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Original Article

Anaesthetic effects of different concentrations of sodium bicarbonate on common carp (*Cyprinus carpio*)

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Abstract
Sedation of fish before handling and transporting can help curtail undue stress that can affect their health. This study investigated the effectiveness of sodium bicarbonate ($NaHCO_3$) utilised as an anaesthetic agent for common carp (*Cyprinus carpio*) with an average weight of 13.5 ± 0.55 g. The experimental fish were grouped and exposed to different concentrations at 0, 40, 45 and 50 g L^{-1} of $NaHCO_3$ dissolved in water. Fishes were bath-immersed in different concentrations of $NaHCO_3$ solution until such time that they became anesthetised. Results showed that induction time and recovery time increases with increasing $NaHCO_3$ concentration. All fish reached complete anaesthesia in more than 3 minutes under a higher concentration of 50 g L^{-1}. No mortality occurred under any of the concentrations tested. The most optimal concentration leading to complete anaesthesia in 2 minutes and recovery in less than 4 minutes was 45 g L^{-1}. This study showed that $NaHCO_3$ is a potential fish anaesthetic for the common carp.

Keywords: baking soda; common carp; *Cyprinus carpio*; dish anaesthetic; sodium bicarbonate

1 | INTRODUCTION

An anaesthetic is a chemical or herbal substance that can cause reversible loss of consciousness or perception (Hasimuna *et al.* 2019). Handling and transportation, in particular, can cause stress in fish, which can have a negative impact on the animal's health. In aquaculture, the use of anaesthetic reduces stress from handling and transportation, as well as when fish are marked, tagged and sampled for weight and length parameters and can sometimes lead to stock mortality. Some common anaesthetics used in fish include clove oil (Masoumeh and Masuomeh 2018), sodium bicarbonate (Altun *et al.* 2009; Avillanosa *et al.* 2019; Hasimuna *et al.* 2019), benzocaine (Bolasina *et al.* 2017), 2-phenoxyethanol (Varkey and Sajeevan 2014), tricaine methanesulfonate or MS-222 and quinaldine (Ramlochnsingh *et al.* 2014; Shokr and Fathy 2018).

The MS-222 is the only chemical anaesthetic approved by the Food and Drug Administration for temporary immobilisation of fish, amphibians and other aquatic, cold-blooded animals (FDA 2022) and the most commonly used anaesthetic substance in aquaculture because induction can take as little as 15 seconds (Coyle *et al.* 2004), but is relatively expensive (Popovic *et al.* 2012; Bolasina *et al.* 2017). The anaesthetic used in aquaculture should be safe, inexpensive and widely available (Velisek *et al.* 2007). Sodium bicarbonate, also known as baking soda, is white, has the chemical formula $NaHCO_3$, dissolves easily in water, emits carbon dioxide and is widely available on the market. The carbon dioxide produced by the dissolu-

tion of baking soda powder can sedate fish for transportation, and carbon dioxide is classified as an anaesthetic for both cold and warm water fishes (Bowser 2001).

Rainbow trout *Oncorhynchus mykiss* (Keene *et al.* 1998), African catfish *Clarias gariepinus* (Githukia *et al.* 2016), common carp *C. carpio* (Altun *et al.* 2009), grass carp *Ctenopharyngodon idella* (Masoumeh and Masoumeh 2018) and various species of tilapia have all been successfully anesthetised with MS-222 (Opiyo *et al.* 2013; Hasimuna *et al.* 2019). Several researches have already been carried out to establish the efficiency of sodium bicarbonate in various fish species. However, there are currently no published studies on the utility of sodium bicarbonate in the Philippines. As a result, the study was carried out to add to the existing data on the effectiveness of various sodium bicarbonate concentrations on common carp (*C. carpio*, L. 1758).

2 | METHODOLOGY

2.1 Water quality

Before adding baking soda to the experimental container, various water quality parameters such as temperature and dissolved oxygen were measured using a multi-parameter water quality meter (model: YSI 550A, USA) and pH by a digital pH meter to ensure that the parameters were within the optimal range for fish (Freshwater-Aquaculture 2019; Table 1).

TABLE 1 Mean water quality parameters in the experimental container.

Water quality parameter	Baking soda concentration (g)				Optimal range
	0	40	45	50	
Temperature (°C)	27.4 ± 0.05	27.6 ± 0.19	27.4 ± 0.09	27.3 ± 0.00	18–26
pH	7.2 ± 0.08	7.2 ± 0.21	7.2 ± 0.12	7.2 ± 0.05	6.1–8.0
Dissolve oxygen (mg L^{-1})	3.3 ± 0.05	3.3 ± 0.05	3.5 ± 0.12	3.5 ± 0.02	3.0–10

2.2 Experimental fish

A total of sixty (60) individuals of common carp fingerling with an average weight of 13.5 ± 0.55 g were obtained from the Wet Laboratory of the College of Fisheries (CF), Central Luzon State University (CLSU). The experimental fish individuals were conditioned for five days and fed twice daily with commercial feed before being starved for 24 hours on the sixth day prior to the experiment to optimise the fish for experimental conditions.

2.3 Experimental designs

The experiment was carried out in the College of Fisheries' Wet Laboratory at CLSU in a 12-piece plastic container with a volume capacity of 6-L. The experimental treatments were different concentrations of sodium bicarbonate at 0 (control), 40, 45 and 50 g L^{-1} for treatments 2, 3, and 4, with 3 replications respectively.

2.4 Experimental procedures

To determine the effective dose of sodium bicarbonate, five fingerlings of common carp were immersed in a bath of various concentrations in a 6-L plastic container. Different concentrations of sodium bicarbonate were added to the twelve plastic containers and thoroughly mixed with water until the powder was completely dissolved.

The experimental fish were observed during the three stages of induction and recovery as well as their behaviour during each stage as described by Iwama *et al.* (1989) and Palic *et al*. (2006) (Table 2). Following anaesthesia, fish individuals were removed from the anaesthetic solution and transferred to a 12-piece plastic container containing clean water for recovery. The time of anaesthesia induction and recovery was recorded and the fish were kept in there for 48 hours to observe their behaviour and potential mortality.

TABLE 2 Stages of induction and recovery considered in the present study (after Iwama *et al.* 1989; Palic *et al.* 2006).

Stages	Description
Stages of induction	
I	Loss of equilibrium
II	Loss of gross body movements but continued opercula movement
III	Same as stage II but opercula movement ceases
Stages of recovery	
I	No body movement but opercula movement starts
II	Regular opercula movements and body movements start
III	Equilibrium regained with pre-anaesthetic appearance

2.5 Data analysis

Data were analysed using the Analysis of Variance (ANOVA) for complete randomised design and Duncan's multiple range test if significant difference among the treatment means was recorded.

3 | RESULTS

The time it took for common carp to go into full anaesthesia or lose consciousness varied depending on the concentration of sodium bicarbonate used. Table 3 shows the induction and recovery times for each concentration. The induction time ranges from 2.22 ± 0.03 to 3.57 ± 0.01 minutes. The highest induction time was observed in sodium bicarbonate concentrations of 50 g L^{-1}, followed by 40 g L^{-1} and 45 g L^{-1} concentration containing treatments. There was no induction by the control concentration of 0 g L^{-1}. There were significant differences among concentrations ($p < 0.05$).

TABLE 3 Induction and recovery time of common carp at different concentrations of sodium bicarbonate.

Sodium bicarbonate concentration (g L^{-1})	Induction time (min)	Recovery time (min)
0	-	-
40	2.49 ± 0.03b	3.49 ± 0.02[a]
45	2.22 ± 0.03[a]	3.57 ± 0.04[b]
50	3.57 ± 0.01[c]	4.18 ± 0.03[c]

The recovery time ranged from 3.49 ± 2 to 4.18 ± 3 minutes. The fastest recorded recovery time was recorded at 50 g L^{-1} concentration, followed by sodium bicarbonate concentration of 45 g L^{-1} and 40 g L^{-1}. Significant differences among concentrations ($p < 0.05$) was recorded for recovery time. This study discovered that as the concentration of sodium bicarbonate increased, so did the recovery time.

Following the experiment, all fish exposed to sodium bicarbonate anaesthetic displayed normal swimming and feeding behaviour on the first day of observation. After three days of post-anaesthesia observation, no mortality was observed in any of the fish exposed to different concentrations of sodium bicarbonate.

4 | DISCUSSION

The study found that sodium bicarbonate could be used as a potential anaesthetic for common carp. It has been established that an anaesthetic with an induction time of less than 3 minutes and a recovery time of less than 5 minutes is suitable for fish handling (Marking and Meyer 1985; Hseu *et al.* 1998; Ross and Ross 1999; King *et al.* 2005). Anaesthesia is essential to modern aquaculture. It lessens stress, which increases the fish's susceptibility to diseases as a result of handling resistance (Ross and Ross 1999; Githukia *et al.* 2016; Hasimuna *et al.* 2019; Avillanosa *et al.* 2019; Park 2019).

Findings of this study support the use of sodium bicarbonate as an alternate anaesthetic for common carp, with an acceptable induction time ranging from 2 to almost 4 minutes, depending on the level of concentration. For fish exposed to sodium bicarbonate of 40 and 45 g L^{-1}, the experimental fish with an average weight of 13.5 ± 0.55 g achieved full anaesthesia in less than 3 minutes, whereas the induction time was more than 3 minutes for fish exposed to a concentration of 50 g L^{-1}. It also obtained a longer recovery time compared to the other two concentrations with a much shorter recovery time.

The shorter induction time at concentration of 40 and 45 g L^{-1} sodium bicarbonate with less than 3 minutes suggest that low concentrations of sodium bicarbonates may have easily diffused into the internal systems of treated fishes, resulting in a faster or shorter recovery period. This observation may be consistent with the findings of King *et al.* (2005) with black sea bass (*Centropritis striata*), in which higher concentrations of clove oil resulted in a shorter induction time but a longer recovery time. This is also consistent with the results of several others who discovered that higher concentrations of sodium bicarbonate resulted in faster anaesthesia in Nile tilapia (Opiyo *et al.* 2013), common carp (Altun *et al.* 2009) and African catfish (Githukia *et al.* 2016).

Githukia *et al.* (2016) have recorded effects of similar concentration of sodium bicarbonate (40 and 50 g L^{-1}) on African catfish (*C. gariepinus*) with an average weight of 10 g. Individuals had an induction time of less than 1 minute which is much shorter than the induction time observed in the present study. This could be explained by the fact that smaller fish have a higher surface area to volume ratio than larger fish and thus absorb anaesthetic more quickly (Githukia *et al.* 2016; Fernandes *et al.* 2017; Park *et al.* 2019). Induction time in the present study agrees with several authors who recommended a period of 3 – 5 minutes for an effective induction time to anaesthesia (Marking and Meyer 1985; Iversen *et al.* 2003, Coyle *et al.* 2004; Mylonas *et al.* 2005; Opiyo *et al.* 2013; Githukia *et al.* 2016).

The recovery time of common carps in the present study ranged from 3.49 to 4.18 minutes. The recovery time from anaesthesia was significantly affected by different anaesthetic concentrations. Common carp fingerlings exposed to 50 g L^{-1} anaesthetic solutions recovered from anaesthesia more slowly than those exposed to 40 and 45 g L^{-1} anaesthetic solutions. The findings of this study are comparable to those of previous studies (e.g. Githukia *et al.* 2016; Avillanosa *et al.* 2019; Hasimuna *et al.* 2021) those showed higher concentrations of anaesthetic were absorbed and accumulated in the central nervous system (CNS) of the fish, rendering CNS activity to a greater degree than lower concentrations and thus prolonging recovery time. Higher anaesthetic concentrations increase recovery time in pike (Zaikov *et al.* 2008), common carp juveniles (Altun *et al.* 2009), Nile tilapia juveniles (Opiyo *et al.* 2013) and African catfish (Githukia *et al.* 2016).

The size of the fish may have an effect on the induction and recovery time of common carp. The smaller common carp (13.5 ± 0.55 g) used in this study resulted in a much shorter induction and recovery time. This finding may be consistent with Githukia *et al*. (2016) where smaller juveniles of African catfish reached full anaesthesia much faster than bigger juveniles. This could also be related to the fact that larger fish have a smaller surface area to volume ratio than smaller fish, as reported in various studies (e.g. Yildiz *et al.* 2013; Githukia *et al.* 2016; Hasimuna *et al.* 2021). However, in contrast to Tsantilas *et al.* (2006) findings where larger (60 g) white sea bream (*Diplodus sargus*) reached full anaesthesia much faster than smaller (30 g) when the fish was exposed to 2-phenoxyethanol. The 45 g L^{-1} concentration of sodium bicarbonate was found to be the most optimal concentra-

tion for induction and recovery time in common carp. Biological factors such as body weight, age, sex as well environmental factors such as salinity, pH, oxygen level and water temperature can be an influence to the dosage regimes among species (Ross and Ross 2008; Zahl *et al.* 2010; Kristan *et al.* 2014; Skar *et al.* 2017).

When used in short-term handling, sodium bicarbonate can be an effective anaesthetic for common carp and can serve as a cheap, alternative fish anaesthetic agent to the commercial, but expensive, MS-222. There was also no mortality observed when fish were exposed to different concentrations of sodium bicarbonate in this study. Following treatment with sodium bicarbonates, common carp were found to be back to their normal swimming and feeding behaviour. These manifestations have demonstrated that sodium bicarbonate, used as a carp anaesthetic, is both safe and effective.

CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHORS' CONTRIBUTION

Both authors have equal contribution.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on a reasonable request from the corresponding author.

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