Original Research Article

Water quality effects on survival and weight of tank-raised African catfish (*Clarias gariepinus*, Burchell, 1822) fed commercial and farm-made feeds

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ABSTRACT

The present study was carried out to assess the effect of water quality on survival and weight of tank-raised *Clarias gariepinus* fed with commercial and farm-made feeds. Nine hundred juveniles (15.15± 3.48g; 128.366± 9.67mm) were stocked in 09 IBC (Intermediate Bulk Container) tanks ($1m^3$ each) at a density of 100 fish/tank and fed with imported (Le), locally pelleted (Lpe) and locally extruded (Lex) feeds thrice a day for 16 weeks. Water quality parameters (water temperature, suspended particles, turbidity, colour, total dissolved solids, electrical conductivity, pH, dissolved oxygen, nitrates, nitrites, ammonia and phosphates) were measured every fortnightly using standard methods. Survivals were determined from the initial and final counts of studied fish and body weight was determined biweekly using a sensitive electronic balance. Regardless of dietary treatments and rearing period, studied water parameters did not differ significantly ($p>0.05$) except for Total Dissolved Solids (TDS), electrical conductivity (EC), pH and nitrites($p<0.05$). The study also revealed that all the parameters were within acceptable or desirable ranges for fish farming except for dissolved oxygen and ammonia which were below (<3mg/l) and above (>0.05mg/l) optimal recommended ranges respectively. In addition, water temperature, turbidity, total dissolved solids, pH and ammonia had a significant effect ($p<0.05$) on the survival and weight of African catfish. The study concluded that dissolved oxygen and ammonia could have detrimental effects on studied fish growth. However, the fact that the studied fish were exposed short term in holding water as an exchange of water was carried out every day and a complete exchange every fortnightly with well oxygenated water, significantly contributed in reducing the abnormal contents of dissolved oxygen and ammonia. This implies that if best management practices are respected, the studied feeds will not deteriorate holding tank waters and thus not affect fish productivity.

Keywords: *Physicochemical parameters, fish feed, Clarias gariepinus, IBC tank, growth, survival*

1. INTRODUCTION

The African catfish (*Clarias gariepinus*, Burchell 1822) is the most cultivated fish in Cameroon[1, 2, 3]. Globally, in terms of quantity in the world's aquaculture production(inland waters), freshwater catfishes are ranked 4th according to the top 10 aquaculture species[4]. The progressive dominance of this species is due to its fast growth rate, high resistance to diseases, tolerance to environmental extremes and high consumer preference[5, 6, 7].

The most common culture media for rearing the above-mentioned species are earthen ponds to a certain extent dams, lakes, swamps, perennial rivers and saline mangroves. Recently, intensive production practices in raised pond systems (tanks, fibreglass, tarpaulin etc.) have gained a lot of prominence amongst catfish farmers given that intensive production practices can be done in less space and closer to home [6, 8, 9]. These practices have usually used high-level management inputs such as feed which are intensively applied following appropriate recommendation rates[10]. However, intensive culture systems are faced with many constraints, one of which is a quality feed which generally accounts for at least 60% of the total production cost [11, 12, 13, 14].

Feeds used in fish farming are either locally farm-made or industrially extruded. The former has had fewer successes with higher feed conversion ratios and longer production cycles (6 to 8 months) when compared to the latter. Farmers using industriallyextruded feed have seen their production cycles shortened by at least 3 months (Personal com.). Moreover, Cho *et al*. [15] stated that the use of good quality pelleted and especially extruded feed, has proven to be less expensive, minimize water pollution and spread of diseases owing to their high digestibility, low conversion rate - better fish growth and less organic waste per kg of fish produced. Therefore, the sustainability of aquaculture depends on supplementary feed sources and management [16]. Overfeeding or poor feed utilization by the fishes could lead to nutrient enrichment of the culture-holding systems with concomitant water quality changes, thereby increasing algal production and degrading habitat which could affect fish abundance and the culture systems [17]. Therefore, feeding practices must be developed to minimize feed wastage and deterioration of water quality.

Water quality is one of the most critical factors besides good feed/feeding in fish farming. It is not constant: - varying with the time of the day, season, water source, soil type, temperature, stocking density, feeding rate and culture systems [8]. Water quality determines not only how well fish will grow in an aquaculture operation, but whether or not they survive. Fish influence water quality through processes like nitrogen metabolism and respiration[18]. Thus, any characteristic of water that affects the survival, growth,reproduction, production or management of fish in any way is a water quality variable [19]. Some water quality factors are more likely to be involved with fish losses such as dissolved oxygen, temperature, and ammonia while others such as pH, alkalinity, hardness and clarity affect fish, but are usually not directly toxic [18, 20]. Each water quality factor interacts with and influences other parameters, sometimes in complex ways. What may be toxic and cause mortality in one situation, can be harmless in another[18]. The importance of each factor, the determination method and the frequency of monitoring depend upon the type and rearing intensity of the production system used[18]. Management in fish farming is synonymous with water management since water of suitable quality and quantity is a prerequisite for any successful aquacultural production [20, 21]. Thus, for a successful aquaculture venture, the dynamics and management of water quality in culture media must be taken into consideration[8, 23].

Several works have been carried out on determining water quality in pond systems[24-30]; in aquaponics systems[10], in concrete tanks[25, 30, 31] and in tanks [32-37]. Based on literature, there are studies on the effect of commercial and local feeds on the water quality of *C. gariepinus* reared in flow-through holding tanks[35, 38]. To date, there is a paucity of information on the effect of water on the survival and growth of non-flow-through tank-raised *C. gariepinus* fed with different feeds. This work therefore evaluates the status and effect of water quality parameters on the survival and weight of non-flow-through tank-raised *C. gariepinus* fed with commercial and farm-made feeds.

2. MATERIALS AND METHODS

2.1 Study area

This study was carried out at the grow-out production unit of the Fish Farming Demonstration Association (FIFADA) Yaoundé, Cameroon. The unit consisted of 03 reservoir tanks and 09 IBC (Intermediate Bulk Container) tanks for grow-out which were exposed to 12h of daylight and 12h of night.

2.2 Experimental fish

A total of nine hundred fingerlings of mean initial weight (15.15± 3.48 g) and length (128.37 ± 9.67 mm) were acclimated in 03 IBC tanks (1x1x1m^3) containing 800L domestic water for two weeks before the commencement of the experiment using an imported extruded feed (Le Gouessant).

2.3 Experimental diets

The following ingredients: fishmeal, soybean cake, groundnut cake, wheat bran, cassava flour, palm kennel cake, premix, L-lysine (FoodChem), methionine (FoodChem) and refined palm oil were purchased from a local market in Yaoundé to formulate the locally pelleted feed (Lpe) by Pearson square method then enhanced with trial-and-error method for perfection. The ingredients were processed, mixed and pelleted with a flat die pelletizer (Capsfeed Ltd), sun-dried and stored in airtight containers at room temperature until further use. Locally extruded (Lex) and imported extruded (Le) feeds (Le Goussant) were respectively purchased from a respectable feed producer (VicFeeds) and a retailer (AgroBio) in Yaoundé, Cameroon. The gross composition of ingredients of the experimental diets is presented on table 1. Proximate analysis carried out according to standard methods AOAC [39] revealed the following: imported feed (42.00% crude protein, 11.00% crude fats and 2.30% crude fibre), locally pelleted feed (32.55% crude protein, 5.15% crude fats and 6.21% crude fibre) and locally extruded feed (33.57% crude protein, 5.57% crude fats and 3.90% crude fibre).

Table 1: Gross ingredient composition of experimental diets

Ingredients	**Le**	**Lpe**	**Lex**
Fish meal	+	+	+
Soybean meal	+	+	+
Groundnut cake	-	+	+
Pig blood products	+	-	-
Rapeseed meal	+	-	-
Methionine	-	+	+
Lysine	-	+	+
Hydrolysed poultry feather meal	+	-	-
Maize	-	-	-
Corn gluten	+	-	-
Wheat	+	+	+
Wheat feed flour	+	-	-
Cassava flour	-	+	+
Fish oil	+	-	-
Rapeseed oil	+	-	-
Vegetable oil	-	+	+
Palm kennel cake	-	+	+
Other by-products of fermentation	+	-	-
Premix	-	+	+
Vitamins	+	+	+
Compounds of trace elements	+	-	-
Binders	+	-	-
Monocalcium phosphate	+	+	+
Oyster shell	-	+	+

Le: imported feed; **Lpe**: Locally pelleted feed; **Lex**: Locally extruded feed; **+**: Present; **-**: absent

2.4 Experimental design

The fish were randomly stocked in 09 IBC tanks at a density of 100 fingerlings per tank in triplicate then reared for 16 weeks. The holding tanks were labelled according to the three dietary treatments: Tanks for Imported feed were labelled Le 1, Le 2 and Le 3; locally extruded were labelled Lex 1, Lex 2 and Lex 3 and locally pelleted were labelled Lpe 1, Lpe 2 and Lpe 3. The holding tanks were displaced in a completely randomized block design. The fish were counted and graded and randomly selected and, in each tank, 100 juveniles of mean weight and length respectively of 38.45±1.04g and 15.20±0.26cmwere stocked. Domestic water (tap) that was well de-chlorinated (left for 48h) and oxygenated (agitation and shower dropping) was used. Water level in each tank was maintained at 800L throughout the study period.

2.5 Feeding and routine work

The juveniles were hand-fed experimental diets thrice daily (between 8:30-9:30am in the morning, between 14:30-15:30pm in the afternoon and between 20:30-21:30pm in the night) for 16 weeks. The studied feeds were given at progressively feeding rates of 5% in the first four weeks, 4% in the second four weeks and 3% until the end of the experiment period of sixteen weeks. The amount of feed was adjusted every fortnightly according to changes in body weight and respected percent. Every morning prior to feeding, uneaten feed and faeces were siphoned using an 8mm pressure pipe [40] and the walls of the tanks cleaned every other day. One third of the holding water was replaced atleast once daily, more replacements were made whenever stress signals (piping at the surface and low feed intake) were observed. Every fortnightly, water was flushed out completely and replaced with fresh water. Thirty fish chosen randomly from each holding tank were weighed using a sensitive electronic balance (nearest 0.01g) every fortnightly. Mortality was recorded daily in order to calculate survival according to following formula:

Survival rate (%) = (final number of fish in tanks/Initial number of fish in tank) *100

2.6 Water quality sampling and collection

Water sampling was carried out for several physicochemical parameters of concern to aquaculture (water temperature, suspended solids, turbidity, colour, total dissolved solids, electrical conductivity, pH, Dissolved oxygen, nitrates, nitrites, ammonia and phosphates) according to Boyd [41]every fortnightly till the end of the experiment. These parameters were analysed within 24 hours of sampling and measured according to the standard techniques ofAPHA [42] and Rodier [43]. Prior to sampling, water temperature, TDS, electrical conductivity and pHwere measured *in situ* using a pen-type multi-test meter. In each tank, 1000ml was sampled between 6:30am and 7:30am and transported to the Hydrobiology and Environment laboratory of the University of Yaoundé I for measurement of dissolved oxygen using an oximeter (HACH HQ14d Oxymeter) while nitrates, nitrites, ammonia, phosphates, suspended solids were measured using a spectrophotometer (HACH/DR 3600).

1.7. Data analysis

All data collected were analysed using the Statistical Package for Social Sciences (SPSS) standard version, release 23.00. One-way analysis of variance (ANOVA) followed by Tukey's HSD Test was used to test effects of dietary treatments on weight at harvest,survival and water quality parameters. Differences were considered significant at $p< 0.05$.

3. RESULTS

3.1 Effect of dietary treatments on physicochemical parameters

Results of the water quality parameters in tanks where the studied African catfish were fed with imported (Le), locally pelleted (Lpe) and locally extruded (Lex)diets are presented in Table 2.

Regardless of dietary treatments, studied water parameters did not differ significantly ($p>0.05$) except for Total Dissolved Solids (TDS), electrical conductivity (EC), pH and nitrites which differed significantly ($p< 0.05$). However, water temperature, dissolved oxygen and ammonia were slightly highest in "Le" treatment while suspended particles, turbidity and colour were slightly highest in "Lpe" treatment and phosphates slightly highest in "Lex" treatment.

Survival did not differ significantly while weight at harvest differed significantly with highest weight observed in "Le" treatment and lowest weight observed in "Lpe" treatment.

Table 2: Mean ± SD values of water quality parameters,survival and weight fed different dietary treatments

Variables	Le		Lpe		Lex		P value	Sig.
	Mean	Range	Mean	Range	Mean	Range		
Water Temperature (^{0}C)	24.60±0.87^{a}	3.10	24.31±0.86^{3a}	2.90	24.29±0.9^{a}	2.90	0.445	NS
Suspended particles (mg/l)	40.04±25.19^{a}	87.00	43.81±28.44^{a}	90.00	36.78±23.30^{a}	77.00	0.605	NS
Turbidity (NTU)	59.81±36.62^{a}	123.00	66.37±39.91^{a}	125.00	52.48±32.63^{a}	116.00	0.381	NS
Colour (PtCo)	284.30±179.90^{a}	702.00	305.00±191.66^{a}	764.00	255.15±156.44^{a}	515.00	0.583	NS

Total Dissolved Solids (mg/l)	172.15±65.04 ^{a}	246.00	112.33±37.79 ^{b}	156.00	90.22±23.63 ^{b}	89.00	0.000	S
Electrical conductivity (µS/cm)	357.26±131.13 ^{a}	495.00	230.15±77.78 ^{b}	315.00	187.37±48.14 ^{b}	181.00	0.000	S
pH (CU)	6.67±0.35 ^{a}	1.26	6.43±0.35 ^{b}	1.14	6.44±0.31 ^{b}	1.06	0.016	S
Dissolved oxygen (mg/l)	2.68±2.08 ^{a}	7.38	2.21±2.31 ^{a}	7.58	2.51±2.29 ^{a}	7.59	0.774	NS
Nitrates (mg/l)	0.12±0.06 ^{a}	0.19	0.12±0.06 ^{a}	0.19	0.12±0.06 ^{a}	0.17	0.911	NS
Nitrites (mg/l)	0.03±0.02 ^{a}	0.07	0.05±0.04 ^{ab}	0.22	0.03±0.02 ^{ac}	0.05	0.031	S
Ammonia (mg/l)	1.19±1.08 ^{a}	5.12	0.89±0.77 ^{a}	3.46	0.73±0.58 ^{a}	2.23	0.130	NS
Phosphates (mg/l)	1.46±1.03 ^{a}	3.25	1.33±1.15 ^{a}	4.21	1.64±1.46 ^{a}	5.66	0.641	NS
Survival at harvest (%)	82.57±3.53 ^{a}	6.81	88.64±3.18 ^{a}	5.91	77.12±7.39 ^{a}	14.55	0.369	NS
Final weight at harvest (g)	758.46±13.79 ^{a}	413.3	276.14±66.10 ^{b}	287.33	339.27±9.34 ^{c}	297.2	0.000	S

Means in each row with different superscript are significantly different at $p<0.05$. **Le**: imported feed; **Lpe**: Locally pelleted feed; **Lex**: Locally extruded feed; **Sig.**: Significance.**S**: Significant; **NS**: Not significant.

3.2 Effect of the status of water quality parameters on survival and weight of the African catfish

The Pearson correlation matrix between physicochemical parameters, survival and weight and the linear regression analysis output for survival and weight of *Clarias gariepinus* fed with the studied diets as a result of different water quality parameters are presented in Tables 3 and 4 respectively.

Regardless of the dietary treatments, water temperature presented a moderate negative significant correlation with survival (r= -0.572; p= 0.000) and a moderate positive significant correlation with weight (r= 0.562; p= 0.000). The same trend was observed with turbidity and total dissolved solids: a weak negative significant correlation with survival and weight respectively (r= -0.331; p=0.001 and r= -0.374; p= 0.000). pH had an imperfect positive correlation with weight (r=0.247; p=0.013) and no relation with survival. Dissolved oxygen and ammonia had an imperfect positive correlation with survival (r= 0.256; p=0.010 and r=0.310; p=0.002 respectively) and an imperfect negative correlation with weight (r= -0.295; p= 0.004 and r= -0.219; p= 0.025 respectively).

Table 3: Correlation matrix of physicochemical parameters with survival and weight

Parameters		Survival	Weight
Water Temperature (^{0}C)	Pearson's correlation	-0.572**	0.562**
	Sig. (1-tailed)	0.000	0.000
	N	81	81
Suspended particles (mg/l)	Pearson's correlation	-0.018	0.032
	Sig. (1-tailed)	0.438	0.387
	N	81	81
Turbidity (FTU)	Pearson's correlation	-0.331**	0.629**
	Sig. (1-tailed)	0.001	0.000
	N	81	81
Colour (PtCo)	Pearson's correlation	0.014	0.053
	Sig. (1-tailed)	0.451	0.321
	N	81	81
Total Dissolved Solids (mg/l)	Pearson's correlation	-0.374**	0.669**
	Sig. (1-tailed)	0.000	0.000
	N	81	81
Electrical conductivity (μS/cm)	Pearson's correlation	-0.017	0.047
	Sig. (1-tailed)	0.442	0.339
	N	81	81
pH (CU)	Pearson's correlation	-0.057	0.247*
	Sig. (1-tailed)	0.308	0.013
	N	81	81
Dissolved oxygen (mg/l)	Pearson's correlation	0.256*	-0.295**
	Sig. (-tailed)	0.010	0.004
	N	81	81
Nitrates (mg/l)	Pearson's correlation	0.045	0.003
	Sig. (1-tailed)	0.346	0.49
	N	81	81
Nitrites (mg/l)	Pearson's correlation	0.084	-0.054
	Sig. (1-tailed)	0.229	0.316
	N	81	81
Ammonia (mg/l)	Pearson's correlation	0.310**	-0.219*
	Sig. (1-tailed)	0.002	0.025
	N	81	81
Phosphates (mg/l)	Pearson's correlation	-0.087	0.037
	Sig. (1-tailed)	0.220	0.371
	N	81	81

**Correlation is significant at the 0.01 level (1-tailed). *Correlation is significant at the 0.05 level (1-tailed).

The regression output for survival and weight as a result of different water quality parameters is presented in Table 4. Only six water quality parameters out of the twelve parameters hypothesized were significant: water temperature, turbidity, colour, Total Dissolved Solids, dissolved oxygen and ammonia.

Table 4: Regression output for water quality parameters effect on survival and weight

Model	Variables	Survival		Weight	
		Coeff	**Sig**	**Coeff**	**Sig**
1	**(Constant)**	245.506	0.000	-3214.438	0.000
	Water Temperature (^{0}C)	-5.729	0.000	116.226	0.000
	Suspended particles (mg/l)	-0.081	0.346	-0.283	0.852
	Turbidity (FTU)	-0.077	0.004	1.889	0.000
	Colour (Pt-Co)	0.016	0.012	-0.271	0.025
	Total Dissolved Solids (mg/l)	0.139	0.014	-2.304	0.030
	Electrical conductivity (µS/cm)	-0.007	0.911	1.167	0.303
	pH (CU)	-2.296	0.468	87.979	0.143
	Dissolved oxygen (mg/l)	0.814	0.020	-19.052	0.004
	Nitrates (mg/l)	-2.521	0.880	-141.556	0.655
	Nitrites (mg/l)	20.497	0.333	-400.946	0.316
	Ammonia (mg/l)	3.139	0.000	-81.425	0.000
	Phosphates (mg/l)	-0.689	0.154	-4.821	0.595
	F value	11.403	0.000[a]	26.998	0.000[b]
	R	0.817		0.909	
	R^2	0.668		0.827	
	Adjusted R	0.609		0.796	

[a] Dependent variable: survival. [b] Dependent variable: weight (g).

F values of 11.403 and 26.988 respectively for survival and weight were significant at 5% level, indicating that there were linear relationships between survival, weight and all the independent variables (studied water quality parameters).

The respective R values of 0.817 and 0.909 for survival and weight showed that these variables and the studied water quality parameters are perfectly positively correlated. Moreover, R^2 values of 0.668 and 0.827 for survival and weight revealed that 66.8% of fish survival and 82.7% of weight were influenced by the studied water quality parameters.

4.DISCUSSION

Water temperatures appeared not to be affected by the studied dietary treatments in this study and were below the acceptable range of 29-30^{o}C favourable for optimal growth of tropical fishes[19, 44,45] such as the African catfish. However, it was within the normal range (20-28^{o}C) for optimum growth of warm water fishes [19]. Temperature is an important factor affecting the growth and survival of all organisms

[46] as observed by the significant correlations observed of temperature with survival and weight. In fact, the regression results revealed that water temperature had a negative and positive effect respectively on survival and weight. This implied that a unit increase in water temperature would reduce survival by 5.73% and increase weight by 116.23g. Pattillo[47] stated that no other physical water variable affects the development and growth rates of fish as much as water temperature as an increase in water temperature increases metabolic and biochemical processes[23, 48]. Although at very temperatures fish may die due to less solubility of oxygen, stress and enhancement of the growth of thermo-tolerant microorganisms, aquatic organisms such as fish can tolerate a broader range of temperatures, if fluctuations are not so dramatic, sudden and of long duration [49-51].

Suspended particles were also not affected by the dietary treatments used in this trial. The obtained values of suspended particles were however, below the limits set of 80.00 mg/l as recommended by Timmons *et al*. [52]and Pillay and Kutty [53]for water criterion for aquaculture and could not affect the fish functioning and survival of studied fish [30]. This was confirmed by the fact that the status of suspended particles had no correlation or effect on the weight and survival of studied fish (regression analysis).

In this study, turbidity and colour were also not affected by the studied dietary treatments. Turbidity was within the acceptable ranges of 75–240NTU as stated by Boyd[19] for aquaculture but above the WHO [54]limit (5 - 25 NTU) for freshwater. Although colour was higher than the recommended standards of 15TCU (WHO, 2011), it appears not to have a direct effect on aquaculture water[48]. These values negate those found by Orobator *et al.* [30] that recorded less than 5NTU in similar rearing conditions. The slightly higher values of turbidity and colour observed in the “Lpe” treatment could be attributed to the suspension of unconsumed pellets which dissociated in the water column rendering the holding water turbid as evidenced by the higher values of suspended particles. Turbidity exhibited an imperfect negativecorrelation with survival and a strong positive correlation with growth corroborating the results of regression analysis which revealed that its status had a negative and positive effect on survival and weight respectively. Thus, a rise in 1NTU decreased survival by 0.077% and increased weight by 1.889g. This inferred that the status of turbidity in the studied holding tanks was favourable for fish health since it did not pose a severe risk to survival [30] and improved growth. Zweig *et al*. [55] stated that in a production system where fish derive a majority of their nutrition from feed inputs, high turbidity content does not pose a problem.

The studied dietary treatments did affect the total dissolved solids (TDS) with highest values observed in "Le" treatment. This higher value was due to the performance of the diet as fish fed this feed exhibited higher growth therefore higher metabolic excretion and raise in a flux of fine silt particles from faecal matters and particles of uneaten food during scrambling for feed thereby leading to suspended particles in water which could eventually cause high TDS[55].TDS values were lower higher than those obtained by Njieassam [36]working on evaluating water quality of catfish tank aquaculture. However, these values were low and optimal for fish productivity [56] and were below the applicable range of 400 to 500 mg/L suitable for fish pond water sample [57]. The status of TDS (regression analysis) for all the studied holding tanks revealed that it had a positive and negative effect on survival and weight respectively. This implied that a unit rise in TDS increased survival by 0.139% and reduced weight by 2.304g.

The studied dietary treatments affected electrical conductivity (EC) values with values highest in "Le" treatment. The higher EC values observed in "Le" treatment could be because it produced more waste (due to the higher growth of its fish) which increased its content of ionizable salts and consequently its electrical conductivity ([58]. The values observed were within the desirable range of 100-2000µm/cm and the acceptable range of 30-5 000 µm/cm as recommended by Boyd and Tucker[59] and Stone and Thomforde [60] for fish culture. In fact, the present study indicated that the electrical conductivity of water samples was favourable for fish growth and corroborates the fact that the status of electrical conductivity did not affect the weight and survival of studied fish.

Mean pH values were affected by the studied dietary treatments with "Lpe" treatment exhibiting slightly acidic values. These values were lower than those of Ajani *et al*. [61], David and Afia [62], Ekenem *et al*. [63] and Mustapha *et al*. [38] working in similar conditions. The differences were could be due to the difference in fish stocking densities. However, the values were within the desirable range (6.5-9.0 CU) for fish production[28, 45, 48]. The slight acidity may have occurred from the effects of respiration and decomposition of unconsumed feeds [65] and did not affect weight and survival as revealed by the regression analysis.

Dissolved oxygen values were not affected by the studied dietary treatments and were below the recommended level of >5mg/l for warm water fish [45, 48, 66]. Similar values were reported by Limbu [67] using the same species and feeding with both commercial extruded and locally farm-made feeds in relatively static holding systems. Summerfelt [68] stated that fish reared in tanks reduce their consumption rate but increase in density (Kg/m^3) and thus water flow rate has to be increase to reduce oxygen depletion. These low values could be associated with the period of sampling [69] given that sampling was done in the morning hours (6:30-7:30 am). In fact, Boyd and Lichkoppler [48] and Francis-Floyd [66] observed that dissolved oxygen is lowest in the early morning just after sunrise. Although the observed low oxygen levels recorded have been reported to slow growth [48] and cause piping (gulping air at the surface) [66] in fish, the studied fish weren't exposed to prolonged low oxygen levels as one-third of the holding water was changed every day and a complete exchange carried out every fortnightly.Moreover, *C. gariepinus* is known to survive under extremely low dissolved oxygen concentrations (0-3mg/l) thanks to the fact that theypossess fully developed arborescent organs which aids in breathing atmospheric oxygen [70-72].

The studied dietary treatments did not affect nitrates concentration but affected nitrite concentrations with highest values observed in "Lpe" treatment. This higher value of nitrite observed in Lpe treatment could be linked to its low dissolved oxygen. In this light, several authors have linked nitrite toxicity to oxygen depletion [19, 45, 47]. Nitrate levels observed were within permissible levels of <3mg/l [73] and favourable range (0.1-4mg/l) of nitrate for fish aquaculture[74-75. Nitrite values in this study were within the desirable range of 0-1mg/l NO^-_2 and the acceptable range of 4 mg/l NO^-_2 as suggested by Stone and Thomforde [60]. These values were also within the optimal nitrite concentrations for aquaculture (<0.1mg/L) as recommended by Boyd & Tucker[59] and Pillay [76].In addition, nitrate and nitrite status revealed by regression analysis were found to not affect both the weight and survival of studied fish.

Unlike nitrites, ammonia concentrations were not affected by the dietary treatments. Ammonia values in all treatments were above the safe concentration (<0.05mg/l) for freshwater fish as suggested by Lawson [45] whereas locally pelleted and locally extruded treatments were within the permissible level (<1.0mg/l) as recommended by Meade [73] for fish culture. The high ammonia contents could be explained by the significant decomposition of organic matter accompanied by high consumption of dissolved oxygen, favouring its production by ammonification [77]. This could also be attributed to the high protein levels in the studied feeds. In fact, Omweno *et al*. [78] stated that ammonia found in the studied holding water was derived from the breakdown of nontoxic ammonium ion (NH_4^+) contained in digestible crude protein which is a component of total nitrogen which is highly toxic to fish. However, good water management practices (daily exchange of one-third of holding water and complete exchange of water every fortnightly) ensured that ammonia did not affect fish growth and survival because it prevented prolonged exposure of fish to toxic un-ionized ammonia concentrations of greater than 0.2mg/l which can depress the appetite of studied fish [47, 79]. The status of ammonia revealed a negative and a positive effect respectively on weight and survival. This implied that a unit increase in ammonia reduced weight by 81.42g and increased survival by 3.14%.

The values of phosphates were not affected by the dietary treatments and were above the desirable level (0.06 mg/l) for fish culture as recommended by Stone and Thomforde [60] and permissible limit of 0.1-0.5mg/l as proposed by Boyd and Tucker [59] but were within the WHO [54] standards of 0.03-2.00 mg/l set for freshwater. These values were higher than those of Maranga *et al*. [80]who obtained 0.47-0.67mg/l and lower than those of Olukunle and Oyewumi [81] who obtained values of 2.06-2.13mg/l both working in tanks. The high concentrations of phosphates observed in this study was derived from feed and fish metabolic waste and were not high enough to comprise fish growth nor cause environmental pollution [82]. This concords with the regression analysis which revealed that its status did not affect the weight and survival of the studied fish.

5. CONCLUSION

The study revealed that regardless of dietary treatments and rearing period, studied water parameters did not differ significantly except for Total Dissolved Solids (TDS), electrical conductivity (EC), pH and nitrites. These parameters were within acceptable, desirable, permissible or recommended ranges for freshwater fish culture except for dissolved oxygen and ammonia. The status of water quality parameters was influenced by the different studied feeds, the rations and the frequency of water replenishment in the holding tanks. The regression results revealed that all the water quality parameters examined had different effects on fish survival and weight with water temperature, turbidity, colour, total dissolved solids, dissolved oxygen and ammonia having significant effects. Although dissolved oxygen and ammonia were respectively below and above optimal ranges, the studied fish were exposed short term as an exchange of water was carried out every day and a complete exchange every fortnightly with well-oxygenated water. This implies that if best management practices are respected, the studied feeds will not deteriorate holding tank waters and eventually fish productivity.

CONSENT

It was not applicable

ETHICAL APPROVAL

It was not applicable

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