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Zoology

Growth Performance, Feed Conversion Ratio and Survival of African Catfish, *Clarias gariepinus* (Burchell, 1822) In Response to Varying Levels of Crude Protein

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Abstract **Original Research Article**

The study evaluated the effect of varying crude protein (CP) levels on the survival and growth performance of Clarias gariepinus reared in in hapas in earthen pond. The fish were stocked at the rate of 70 per 2 m by 2 m hapa net (0.5 mm mesh size) and fed on diets formulated from soybean, *Caridina nilotica* (Lake Victoria shrimps), cotton seedcake and wheat pollard. Vitamins and mineral supplements were incorporated at 1% each. Three groups of formulated diets of 35%, 30%, 25% CP and a commercial diet (28% CP control diet) with three replicates each, were fed to *C. gariepinus* with initial average weight of 3.0 ± 0.001 g and total length of 20 mm at an initial stocking density of 70 fish in a 2 m by 2 m hapa net. The hapas were placed in a 200 m^2 earthen pond. The study was evaluated in terms of the growth performance of weight, length, feed conversion ratio (FCR), feed conversion efficiency (FCE), and survival rates of Clarias gariepinus when fed on varying CP diets. The data showed that *C. gariepinus* fed on locally formulated diets had a higher growth performance in respect to weight gain, length gain, FCR, FCE than those fed on commercial diet. Further, the survival of *C. gariepinus* fed on locally formulated feeds was comparatively higher than for those fed commercial feed. Of note, growth performance and survival of fish fed on 35% CP was the highest. These results demonstrated that *C. gariepinus* fed on locally formulated diets, especially 35% CP, exhibited higher growth performance in terms of the parameters above compared to those fed on commercial feed. Thus, locally formulated feed with about 35-25% CP could potentially be adopted as an alternative replacement to the commercial feed in *C. gariepinus* farming.
Keywords: Clarias gariepinus, Catfish, Crude protein, Survival rate, Hapa net.

INTRODUCTION

Fish culture can be done in several systems, such as ponds, raceways, recirculating systems or cages [1]. Hapa nets (with small mesh sizes) which are a form of cages, have been used to produce Nile tilapia, *Oreochromis niloticus* seed [2]. Considering the progressive decline of the wild capture fisheries and human population upsurge worldwide, aquaculture is expected to play a pivotal role in ensuring sufficient fish in the market. Thus, aquaculture is promoted by world food production agencies and governments, and has experienced substantial growth. In 2013 and 2015, the relative share of aquaculture contribution to the global fish production and consumption was 44% and 50%, which is projected to increase to 52% and 57% by 2025 respectively [3].

A study by Omeru and Solomon evaluated the growth performance of *C. gariepinus* fed on earthworm fish meal and Coppens Commercial Feed for three months. The mean growth rate, weight gain, growth rate, and specific growth rate of *C. gariepinus* fed on earthworm fish meal were significantly higher than for those fed the commercial feed [4]. However, earthworm could be largely unavailable to most farmers, hence unsustainable for large-scale fish production. Further, a several reports showed that growth performances of hybrid catfish fry [5], *Chrysichthys nigrodigitatus* fingerlings [6] and in *Heterobranchus longifilis* [7] were influenced by the CP levels in the diets. More specifically, Diyaware and colleagues [5] reported that growth rate and weight gain increased progressively with dietary protein level to a maximum of 50%. A high weight gain and specific growth rate (SGR) was observed in milkfish (*Chanos chanos*) fed at 40% protein level [8]. Further, a report showed that cage-reared *C. gariepinus* fed on 45% CP exhibited better growth performance than those reared in tanks. However, there was no significant difference in survival of fish reared in cage or tanks [9]. However, the two previous studies evaluated high levels of CP which could be expensive to fish farmers.

Although C. gariepinus is capable of alleviating food insecurity due to its high fecundity, fast growth, good adaptability and high tolerance to environmental changes, its production is limited by lack of affordable feeds and production systems. Thus, there is need for studies to better understand the performance of *C. gariepinus* on low and cheaply available sources of proteins which has the potential to make a significant contribution to aquaculture growth. Currently, *O. niloticus* is the only fish cultured in cages [10], there is need to evaluate the performance of *C. gariepinus* in cages (hapas), which can reduce disappearance of *C. gariepinus* in muddy ponds.

Therefore, the present study sought to understand the growth performance (weight gain, total length increase, feed conversion ratio, feed conversion efficiency, and survival rates of *C. gariepinus* in response to diets formulated from cheap and locally available sources of proteins, such as soybean, *Caridina niloticus*, cotton seedcake and wheat pollard in comparison to commercial feed.

MATERIALS AND METHODS

Study area

The *C. gariepinus* experiments were conducted at the Kenya Marine and Fisheries Institute (KMFRI), Sangoro station, Kenya (Latitude: 0° 21' 13" S and longitude: 34° 45' 26" E).

Experimental design

Eight hundred and forty healthy fingerlings of *C. gariepinus* (2.5-3.0 g) were purchased from Kibos Integrated fish farm located approximately 10 km East of Kisumu city, Kenya, and transported to Kenya Marine and Fisheries Research Institute (KMFRI), Sangoro Centre (Latitude: 0° 21' 13" S and longitude: 34° 45' 26" E). They were acclimatized to the conditions at the Centre for 15 days using two large hapa nets, each measuring 4 m by 6 m placed in a 15 m by 10 m earthen pond. During acclimatization, the fish were fed with a commercial diet of crude protein 28%. Fish were weighed individually and seventy uniform-sized healthy fish (mean weight 3.0 ± 0.001 g) were randomly distributed in four dietary treatment groups, T1 (35% CP diet), T2 (30% CP diet), T3 (25% CP diet) and T4 (28% CP diet) with three replicates each and stocking density of 4 fish/m^2 in a 2 m by 2 m hapa of 0.5 mm mesh size which was placed in 200 m^2 earthen pond.

Diet preparation and proximate analyses

The experimental feed ingredients, namely cotton seedcake, soybean meal and wheat pollard were procured from a local open-air market in Kisumu city, Kenya while the fresh water shrimps were obtained from *L. Victoria*. At the outset, all the ingredients except for vitamin and mineral premixes were thoroughly mixed and water added and further mixed to form dough. Vitamin and minerals were then added followed by thorough mixing before pellets were made using an extruder DGP 70 dry type fish feed machine (Jinan Sunward Machinery Co. Limited, China) to get uniform size pellets (2 mm) and sun dried for two hours. The dried pellets were kept in airtight sacs before use.

Proximate analyses of the feed ingredients and the experimental diets were as per the procedure from AOAC [12]. The analyses involved the following nutrients: crude protein (CP), ether extract (EE), ash content, nitrogen-free extracts (NFE) and crude fiber (CF). The CP was estimated from Kjeldahl nitrogen. Crude lipid was quantified as the loss in weight after extraction of the sample with petroleum ether (40–60^{o}C). Ash content was determined by burning the samples in a muffle furnace at 550^{o}C for 4 hours. CF was quantified by alkaline/acid digestion followed by ashing at 550°C in a muffle furnace for 4 hours. The NFE was determined by the difference method (DM-CP-EE-CF-Ash). Proximate analyses of the feeds were carried out in triplicate.

Fish feeding and sampling

The fish in hapa were fed at 3% of their body weight daily. The weighed out feed was divided into 3 portions which were supplied to the fish thrice a day as follows: at 900 hours, at 1300 hours and at 1700 hours.

Fish sampling from the hapas-in-pond was performed by use of scoop-nets fortnightly. Weight and total length measurements were done on all the fish from the hapa at every sampling time. This continued throughout the experiment. Live weight gain, the difference between initial and final weights recorded for the entire study period indicated the growth (productivity), and this parameter was used to determine growth and feed conversion ratio for the diets used. The length weight data were used to analyze and determine the length-weight relation and condition indices. No signs of diseases were observed in the experimental period.

Water quality analyses

Samples for water quality analyses were taken monthly using a 112 cm water column sampler as previously described [12]. The analyzed water quality variables include nitrate-nitrogen, nitrite-nitrogen, total ammonia nitrogen, soluble reactive phosphorus, total phosphorus, total alkalinity, total hardness, and pH. Water quality analyses were carried out according to the methods described in American Public Health Association (APHA) [14]. A glass electrode pH meter, Hi-9024 microcomputer (Hanna Instruments Ltd., Chicago, IL, USA), was used to measure pH. Temperature and dissolved oxygen, measurements were taken using model 57 oxygen meter (YSI Industries, Yellow Springs, OH, USA). Other environmental parameters in each hapa including salinity, conductivity and turbidity were also analyzed using procedures as stated in APHA [14].

Data calculation

The following formulae were used to calculate variables in this study:

$$\text{Length gain} = \text{Average final length} - \text{Average initial length}$$
$$\text{Weight gain} = \text{Average final weight} - \text{Average initial weight}$$
$$\%\ \text{SGR in weight per day} = \frac{In\mathrm{W}_{t2}}{In\mathrm{W}_{t1}} \times 100$$
$$\text{FCR} = \frac{\text{Total feed given (g)}}{\text{Body weight gain (g)}}$$
$$\%\ \text{Survival rate} = \frac{\text{Total number survived}}{\text{Total number stocked}} \times 100$$
$$\text{FCE} = \frac{\text{Weight gain} \times 100}{\text{Feed intake}}$$
$$\text{Condition factor} = \frac{\text{Weight } \times 100}{L^3}$$

Where; W_{t2} = final live body weight (g) at time $T_{t2;}$ W_{t1} = Initial live body weight (g) at time $T_{t1;}$ Ln_{t2} = Final total body length; Ln_{t1} = Initial total body length; L = total length

Statistical analysis

Statistical analysis was performed using GraphPad Prism software version 5.03 (GraphPad Inc., California, USA). Data normality was verified using Shapiro-Wilk test. Data are presented as mean ± standard error of the mean (SEM). Statistical differences between treatment groups were determined using one way analysis of variance (ANOVA) with Tukey's post-test. A difference with a p-value less than 0.05 was considered significant.

Results and Discussion

Proximate nutrient composition and physico-chemical parameters

In this study, the effectiveness of four diets on *C. gariepinus* growth performance and survival were evaluated. Prior to the evaluation, the proximate contents of the diets such as crude protein, lipid, moisture and ash were analyzed. Analysis of the diets showed proximate composition of 35% CP, 30% CP, and 25% CP and 28% CP as presented in details elsewhere [15].

Table-1: The physico-chemical parameters of the water in hapas used for raising *C. gariepinus*

Parameters	Measured values
Temperature (°C)	23.54 ± 1.11
Conductivity (µS/cm)	411.75 ± 20.99
DO (mg/L)	5.29 ± 1.75
pH	8.28 ± 0.51
TDS (mg/L)	205.75 ± 10.58
Salinity (ppt)	0.20 ± 0.00
ORP (mV)	63.78 ± 20.41
Turbidity (NTU)	325.50 ± 170.40
Nitrates (μgL^{-1})	38.29 ± 7.44
Nitrites (μgL^{-1})	26.17 ± 11.19
NH3-N (μgL^{-1})	25.24 ± 48.11
NH4-N (μgL^{-1})	61.36 ± 117.39
SRP (μgL^{-1})	261.86 ± 289.89
Silicates (mgL^{-1})	20.49 ± 3.05
Alkali (mgL^{-1})	207.50 ± 0.00
Hardness (mgL^{-1})	67.00 ± 9.17

Note: The values represent the mean ± SEM taken monthly during the experimental period

Water quality being a key determinant of the growth performance of any fish species, the physico-chemical parameters of water that are likely to affect growth of fish were monitored throughout the experimental period (Table 1).

The parameters were within the acceptable standard limits. Taken together, the data presented show that all the *C. gariepinus* culture conditions were similar and within acceptable range; hence, the differences in the overall fish performance are attributable to the differences in the CP levels.

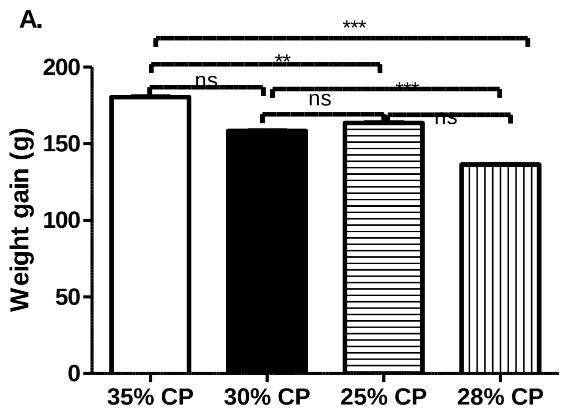

Fig-1: Comparison of the weight gains of *C. gariepinus* fed on different CP levels. The weight gains of *C. gariepinus* fed on 35%, 30%, 28% or 25% CP diets were measured. The bars represent the mean ± SEM. The weights were measured in triplicates fortnightly over the 182 day period. The statistical comparison was determined using One way-ANOVA with Tukey's post-test (ns, $p > 0.05$; **, $p < 0.01$; ***, $p < 0.001$)

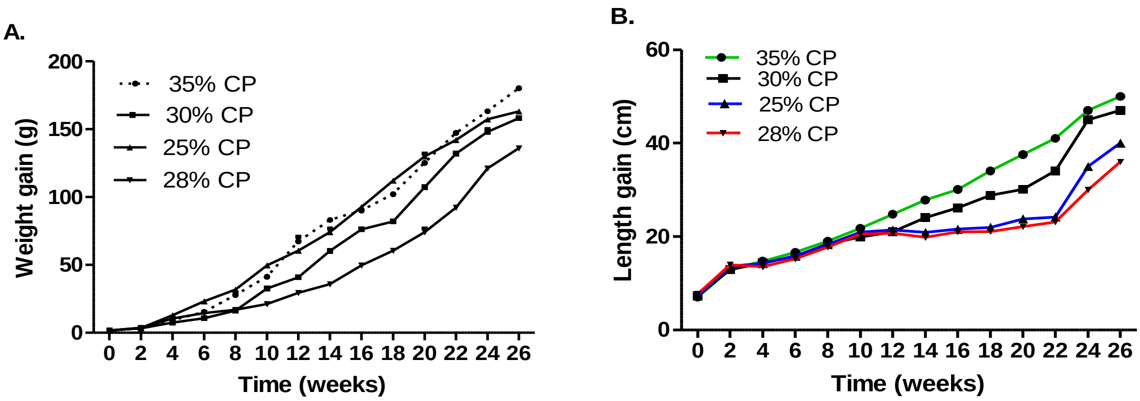

Fig-2: Growth of *C. gariepinus* fed on different CP diets over time. The weight gain (A) and length gain (B) were taken over the 26-week period for fish fed on 35%, 30%, 28% or 25% CP. The experiments were conducted in triplicate. Each plot represents the mean ± SEM

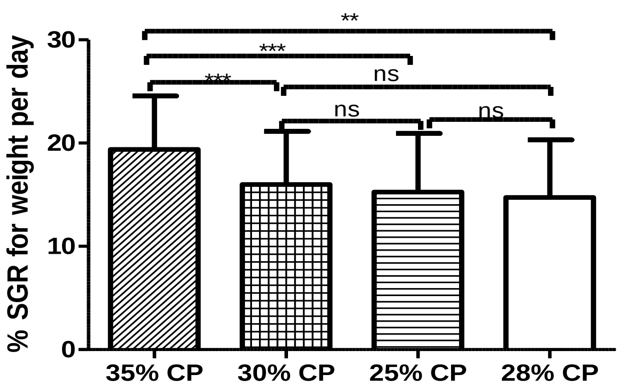

Fig-3: Comparison of SGR in weight of *C. gariepinus* fed different CP levels

The percent SGR in weight of *C. gariepinus* fed on 35%, 30%, 28% or 25% CP diets were measured. The bars represent the mean ± SEM. The SGR were measured in triplicates fortnightly over the 182 day period. The statistical comparison was determined using One way-ANOVA with Tukey's post-test (ns, $p > 0.05$; **, $p < 0.01$; ***, $p < 0.001$).

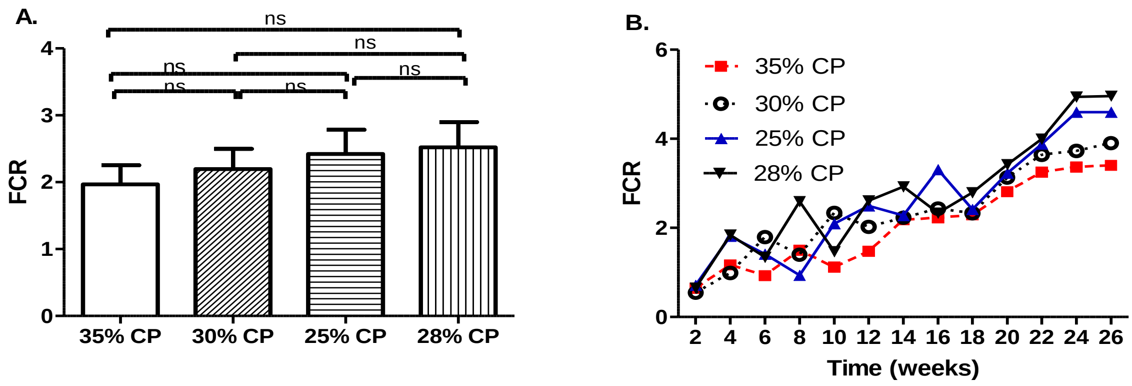

Fig-4: Comparison of FCR *C. gariepinus* fed on different CP levels

The FCR of *C. gariepinus* fed on 35%, 30%, 28% or 25% CP over a 182 day period were measured. The experiments were conducted in triplicate. Bars or plots represent the mean ± SEM. The FCR were calculated in triplicates fortnightly over the 182 day period. The statistical comparison was determined using One way-ANOVA with Tukey's post-test (ns, $p > 0.05$).

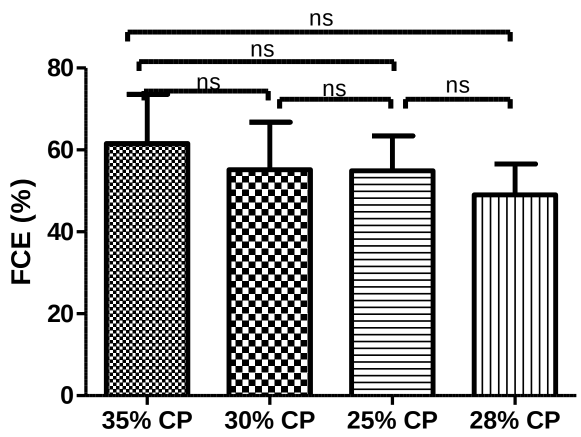

Fig-5: Comparison of FCE of *C. gariepinus* fed on different CP levels.

The FCE of *C. gariepinus* fed on 35%, 30%, 28% or 25% CP over a 182 day period were measured. The experiments were conducted in triplicate. Bars represent the mean ± SEM. The FCE were calculated in triplicates fortnightly over the 182 day period. The statistical comparison was determined using one way-ANOVA with Tukey's post-test (ns, $p > 0.05$).

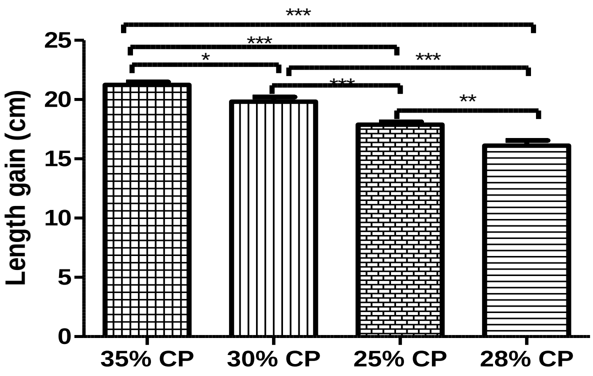

Fig-6: Comparison of the length gains of *C. gariepinus* fed on different CP levels

The length gains by *C. gariepinus* fed on 35%, 30%, 28% or 25% CP diets were measured. The bars represent the mean ± SEM. The lengths were measured in triplicates fortnightly over the 182 day period. The statistical significance was determined using One way-ANOVA with Tukey's post-test (*, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$).

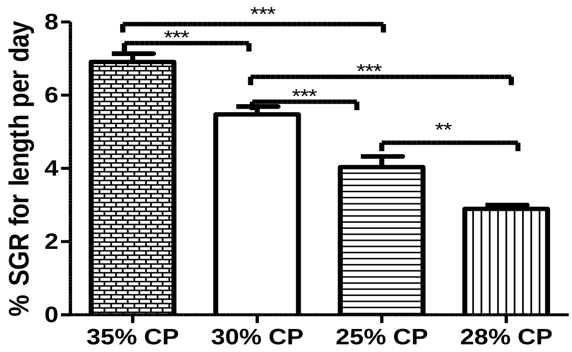

Fig-7: Comparison of SGR in length of *C. gariepinus* fed different CP levels

The percent SGR in weight of *C. gariepinus* fed on 35%, 30%, 28% or 25% CP diets were calculated. The bars represent the mean ± SEM. The SGR were calculated in triplicates fortnightly over the 182 day period. The statistical comparison was determined using One way-ANOVA with Tukey's post-test (**, $p < 0.01$; ***, $p < 0.001$).

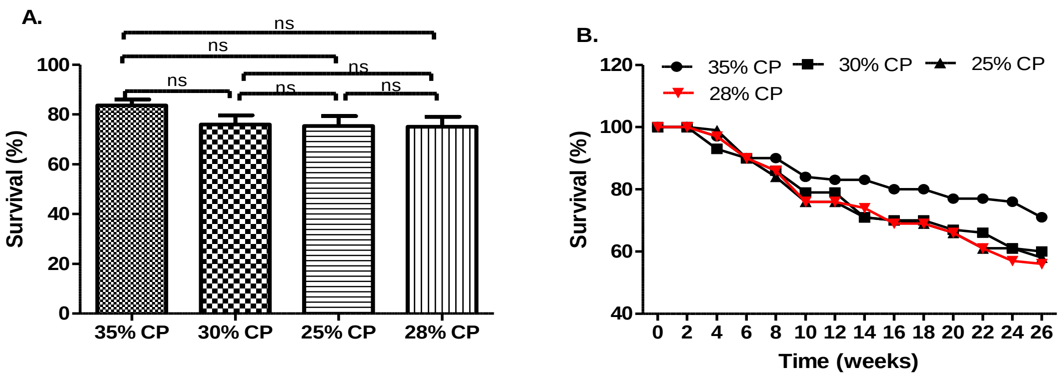

Fig-8: Comparison of survival *C. gariepinus* fed on different CP diets

The comparison of survival (**A**) and survival trend over time (**B**) of *C. gariepinus* fed on 35%, 30%, 28% or 25% CP over a 182 day period were measured. The experiments were conducted in triplicate. Bars or plots represent the mean ± SEM. The survival was determined in triplicates fortnightly over the 182 day period. The statistical comparison was determined using one way-ANOVA with Tukey's post-test (ns, $p > 0.05$).

Growth performance of *C. gariepinus* fed on diets containing different crude protein levels

To compare the growth performance of *C. gariepinus* in response to the four CP levels, the fish were fed on the diets for 182 days. There was a significant difference in the weight gains by the fish fed on the four diets (Figure 1; One-way-ANOVA, $p < 0.0001$). Tukey's post-test revealed that *C. gariepinus* fed on 35% CP had significantly higher weight gain than the 28% CP ($p < 0.01$) and 25% CP ($p < 0.001$). Further, the weight gain by fish fed on 30% CP was significantly higher than those fed 25% CP over the same duration ($p < 0.001$). However, there was no significant difference in the weight gains of fish fed 30% or 28% CP and 25% CP ($p > 0.05$) (Figure 1). Moreover, the weight gains of *C. gariepinus* were observed to be increasing gradually over time (Figure 2A). Taken together, the results implied that 35% CP gave the best weight gain but 25% CP was as good as the commercial feed (28% CP).

Further, it was observed that the % SGR in weight per day was significantly different for *C. gariepinus* fed on the four diets for 182 days (Figure 3; One-way-ANOVA, $p < 0.0001$). Tukey's post-test revealed that *C. gariepinus* fed 35% CP had significantly higher % SGR in weight per day than those fed 30% CP ($p < 0.001$), 28% CP ($p < 0.001$) or 25% CP ($p < 0.01$). However, no significant differences in the % SGR in weight per day was observed in *C. gariepinus* fed 30%, 25% or 28% CP diets ($p > 0.05$). Taken together, the findings implied that 35% CP exhibited significantly higher SGR in weight and that 25% CP gave similar SGR in weight just as 28% CP (commercial feed).

Moreover, no significant difference in the FCR of fish fed on the four diets was observed (Figure 5; One-way ANOVA, $p = 0.5872$). The FCR was considerably higher for fish fed on 30% CP followed by 35% CP, 30% CP and 25% CP in that order. These results implied that the CP diets were almost equally converted to body weights by the *C. gariepinus* .

In addition, no significant difference in the FCE of *C. gariepinus* fed on the four diets was observed (Figure 6; One-way ANOVA, $p = 0.9585$). These results implied that the CP diets were almost equally converted to body weights with 35% CP diet having significantly higher FCE.

Further, there was a significant difference in the length gains by the fish fed on the four diets (Figure 7; One-way-ANOVA, $p < 0.0001$). Tukey's post-test revealed that *C. gariepinus* fed on 35% CP had significantly highest length gain followed by 30% CP ($p < 0.05$), 25% CP ($p < 0.001$) and 28% CP ($p < 0.001$) in that order. Further, the length gains of *C. gariepinus* increased gradually over time (Figure 2B). Taken together, the results indicated that 35% CP intake resulted in higher length gain and that length gain was directly dependent on the CP level fed.

In addition, it was observed that the % SGR in length per day was significantly different for *C. gariepinus* fed on the four diets for 182 days (Figure 8; One-way-ANOVA, $p < 0.0001$). Tukey's post-test revealed that *C. gariepinus* fed 35% CP had significantly higher % SGR in weight per day than those fed 30% CP ($p < 0.001$), 25% CP ($p < 0.001$) or 28% CP ($p < 0.01$). Taken together, the findings implied that 35% CP gave the highest SGR in length in comparison to the other CP levels.

The present findings concur with a previous report on growth performance of *C. gariepinus* fed on different CP diets, but not on the feed conversion efficiency [4]. The present observation that growth performances of *C. gariepinus* were influenced by the CP levels is consistent with several previous reports on hybrid catfish fry [5], *C. nigrodigitatus* fingerlings [6] and in *H. longifilis* (Babalola & Apata, 2006). More specifically, Diyaware and co-workers [5] reported that growth rate and weight gain increased progressively with dietary protein level to a maximum of 50%. A high weight gain and SGR was observed in milkfish (*C. chanos*) fed at 40% protein level [8]. Moreover, catfish fingerlings fed with 40% protein gave the best growth [16]. The highest FCR of 0.06 obtained in this study was better than 1.28 observed in *C. gariepinus* fed with 40% protein [17]. However, the present study contradicts a previous report, which showed that *C. gariepinus* raised in hapas and fed on different CP levels had no significant difference in growth performance [18]. The discrepancy between the present and previous outcomes could be related to differences in geographical or environmental conditions. However, the previous reports evaluated high CP levels or utilized fingerlings hence, may not be easily embraced by farmers or formulated from locally available ingredients.

In the present study, higher growth performance was observed in fish fed 35% CP. The differences observed between the present findings and the previous could be explained by the intraspecific differences, the varying methodologies used, such as feed formulation and feeding rate tests or type of culture system used in the individual experiments. In this study, low CP in diet resulted in fairly good performance in relation to the commercial feed currently recommended for *C. gariepinus* farmers in Kenya. This is clearly seen in *C. gariepinus* fed on 25% and 28% CP producing almost similar growth performance. Taken together, the present findings suggested that *C. gariepinus* has a capacity to accept and utilize low protein diets formulated from locally available materials to perform optimally.

Survival and condition factors of *C. gariepinus* raised on different CP diets

In the present study, the survival rate of *C. gariepinus* fed on the four CP diets was assessed. No significant difference in the survival of fish fed on the four diets was observed (Figure 9; One-way ANOVA, $p = 0.2714$). However, the survival was slightly highest for fish fed on 35% CP followed by 30% CP, 28% CP and 25% CP. Further, the survival was shown to decrease gradually with time (Figure 9B). These results implied that the survival of *C. gariepinus* is not dependent on the CP content of the diet. The survival percentages of the present study are comparable to those of a previous report, which involved comparing effect of stocking densities on the survival rates of tilapia fed on 34.55% CP [18]. Although the previous studies used net hapas, they only focused on tilapia and did not evaluate the effect of CP levels. The slight discrepancy in the survival rates observed between the previous and present studies could be attributed to the differences in the experimental fish species or geographical locations. The present findings suggest that low protein levels could be used to raise *C. gariepinus* with minimum mortalities.

CONCLUSIONS

In summary, the present study demonstrated that *C. gariepinus* fed on locally formulated diets, especially 35% CP, exhibited better growth performance in terms of the parameters above compared to those fed on commercial feed. Thus, locally formulated feed with about 35-25% CP could potentially be used as an alternative replacement to the commercial feed in *C. gariepinus* farming.

Competing interests

The authors declare that they have no competing interests.

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