Vol. 16(6), pp. 931-938, June, 2020
DOI: 10.5897/AJAR2019.14420
Article Number: A06F2E764080
ISSN: 1991-637X

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African Journal of Agricultural Research

Full Length Research Paper

Response of wild smooth-head catfish (*Clarias liocephalus*) fingerlings reared in earthen ponds

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Received 22 August, 2019; Accepted 1 June, 2020

***Clarias liocephalus*, an important small fish in the diet of rural households, is threatened by wetland degradation and overfishing for use as live bait. This study aimed at establishing the survival, condition, growth rate and feed utilization indices of *C. liocephalus* wild fingerlings reared outside the wetland environment through a feeding experiment. Fingerlings were fed with an isocaloric feed with four levels of crude protein for eleven weeks. Results showed that *C. liocephalus* could endure wide ranges of water temperatures, low levels of dissolved oxygen and could efficiently utilize artificial feeds. The 35% crude protein diet was the best utilized with a feed conversion ratio of 4.18. The mean specific growth rate was 2.2 to 2.5%, which is comparable to that of other reared Clariidae. Fish condition was best with the 30 and 35% diets and mean survival was 46.44% (±3.159SE) and not significantly different (p<0.05), for the four diets. This new information is useful as reference in recommending the species for aquaculture. Rearing *C. liocephalus* could also reduce rural malnutrition and fish-protein deficiency especially in rural poor communities. Rearing trials for longer periods and measurement of other key production indices required in aquaculture of *C. liocephalus* were recommended.**

Key words: Wetland habitats, micronutrients, hapas, fish feeds.

INTRODUCTION

Today, national development plans are focusing on ensuring economic and food security for the ever increasing human population, projected to hit 8.6 billion by 2030, alongside strategies to manage the apparent degradation of terrestrial and aquatic ecosystem resources (Bierbaum and Cowie, 2018). Fisheries and aquaculture constitute a substantial sector in agricultural development for economic and nutritional purposes and its contribution in the alleviation of nutritional and economic insecurity is upheld from global to local perspectives (FAO, IFAD, UNICEF, WFP, WHO, 2019). Fish provide an essential protein-rich component to the

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human diet especially in communities with predominantly carbohydrate-based diets common in developing countries (Thilsted, 2012). As a rich source of multiple micronutrients including zinc and iron, fish have the capacity of meeting the micronutrient deficiencies predominant among the vulnerable groups in sub-Saharan Africa (Phillips et al., 2015).

As captured fisheries become unsustainable due to over-fishing, habitat loss and aquatic environmental pollution, aquaculture is increasingly being considered as the alternative to the development and improvement of fisheries resources and revitalization of the ecosystems. Investment in environmentally sustainable aquaculture production presents opportunities for food and economic securities particularly for developing countries (World Bank, 2013).

Uganda's per capita fish consumption reported to be about 6 kg person^{-1} year^{-1} (MAAIF, 2004; NARO, 2017), is still well below the WHO-FAO recommended level of 17.5 kg person^{-1} year^{-1}. The slight increase, despite the greatly reduced wild fish stocks, could partly be attributed to the growing aquaculture industry, now at about 100,000 tonnes anum^{-1} (NARO, 2017). However, the high price tag on fish in Uganda today dictates that only the economically stable communities can access it. According to Uganda's Demographic Health Survey (UDSH) report of 2016, the indicators of malnourishment that include stunting and iron deficiency are specifically high among the rural poor communities (Uganda Demographic and Health Survey [UDSH], 2017). It is worth noting that the human population in Uganda is now at >39 million and 76% of this population lives in rural areas as indicated in the 2018 statistical abstract (Uganda Bureau of Statistics [UBOS], 2018). It is possible that a large proportion of the Ugandan rural population could be nutritionally deficient in essential proteins and micronutrients partly provided through adequate fish consumption.

Evaluating the potential of some locally available small fish like *Clarias liocephalus*, which may not be as expensive to rear but nutritionally competent, could make a significant contribution towards addressing the problem of fish-food deficiency and indirectly reduce malnutrition and poverty in rural poor households. Since most of the local small fish species are not domesticated (Kumar, 2010) and their natural habitats, especially wetlands, are threatened (Chapman et al., 2001; Ministry of Water and Environment, 2018), it is increasingly becoming necessary to promote the rearing of such fish, at least from the perspective of conservation. The motivation behind this study was to test whether the Clariidae catfish *C. liocephalus,* a small wild wetland fish species, could survive and grow outside its natural environment thriving on an artificial diet. The study hypothesized that *C. liocephalus* could grow and survive under culture conditions and that it could offer parallel nutritional attributes like other established cultured fishes especially the commonly cultured species of tilapias and *Clarias gariepinus*. The choice for *C. liocephalus* was based on the fact that it is highly acceptable in the diet of local people in the study area; seems to tolerate a wide range of environmental conditions and that its survival in the wild is threatened by habitat loss and the unregulated live-bait market (Ajangale, 2007; Yatuha et al., 2012). *C. liocephalus* exhibits some basic qualities required in a potential aquaculture fish species like being a generalist feeder and possessing an air-breathing accessory organ to boost survival in environments with low dissolved oxygen levels (Yatuha, 2015); however, its production indices which are important for fish farmers, are not yet adequately defined and its response outside its natural wetland environment is poorly documented. A feeding experiment was mounted to define the diet at which *C. liocephalus* would attain maximum growth response and nutrient utilization. The study specifically evaluated the effect of dietary crude protein level on growth performance, feed utilization, survival and general condition of wild *C. liocephalus* fingerlings kept under pond conditions for eleven weeks. Determining the minimum feed needed to meet the species protein requirements and achieve maximum growth is important because there is an economic advantage in identifying and feeding fish at an optimal rate, that is, at the lowest feed conversion ratio (FCR) and highest specific growth rate (SGR) point (De Silva and Anderson, 1995; Kim and Lee, 2009). Knowledge of the growth rate and proximate body composition of a species for a given diet level provides a useful guideline in selecting a diet that is both nutritionally adequate and most affordable. Principal factors that determine fish growth and body composition are important when considering the role of fish as a source of nutrition (Ahmed et al., 2010).

MATERIALS AND METHODS

About 2500 *C. liocephalus* fingerlings of mean wet weight of 2.83 g (±0.003SE) were fished from Kigambira wetland, found in Lake Mburo National Park Uganda, using local basket traps. The wetland is a constituent of the Rwizi-Rufuha wetland system that drains the southwestern part of the Lake Victoria basin. The fingerlings were allowed to acclimate in a collection tank for seven days and were fed on a 30% crude protein (CP) general juvenile *Clarias* diet (Jauncey et al., 2007).

An isocaloric complete commercial floating diet with 4 levels of crude protein (CP) graded as low protein (25% CP), medium protein (control: 30% CP), high protein (35% CP) and very high protein (44% CP) was sourced and its proximate composition established (Table 1) before they were used for the experimental feeding. Each of the test diets was replicated four times giving a total of 16 units. The feed pellet size for each of the four diets was graded to 3±0.5 mm, which is 30% of the average gape size of *C. liocephalus* fingerlings (Yatuha, 2015).

The experimental fish were reared in a semi-intensive setting in an earthen fish pond which was selected and prepared from a set of other fish ponds at Mbarara Zonal Agricultural Research and Development Institute (MBAZARDI) near Mbarara University of Science and Technology in Mbarara municipality, Southwestern

Table 1. Proximate composition (%) of the test diets used in *C. liocephalus* feeding experiment.

Diet	Diet code	Dry matter (g)	Ash (g)	Crude fat (g)	Crude fibre (g)	Crude protein (g)
25% CP	1	27.78±0.026SE	6.20± 0.039SE	8.79± 0.013SE	3.44± 0.008SE	24.99± 0.024SE
30% CP	2	33.38±0.005SE	6.93± 0.060SE	14.69± 0.102SE	3.38± 0.024SE	30.20± 0.017SE
35% CP	3	38.15±0.044SE	7.35± 0.066SE	20.56± 0.186SE	3.15± 0.006SE	34.62± 0.040SE
44% CP	4	47.82±0.112SE	6.33± 0.083SE	28.87±0.023SE	3.64± 0.086SE	43.71± 0.021SE

Figure 1. Set up of experimental units in the pond for the feeding experiment of *C. liocephalus*.

Uganda. Mbarara municipality is at altitude 1,432 masl; 0.6167° S, 30.6568° E; average annual temperature 25°C and rainfall of 1125 mm. The pond was fitted with 16 nylon hapas of size 1.73 m^2 (1.2 m × 1.2 m × 1.2 m) and a mesh size of 1 mm. The hapas were arranged at a depth of 1.3 m in a line at a distance of 1.5 m between any two hapas (Figure 1).

At the start of the experiment, after the fish had not been fed for 24 h to enable them to empty their stomachs, one thousand six hundred (1 600) fish with an average weight of 2.83 g (±0.003SE) body weight were selected, visually identified, individually weighed and measured for total length and randomly assigned into the 16 hapas (experimental units) at a stocking rate of 100 fingerlings per hapa. The four diets in their four replicates were randomly assigned to the 16 stocked experimental hapas. A general commercial *Clarias* feed formula (30% CP) was used as a control having been a standard catfish diet for a long time (Legendre, 1986; Robinson et al., 2001). Since there were no data on the nutrient requirements of juvenile *C. liocephalus*, it was acceptable to adopt from closely related species (Kaushik, 2000).

The experimental fish were fed at 5% body weight, regarded as apparent satiation (Jauncey, 1982) two times a day for 11 weeks and records of daily feed intake were kept. The duration of the feeding experiment was deemed adequate to get the required results since results of growth performance in *Clarias* fingerling feeding experiments have been realized from experiments of six weeks (Solomon and Okomoda, 2012) or eight weeks (Odulate et al., 2014; Adebisi and Ologhoba, 1998). About 10% of the pond water was exchanged for fresh water once every three days, from a common reservoir that supplied the other ponds on the fish farm. To prevent clogging by algae and left over feeds, the hapas were washed weekly during the time of weekly measurement of the fish.

Data collection and analysis

Three water quality parameters were recorded in this study. The general pond water temperature was measured daily between 6:00 and 7:00 am in the morning and between 12:00 and 1:00 pm in the afternoon. The dissolved oxygen (DO) and pH of the pond water were measured twice a week between 10:00 and 12:00 h. A digital thermometer, a pH meter (pH meter model HANNA HI98129) and DO meter (Oxy meter model YSI 550A) were used for measuring the said water quality parameters.

At weekly intervals, all the fish in each hapa were removed and counted to establish the survival. Fifty percent (50%) of the fish were randomly sampled and individually weighed and measured for total length.

The mean weight gain (WG) was established by subtracting the mean initial weight (g) from the final mean weight.

WG = Final mean weight - Initial mean weight and the percent weight gain (WG %) = [Final mean weight (g) - Initial mean body weight g) / Initial body weight] × 100 (1)

The Feed Conversion Ratio (FCR) was expressed as the proportion of dry feed fed per unit live weight gain of fish calculated as:

FCR = Dry weight of feed (g) / Wet weight gain by fish (g) (2)

The Specific Growth Rate (SGR), that is, the weight gained by fish per day was calculated as:

$$SRG = [Ln (W_2) - Ln (W_1) \times 100] / T_2 - T_1 \quad (3)$$

where W_2 = Weight of fish at time T_2, W_1 = Weight of fish at time T_1, Ln = Natural log.

Survival (%) was calculated as follows:

Survival = (Initial number at start of experiment - Number at end of experiment) × 100 (4)

Condition factor: Fulton's Condition Factor (Froese, 2006) was calculated thus:

$$K = (100W) / L3 \quad (5)$$

where K=Condition factor, L=Standard length (cm) and W=Wet weight (g).

Data were analyzed using SPSS Inc.17 (IBM Corp. Chicago, USA) and Minitab Inc. 14 statistical software. Relationships in the datasets were subjected to correlation-regression analyses and variations to ANOVA followed by Tukey HSD test (or its non-parametric Kruskal Wallis Test) at a significance threshold of 0.05.

RESULTS

The overall mean dissolved oxygen of water in the experimental pond was 1.39 mg l^{-1}, indicating a general poor oxygen circulation in the experimental units. Mean pH was 6.65, well within the range of freshwater fishes and the mean morning and afternoon temperatures were

Table 2. Mean dissolved oxygen (mg/L) pH and temperature (^{o}C) in the experimental pond water through the experimental period.

Week	Mean DO Mg/L	pH	Temperature (mean and SE)	
			Morning	Afternoon
1	2.17±0.58	6.11±0.28	19.72±0.456	27.59±0.525
2	1.35±0.22	6.32±0.71	20.81±0.998	28.22±0.872
3	1.27±0.24	6.51±0.19	19.33±0.235	27.33±1.269
4	0.77±0.17	6.81±0.06	21.76±0.495	29.38±0.416
5	1.59±0.12	7.03±0.11	20.53±0.461	28.69±0.779
6	1.69±0.50	6.65±0.35	18.96±0.460	26.55±0.599
7	1.05±0.12	6.8±0.00	19.52±0.367	26.72±0.330
8	1.09±0.15	6.77±0.75	19.81±0.481	27.12±0.355
9	1.19±0.08	6.72±0.02	18.22±0.236	27.38±0.505
10	1.40±0.10	7.07±0.00	17.35±0.109	27.75±0.512
11	1.5±0.24	7.14±0.14	18.57±0.370	28.30±0.336

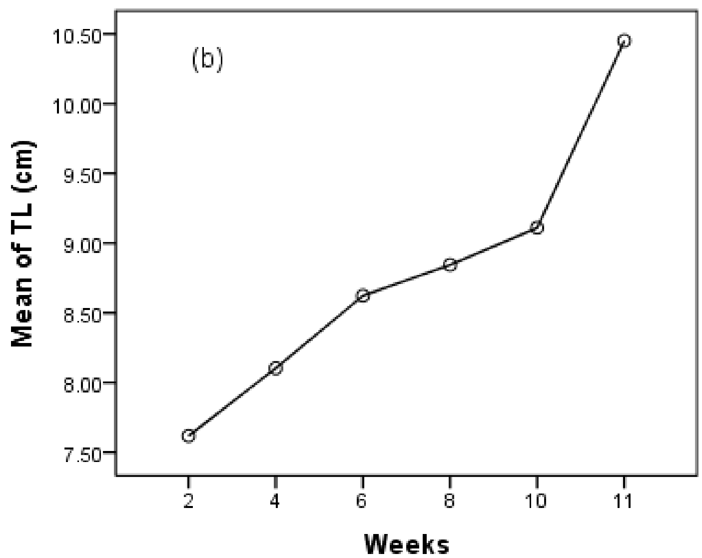

Figure 2. Fish body weight increment (a) and total length increment (b) in *C. liocephalus* experimental fish over the 11 weeks period of experimental feeding.

19.36°C ±0.153SE and 27.53°C±0.162SE, respectively. The results for DO, pH and temperature over the experimental period are summarized in Table 2.

The overall growth response of *C. liocephalus* fingerlings in terms of mean weight gain and length increment showed a positive trend especially after the 5th week of the feeding experiment (Figure 2). While there was no significant difference in weight and length between treatment groups at the start of the feeding experiment (Kruskal Wallis Test P=0.122, n=1600); the difference became significant (P<0.01) by the end of the experiment (Kruskal Wallis Test P=0.001 and 0.000 for weight and TL, respectively). Fish fed on the diet of 30% CP registered the highest weight gain and had the heaviest individual fish by the end of the experiment (20.7 g) while that of 25% CP had the lowest weight gain and had the lightest individual fish that weighed only 2.2 g at the end of the experiment (Table 3).

The mean feed conversion ratio (FCR) of the fish fed on the four test diets over the experimental period was 5.01, 4.18, 4.53 and 4.85, respectively (Table 3). It was noted that FCR values were high in the first weeks of the experiment and steadily improved with time (Figure 3). There was a significant difference in FCR between the first and last weeks of the experiment period (FCR 23.7, p<0.001). Specific growth rate was the highest in the 35%

Table 3. Growth response parameters of *C. liocephalus* fed on four different diets over 11 experimental weeks (±SE).

Parameter	Treatment			
	D1 (25% CP)	**D2 (30% CP)**	**D3 (35% CP)**	**D4 (44%CP)**
Initial mean weight (g)	3.14±0.06	3.09±0.07	2.98±0.06	3.21±0.06
Final mean weight (g)	8.52±0.36	9.40±0.31	9.71±0.27	8.49±0.25
Final minimum weight (g)	2.2	2.2	3.7	2.8
Final maximum weight (g)	14.6	20.7	19.7	17.0
Initial mean TL (cm)	7.58±0.05	7.59±0.05	7.45±0.06	7.56±0.06
Final mean TL (cm)	10.14±0.16	10.30±0.12	10.36±0.10	10.31±0.10
Initial mean Feed Conversion ratio (fcr)	5.74±0.05	6.77±0.21	7.46±0.22	7.38±0.20
Final Mean Feed Conversion ratio (fcr)	3.32±0.10	3.18±0.06	2..98±0.04	3.48±0.05
Condition (K)	1.04±.0053[a]	1.06±.0047[b]	1.05±.0052[b]	1.01±.0040[a]
Specific growth rate (SGR)	2.10	3.03	3.10	2.81
Survival (%)	43	46	49	47
Total feed fed (g)	312	451	474	457

*Mean values in the same row with different superscript are significantly different (ANOVA, P<0.05).

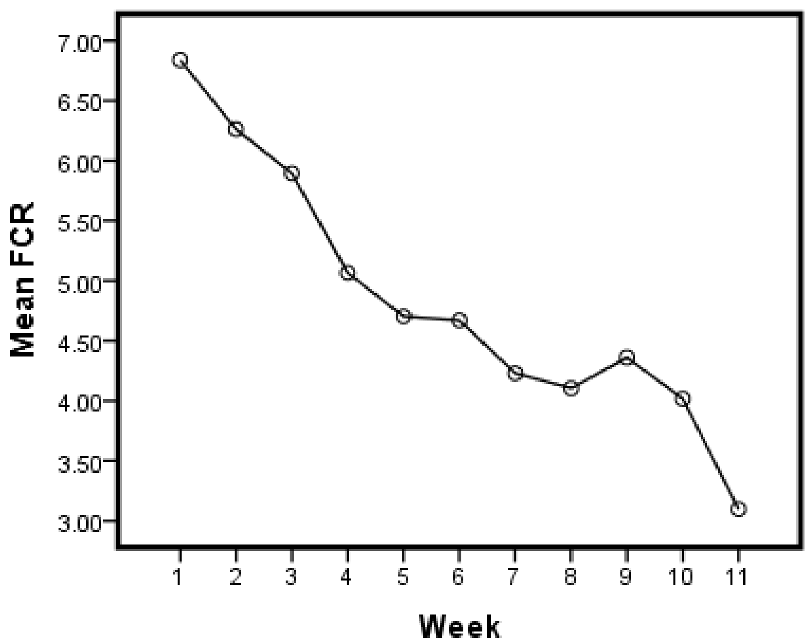

Figure 3. FCR trends of *C. liocephalus* fingerlings fed on 4 test diets over 11 weeks.

diet and the lowest in the 25% CP diet (Table 3).

Percent survival was 46.44% ±3.159SE for all the four treatment diets. The individual means for diets 1 to 4 were 43, 46, 49 and 47%, respectively. Percent mortality was the highest in the first four weeks, but dropped to almost 0% from week 5 to the end of the experiment (Figure 4).

The condition of fish fed on Diet 1 (25% CP) and 4 (40% CP) was poor and significantly different from fish fed on Diets 2 (30% CP) and 3 (35% CP).

DISCUSSION

This study intended to establish whether *C. liocephalus*, a wild wetland small catfish, could survive in an artificial environment, utilize an artificial diet to grow in weight and length, maintain good condition and adequately convert the feed into fish flesh. The over 40% overall survival is a clear indication that *C. liocephalus* can survive in an artificial environment and on artificial diet and the fact that some of the experimental fish greatly increased in body

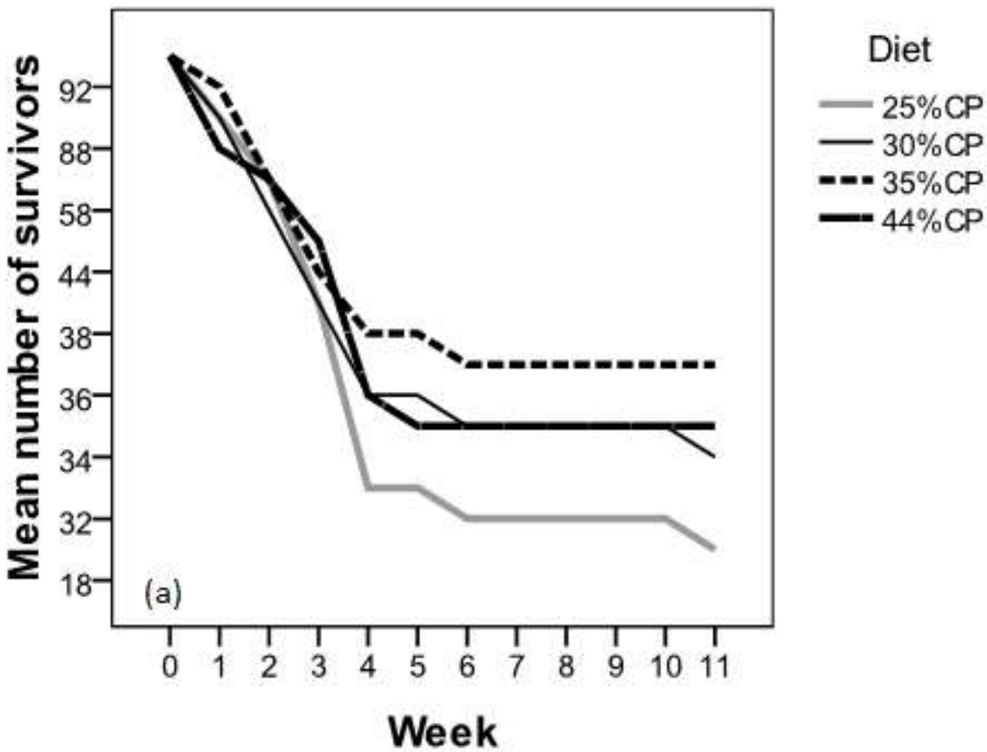

Figure 4. Survival trends of *C. liocephalus* fingerlings fed on 4 test diets over 11 weeks

mass (from 5.5 g maximum at beginning to 20.7 g maximum at end of experiment), is a positive indicator that *C. liocephalus* could attain table size in a relatively short period. However, there was size disparity within the stocked fish in all the treatments although similar sized fish were stocked at the beginning of the feeding experiment. Size disparity is a common phenomenon in catfish stocks during the initial stages of development (De Graaf and Janssen, 1996). Since size-grading was not done during the course of the experiment, size disparity could be partly explained by the nature of the fish species. Persistence of stunted individuals throughout the study period could be attributed to poor seed quality because the stocked juveniles were randomly picked from the wild. Besides feed quality, seed quality is known to be a very important factor in fish production (De Graaf and Janssen, 1996; Pouomogne, 2008). Stunted growth could also be attributed to starvation because of competition with larger individuals. Since feeding was done only twice a day, it is possible that less competitive individuals could have starved. It has been reported that when frequently fed, fish yielded more because dominant individuals become less aggressive in such circumstances (Aderolu et al., 2010). Feeding three times a day is known to be the most efficient frequency for effective growth and nutrient utilization for juveniles and fingerlings of *C. gariepinus* (Aderolu et al., 2010).

The feed conversion ratio (FCR) for the 4 treatments was generally higher than expected given the typical 1.4 to 2.5 recorded in catfish production experiments (Robinson et al., 2001). However, a consistent reduction in FCR from high figures in the first weeks and low figures in the last weeks was noted. This is an indication that as the fish grew and became used to the feed, utilization improved. If the experiment was to run for more time (up to normal harvest time), the results suggest that the FCR would have dropped to acceptable levels of two and below. The FCR could also have been influenced by the low DO levels since the water in the experimental pond was not on a flow through design and therefore poorly aerated. The oxygen levels were below the required minimum most of the time during the experiment (overall mean of 1.39 mg/l), and this could have compromised the quality of the water. Low DO levels have significant effects on fish growth as well as food conversion (Chang and Ouyang, 1988). In poorly aerated waters, catfish spend a lot of energy to obtain atmospheric oxygen and this stresses the fish and lowers its appetite and feed utilization (De Graaff and Janssen, 1996). Lack of flow-through water system and short duration of experiment have been implicated for poor values of FCR in other fish feeding experiments (Mwangamilo and Jiddawi, 2003). The SGR of 2.2 to 2.5%, is comparable to that reported in other Clariidae reared within an almost similar experiment duration (Akinwande et al., 2009; Solomon and Taruwa, 2011).

However, SGR in *C. liocephalus* was low compared to *C. gariepinus* (5.7%) fed on a diet of maggots (Otubusin and Ifili, 2000). The difference could lie in the source of feed, duration of the experiment, seed quality and other conditions in the experimental environment.

In the first four weeks of the experiment, mortality was the highest and dropped to almost 0% in the last weeks. The high mortalities could be attributed to handling stress as well as high stocking density. One hundred fingerlings in a 1 m^3 hapa in a non-recirculatory water system could have been stressful and a likely cause of mortality and high survival after the stock fell by almost 50%. High mortalities in the first weeks of feeding experiments have been reported in other catfish (Akinwande et al., 2009).

The findings of this study indicate that *C. liocephalus* has a number of attributes that could make it a suitable choice for subsistence aquaculture in rural settings. Subsistence aquaculture has the potential to contribute to most of the relevant sustainable development goals (SDGs). This is due to the family level of operations, where work is well distributed, meaningful and empowering. While there is no direct impact on poverty, it does provide a regular supply of high quality protein, sparing income for other food and living expenses. It is also environmentally efficient, especially when integrated into other farming activities. It can make households and communities more resilient to economic or environmental shocks.

CONCLUSIONS AND RECOMMENDATIONS

From the findings of this study, we conclude that *C. liocephalus* can grow and survive outside its natural wetland environment. The species can endure low levels of DO and a wide range of temperature variations and register a specific growth rate that is comparable to that reported in other reared Clariidae. The species exhibited a key aquaculture advantage in its ability to survive both in hypoxic and hyperoxic water environments that are typical of fish pond waters in a tropical rural setting. Unlike some obligate air-breathers like *Protopterus* species, which die if deprived of atmospheric oxygen, *C. liocephalus* can survive under stress of both atmospheric and dissolved oxygen. The survival of *C. liocephalus* in turbid water ponds at low dissolved oxygen levels is a positive indicator that the species has some desirable qualities for survival in the prospects of climate change, where predicted droughts will likely cause deterioration of water quality. That *C. liocephalus* can withstand a wide range of water quality parameters is an opportune coping strategy to provide nutrition and revenue to rural communities in the face of global demand for aquatic food. Since the species has the required traits to be raised in an artificial environment, further rearing trials for longer periods and measurement of the rest of the production indices required in aquaculture fish species are recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors are indebted to RUFORUM and partners who provided financial support for this study, Lilongwe University of Agriculture and Natural resources, Mbarara University of Science and Technology and Makerere University for the expert support in the analysis of the samples, National Fisheries Research Institute Kajjansi and MbaZARDI for hosting the experiments.

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