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The effects of rearing water depths and feed types on the growth performance of African catfish (*Clarias gariepinus*)

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Abstract

African catfish (*Clarias gariepinus*) has been growing in popularity as a culture species globally. Although considerable research has been carried out on this species' feeding preferences, no research has been carried out on optimum water level for growth. This is particularly surprising given this species' benthic nature. This study assessed the effect of different combinations of water levels and types of feed on the growth performance of African catfish. The study employed a 3 × 2 factorial design with three ponds of different water levels (0.5, 1 and 1.5 m) and two types of feeds (floating and sinking). Twelve earthen ponds (1 × 2 m) were each stocked with 16 catfish fingerlings (mean weight ~100 g), and their growth was monitored for 12 weeks. The fish cultured in the shallowest water grew significantly faster than those cultured in the deepest ponds. At the same time, fish cultured in the shallowest ponds had the lowest feed intake rates and consequently the lowest feed conversion ratios. Catfish fed sinking pellets grew faster than those fed floating pellets although the difference was not significant. There was no significant interaction between pond water depth and feed type. The results of this study suggest that the growth and feeding efficiency of *C. gariepinus* can be optimized by culturing in fairly shallow ponds (0.5 m).

KEYWORDS

fish feed efficiency, floating and sinking fish feed, growth, pond water level

1 | INTRODUCTION

The suitability of the African catfish (*Clarias gariepinus*) to aquaculture throughout its distributional range started to be recognized in the middle of the 1980s. Over 30 years later, this species is now farmed either commercially or for subsistence in almost every country in sub-Saharan Africa as well as in North Africa and many other countries around the world (Dauda, Natrah, Karim, Kamarudin, & Bichi, 2018). Given its biology, it is easy to understand the appeal of *C. gariepinus* for aquaculture. Its ability to air breathe enables it to thrive in both temperate and tropical climates which helps explain why it is so widely distributed. In addition to its air breathing ability, which makes it hardy and versatile, it is able to feed on a diverse array of natural prey and it is highly fecund which makes it easy to spawn in aquaculture conditions. Of particular appeal is the ability of *C. gariepinus* to tolerate fairly poor water quality and to be cultured at higher stocking densities without additional pond aeration or high rates of water exchange (Hengsawat, Ward, & Jaruratjamorn, 1997).

*deceased

With favourable food conversion ratios ranging from 1:6 using agricultural waste to 1:1 using formulated low-cost feeds and production levels of up to 40 tonnes per hectare, it is regarded as a fairly economical species to farm (Hecht, Oellermann, & Verheust, 1996). However, current reported levels of catfish production in Africa are believed to be considerably lower than the maximum potential (Dauda et al., 2018). There are a number of reasons for this including variable consumer demand and relatively high production costs compared with the price that consumers are willing to pay for a fish of perceived moderate nutritional value (Githukia, Obiero, Manyala, Ngugi, & Quagrainie, 2014). The price of feed and availability of fingerlings have also been reported as obstacles to the growth of the sector (Fagbenro & Adebayo, 2005).

In traditional small-scale farms in North Africa and sub-Saharan Africa, *C. gariepinus* is typically fed both floating and sinking pellets, depending on the availability and price of each type of feed (Adewumi & Olaleye, 2011; Kannadhason, Muthukumarappan, & Rosentrater, 2009; Mustapha, Akinware, Faseyi, & Alade, 2014). In Egypt for example, catfish farmers tend to prefer sinking pellets since they are often cheaper than floating pellets (based on unpublished information obtained from catfish farmers surveyed by the authors). At the same time, other catfish farmers in Egypt have expressed a preference for using floating pellets since it makes it easier to visually identify problems with their fish based on how much and how quickly the animals finish their allocated feed (based on anecdotal evidence obtained during the completion of this study). However, given that catfish are bottom feeders, one would imagine that sinking pellets would be the obvious choice.

There has only been one published study on this topic which reported similar growth for catfish cultured on both floating and sinking pellets with a slight improvement in fish fed floating pellets (Ajani, Dawodu, & Bello-Olusoji, 2011). Given that feed represents up to 70% of the costs of African catfish production, it is clearly important to optimize the use of feed for growth. To do so, a detailed understanding of catfish preferences for floating or sinking pellets is needed. In addition, it is important to understand how the depth and the water level of the pond in which catfish are cultured affects their growth and how this interacts with the type of feed used. From the review of the literature, it would seem that the only study that has previously explored pond water depth as a factor in catfish farming was El Naggar, John, Rezk, Elwan, and Yehia (2006) and in that study water depth was solely explored in relation to its impact on spawning success. As such, this study explored the interaction effect between pond water level and feed type on the growth performance of *C. gariepinus* in a traditional Egyptian catfish farm modified for the purposes of this experiment.

2 | MATERIALS AND METHODS

2.1 | Ethical approval

Ethical approval for this study was obtained from the Committee of Aquatic Animal Care and Use in Research at Kafr El-Sheikh University, Egypt (Approval number: IAACUC-KSU-2-2018).

2.2 | Experimental design

A 3 × 2 factorial treatment design was used to evaluate the effect of three pond water levels (0.5, 1 and 1.5 m) and two types of feed (floating and sinking) on the growth performance of African catfish. These water levels were chosen to reflect the traditional water level used in Egypt of between 1 and 1.5 m. Similar depths of 1 to 1.5 m are used in other African countries (e.g., Hecht et al., 1996; Shoko, Limbu, Mrosso, & Mgaya, 2014); however, use of 0.5 m deep ponds has been reported in Uganda (Limbu, 2015, 2019). There were two replicates per treatment, and the study was carried out for 12 consecutive weeks. The experimental animals (African catfish fingerlings, *C. gariepinus*) were purchased from a private fish farm in the Kafr El Sheikh Governorate of Egypt. The ponds were constructed in an open area and were exposed to direct sunlight and an air current. After the banks of the earthen ponds were reinforced, the ponds were left to dry and then filled with water. Each pond had its own water inlet and outlet connected to the same principal irrigation and drainage sources but not to each other. Upon filling the ponds with water to the desirable level, animals were stocked at a rate of 16 animals per pond. The animals were fed once per day in the morning by hand. Feed was distributed evenly on the surface of each pond.

2.3 | Animal husbandry system

The experiment was conducted in 12 equal-sized earthen ponds (1 × 2 m) with different water levels (0.5, 1 and 1.5 m). The animals were exposed to the following treatments; one receiving floating feed and the other sinking feed at three water levels (0.5, 1 and 1.5 m), with two replicates each. Water exchange was carried out every two days at a rate of 5%–10% by volume. Each pond was randomly stocked with 16 animals at an average weight of 100.15 ± 3.480 g. The animals were left to acclimatize for one week prior to the start of the experiment. Animals were fed the same feed during the acclimation period as during the experiment. All animals were fed a quantity of approximately 3% of their body weight each morning for 12 weeks and were weighed every 3 weeks. In order to minimize the stress induced by culturing the fish in earthen ponds, fish handling was restricted to a minimum and fish were stocked at low densities. To further minimize stress, wastes were removed from the bottom of the pond once a week through the pond outlet, and fish were fed at the same time every day. Feed was distributed evenly on the surface of the pond to give each animal equal access to the feed. No mortality was observed in the animals used in this study.

2.4 | Experimental feeds

A commercial floating and sinking feed (30% crude protein and 12.6 MJ/kg digestible energy) were purchased from a local feed factory (Al-Ekhwa® Feed Factory). The content of both feeds was almost identical, and they differed only in form (floating vs. sinking). The complete nutritional and chemical composition of the two diets

TABLE 1 Composition and chemical analysis of the experimental feeds used in the trial (estimated on dry matter)

	Floating feed	Sinking feed
Composition (%)		
Fishmeal (72% crude protein)	10	10
Soybean meal (45% crude protein)	40	40
Yellow corn	24	24
Wheat bran	10	10
Rice bran	10	10
Corn oil	3	3
Dicalcium phosphate	1	1
Vitamin and mineral mixture	2	2
Total	100	100
Chemical analysis (%)		
Dry matter (DM %)	93	92.15
Crude protein (CP %)	30.85	30.84
Ether extract (EE %)	7.94	7.91
Crude fibre (CF %)	4.95	5.01
Ash %	8.66	8.29
Nitrogen-free extract (NFE %)	48	47.85
Calculated energy value		
Gross energy (kcal/kg)	4,496.36	4,492.48
Digestible energy (kcal/kg)	3,372.27	3,394.36
Metabolizable energy (kcal/kg)	365.63	362.09

used in this experiment is provided in Table 1. Feed with 30% crude protein was selected based on the optimum feed typically used for Nile tilapia since catfish in Egypt are typically farmed in polyculture with Nile tilapia. In such a polyculture setting, the pond is stocked predominantly with juvenile Nile tilapia (large enough not to be eaten by catfish) with a lesser quantity of catfish.

2.5 | Growth performance and feed conversion

The initial body weight (IBW) of each animal (n = 96) was recorded 24 hr before starting the experiment using a digital balance. The intake of feed by fish (FI) was recorded on a daily basis, and growth was monitored every three weeks for 12 weeks. For floating feed, feed intake was estimated by visually observing the quantity of feed consumed at the surface. All floating feed was consumed at the surface. For sinking feed, researchers estimated feed intake by visually observing the bottom of the pond 20 min after distributing the feed and estimating the proportion remaining. This was possible due to the use of clean, frequently changed water and the dark colour of the soil allowing for contrast with the colour of the feed. The quantity of feed provided was calculated according to the level of biomass stocked, as such there was hardly any unconsumed feed at the end of each feeding session.

Upon conclusion of the experiment, 50% of all animals were sacrificed (eight fish/replicate). The animals were sampled using a net and placed in water containing MS222 (500 mg/L); they were then wiped dry before recording final body weights (FBW). The other growth performance parameters were calculated in line with standard methods: body weight gain (BWG) = (FBW − IBW); specific growth rate (SGR, percentage of body weight gained per day) = [(FBW − IBW)/experimental period in days] × 100; and feed conversion ratio (FCR) = FI/BWG.

2.6 | Length, circumference, condition factor and biometric indices

The circumference of each animal was measured using a measuring tape at the central point between pectoral and pelvic fin on the first day of the experiment (initial circumference, IC) and at the end of the experiment (final circumference, FC). The circumference gain (CG) is the increase in the circumference of the animal during the experimental period. It was calculated as CG (cm) = (FC − IC). The length of each individual was measured on a measuring board from the tip of the mouth to the tip of the caudal fin on the first day (initial length, IL) and the last day of the experiment (final length, FL). The length gain (LG), which is the increase in the animal's length throughout the experiment, was calculated by subtracting IL from FL. The standard Fulton's (K) condition factor (CF) was used (i.e., $K = 100 \times \text{total weight}/\text{total length}^3$). At the end of the experimental period, 16 animals from each treatment were dissected, and the whole liver, gonad and viscera were rinsed using normal saline solution, dried using clean filter paper and weighed to the nearest 0.1 g. The following indices were determined for each individual: hepatosomatic index (HSI) = [(liver weight/weight of fish) × 100], gonadosomatic index (GSI) = [(gonad weight/weight of fish) × 100] and viscerosomatic index (VSI) = [(viscera weight/weight of fish) × 100].

2.7 | Analysis of water quality

In each pond, temperature and dissolved oxygen (DO) were measured at 25 cm below the surface of the water using a digital meter (OxyGuard Polaris). Water was sampled weekly in each pond through the insertion of an inverted 250-ml glass bottle 25 cm below the surface of the water which was then used to determine the total ammonia nitrogen concentration on a handheld colorimeter (Martini MI 405), pH on a pH meter (Hach PHC725) and salinity on a refractometer (EXTECH RF20). Unionized ammonia (UIA) was determined from the pre-estimated total ammonia nitrogen (formulas used for calculation were adapted from Zhang et al., 2018).

2.8 | Statistical analysis

Data were tested for normality and homogeneity of variance (by assessing frequency of distribution in the histogram). Log transformation of the raw data was used for some measured parameters (FBW, WG, FL and LG) because of the large range across the data. Statistics were carried out in IBM SPSS® Statistics v. 22.0 and GraphPad Prism

v. 6.0 for Windows, and all results were reported as means with *SEM*. A two-way ANOVA was carried out to compare the main effects of pond water level and feed type. A Tukey's multiple comparison post hoc test was used for the interaction of the two factors.

3 | RESULTS

3.1 | Growth performance and feed conversion

The fish cultured in the shallowest ponds (0.5 m) grew significantly faster than those cultured in the deeper ponds (1 and 1.5 m; see Tables 2 and 3). The greatest body weight gain and growth rates (including length, circumference as well as VSI and GSI) were recorded in the shallowest ponds (0.5 m) followed by 1 and 1.5 m. The same pattern was observed in terms of feed intake and feed conversation ratios with the lowest feed intakes and feed conversion ratios occurring in the shallowest ponds. Whilst animals raised in the shallowest ponds (0.5 m) increased in weight significantly faster than the other treatments, the difference in weight gain between animals raised in the 1 and 1.5 m ponds was not significant. The highest feed intake was recorded in the "intermediate" water level (1 m) which was significantly greater than that recorded in the other treatments. The largest FCR was recorded in the animals cultured in the

TABLE 2 Effect of pond water level and feed type on the growth performance of African catfish, *Clarias gariepinus*

	IBW (g)	FBW (g)	BWG (g)	FI (g)	FCR	SGR (%)
Water level						
0.5 m	100.3	423.3^{a}	323.0^{a}	4.714^{c}	1.627^{b}	3.076^{a}
1.0 m	100.2	392.3^{b}	292.3^{b}	4.746^{a}	1.727^{b}	2.784^{ab}
1.5 m	100.0	373.1^{b}	273.1^{b}	4.734^{b}	2.004^{a}	2.601^{b}
Feed type						
Floating	100.1	391.9	291.8	4.731	1.821	2.816
Sinking	100.2	400.6	300.5	4.733	1.751	2.825
SEM	3.475	23.55	27.32	0.034	0.107	0.184
p-value						
Water level	0.989	0.012*	0.038*	0.001*	0.002*	0.038*
Feed type	0.999	0.522	0.581	0.481	0.428	0.948
Interaction	0.999	0.588	0.674	0.876	0.443	0.580

Note: Means within a column and effect that lack common superscripts differ significantly (Tukey's multiple comparison test, $p \le .05$). Asterisks indicate significant differences between groups (two-way ANOVA *$p \le .05$). *SEM*, standard error of the mean.

Abbreviations: BWG, body weight gain; FBW, final body weight; FCR, feed conversion ratio; FI, feed intake; IBW, initial body weight; SGR, specific growth rate.

TABLE 3 Effect of pond water level and feed type on the biometric indices of African catfish, *Clarias gariepinus*

	IL (cm)	FL (cm)	LG (cm)	CF	IC (cm)	FC (cm)	CG (cm)	HSI %	VSI %	GSI %
Water level										
0.5 m	24.41	39.53^{a}	15.12^{a}	0.685	10.48	16.75^{a}	6.297^{a}	0.950	13.22^{a}	1.001^{a}
1.0 m	24.77	38.29^{ab}	13.52^{b}	0.703	10.61	16.20^{ab}	5.594^{ab}	1.003	12.39^{b}	0.591^{c}
1.5 m	24.71	37.92^{b}	13.21^{b}	0.675	10.45	15.84^{b}	5.391^{b}	0.995	10.64^{b}	0.972^{b}
Feed type										
Floating	24.80	38.16	13.37	0.700	10.55	16.10	5.573	1.053	11.82	0.686
Sinking	24.46	38.99	14.53	0.675	10.48	16.43	5.948	0.912	12.34	0.648
SEM	0.239	0.647	0.423	0.019	0.213	0.278	0.313	0.053	0.550	0.052
p-value										
Water level	0.282	0.038*	0.001*	0.337	0.741	0.006*	0.012*	0.565	0.001*	0.001*
Feed type	0.089	0.119	0.001*	0.099	0.676	0.159	0.146	0.005*	0.261	0.391
Interaction	0.174	0.779	0.576	0.057	0.643	0.925	0.824	0.002*	0.001*	0.001*

Note: Means within a column and effect that lack common superscripts differ significantly (Tukey's multiple comparison test, $p \le .05$). Asterisks indicate significant differences between groups (two-way ANOVA*$p \le .05$). *SEM* = standard error of the mean.

Abbreviations: CF, condition factor; CG, circumference gain; FC, final circumference; FL, final length; GSI, gonadosomatic index; HSI, hepatosomatic index; IC, initial circumference; IL, initial length; LG, length gain; VSI, viscerosomatic index.

deepest treatment (1.5 m), which was significantly greater than the other two treatments. However, the difference in FCR between the other two treatments was not significant. Despite the differences not being significant, a number of improved growth, biometric and morphological parameters were recorded in the animals fed sinking pellets, with the exception of CF, HSI and GSI (see Tables 2 and 3). A significant interaction was recorded between pond water level and HSI, VSI and GSI. There was no significant interaction between pond water level and feed type on growth performance.

3.2 | Water quality parameters

The effect of pond water level on water quality is presented in Table 4. All measured water quality parameters were similar throughout the study. These results suggest that culture water quality is not significantly affected by the different pond water levels used in this study or by using floating versus sinking pellets.

4 | DISCUSSION

The reason for improved growth in shallow ponds could be a result of a reduction in area for swimming thereby reducing opportunities to exhibit territorial or aggressive behaviour, which would allow greater allocation of energy resources to growth. Aggression in the African catfish is a well-studied phenomenon and is routinely noted as an obstacle to farming this species (Adewumi & Olaleye, 2011; Almazán-Rueda, Helmond, Verreth, & Schrama, 2005). In the only study to explore African catfish movement behaviour, Hocutt (1989) used radio tags to track wild African catfish in Zimbabwe over a number of months and reported no consistent fish swimming activity or pattern. As such, the typical activity levels of *C. gariepinus* remain unclear.

The increase in length and circumference of the animals suggests superior health and welfare of the individuals reared at the lowest water levels and fed sinking pellets. Furthermore, the lower HSI and the higher VSI and GSI in the animals reared in the shallowest ponds and fed sinking pellets suggest improved feed absorption and potentially improved reproductive capability. The results from this study are also in line with those of Ekanem, Eyo, Obiekezie, Enin, and Udo (2012) that reported faster growth in *C. gariepinus* fed sinking pellets. These findings contrast those of Ajani et al. (2011) that observed a lack of significant difference in weight gain of catfish fed floating pellets. Limbu (2015) also reported no significant differences in growth performance of *C. gariepinus* fed floating or sinking pellets. The results from this study and other studies therefore suggest that African catfish farmers can successfully utilize both sinking and floating pellets but should perhaps consider leaning towards using sinking pellets where possible. Moreover, catfish farmers should measure the water level of their ponds and aim to keep it below 1 m, preferably around 0.5 m. A documented pond water depth of 0.5 m seems to be in use at least in Uganda (Limbu, 2015, 2019).

The only study that explored the topic of pond water depth reported significantly higher spawning success (56.5%) in African catfish cultured in shallower ponds (25 cm) than in deeper ponds (12% in 75 cm ponds; El Naggar et al., 2006). Spawning success was also higher in 25 cm ponds than in 50 cm ponds (which in turn were higher than in 75 cm ponds) although the difference was not significant. However, the fish in that study were much larger (>500 g) than the ones used in the present study (~100 g) as such it is not clear if the results of that study can help explain the outcomes of this study. It provides further evidence however

TABLE 4 Effect of pond water level and feed type on the water quality parameters of African catfish, *Clarias gariepinus*

	DO (mg/L)	Temperature (°C)	Salinity (ppt)	pH	Total ammonia (mg/L)	UIA (mg/L)
Water level						
0.5 m	4.673	20.93	4.417	8.329	0.657	0.062
1.0 m	4.668	20.83	4.458	8.325	0.665	0.062
1.5 m	4.664	20.80	4.458	8.321	0.605	0.057
Feed type						
Floating	4.553	20.90	4.445	8.322	0.644	0.059
Sinking	4.797	20.81	4.444	8.328	0.641	0.061
SEM	0.356	0.863	0.149	0.036	0.058	0.008
p-value						
Water level	0.998	0.989	0.950	0.973	0.546	0.763
Feed type	0.403	0.900	0.999	0.850	0.940	0.708
Interaction	0.868	0.996	0.856	0.991	0.529	0.710

Note: Means within a column and effect that lack common superscripts differ significantly (Tukey's multiple comparison test, $p \leq .05$). No significant differences were detected among the measured water quality parameters. *SEM* = standard error of the mean.
Abbreviations: DO, dissolved oxygen; UIA, unionized ammonia.

that shallower ponds (25–50 cm) may confer several advantages to catfish in culture conditions and across multiple stages of their life history. This may be indeed why 0.5 m pond depth is recommended in Ugandan aquaculture (Limbu, 2015, 2019). Given the limited studies on this topic, it is not clear if such a pond water depth (0.5 m) is commonly used elsewhere as well. Nevertheless, an appropriate balance needs to be found given that excessively low water levels are a well-established stressor to most species of fish (Carragher & Rees, 1994; Einarsdóttir & Nilssen, 1996; Frisch & Anderson, 2000).

The present study recognizes the potential stress introduced by sampling catfish in ponds versus aquaria. Amongst other measures, stress could have been minimized by selecting softer substrate for the ponds. This would have allowed for greater accuracy of the data. To further validate the results of the present study, it would be useful to repeat this study wherein the proximate composition of the fish is also measured.

5 | CONCLUSION

The results of this study suggest potential benefits to African catfish farmers in controlling pond water levels and in experimenting with farming catfish in ponds of varying practical water levels in order to find an optimum level. It is possible that African catfish grow faster in shallower waters. Moreover, from this study and others, it is clear that *C. gariepinus* can be fed using both floating and sinking pellets.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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DATA AVAILABILITY STATEMENT

All relevant data are available from the authors upon request.

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