Value
2 mgL <sup>-1</sup>	59.7 ± 1.4	67.5 ± 12.3	0.7125	44.3 ± 9.7	54.8 ± 7.9	0.4862
4 mgL <sup>-1</sup>	59.3 ± 5.4	53.1 ± 1.5	0.3864	50.0 ± 1.9	97.8 ± 2.2	0.0038**
6 mgL <sup>-1</sup>	53.4 ± 1.0	53.9 ± 1.8	0.5101	60.8 ± 13.3	92.9 ± 23.1	0.0361*
8 mgL <sup>-1</sup>	53.1 ± 0.5	61.3 ± 2.1	0.0604	74.7 ± 1.5	99.4 ± 0.2	0.027*
10 mgL <sup>-1</sup>	54.9 ± 3.6	52.5 ± 1.7	0.1961	82.6 ± 6.3	96.9 ± 2.1	0.05*

\*Student T-test significant at P&lt;0.05

\*\* Student T-test significant at P&lt;0.01

**Table 2.** Hatch rate and survival to first feeding (comparison among concentrations for dip and continuous treatments).

Treatment	Dip treatment		Continuous treatment	
	% Hatch	% Survival	% Hatch	% Survival
0 mg l <sup>-1</sup>	42.1 ± 1.5 <sup>b</sup>	33.3 ± 1.8 <sup>c</sup>	38.1 ± 1.5 <sup>b</sup>	33.3 ± 1.8 <sup>b</sup>
2 mg l <sup>-1</sup>	59.7 ± 1.4 <sup>a</sup>	44.3 ± 9.7 <sup>bc</sup>	67.5 ± 12.3 <sup>a</sup>	54.8 ± 7.9 <sup>b</sup>
4 mg l <sup>-1</sup>	59.3 ± 5.4 <sup>a</sup>	50.0 ± 1.9 <sup>bc</sup>	53.1 ± 1.5 <sup>a</sup>	97.8 ± 2.2 <sup>a</sup>
6 mg l <sup>-1</sup>	53.4 ± 1.0 <sup>a</sup>	60.8 ± 13.3 <sup>ab</sup>	53.9 ± 1.8 <sup>a</sup>	72.9 ± 23.1 <sup>a</sup>
8 mg l <sup>-1</sup>	53.1 ± 0.5 <sup>a</sup>	74.7 ± 1.5 <sup>a</sup>	61.3 ± 2.1 <sup>a</sup>	99.4 ± 0.2 <sup>a</sup>
10 mg l <sup>-1</sup>	54.9 ± 3.6 <sup>a</sup>	82.6 ± 6.3 <sup>a</sup>	52.5 ± 1.7 <sup>a</sup>	96.9 ± 2.1 <sup>a</sup>

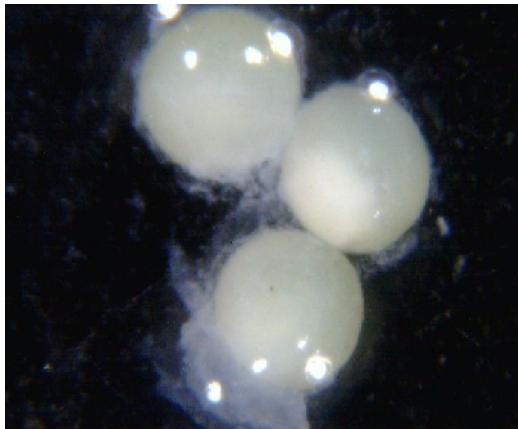
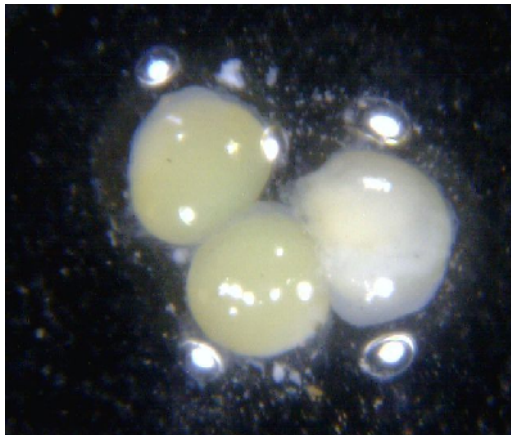
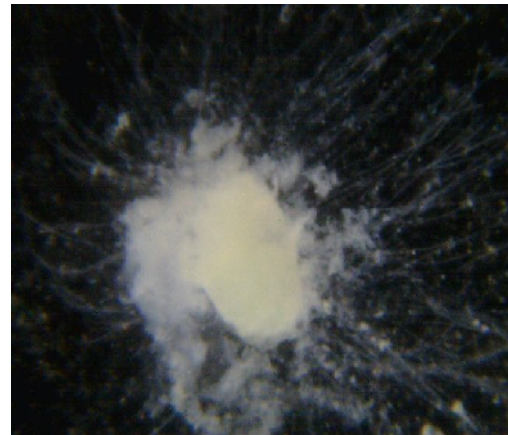
Means in the same column with different superscripts differ significantly (P&lt;0.05).

**Table 3.** Growth and survival of *C. gariepinus* fry in the continuous treatment with different concentrations of CuSO<sub>4</sub> for 12 days.

Treatment	MIW (mg)	MFW (mg)	MWG (mg)	SGR	% Survival
0 mg l <sup>-1</sup>	9.1 ± 0.1	33.5 ± 0.1 <sup>b</sup>	24.3 ± 0.3 <sup>b</sup>	10.8 ± 0.2 <sup>b</sup>	19.8 ± 0.2 <sup>d</sup>
2 mg l <sup>-1</sup>	9.2 ± 0.2	38.4 ± 0.6 <sup>a</sup>	29.3 ± 0.5 <sup>a</sup>	12.0 ± 0.0 <sup>a</sup>	60.1 ± 0.1 <sup>a</sup>
4 mg l <sup>-1</sup>	9.3 ± 0.1	31.7 ± 0.7 <sup>b</sup>	22.4 ± 0.7 <sup>b</sup>	10.2 ± 0.0 <sup>b</sup>	58.8 ± 0.8 <sup>a</sup>
6 mg l <sup>-1</sup>	9.1 ± 0.1	32.1 ± 0.1 <sup>b</sup>	23.0 ± 0.2 <sup>b</sup>	10.5 ± 0.1 <sup>b</sup>	53.6 ± 0.6 <sup>b</sup>
8 mg l <sup>-1</sup>	9.3 ± 0.1	24.4 ± 0.1 <sup>c</sup>	15.3 ± 0.0 <sup>c</sup>	8.2 ± 0.1 <sup>c</sup>	40.1 ± 0.1 <sup>c</sup>
10 mg l <sup>-1</sup>	9.1 ± 0.1	23.0 ± 0.1 <sup>d</sup>	13.7 ± 0.0 <sup>d</sup>	7.5 ± 0.1 <sup>d</sup>	40.2 ± 0.2 <sup>c</sup>

(MIW= Mean Initial Weight, MFW= Mean Final Weight, MWG= Mean Weight Gain, SGR= Specific Growth Rate).

Means in the same column of treatments followed by different superscripts differ significantly (P&lt;0.05).

Continuous treatment, 2 mgL<sup>-1</sup>Dip treatment, 2 mgL<sup>-1</sup>Continuous treatment, 4 mgL<sup>-1</sup>Dip treatment, 4 mgL<sup>-1</sup>Continuous treatment, 10 mgL<sup>-1</sup>Dip treatment, 10 mgL<sup>-1</sup>

**Fig. 1.** Unfertilized *Clarias gariepinus* eggs at 72 hours treated continuously or by dip with CuSO<sub>4</sub>.

## Discussion

Fungus samples from this study were identified morphologically as *Saprolegnia* spp. Common genera implicated in saprolegniasis are mainly *Saprolegnia* spp. and *Achlya* spp (Tucker and Robinson 1990; Noga 1996; Hawke and Khoo 2004). *Aphanomyces* spp. was however reported by Straus et al. (2009b), hence suggesting that species of fungus causing saprolegniasis on catfish eggs are more diverse and probably are defined by locality and other environmental factors. Despite Fig.1 elucidating the effectiveness of the continuous use method of  $\text{CuSO}_4$  in the control of *Saprolegnia* spp. growth on eggs during incubation, it was observed that hatch rate was statistically similar between dip and continuous treatment methods and across all concentrations for both methods, but significantly differed from the control. However, survival to first feeding was statistically higher in the  $4 \text{ mg}\cdot\text{L}^{-1}$  continuous treatment and higher concentrations compared to the dip treatment (Table 1).

Differences in fungal susceptibility and other non fungal pathogens (i.e., bacteria, ciliates, etc.) probably caused by the application of the different treatments may have led to differences in survival recorded in both treatments across the concentration (Straus et al. 2009a). The mean egg survival in the US catfish industry has been estimated to be approximately 60% (Wolters 2001) when along with other best management practices, formalin and iodine are used as needed to control fungal infections. The present study confirms this with hatch rates between 53.1-67.5% in all treatments administered with copper sulphate. A  $10 \text{ mg}\cdot\text{L}^{-1}$   $\text{CuSO}_4$  concentration was recommended for sufficient fungi control on eggs of channel catfish *I. punctatus* by Straus et al. (2009b); a survival rate of 67.4% was reported for hatched fry in the  $\text{CuSO}_4$ -treated eggs while severe fungal growth in the control treatments resulted in 8% survival. Mitchell et al. (2010) demonstrated the effectiveness of  $\text{CuSO}_4$  in the control of fungi as lesser film of fungal growth (2.9 cm) was reported on eggs treated in  $10 \text{ mg}\cdot\text{L}^{-1}$   $\text{CuSO}_4$  compared to 7.2 cm coverage of fungi observed in the control. Akpoilih and Adebayo (2010) also reported a similar trend with formalin in preventing fungal growth on eggs. Copper sulphate is usually administered daily during the egg incubation period of channel catfish (USDA 2003; Steeby and Avery 2005) until the eggs become “eyed” (eye pigment is first seen in the embryos). However with appreciable mortality rates recorded in the present study, copper sulphate can be used continuously to ensure optimum production of cultured *C. gariepinus* (Teugels 1986). Straus et al. (2009b) reported that numerous unfertilized eggs contributed greatly to fungal development and consequently mortalities as they provide a suitable substrate for fungus to grow. The present study observed statistically similar hatching rates and consequently the same dead egg proportion resulting from a statistically similar fertilization rate, the difference in the results obtained for survival must have been due to the effectiveness of the prophylactic application of the copper sulphate at different levels. Though hatch rate among both methods and treatment concentration did not differ, the 20 second dip treatment did not prevent the growth of fungi. According to Straus et al. (2009a), *Saprolegnia* spp. are present in most water sources. The usual egg/fry management practices of refreshing the water quality through water dilution with fresh water during the incubation and rearing to first feeding under static method of fish breeding would have led to re-inoculation of the experimental units with new fungi spores from the fresh water. However, this

was not the case with the continuous treatment as the  $\text{CuSO}_4$  concentrations were added at every water change.

Reports of prophylactic administration for other commonly used chemicals are highly varied according to species administered and stage of development. Mbaru et al. (2011) suggested the use of formalin for 15 min bath dip at  $500 \text{ mg}\cdot\text{L}^{-1}$  for yolk sac fry, and for 15 min at  $600 \text{ mg}\cdot\text{L}^{-1}$  for free-swimming fry to reduce fungal and parasitic outbreaks. Martin (1968) recommended the use of  $1 \text{ mg}\cdot\text{L}^{-1}$  malachite green dip for 5 min to control *Saprolegnia parasitica* (Coker 1923) in fish and fish eggs. For the treatment of carp eggs infected with *Saprolegnia* spp., a 1 h treatment in a malachite green bath at  $4\text{-}5 \text{ mg}\cdot\text{L}^{-1}$  proved effective (Citek et al. 1998). Fish egg treatments with concentrations of  $5\text{-}10 \text{ mg}\cdot\text{L}^{-1}$  were recommended in the Czech Republic to be applied for 5–30 min, once or twice daily, or twice weekly (Citek et al. 1998). However the present study has demonstrated that continuous exposure of African catfish eggs to up to  $10 \text{ mg}\cdot\text{L}^{-1}$   $\text{CuSO}_4$  for 24 h and hatched fry for 3 days significantly increased the hatch rate, the effectiveness of fungal control and caused appreciable survival of larvae to first feeding. Meyer and Jorgenson (1983) reported that a malachite green bath treatment of rainbow trout eggs delayed the time of sack-fry hatching by 5 to 8 days compared with controls. Furthermore, they observed that treated eggs exhibited an increased frequency of abnormalities (malformation of the head and jaws, spine deformation or missing fins). The present study observed neither delay in incubation and hatching period (though the African catfish have a considerably shorter hatching period of 24 h compared to the rainbow trout) nor deformity in hatched larvae; hence this compound may be considered better than malachite green. Straus (2008b) reported that treatments of channel catfish eggs with copper sulphate was stopped at the eyed stage because embryos within the same rearing unit may be hatching and the doses of the chemical is toxic to the fry. Hence, differences in the sensitivity of larvae of the different species to Cu toxicity may have led to higher survival of the African catfish even in the continuous exposure method.

The mean water quality parameters obtained in the present study indicated fouling in the dip treatment with an elevated level of ammonia differing significantly among the concentrations compared to the continuous treatment. The level of  $\text{NH}_3$  observed in this study was at a range of  $0\text{-}2 \text{ mg}\cdot\text{L}^{-1}$  which is not detrimental to tropical fish (Stone and Thomforde 2004). Results obtained for water quality in the continuous treatment were similar to the findings of Akpoilih and Adebayo (2010) who reported a decrease in DO as the concentration of  $\text{CuSO}_4$  increases. This decrease may be due to complete eradication of photosynthetic activity as a result of the copper sulphate therapeutic effect on non-target microscopic flora in the water.

Growth performance of fry showed that  $2 \text{ mg}\cdot\text{L}^{-1}$   $\text{CuSO}_4$  is the best concentration for raising fry for 2 weeks after first feeding. Beyond this level mortality increased while growth decreased.



## Conclusion

The present study provides base line information on the prophylactic use of CuSO<sub>4</sub> in hatchery production of *C. gariepinus*. The study has not only indicated the suitability of CuSO<sub>4</sub> for prophylactic use in aquaculture but suggested continuous exposure as a better treatment procedure for increased hatch rate, growth and survival of eggs and fry. However, efforts should be intensified to further study the best use of CuSO<sub>4</sub> on a long-term basis and considerable attention should be focused on possible long-term residual effects.

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