EFFECT OF WATER PHYSICOCHEMICAL VARIATIONS ON THE BREEDING PERFORMANCE OF AFRICAN CATFISH (*C. gareipinus*) IN EBONYI STATE

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ABSTRACT

This study investigated the effects of physicochemical parameters of four different water sources on hatchability, growth and survival of *Clarias gariepinus* larvae. The water sources used were: rain water (T1), borehole water (T2), river water (T3) and well water (T4). The study entailed artificial induced breeding of *C. gariepinus* using the aforementioned water sources as incubation media. Vital water physicochemical parameters assessed were temperature, pH, dissolved oxygen and ammonia, conductivity and total hardness. Hatchability rate was estimated 24 hours after incubation whereas larval survival rate was determined at yolk-sac fry stage which is 4 days' post hatching. Data from the experiment were subjected to one-way analysis of variance (ANOVA) at ($P<0.05$) significance level. At the end of the experiment, results obtained for water physicochemical parameters in the four water treatments for conductivity and total hardness were significantly different ($P<0.05$). Rain water (T1) recorded a low mean conductivity value of 24.3±0.88 μS^{cm} and low mean total hardness value of 3.33±0.3 mg^{l}. Percentage hatchability in all treatments was relatively high with the highest mean value of 93.1±1.60 % obtained in T1. Fry survival rate at 4 days post hatching was comparatively above average with the highest mean value of 63.7±2.41 % recorded in T2 while T1 recorded the lowest mean value of 44.2±0.55 %. Also yolk-sac fry in T2 recorded the highest mean weight of 0.2165g. This study has shown that borehole water (T2) is the most suitable water physicochemical parameters for breeding and survival of *C. gariepinus* fry.

Keywords: Water quality, Hatching, Artificial propagation, Fish seed, Water hardness

INTRODUCTION

Fish farming is acknowledged universally as a method of expanding the production of fish and fish products. That is why the venture has been expanding at a pace that surpassed that of artisanal fisheries as well as livestock production (FAO, 2020). Fish has become an essential food item. It is also a source of revenue, jobs and leisure for the community. Both humans and livestock in developed and developing nations greatly depend on fish and fish products for their protein supply. The importance of fish food and its high protein content underscores the need for its abundant supply. Human beings will be healthy if sufficient supply of fish protein in right quantities is made available in their diets (Adebayo, 2018). Ozigbo *et al*. (2014); Alabi & Ocholi (2019) asserts that fish farming if effectively managed, has the potential of improving Nigeria's gross domestic product (GDP) as well as resolving the problem of redundancy among our youth population.

Physicochemical parameters of water are extremely essential to the growth and survival of organisms that inhabit the water bodies. They play important roles in the physiological development, reproduction and general well-being of aquatic organisms such as fish (Ukwe and Abu, 2016). In aquaculture, it is always an excellent practice to use a reliable source of water during breeding operations. This is because physicochemical characteristics of water are known to influence fish breeding performance in positive and negative ways (Akombo *et al*., 2018). Hence, the success of every fish breeding venture is reliant on the quality of water on hand in the hatchery. Fertilization, hatching and early survival of larvae are crucial for successful propagation of the African catfishes. Optimum hatchability of eggs and survival of hatchlings are equally dependent on good water quality (Ataguba *et al*., 2009).

A number of hatcheries are challenged with some operational difficulties such as low hatchability and low survival rates (Kareem *et al*., 2017). These drawbacks are linked to water quality in the hatchery system (Akinwole *et al*., 2006). According to Uka and Kalu, (2019) water quality is the physical, chemical and biological constituents of water. A good water quality for fish culture ought to satisfy the minimum conditions for reproduction, survival and growth of cultivable fish species. Optimal fish production to a very large extent is absolutely dependent on the physical, chemical and biological qualities of water (Bhatnagar and Devi, 2019). Hence, successful hatchery operations require an understanding of water quality. However, it is apparent that, poor water quality in hatcheries may cause low survival of eggs, larvae or fry (Summerfelt, 1998).

JUSTIFICATION OF THE STUDY

In Ebonyi State, South Eastern Nigeria there has been reports of breeding failures and high larval mortalities during breeding operations. This crisis of larval mortalities during early stages of breeding had been documented, with water quality being the major causative factor (Awoke *et al.,* 2021). According to Opoke and Osayande, (2018) the quality of surface and ground waters in Ebonyi state has been compromised due to its hardness. This has been attributed to the occurrence of mineral deposits and heavy metal ores under the ground (Nwabunike, 2016). This therefore leads to variability of common sources of water in the region for successful aquaculture. It therefore became imperative to ascertain the physicochemical properties of commonly available sources of water in the area to ascertain its suitability for fish breeding. As posited by Bhatnagar and Devi, (2019) the determination of physicochemical characteristics of water is essential for assessing the suitability of water for various purposes like drinking, domestic, aquaculture and irrigation.

For that reason, a complete study on the physicochemical properties of common sources of water available to local fish farmers in Ebonyi state is imperative to determine its suitability for breeding operations. It is thus believed that the result of this research work will help solve the perennial problem of breeding failures and boost the production of *C. gariepinus* fingerlings particularly in Ebonyi state and Nigeria generally.

OBJECTIVES OF THE STUDY

The major objective of this investigation is to compare breeding performance of *C. gariepinus* artificially propagated in rain water, borehole water, river water and well water from Abakaliki metropolis.

Specifically, the study intends to:

1. Compare the best physicochemical properties of the water sources and determine the one that yielded the best result.
2. Compare the fertility rate of *C. gariepinus* spawned and reared in rain water, borehole water, river water and well water.
3. Determine the hatchability rate of *C. gariepinus* spawned and reared in rain water, borehole water, river water and well water.
4. Compare the survival rate of *C. gariepinus* spawned and reared in rain water, borehole water, river water and well water.
5. Compare the growth performance of early fry of *C. gariepinus* spawned and reared in rain water, borehole water, river water and well water.

MATERIALS AND METHODS

Study Area

The research was conducted at the Hatchery unit, Department of Biology Fish farm Complex, Ebonyi State College of Education, Ebonyi State, Nigeria. Ebonyi State is situated between latitudes 6.24 °N and 6.28 °N and longitudes 7.00 °E and 7.06 °E on the South-East of Nigeria. The mean temperature range is 27ºC to 31°C minimum and maximum respectively.

Brood Fish Selection and Acclimation

Eight (4 males and 4 females) sexually matured samples of *C. gariepinus* brood stock size ranging from 800g-1.3kg total body weight was procured from a reputable fish farm in Abakaliki, Ebonyi State. All selected brood fish were transported to hatchery unit, Department of Biology Fish farm Complex, Ebonyi State College of Education,in aerated tanks. Selection of gravid fish was done following the methods of (Gikonyo *et al*., 2017). They were kept separately in two 45 L indoor concrete tanks (2 m × 2 m × 1 m) and fed 35% crude protein diet (Madu, 2006) for two weeks before commencement of experiment.

Water Physicochemical Parameters

The physicochemical parameters of the incubation water treatments were analyzed before the commencement and within the period of experiment. Mercury in glass thermometer was used to measure daily room and water temperature. The water pH was measured using the pH Hannah Portable Meter model HI 991 300. Dissolved oxygen (DO) of water was also measured using Hannah Portable Meter model HI 9142 and also by the modified Winkler azide method (APHA, 1989). Hannah Portable Meter model HI 9142 was equally used to determine water conductivity and total hardness. Nitrate, nitrite and ammonia in water were measured daily with the aid of Fresh Innovative Multitech, (NIFFRI) water testing kits.

Experimental Design

The complete randomized design (CRD) was used for this experiment. The study adopted the partial water flow through incubation technique and lasted for approximately two months. Four different water sources constituted the incubation media. They are: rain water (T1), borehole water (T2), river water (T3) and well water (T4). The incubation trough consisted of 4 hatchery circular 30 L plastic tanks. The circular 30 L plastic tanks were filled with the four different water media enumerated above and hereafter called treatments. Three replicates per water source at each trial were carried out to reduce sampling error. This brings a total of 12 circular 30 L plastic tanks. Prior to incubation, the tanks were properly washed with water and salt then dried. Each tank was securely laced with suspended 0.2mm nylon mesh net (kakabans) which will act as adhesion substrate for the eggs.

Extraction of Milt, Stripping, Artificial Fertilization and Incubation of Eggs

Extraction of milt was done following standard procedures as described by Watson and Chapman (2002). The milt obtained from the gonad was squeezed into a beaker containing the normal saline water (0.9% chloride). After 9 hours' latency period at a room temperature of 27 °C and water temperature of 28 °C, the eggs were stripped. Egg stripping was done according to the method described by Amoah *et al*. (2020). Fertilization of eggs in this experiment was conducted following the procedure adopted by Ndimele and Owodeinde (2012). This process facilitated a complete fertilization process and the fertilized eggs ready for incubation. With the aid of a sensitive weighing balance, (JT210N Electronic Top Loading weighing balance), 1 g of the fertilized eggs was measured, counted and gently spread, separated and well distributed on the pre- treated netting material inside the incubation tanks for each triplicate treatment. This procedure was done for all the three treatments and the entire set up was kept undisturbed in the hatchery for the period of the hatching session.

Hatching and Estimation of Percentage Hatchability

Incubated eggs were monitored and water temperature was maintained at 28° C. Larval movement was noticed between 18-24 hours. At the end of the hatching, duration of egg incubation for each water treatment was established. Dead, un-hatched eggs, hatched but dead larvae and hatched but deformed larvae were visually determined, counted and recorded. The netting was carefully removed and egg shells, dead larvae and all hatching remnants were siphoned out of the incubation media (Amoah *et al.,* 2021). The number of successfully hatched larvae were noted and recorded. Daily larval mortalities were recorded for each water treatment. The percentage (%) hatchability was determined subjectively after 12-15 hours of fertilization by identifying the healthy developing eggs which were transparent and brownish in colour, while the dead eggs were estimated according to Abolude *et al*. (2013). Total number of successfully hatched larvae in each of the incubation water treatment and the number of deformed larvae were determined visually by simple count. The percentage hatchability was calculated according to the method described by Ndimele and Owodeinde (2012) using the formula:

$$\text{Hatchability (\%)} = \frac{\text{Total number of hatched eggs}}{\text{Total no of fertilized eggs}} \times 100$$

Larvae Management and Estimation of Survival Percentage after 4 Days

At the end of 4 days' post hatching, the number of survived hatchlings in each water treatment was calculated and recorded. The percentage fry survivals up till the 4th day were estimated according to the method of Amachree *et al.* (2018) thus:

$$\text{Survival rate (\%)} = \frac{\text{Number of hatchlings alive up to larval stage on 4th day}}{\text{Total number of viable larvae initially hatched}} \times 100$$

Determination of Growth Performance

At the end of the experiment, growth rate was determined by randomly selecting ten fry from each treatment and batch weighing them with a sensitive weighing balance (JT210N Electronic Top Loading weighing balance) to determine the weight of fry in each treatment.

Statistical Analysis

Data from each treatment were then subjected to one-way analysis of variance (ANOVA) at $p > 0.05$ significance level. The significance of difference between means was determined by Duncan's Multiple Range Tests (DMRT) using the SPSS computer statistic package for windows 7 (version 21). Graphs were generated by using Microsoft Excel (2021) and all values were expressed as means ±SE.

RESULTS

Results of water physiochemical characteristics of the four different water treatments namely, rain water (T1), bore hole water (T2), ebonyi river water (T3) and well water (T4) used as incubation media during the experiment are shown in figure 1-4. The result shows that the four water treatments differ slightly in their physic chemical constituents. There were fluctuations in temperature, dissolved oxygen, conductivity and hardness. However, pH, ammonia and nitrate levels in the treatments were normal.

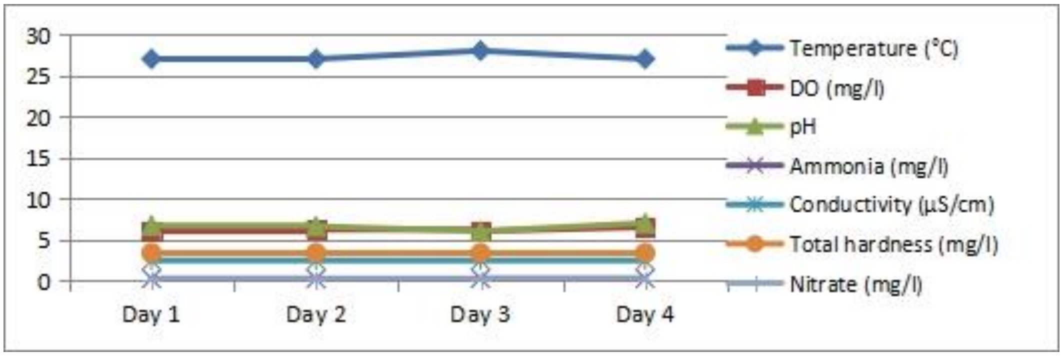

Figure 1: Physiochemical parameters for T1 (Rain Water) Used to Breed *C. gariepinus*

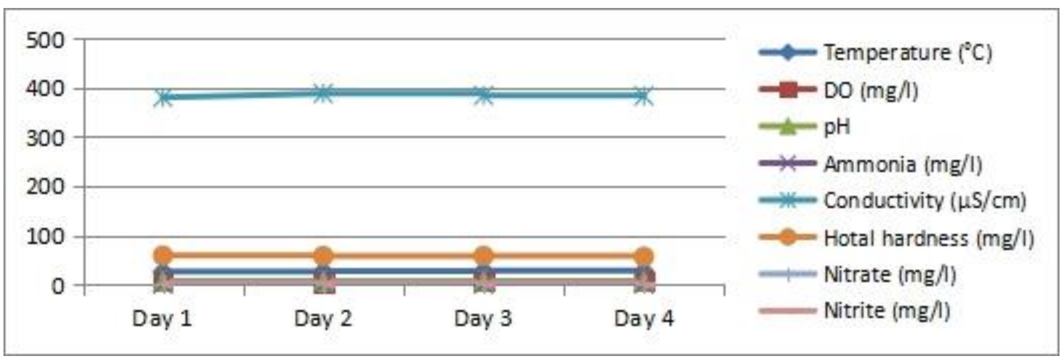

Figure 2: Physiochemical parameters for (T2) Borehole Water Used to Breed *C. gariepinus*

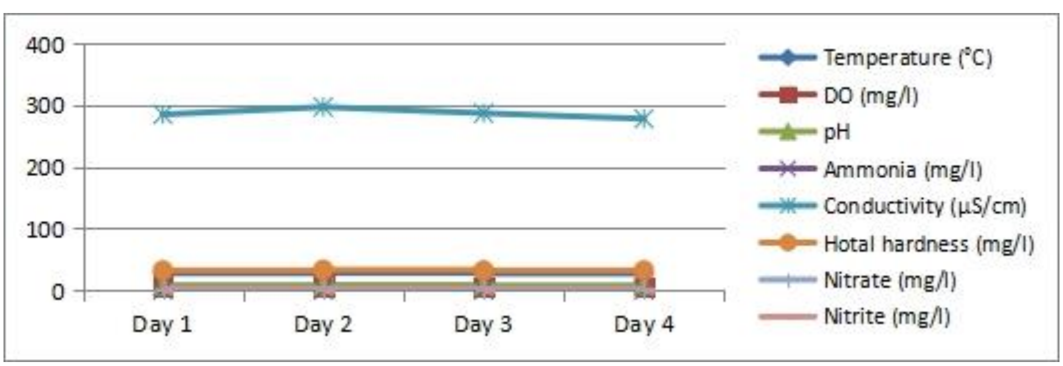

Figure 3: Physiochemical parameters for (T3) Ebonyi (River Water) Used to Breed *C. gariepinus*

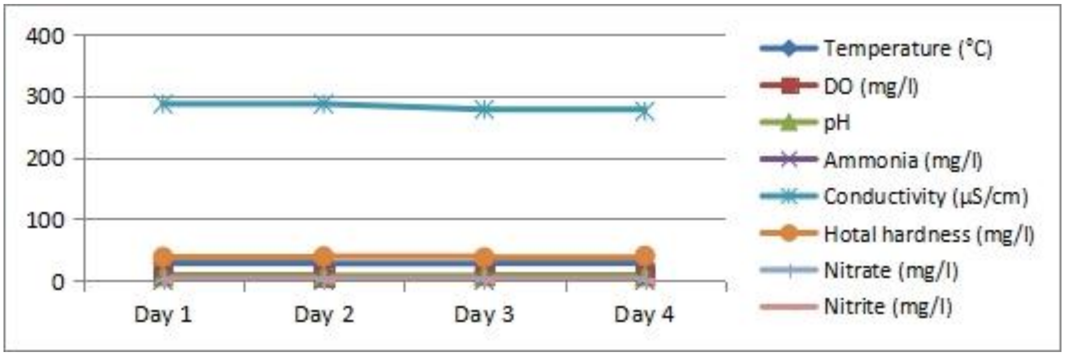

Figure 4: Physiochemical parameters for (T4) Well water Used to Breed *C. gariepinus*

Results of the mean water quality parameters tested during the 4 days breeding performance of *C. gariepinus* larvae in different water sources are presented in Table 1. There was no significant difference (P>0.05) in temperature, dissolved oxygen (DO) and ammonia values obtained during the experiment. The mean water temperature during the time of the experiment was (27.00 ± 0.00°C - 28.00 ± 0.00 °C), while the mean pH of water ranged between 6.5 ± 0.0 - 7.5 ± 0.0. The mean dissolved oxygen value of water ranged between 5.28±0.00 - 8.20±0.00 mg^{l} while mean values of ammonia ranged between 0.21±0.00 - 0.40±0.00 mg^{l}.

Table 1: Water Quality Requirements of African Catfish Hatchery

Parameters	Acceptable Range Limits
Temperature	26-28 °C
Dissolved Oxygen (DO)	>4 mgL^{-1}
Water pH	7-7.5
Ammonia	0-0.5 mg/l
Conductivity	200–1000 µS/cm
Total Hardness	30 – 180 mg/l

Source: Pronob Das *et al*., (2011).

Table 2: Mean Physicochemical Parameters of Different Water Sources Used to Breed *Clarias gariepinus* Larvae for 4 days.*

	Treatments			
	T1	**T2**	**T3**	**T4**
Parameters				
Temperature (°C)	27.00±0.00[a]	28.00±0.00[a]	27.00±0.00[a]	28.00±0.00[a]
Dissolved Oxygen (mg/l)	6.20±0.00[a]	5.82±0.00[a]	7.20±0.00[a]	8.20±0.00[a]
pH	7.00±0.00[a]	6.50±0.00[a]	7.50±0.00[a]	6.50±0.00[a]
Ammonia (mg/l)	0.21±0.00[a]	0.40±0.00[a]	0.21±0.00[a]	0.38±0.00[a]
Conductivity (µS/cm)	24.3±0.88[a]	383.3±0.78[b]	285.2±0.00[c]	287.1±0.00[b]
Total Hardness (mg/l)	3.33±0.33[a]	57.7±0.88[c]	32.3±0.33[b]	38.6±0.67[b]

*Values in the same row with different superscripts are significantly different (P < 0.05)

***T1= rain water, T2=borehole water, T3=river water, T4=well water

However, there was a significant difference (P<0.05) in values obtained for conductivity and total hardness tests (Table 2). Rain water (T1) recorded the lowest conductivity (24.3±0.88 μS^{cm}) while T2 recorded the highest conductivity (383±0.00 μS^{cm}) followed by T4 (285.2±0.00 μS^{cm}), while T3 recorded (287.1±0.00 μS^{cm}). Total hardness value was lowest in T1 (3.33±0.33 mg^{l}) and highest in T2 (57.7±0.88 mg^{l}) while T3 and T4 recorded 32.3±0.33 mg^{l} and 38.6±0.67 mg^{l} respectively.

Breeding Performance

Fertilization rate

The mean fertilization rates of *C. gariepinus* incubated in different water sources are shown in Table 3. Mean percent of fertilization was obtained after 9 hours of incubation. The result demonstrate that fertilization rates amongst the treatments was not significantly different (P>0.05). Nonetheless, the highest fertilization percentage was observed in well water which recorded 355 fertilized eggs representing (55.4%), followed by rain water that obtained 354 fertilized eggs representing (55.3%), river water recorded 347 hatchlings representing 54.2 % and bore hole water recorded the lowest fertilization rate of 345 representing (53.9%).

Table 3: Breeding performance of *Clarias gariepinus* in Different Water Media for 4 days*

	Treatments			
	T1	**T2**	**T3**	**T4**
Parameters				
Weight of female brood stock (kg)	1.3	1.3	1.3	1.3
Estimated Number of Eggs used/treatment	640 ± 0.00^{a}	640 ± 0.00^{a}	640 ± 0.00^{a}	640 ± 0.00^{a}
Estimated Number of Fertilized Eggs	354 ± 12.5^{a}	344 ± 10.9^{a}	367 ± 10.9^{a}	355 ± 5.56^{a}
Estimated Number of Eggs Hatched	333.0 ± 15.2^{a}	292.0 ± 3.21^{b}	322.0 ± 3.21^{b}	326.7 ± 6.6^{a}
Hatchability Rate (%)	93.1 ± 1.60^{b}	84.9 ± 3.12^{a}	91.0 ± 3.12^{ab}	92.0 ± 2.21^{b}
Duration of hatching	18	24	22	24
Larval Survival Rate at 4 days (%)	44.2 ± 0.55^{a}	63.7 ± 2.41^{c}	55.8 ± 3.00^{b}	61.4 ± 3.00^{bc}
Weight of 4 days old fry (g)	0.0850 ± 2.41^{a}	0.2165 ± 10.6^{c}	0.1268 ± 3.21^{b}	0.1850 ± 3.21^{bc}

*Values in the same row with different superscripts are significantly different ($P < 0.05$)

*****T1= Rain water, T2=Borehole water, T3=River water, T4=Well water

Hatchability rate

The results of the mean hatchability rates of *C. gariepinus* incubated in rearing units of different water media is presented in figure 6. There was significant difference ($P>0.05$) in hatching rates among the treatments. The mean values of percentage hatchability from the fertilized eggs incubated shows that hatchlings had relatively high mean values of (93.1 %) in rain water, (92.0 %) in well water, 91.0 % in river water and borehole water obtained the least value of (84.9 %).

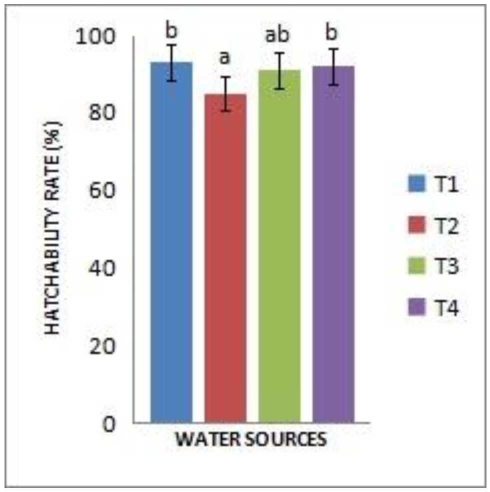

Figure 5: Mean Hatchability Rates (%) of *C. gariepinus* eggs incubated in different Water Sources. Vertical bars symbolize the mean ± S.E. (Duncan's Multiple Range Test, P > 0.05). Different letters indicate significant differences. *T1=rain water, T2=borehole water, T3=river water, T4=well water.

Survival Rates

The result of mean survival rates of *C. gariepinus* fry bred and reared for 4 days in different water media are shown in Figure 7. In the present study, larval survival rate was significantly different (P<0.05) in all four treatments. However, T2 recorded the highest larval survival rate representing 63.7 %, followed by T3 which recorded 61.4 % while T4 recorded 55.8 % and T1 recorded the lowest larval survival rate of 44.2 %.

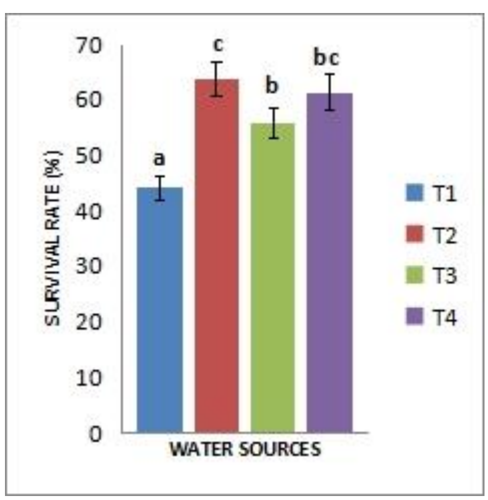

Figure 6: Mean Survival Rates (%) of *C. gariepinus* fry Bred in different Water Sources for 4 days. Vertical bars symbolize the mean ± S.E. (Duncan's Multiple Range Test, $P < 0.05$). Different letters indicate significant differences. *T1=rain water, T2=borehole water, T3=river water, T4=well water

Growth Performance

The result of growth performance of *C. gariepinus* bred in different water media is shown in Figure 8. The growth rates are significantly different among the treatments. T1 (bore hole water) recorded the highest growth after end of 4 days after hatching (yolk sac fry stage). Mean weight of fry in bore hole water was 0.2165 g, closely followed by fry bred in well water which recorded a mean weight of 0.185 g. Fry bred in (T3) river water recorded a mean weight of 0.1268 g and the lowest mean weight was recorded by fry bred in (T1) rain water.

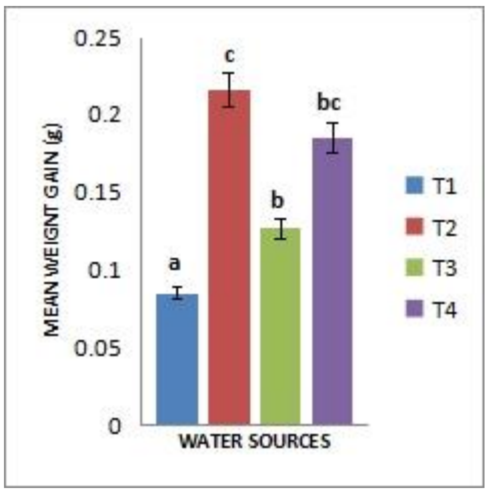

Figure 7: Mean Weight (g) of 4 days old *C. gariepinus* fry Bred in different Water Sources. Vertical bars symbolize the mean ± S.E. (Duncan's Multiple Range Test, $P < 0.05$). Different letters indicate significant differences. *T1=rain water, T2=borehole water, T3=river water, T4=well water

DISCUSSION

Water physicochemical parameters are critical in the physiology and reproduction of aquatic organisms (Amachree *et al.*, 2018). In the present experiment, four different water treatments were used to propagate *C. gariepinus*. The water treatments exhibited varying physicochemical parameters as shown in figures 1-4. Table 1 shows acceptable range limits of vital water physicochemical parameters for the propagation of African catfishes. Mean values obtained for temperature (°C) (27.00±0.00 °C - 28.00±0.00 °C), dissolved oxygen (5.28±0.00 - 8.20±0.00 mg^{l}), pH (6.5±0.0 - 7.5 ± 0.0), and ammonia (0.21±0.00 - 0.40±0.00 mg/l) were within acceptable limits for successful propagation and culture of *C. gariepinus* (Table 2). These results indicate that these parameters did not negatively affect hatchability and survival of *C. gariepinus* larvae in all the treatments. This result is in agreement with the values obtained by Ukwe and Abu (2016); Alabi and Ocholi, (2019); Uka and Kalu (2019) in similar experiments.

However, rain water (T1) recorded a low conductivity value of 24.3±0.88 μS^{cm} but values obtained for borehole water (T2), river water (T3) and well water (T4) were within acceptable range for the successful propagation of African catfish (Table 3). According to Russell *et al.* (2011) water conductivity range of 200 - 500μS^{cm} is ideal for fish breeding. The low conductivity value recorded for T1 is not within the acceptable optimal conductivity range for fish propagation and rearing. This may have been responsible for the high larval mortalities and low survival rates observed in fries bred in T1. This finding aligns with the report of Makori *et al.* (2017) who assert that mid range conductivity of 200 - 1000 μS^{cm} is favourable for larval development and fry survival but low conductivity of 0 - 200 µS/cm and high conductivity of 1000 - 10,000 µS/cm discourages larvae/fry survival.

In the same manner, rain water (T1) recorded a low total hardness value (3.33±0.33 mg^{l}) while the other three treatments recorded values that are within acceptable range for successful fish breeding (Table 3). Krishnakumar *et al*. (2020) opined that the most excellent range of water hardness for optimal egg hatching and larvae viability of *C. gariepinus* is 30 – 500 mg^{l} $CaCo_3$. So, the mortalities and poor growth performance recorded for larvae in T1 may be attributed to low water hardness. This finding aligns with the report of Silva *et al*. (2003) who asserted that low water hardness lowers hatching rates and reduces post hatch survival.

Results of the mean fertilization rate obtained from the experiment shows that all the water sources under study performed above average. This shows that fertilization was successful among the treatments. Therefore, observed fertilization rates obtained in the four water treatments were not significantly different (Table 3). These favourable hatching rates may be attributed to viability of the female brood stock eggs and not on water quality indices. According to Nwokoye *et al.* (2007) fertilization rate is dependent on egg and milt quality of the brood fish. In the present study, the weight of the brood stocks for the research weighed between 1 kg to 1.3 kg. This was good thereby showing high fecundity which resulted in good fertilization rates. This result is in agreement with Yisa *et al*. (2013); Bichi *et al.* (2014); Egwenomhe *et al*. (2020) and Amoah *et al*. (2020) who reported high fertilization rates from mature, average sized *C. gariepinus* brood-stocks.

Hatchability rates were relatively high in all treatments but borehole water (T2) was significantly higher than others (Figure 5). These favourable hatching rates indicate that physicochemical parameters of the different water media may not have affected hatchability. Rather, it may be attributed to viability of the brood stock eggs and milt. Since the brood stocks are farm bred, they were fed ad libitum with feed containing nutrients in their correct proportions, thus improving their development and maturity (Amoah, *et al*., 2020). Consequently, this enabled the brood stocks to produce good quality eggs and milt in adequate quantity. The percentage hatchability rate recorded in the present study is similar to the results obtained by Olaniyi *et al.* (2018); Uka and Kalu (2019) and Amoah, *et al.* (2020).

Borehole water (T2) had the highest survival rate followed by well water (T4) and river water (T3) while rain water (T1) obtained the lowest value (Figure 6). The low larval survival rate observed in T1 may be as a result of variations in water physicochemical characteristics. Two physicochemical parameters namely: conductivity and total hardness were significantly low in T1 but were within acceptable range in other treatments. Conductivity and total hardness are two important parameters that affect larval and fry survival (Bhatnagar and Devi, 2019). Therefore, low conductivity and very low total hardness may have contributed to low survival rates of larvae bred and nursed in rain water treatment (T1). The survival rate recorded in the present study is similar to the results obtained by Olaniyi *et al*. (2018); Uka and Kalu (2019) in related experiments.

In the same vein, *C. gariepinus* fry bred in T2 bore hole gained more weight at the end of 4 days (yolk-sac fry stage) than other water media (Figure 7). This is an indication that the physicochemical properties of borehole water encouraged maximum growth and development in the fry than other water treatments. This finding aligns with the result obtained by Awoke *et al.* (2023) in a related study.

CONCLUSION

Result from the study indicates that rain water may have the most suitable physicochemical qualities for incubating and breeding *C. gariepinus* eggs but may not be suitable for larval, early fry culture. The study has equally demonstrated that river water, borehole water and well water have desirable physicochemical characteristics for breeding and culturing *C. gariepinus* larvae though borehole water may be the most suitable.

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