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Zootechnical performances of *Clarias gariepinus* (Burchell, 1822) reared in tanks and cages, based on commercial feed

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Abstract
The aim of this study was to assess for 150 days, the influence of the breeding system (tank, floating cage) and sex (male, female) on the growth of *Clarias gariepinus*. Then, 6,400 *C. gariepinus* fry (Average body weight : 103.91±32.74g and total length: 24.08±2.31 cm) were distributed into two floating cages (5 x 5 x 2.5 m^3) on Lake Toho in Benin and two concrete tanks (3.8 x 3.8 x 1.5 m^3) at densities of 2000 individuals / cage and 1200 individuals / tank. The fish were hand-fed three times daily until apparent satiety, with a pelleted commercial feed containing 45% crude protein. At the end, the mean daily weight gain, protein efficiency ratio, specific growth rate, feed conversion rate, fish survival, and water quality parameters were evaluated. The results showed that cage-reared fish performed better than those in tanks, even though the survival rate showed no significant difference.

Keywords: *Clarias gariepinus*, cage, tank, sex effect, zoo technical performances

1. Introduction

The challenge in developing countries is to develop sustainable aquaculture, which can produce at a steady pace, in proportion to the demand, by using species adapted to ecological constraints and likely to respond to an improvement in their performance. This justifies the choice of *C. gariepinus*, which is a hardy fish and tolerates adverse conditions. It can be raised to high densities with net yields of 6t to 16t / ha / year. It also has rapid growth and breeds easily in captivity (Froese and Daniel, 2011) [1]. The high quality and the best taste of its flesh make it a popular fish, hence the need to increase the local production of this species at lower production cost (Sogbesan and Ugwumba, 2008) [2]. This species has an average adult length of 1 to 1.5 meters, reaching a maximum length of 170 cm, and weighs up to 29 kg. It grows fast and feeds on a wide range of agricultural by-products. Cage breeding can increase its yield. In fact, cage aquaculture is a well-known production system that has already developed successfully in Asia, Europe and America (Bardach *et al*., 1972; Beveridge, 1987) [3, 4]. Beginning at the end of the 19th century, cage culture is done in freshwater and in the marine environment, including high seas, estuaries, lakes, reservoirs, ponds and rivers (Balcazar *et al*., 2006; Eng and Tech, 2002) [5, 6]. In Africa and Benin, this breeding technology is still embryonic, although it could significantly contribute to reducing protein demand according to Moniruzzaman *et al*. (2015) [7]. This study is therefore designed to determine the performance of *C. gariepinus* according to the sex and the system of breeding (floating cage versus tank).

2. Material and Methods

This experiment was conducted on two sites for 150 days (from 15 July 2015 to 15 December 2016), in tanks and floating cages. Both sites are Benin Aquaculture Research and Incubation Center (BARIC) of TONON Foundation located in Ouedo in Abomey-Calavi (6 ° 26 '55' 'NORTH, 2 ° 21' 20 " EAST) and Toho Aquaculture Incubation Center (TAIC) located in Pahou in Ouidah (6 ° 22 '00' 'NORTH, 2 ° 05' 00 " EAST). The starting population consists of 6400 *Clarias gariepinus* fry (initial mean weight, 103.91±32.74g and length, 24.08 ± 2.31 cm) produced with commercial feed and supplied by BARIC. The breeding system consists of two (02) concrete square tanks (3.8 m x 3.8 m x 1.5 m) and two (02) square floating cages (5 m x 5 m x 2.5 m) (Picture 1).

The fish were hand-fed until apparent satiety three times per day (9 h, 13 h and 17 h), with a pelleted commercial feed "SKRETTING®" containing 45% crude protein. After 150 days, a sample of 4000 fish (both sexes) of which 700 per tank and 1300 per cage were collected to determine some measurements and zootechnical parameters for instance (Table 1): body weight (BW), daily weight gain (DWG), total length (TL), mean body weight (MBW), specific growth rate (SGR), feed conversion rate (FCR), protein efficiency ratio (PER) and survival rate (SR). For the assessment of mortality and water quality, parameters such as temperature, pH, dissolved oxygen, nitrite, nitrate and ammonium were recorded every 72 hours (i.e. 51 collection sessions) in the tank and floating cage.

Table 1: Description of zootechnical parameters evaluated on *C. gariepinus* after a rearing period of 150 days.

DWG (g) = [Final weight (g) – Initial weight (g)] / Rearing period (in days)
MBW (g) = Biomass / Number of fish
SGR (%day^{-1}) = 100* [ln (Final body weight) – (Initial body weight)] / Rearing period (in days)
FCR = Weight of feed given (g) / [Final biomass (g) – Initial biomass (g)]
PER = Fish weight gain (g) / Protein intake (g)
SR = 100 * (Number of fish that survived / Total number of fish stocked)

The material used is composed of an electronic scale (AND: A & D Company Limited, SHS: Super Hybrid Sensor, maximum range 2200g, accuracy 0.01 g) for the weighing of small fish; other electronic scale (UWE, maximum range 30 kg, accuracy 5 g) for weighing large specimens. For measurement, an ichthyometer (length: 1 m, graduated in centimeter) for large fish; a Vernier caliper (graduated in centimeter) for small specimens and other measurements. For water quality, temperature and pH were measured using a thermo-pH-meter (*pHep 3*); dissolved oxygen was measured using the test kit *Vunique V-Color 9780*; the *Vunique V-Color 9750* for ammonium and *API FRESHWATER MASTER* test kit for nitrite and nitrate.

Pic 1: Breeding systems of *C. gariepinus*: concrete tank (left); floating cages (right)

3. Statistical analysis

3.1 Assessment of growth and effects of rearing system and sex

The generalized linear model procedure (Proc GLM) of the SAS (Statistical Analysis System, 9.2, 2008) was applied to the weight and total length data. The mean calculated, were compared by the t-test. Fixed effects consist of the breeding system (tank, floating cage) and sex (male, female). This model is as follows:

$Y_{ijk} = \mu + D_i + S_j + e_{ijk}$, with

Yijk: weight, total length of each fish of breeding system i and sex j;
μ: the value of the overall average;
Di: fixed effect of the breeding system i (tank, floating cage);
Sj: fixed effect of sex (male, female)
eijk: random residual effect

3.2 Length-weight relationship

The length and body weight of each fish were used to establish the length-weight relationships from the equation $BW = a + TL^b$, where *BW* represents the body weight (g) of the fish; *TL* the total length (cm); *a* and *b* being characteristic factors of the environment. The parameters *a* and *b* were obtained by logarithmic transformation of the equation which makes it possible to establish a linear type relation: $log\ BW = log\ a + b\ log\ TL$, and to reduce the variability and to homogenize the two variables (*BW* and *TL*). The coefficient *b* (slope of the regression line) expresses the relative shape of the body of a fish. When $b=3$, growth is called isometric; there is a good distribution in the body development of fish (Pauly, 1983) [8]. However, when $b<3$, growth is negative allometric; which indicates a better growth in length than in weight. On the other hand, when $b>3$, the fish has positive allometric growth, and growth is therefore better in weight than in length (Micha, 1973; Ricker, 1973; Weatherley and Gill, 1987) [9, 10, 11].

3.3 Feed utilization, water quality Parameters and mortalities

The means (± standard deviation) of the feed utilization parameters (feed conversion ratio: FCR, protein efficiency ratio: PER, specific growth rate: SGR), physico-chemical parameters of the water (temperature, pH, dissolved oxygen, nitrite, nitrate and ammonium) and mortalities were calculated. Comparisons of the means between tank and cage were made by Student's *t*-test at 0.05 significance. Pearson Correlations (*Proc corr*) between the physico-chemical parameters of the water were evaluated at the threshold of 5%.

4. Results and Discussion

4.1 Effect of the rearing system on fish growth

Table 2 shows that the average body weight and total length of the cage-farmed *Clarias gariepinus* are all higher than those reared in tank. Sex does not influence ($p > 0.05$) body weight (BW) but affects total length ($p < 0.05$). The result obtained from this investigation also revealed that the SGR is lower in tank than in floating cage (0.54±0.04%day^{-1} vs 0.72±0.03%day^{-1}, $p < 0.05$). In spite of an initial mean body weight of 103.91±32.74 g, the fish reached a final weight of 661.91±230.51 g in tank and 1245.43±479.33 g in floating cage. This is in agreement with Otubusin and Olaitan (2001) [12] who reported for the same species reared in floating bamboo net-cage, a final body weight of 722 g, greater than 661.91±230.51 g obtained in tank, but less than 1245.43±479.33 g in floating cages in this study.

The DWG values obtained in tank and cage are 3.72±0.29 g and 7.61±2.50g respectively (Table 2). The value obtained in tank is also less than those of 4.2 g reported by Otubusin and Olaitan (2001) [12] for the same species and 3.95 g under optimal conditions for *Oreochromis niloticus*, while the DWG obtained in cage is higher. However, the DWG of the cage-farmed *C. gariepinus* in this study is very close to the range of 8 to 10 gday^{-1} for *Heterobranchus longifilis* under optimal rearing conditions (Legendre, 1983; Otémé *et al*., 1996) [13, 14], but higher than that of *C. gariepinus* grown in concrete tank.

Table 2: Growth performance of *Clarias gariepinus* reared with commercial feed in concrete tanks and floating cages

Growth Parameters	Concrete Tanks	Floating cages
Initial mean body weight (g)	103.91±32.74	103.91±32.74
Final mean body weight (g)	661.91±230.51	1245.43±479.33
Daily weight gain (DWG)	3.72±0.29	7.61±2.50
Feed conversion rate (FCR)	1.40±0.02	1.20±0.05
Protein efficiency ratio (PER)	1.59±0.02	1.85±0.07
Specific growth rate (SGR)	0.54±0.04	0.72±0.03

The effect of the farming system can be justified by the fact that the fish found themselves in their natural habitat once in a floating cage, offering them, the spontaneous renewal of the breeding water favorable to a good growth. Considerable variation is reported by Grobler *et al*. (1992) [15] and Van der Waal (1998) [16] in catfish growth, both in fish culture and in the wild. Another plausible interpretation, according to Conover (1992) [17], is that growth in fish results from the concomitant action of specific endogenous factors (genetic baggage) and exogenous factors that constitute the abiotic characteristics (temperature, dissolved oxygen concentration, brightness, etc.) and biotic (availability of feed resources, intra or interspecific competition for feed) (Ezewaji and Ikusemju, 1981; De Merona *et al*., 1988; Panfili *et al*., 2002; Fontaine and Le Bail, 2004) [18, 19, 20, 21].

4.2 Effect of sex on fish growth

Sex, has no significant influence on the weight of *C. gariepinus* (P>0.05). This could be explained by the fact that in captivity, that species does not breed spontaneously. Therefore, the energy from the feed is used by fish only for growth. This observation is corroborated by the isometric growth showed by the fish in both rearing systems (tanks and floating cages). However, the difference in isometric and positive allometric growth observed respectively between females and males raised in floating cages is related to sexual dimorphism in this species. This is confirmed by De Kimpe and Micha (1974) [22] for whom, in *Clarias gariepinus*, males grow faster and reach a larger final size than females. Mean weights of 427 g and 292 g were reported by the same authors for males and females respectively under aquaculture conditions. In the same order, El Bolock (1972) [23] indicated the weights of 207 g and 188 g respectively for two-years old males and females in semi-natural *C. gariepinus* population in Egypt.

Table 3: Growth of *C. gariepinus* by sex and rearing system at day 150.

Fixed factors	Weight and total length at day 150	
	BW	TL
Sex	NS	**
F	973.98±26,44	47.93±0,41
M	879.79±16,21	47.76±0,26
Breeding system	***	***
Tank	661.91±9.64	43.48±0,19
Floating cage	1245.43±22.65	53.38±0,30

BW: body weight; TL: Total length; F: female; M: male;
*p< 0.05; **p<0.01; ***p<0.001; NS: no significant.

4.3 Weight-length relationship

In both culture systems, populations of *C. gariepinus* showed isometric growth (Figures 1 to 6), because the values of the parameter *b* are not different from 3 (2.831 and 2.9946 vs 3). This observation is similar to that made by Chikou *et al*. (2008) [24] on a mixed sex *C. gariepinus* population collected from the Oueme delta in Benin. According to the sex effect in floating cage, females showed isometric growth (b = 2.9165), while positive allometric growth (b = 3.1499) was observed in males. Conversely, in tanks, growth was negative allometric (b = 2.6694) in females and isometric (b = 3.0618) in males (Table 4). The growth in cage-farmed females and tank-raised males is similar to that of wild females of the same species studied in the ASI River (Yalcin *et al*., 2002) [25]. In addition, the values of the parameter *b* of tank-raised females in this study and wild males collected in the ASI River by these same authors are all less than 3 (2.6694 and 2.74 vs 3), indicating negative allometric growth.

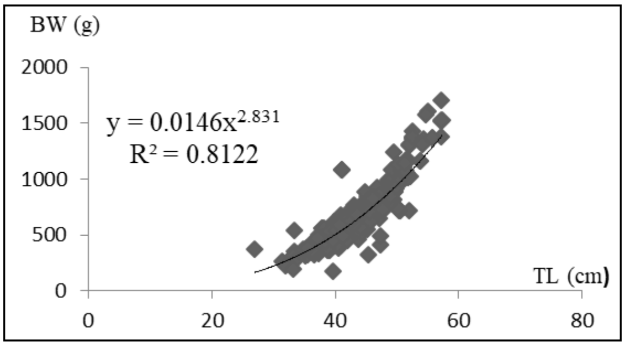

Fig 1: Weight-length relationship of growing-finishing tank-raisedd *C. gariepinus* (mixed sex)

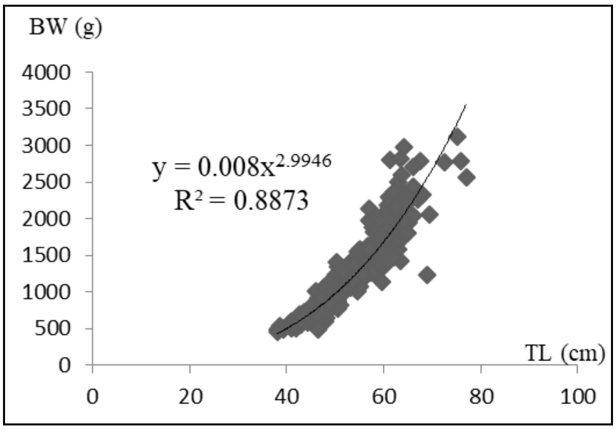

Fig 2: Weight-length relationship of growing-finishing cage-farmed *C. gariepinus* (mixed sex)

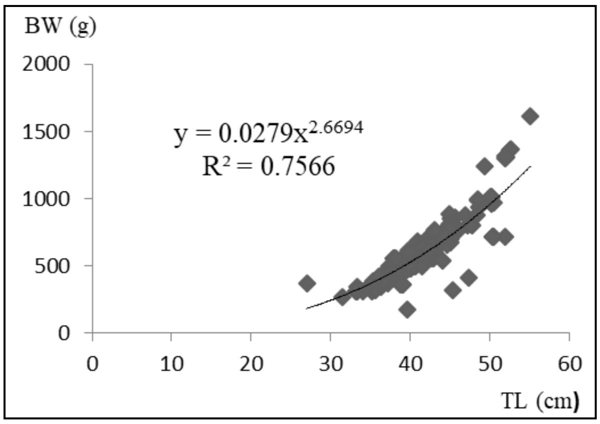

Fig 3: Weight-length relationship of growing-finishing tank-raised *C. gariepinus* (females)

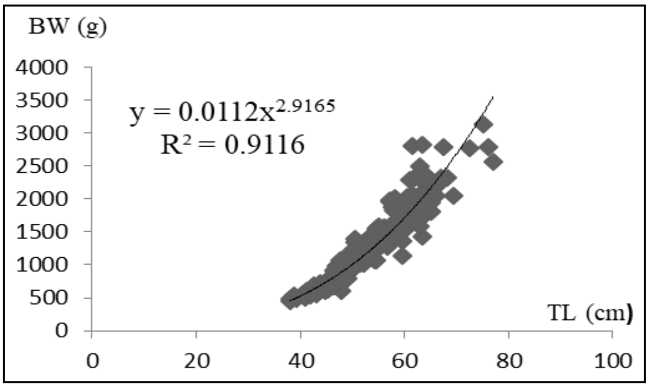

Fig 4: Weight-length relationship of growing-finishing cage-farmed *C. gariepinus* (females)

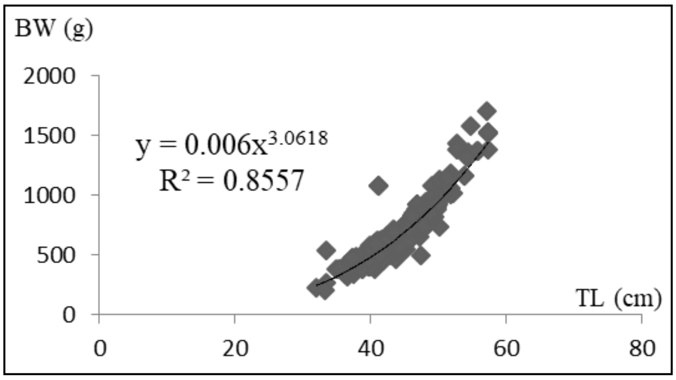

Fig 5: Weight-length relationship of growing-finishing tank-raised *C. gariepinus* (males)

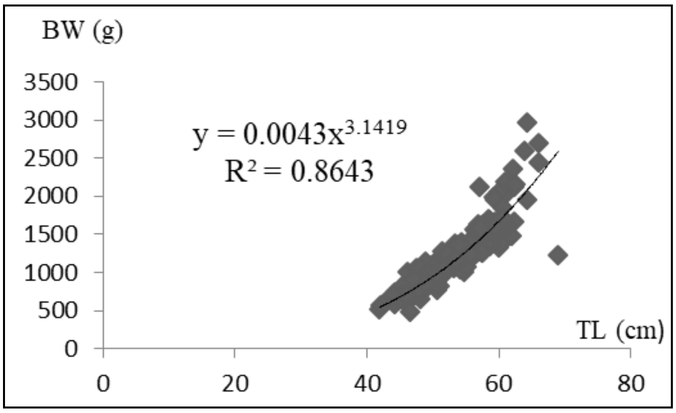

Fig 6: Weight-length relationship of growing-finishing cage-farmed *C. gariepinus* (males)

Table 4: Weight-length relationships of *C. gariepinus* based on system by sex

Sex	Concrete tank		Floating cage	
	Equation	R^2	Equation	R^2
Females	ln BW = ln 0.0279 + 2.6694 * ln TL	0.7566	ln BW = ln 0.0112 + 2.9165 * ln TL	0.9116
Males	ln BW = ln 0.006 + 3.0618 * ln TL	0.8557	ln BW = ln 0.0043 + 3.1419 * ln TL	0.8643
Global	ln BW = ln 0.0146 + 2.831 * ln TL	0.8122	ln BW = ln 0.008 + 2.9946 * ln TL	0.8873

4.4 Feed utilization, physico-chemical parameters and mortalities

4.4.1 Feed conversion

Table 2 shows at the end of the trials that, the feed conversion rate and the protein efficiency ratio of *C. gariepinus* were better in floating cages (1.20 ± 0.05 and 1.85 ± 0.07) than in concrete tanks (1.40 ± 0.02 and 1.59 ± 0.02) ($p < 0.05$). These results revealed a better use in cages of the commercial pelleted feed distributed, than in tanks. Furthermore, the feed conversion rates (1.40 ± 0.02 and 1.20 ± 0.05 respectively) obtained in tanks and cages at the end of the present study were better than 2.12 reported by Otubusin and Olaitan (2001) [12] for the same species raised in bamboo cages.

4.4.2 Physico-chemical parameters of water

Table 5 reveals no difference ($p > 0.05$) between tank and floating cage for the dissolved oxygen content, ammonium, nitrite and nitrate. On the other hand, the difference is significant ($p < 0.05$) for temperature and pH. These physico-chemical parameters of water outside ammonium meet the standards required for the growth of this species, i.e. a temperature between 17 ° C and 32 ° C (Hecht *et al*., 1988) [26]; pH between 6.5-9.0 (Hepher and Pruginin, 1981) [27]; dissolved oxygen content ≥ 3 mgL^{-1}(Viveen *et al.*, 1985) [28]; nitrite content <250 mgl^{-1} (Viveen *et al*., 1985) [28], followed by a nitrate content of 0.2-10 mgl^{-1} (Boyd, 1998) [29]. The ammonium content in both breeding systems is higher than the norm of 0.05 mgl^{-1} reported by Viveen *et al*. (1985) [28]. This high content could be attributed to the frequency of feeding which was of three times a day, the rate of nutrition, the stocking density, faeces emitted by fish, and the low circulation or renewal of the water. Indeed, Cao *et al*. (2007) [30] reported that ammonia is the main nitrogenous waste produced by aquatic animals, via metabolism, and is excreted through the gills. Its high rate in fish farming could be due firstly to excrement released by fish (Nyanti *et al*., 2012) [31] and secondly, to high fish densities and high feeding rates which often reduce dissolved oxygen and increase ammonium content in and around cages, especially in the absence of water movement through the cages (Kamatak and Kumar, 2014) [32].

Table 5: Physico-chemical parameters of *C. gariepinus* rearing water in tanks and cages

Breeding system	Concrete tanks	Floating cages	Global Means
Water quality parameters			
Temperature (°C)	28.32±0.49^{a}	27.81±0.56^{b}	28.07±0.58
pH	7.61±0.32^{a}	7.40±0.29^{b}	7.51±0.32
O2 (mg/l)	4.21±0.54^{a}	4.31±0.59^{a}	4.26±0.57
NH3/NH4 (mg/l)	0.28±0.13^{a}	0.27±0.15^{a}	0.28±0.14
NO2 (mg/l)	0.42±0.13^{a}	0.40±0.15^{a}	0.41±0.14
NO3 (mg/l)	0.32±0.13^{a}	0.30±0.13^{a}	0.31±0.13
Survival parameter			
Mortality (%)	11.50±5.93^{a}	11.36±4.88^{a}	11.43±5.4

Table 6 highlights the positive correlation in tanks for the following pairs of parameters: pH - dissolved oxygen (r = 0.58, p = 0.000); pH - nitrite (r = 0.54, p = 0.000), expressing the variation of these parameters in the same direction. On the other hand, a negative correlation was observed for parameter pairs such as: pH - nitrate (r = -0.41, p = 0.01); pH - mortality (r = -0.38, p = 0.02); ammonium - nitrite (r = -0.37, p = 0.02). Conversely to the observation made in tanks, the pH - dissolved oxygen pair of the Sô river water showed a high negative correlation, while the pH - nitrite and ammonium - nitrite pairs on the other hand correlated with that in tanks (Koudenoukpo *et al*., 2017) [33].

In floating cages, a positive correlation was observed for the following parameter pairs: dissolved oxygen - pH (r = 0.34, p = 0.03); nitrite - pH (r = 0.33, p = 0.04); nitrate - dissolved oxygen (r = 0.47, p = 0.00); and ammonium - mortality (r = 0.33, p = 0.04). Nevertheless, a positive correlation exists between nitrate and ammonium (r = 0.53, p = 0.00) indicating that they vary in the same direction while a negative correlation was revealed between nitrite and ammonium (r = -0.54, p = 0.00) causing a variation of these parameters in opposite directions. However, there is no relationship between temperature and all other parameters of water quality and mortality. Notwithstanding, Onada *et al*. (2015) [34], reported a strong positive correlation for the temperature-dissolved oxygen pair on the one hand, and a negative and positive correlation respectively for the mortality-pH and ammonium-mortality pairs in earth pond.

Table 6: Pearson correlation between water parameters and mortality

	Concrete tanks						
	Temp	**pH**	**O2**	**NH3/NH4**	**NO2**	**NO3**	**Mortality**
Temp		0.28 (0.09)	0.07 (0.65)	0.08 (0.60)	0.19 (0.2)	0.005 (0.97)	0.03 (0.84)
pH	-0.11 (0.5)		0.58 (0.000)	-0.19 (0.24)	0.54 (0.000)	-0.41 (0.01)	-0.38 (0.02)
O2	-0.04 (0.7)	0.34 (0.03)		-0.10 (0.55)	0.13 (0.44)	-0.30 (0.06)	-0.15 (0.37)
NH3/NH4	0.03 (0.85)	-0.12 (0.48)	0.20 (0.23)		-0.37 (0.02)	0.33 (0.04)	0.17 (0.30)
NO2	-0.04 (0.81)	0.33 (0.04)	0.18 (0.28)	-0.54 (0.00)		-0.51 (0.00)	-0.05 (0.7)
NO3	0.001 (0.99)	0.02 (0.89)	0.47 (0.00)	0.53 (0.00)	-0.08 (0.61)		-0.13 (0.4)
Mortality	-0.15 (0.36)	-0.16 (0.34)	-0.04 (0.79)	0.33 (0.04)	-0.05 (0.74)	-0.005 (0.97)	
Floating cages							

4.4.3 Mortality

The mortality rates obtained from the trials in both breeding systems (Table 5) were relatively low (11.50 ± 5.93 vs 11.36 ± 4.88%), and did not vary significantly (p>0.05) in function of the rearing system and despite the high ammonium content of the rearing water. This performance could be attributed, firstly, to the quality of the commercial feed used and the low degradation of the overall quality of the rearing water. According to Masser (1997) [35], oxygen is the most important stressor and can have a direct impact on the health and survival of fish in cages. However, the oxygen content of water in the present study has met the standards required for the survival of the species.

5. Conclusion

It is observed that *C. gariepinus* adapts and then develops very well in floating cages. This breeding system has a double advantage; in addition to exempting the extra cost of pumping water in the concrete tanks with electrical energy, it promotes the natural renewal of water within the floating cages. In addition, in nature (ponds, rivers, lakes), the ratio biomass by volume of water is low; the amount of waste produced will be consumed by bacteria that grow naturally in the environment in large numbers. Also, in addition to benefiting from complete commercial feed, fish feel in their natural environment and have the opportunity to enhance the zoo and phytoplankton, conditions that undoubtedly improve the growth performance of the species. All in all, the technology of cage culture should be promoted through training programs for producers in view of the importance of the hydrographic network available to Benin. It could extend to other aquatic species and contribute more effectively to the development of aquaculture.

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