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Growth and Production implications of a 3-days and 5-days Intermittent Feed Deprivation and Re-feeding Strategies in Juvenile *Clarias gariepinus* Catfish Farming.

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ABSTRACT

Clarias gariepinus catfish is an important fish farmed in West African. However, the successful culture of this fish is hampered by the ever-increasing cost of feed. Study was conducted to exploit the compensatory growth patterns that has been reported in fish and to determine the effects of intermittent feed deprivation and refeeding on the production performance of juvenile Clarias gariepinus. One hundred and sixty (160) juvenile fish (80 ± 23 g; 23.55 ± 7.31 cm) were randomly distributed into four 200-liter aquaria labeled A, B, C and D. Fish in group A (the control) were fed continuously; fish in group B, were subjected to a 3-days feed deprivation and 3-days refeeding regimen; fish in group C, were subjected to a 5-days feed deprivation and 5-days refeeding regimen; and fish in group D were subjected to a 5-days feed deprivation and 7-days refeeding regimen. Growth parameters were measured in all groups for 98 days. Results shows that there were no significant variations ($p > 0.05$) in the final weight gained by fish in group B compared to fish in group A. Fish in groups C and D exhibited compensatory growth and had significantly higher weight gains compared to fish in group A. Fish in group B exhibited the highest compensation coefficient of 2.348 compared with 2.212 and 1.287 for groups C and D respectively. It is concluded that juvenile Clarias gariepinus can be produced following a feed deprivation and refeeding regimen, without significantly affecting its growth and production performance. The economic implication of this strategy is that production can be maximized while significantly reducing the cost of feeding. It is recommended that a 5-days feed deprivation and 5-days refeeding regimen be employed as this results in high weight gain at a reduced cost.

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INTRODUCTION

Fish is an important part of a healthy diet as it provides unique health and nutritional benefits being a source of essential nutrients such as proteins and long chain omega-3 fatty acids [1]. *Clarias gariepinus* also, commonly known as African sharp toot catfish, is the most cultured fish species in Nigeria and Africa at large. This fish is commonly farmed due to its high economic value, fast growth rate, high resistance to disease and tolerance to environmental stress [1, 2].

Nutrition and feeding in fish are reported to be an area in fish culture that requires further investigation [3, 4]. The cost of feed constitutes about 60-70% of the total cost of farmed fish production, and this is a very significant aspect in the success of operating a fish farm [5] [6]. However, an increased growth rate and feed efficiency in various fish species can be achieved by short-term or multiple periods of feed deprivation and re-feeding [6]. It has been reported that some organisms show faster growth during recovery from a period of feed deprivation than they do during periods of continuous feeding [7].

The phase of accelerate growth, termed 'compensatory growth', has been variously defined as a phase of growth that is higher than the normal growth following a period of feed deprivation, stock under nutrition and/ or unfavorable environmental conditions [8, 9, 10]. Other factors that affect the degree of compensatory growth, includes the species of the fish, the age and weight of the fish, the duration of feed deprivation, the pattern of feeding and the quality of the feed fed to the fish [11].

In the wild, most fish species including the carnivorous fishes, feed once every two days [10]. This is an indication that farmed fish can be reared on a 'skip-a-day' system as practiced in poultry production, without significant deleterious effects on production [12]. It is reported that fish can adapt anatomically and physiologically to intermittent feeding by increasing the relative stomach weight and volume, thereby enabling the ability of the fish to consume more food in periods of abundance [13, 14]. According to [15], compensatory growth is characterized by a phase of accelerated gain in weight following a period of feed restriction. In addition, compensatory growth is further classified into overcompensation, full compensation and or partial/no compensation [16].

The objective of the present study is to determine the implications of a 3-days, and 5-days intermittent feed deprivation and re-feeding strategies on the growth and production performance of juvenile *Clarias gariepinus* catfish.

MATERIALS AND METHODS

Experimental Fish and Culture Conditions

One hundred and sixty (160) juvenile *Clarias gariepenus* (80 ± 23 g; 23.55 ± 7.31 cm) were obtained from a local supplier and reared within the Aquaculture Unit of the Faculty of Veterinary Medicine Teaching and Research Farm of the University of Abuja. The experimental fish were acclimatized for two weeks in a 1000 cm^3 capacity holding tank, after which they were randomly grouped depending on the proposed feed deprivation and re-feeding regimen into four groups consisting of a control group (Group A) and three treatment groups (Groups B, C and Group D). The feed deprivation and re-feeding durations applied in the experimental groups consisted of the following; Group B (three days feed deprivation, followed by three days re-feeding); Group C (five days feed deprivation followed by five days re-feeding) and Group D (five days feed deprivation followed by seven days re-feeding). The culture water was derived from the city water supply and had been reported to meet the water quality parameters requisite for the culture of the *Clarias gariepinus* fish species [17].

Experimental groups were held in 200 liters aquaria covered with mosquito nets to prevent the entry of predators. Fish were fed twice (8:00 AM and 6.00 PM) daily.

Experimental Design
After a period of 14 days acclimatization, the fish were randomly distributed into any of the experimental groups consisting of 40 fish per group.

Group A (continuously fed daily to satiation).

Group B (three days feed deprivation and three days refeeding regimen).

Group C (five days feed deprivation followed by five days refeeding regimen)

Group D (five days feed deprivation and seven days refeeding regimen).

At set sampling time points (days 0, 7, 63 and day 98), four fish were randomly selected from each group, weighed (using a sensitive weighing scale) and total length measured (using a graduated ruler) to determine growth parameters. All measurements were throughout the 98 days duration of the study.

Water Analysis
Water samples were collected from each culture aquaria at the fish sampling days and analyzed according to the methods of [18]. Temperature, dissolved oxygen, $_{P}H$ and conductivity were measured at specific time points prior to fish sampling.

Biometric Evaluations
Biometric measurements and organ sampling were made on the euthanized fish. Each fish was weighed using an electronic sensitive scale; the total body weight of each fish was measured and recorded. The length was measured using a transparent meter rule which was placed parallel to the fish from the head to the tip of its tail fins and the result recorded. The specific growth rate (SGR) was determined as described by [19], using the formular.

$$SGR = 100 \times (\ln W_2 - \ln W_1)/T.$$

Where, W_2 and W_1 are the final and initial weight measured respectively.

The percentage weight gain (PWG) was determined as described by [20], using the formula:

$$PWG = 100 \text{ x } (W_2 - W_1)/W_1.$$

Where, W_2 and W_1 are the final and initial weight measured respectively.

The Condition Factor (CF) was determined as described by [20], using the formula:

$$CF = (W/L^3) \text{ x} 100.$$

Where W = Body weight (g) and L = length (cm).

The Organo-somatic indexes were determined as described by [20], using the formula:

Organo-somatic index

$$= 100 \times (\text{organ weight / total body weight}).$$

The Percentage survival was determined as described by [21], using the formular.

Percentage survival
$= 100 \times (\text{final number of fish/initial number of fish}).$

The compensation coefficient (CC) was determined according to [16] using the formula:

Compensatory Coefficient (CC) = $\Delta T/\Delta C$
Where ΔT = average weight gained in treatment group (g)/number of feeding days (day), and ΔC = average weight gain in the control group (g)/number of feeding days (day).

Statistical Analysis
Results were expressed as means ± standard deviation of the means. The relationships between the groups were assessed using a one-way analysis of variance (ANOVA). Variant means were separated using Turkeys multiple range post hoc test with $p < 0.05$.

RESULTS
The values obtained for water quality

parameters are temperature: 29.15 ± 0.61^{O}C; dissolved oxygen: 10.56 ± 0.15mg/dl; ph: 8.05 ± 0.01 and conductivity: 497.7 ± 0.9 µS/cm (These values were within the acceptable water quality parameter ranges in freshwater fishes).

The results obtained for the assessment of the growth performance of juvenile *Clarias gariepinus* following varying periods of feed deprivation and refeeding regiment for a period of 98 days are presented in tables 1, 2, 3 and table 4.

Table 1 shows that the initial weight of the groups of fish that were on different feed deprivation and refeeding regimen were not significantly different (P > 0.05) from the group of fish that were on the continuous feeding regimen. One way analysis of variance (ANOVA) shows the final weight of the groups of fish subjected to varying periods of feed deprivation and refeeding regimen varied significantly compared with the final weight of fish subjected to continuous feeding regimen ($p < 0.05$). The Turkey's post hoc test indicates that the final weight of fish subjected to 5-days feed deprivation and refeeding regimen was significantly higher ($p < 0.05$) compared with the final weight of fish subjected to continuous feeding regiment. Turkey's post hoc analysis further reveals, that although, there were no significant variations ($p > 0.05$) in the final weight of fish subjected to 5-days feed deprivation and 5-days refeeding regimen compared with the final weight of fish subjected to 5-days feed deprivation and 7-days refeeding regimen; the final weight of fish in group subjected to 5-days feed deprivation and 5-days refeeding regimen was significantly higher compared with the final weight of fish subjected to 3-days feed deprivation and 3-days refeeding regimen.

Table 1: Growth performance of juvenile *Clarias gariepinus* subjected to varying periods of feed deprivation and refeeding regimen for 98 days.

Parameters	Group A	Group B	Group C	Group D
Final weight (g)	221.1 ± 18.48^{a}	195.5 ± 33.08^{a}	288.8 ± 14.90^{bc}	244.6 ± 23.57^{ac}
Initial weight (g)	83.75 ± 28.19^{a}	68.5 ± 15.50^{a}	72.50 ± 11.82^{a}	61.25 ± 27.39^{a}
SGR (g/day)	0.010 ± 0.00^{a}	0.011 ± 0.00^{ab}	0.014 ± 0.00^{bc}	0.011 ± 0.00^{ac}
% Weight gained	162.6 ± 78.79^{a}	210.1 ± 38.58^{ab}	299.6 ± 60.92^{bc}	220.8 ± 10.50^{ac}
Compensation coefficient	1.0	2.348	2.212	1.287
Survivability %	95.00	82.50	85.00	85.00

Different superscripts indicate significant difference between the groups within each row. Group A = continuous feeding, Group B = 3-days feed deprivation and 3-days refeeding, Group C = 5 days feed deprivation and 5-days refeeding, Group D = 5-days feed deprivation and 7-days re-feeding.

One way analysis of variance also shows that the Specific growth rate of fish subjected to 5-days feed deprivation and 5-days refeeding regimen were significantly ($p < 0.05$) compared with the specific growth rate of fish subjected to continuous feeding regiment. Turkey's post hoc test shows, there were no significant variations in the specific growth rate of fish subjected to continuous feeding regimen compared with the specific growth rate of fish of fish subjected to 3-days feed deprivation and refeeding regimen and fish subjected to 5-days feed deprivation and 7-days refeeding regimen (Table 1).

One way analysis of variance (ANOVA) shows the percentage weight gain of fish subjected to 5-days feed deprivations and 5-days refeeding regimen was significantly ($p < 0.05$) higher compared with the specific growth rate of fish subjected to continuous feeding regimen. Turkey's post hoc test shows there were no variations ($p > 0.05$) in the specific growth rate of fish subjected to 3-days feed deprivation and 3-days refeeding regimen compared to the specific growth rate of fish subjected to 5-days feed deprivation and 7-days refeeding regimen (Table 1)

Table 2: The condition factor of juvenile *Clarias gariepinus* subjected to varying periods of feed deprivation and refeeding regimen for 98 days.

Sample days	Group A	Group B	Group C	Group D
Day 0	0.710 ± 0.21^{a}	0.770 ± 0.01^{a}	0.800 ± 0.06^{a}	0.827 ± 0.07^{a}
Day 7	0.797 ± 0.06^{a}	0.823 ± 0.08^{a}	0.737 ± 0.05^{a}	0.807 ± 0.03^{a}
Day 63	0.593 ± 0.06^{a}	0.553 ± 0.01^{a}	0.427 ± 0.05^{a}	0.547 ± 0.14^{a}
Day 98	0.567 ± 0.01^{a}	0.640 ± 0.04^{a}	0.827 ± 0.11^{b}	0.630 ± 0.07^{a}

Different superscripts indicate significant difference between the groups within each row. Group A= continuous feeding, Group B= 3days feed deprivation and 3days refeeding, Group C= 5days feed deprivation and 5days refeeding, Group D= 5days feed deprivation and 7days refeeding.

Table 2 shows that the condition factor of the groups of fish that were on different feed deprivation and refeeding regimen were not significantly different ($P > 0.05$) from the group of fish that were on the continuous feeding regimen during the sample days 0, 7 and day 63. It also shows that on day 98, the condition factor for the groups of fish that were on different feed deprivation and refeeding regimen were significantly different ($P < 0.05$) from the group of fish that were on the continuous feeding regimen.

The Turkey post hoc test that there was significant difference between the fish on the continuous feeding regimen and the fish that were on 5-days feed deprivation and 5-days refeeding regimen. There was also significant difference between the fish that were on 3-days feed deprivation and 3-days refeeding regimen and the fish that were on 5-days feed deprivation and 5-days refeeding regimen. The post hoc test also indicated that there was significant difference between the fish that were on 5-days feed deprivation and 5-days refeeding regimen and the fish that were on 5-days feed deprivation and 7-days refeeding regimen.

Table 3: Organo-somatic index of juvenile *Clarias gariepinus* subjected to varying periods of feed deprivation and refeeding regimen for 98 days.

Parameters	Group A	Group B	Group C	Group D
HSI (Day 0)	3.910 ± 0.87[a]	3.178 ± 0.53[a]	3.195 ± 0.79[a]	3.273 ± 0.42[a]
(Day 98)	1.675 ± 0.11[a]	1.470 ± 0.05[a]	2. 065 ± 0.01[b]	1.175 ± 0.20[c]
GSI (day 0)	5.860 ± 1.56[a]	3.903 ± 0.85[a]	5.560 ± 2.19[a]	7.358 ± 4.58[a]
(Day 98)	1.140 ± 0.01[a]	1.485 ± 0.18[a]	1.415 ± 0.36[a]	1.950 ± 0.09[b]
ESI (day 0)	4.135 ± 0.94[a]	4.035 ± 0.84[a]	4.092 ± 1.49[a]	2.580 ± 1.87[a]
(Day 98)	1.345 ± 0.17[a]	1.840 ± 0.46[a]	1.310 ± 0.23[a]	1.595 ± 0.38[a]

Hepato-somatic index = HSI; Gastro-somatic index = GSI; Entero-somatic index = ESI. Different superscripts indicate significant difference between the groups within each row. Group A = continuous feeding, Group B= 3days feed deprivation and 3days refeeding, Group C= 5 days feed deprivation and 5days refeeding, Group D = 5-days feed deprivation and 7-days refeeding.

Table 3 shows that, at the start of the feeding trial (i.e day 0), the hepatosomatic index (HSI), the gastro-somatic index (GSI) and the entero-somatic index (ESI) of the groups of fish that were subjected to varying durations of feed deprivation and refeeding were not significantly different ($P > 0.05$) compared to the HSI, GSI and ESI of fish that were subjected to continuous feeding regimen (Group A, the control). Table 3, further shows that at the 98th day of the feeding trial, the hepatosomatic index (HSI) of fish subjected to a 5-days feed deprivation and 5-days refeeding regimen, and fish subjected to a 5-days feed deprivation and 7-days refeeding regimen, were significantly higher compared to the HSI of fish subjected to a 3-days feed deprivation and 3-days refeeding regimen (Group B) and fish subjected to continuous feeding regimen (Group A, the control group).

At the commencement of the feeding trial, the gastro-somatic index (GSI) of the fish that were subjected to varying durations of feed deprivation and refeeding regimen were not significantly different ($P > 0.05$) from the group of fish that were subjected to continuous feeding regimen. However, at the 98th day of the feeding trial, the GSI of fish subjected 5-days feed deprivation and 7-days refeeding regimen was significantly higher ($p < 0.05$) compared with the GSI of fish subjected to 3-days feed deprivation and 3-days refeeding regiment. One way analysis of variance also reveals the GSI of fish subjected to 5-days feed deprivation and 7-days refeeding regimen was also significantly higher compared with the GSI of fish subjected to 5-days feed deprivation and 5-days refeeding regimen (Table 3). The Turkey post hoc test shows there were no significant variations in the GSI of fish in the continuous feeding regimen compared to fish subjected to 3-days feed deprivation and 3-days refeeding (Group B), and fish subjected to 5-days feed deprivation and 5-days refeeding regimen (Group C).

The results for the entero-somatic index of fish subjected to various feeding regimen are as presented in Table 3. One way analysis of variance (ANOVA) shows there were no significant variations ($p > 0.05$) in the ESI of fish subjected to continuous feeding (Group A) compared to the ESI of fish subjected to various durations of feed deprivation and refeeding (Groups B, C and Group D).

Water quality Mean water temperature during the experiment was 35.9˚C (SD = 0.47), dissolved oxygen was 9.9 mg L-1 (SD = 0.3), salinity was 0.3 (SD = 0.04), pH was 7.7 (SD = 0.1), total ammonia nitrogen was 0.0 mg L-1 (SD = 0.03), nitrate was 1.5 mg L-1 (SD = 0.65), and nitrite was 0.0 mg L-1 (SD = 0.01).

DISCUSSION

The objective of this study was to determine the economic and production implication of a 3 and 5-days intermittent feed deprivation and re-feeding strategies on juvenile *Clarias gariepinus* The water quality parameters as determined throughout the study period meets the water quality parameters needed for the culture of clariid fishes [8] and as such may not have contributed in any away to the outcome of the study. The survivability rate of fish in group A (control group) was significantly higher than the feed deprived groups. This indicates that the number of fish that survived during the study was higher in control group than the feed deprived groups; this agrees with the report of [22], wherein it was observed that starvation results in mortality.

At the 98th day of the study, the final mean weight of the fish in group C (5-days feed deprivation and 5-days refeeding regimen) and group D (5-days feed deprivation and 7-days refeeding) were higher than that of the group A (control group). The mean weight of the control group was slightly higher than group B (3-days feed deprivation and 3-days refeeding). One, way ANOVA shows that there was no significant difference in the means of the two groups. The difference between the fish in the group A (control group) and those in groups C (5-days feed deprivation and 5-days refeeding), indicates an overcompensation as reported by [23], who reported overcompensation to have occurred when weight gained by the feed deprived group is higher than the weight gained by groups on continuous feeding. [9], also reported overcompensation in weight gain in the hybrid sunfish following periods of feed deprivation and refeeding.

There was no significant difference in the specific growth rate of the fish in group A (control group) compared to the specific growth rate of fish in groups B (3-days deprivation and refeeding) and fish in group D (5-days feed deprivation and 7-days refeeding). The SGR of fish in the control group was, however, significantly different compared with those of fish in group C (5-days feed deprivation and 5-days refeeding). The implication of this result is that it may be more profitable to produce *Clarias gariepinus* catfish using the 5-days feed deprivation and 5-days refeeding regimen. This finding is in line with the report of by [24], who reported that the SGR value of the feed deprived Asian sea bass (Lates calcarifer) were significantly higher than those of the control group.

Condition factor is a measure of the overall condition, fatness (plumpness) and well-being of the fish. It is a relationship between the weight and the length of the fish. The condition factor of the feed deprived groups B (3-days feed deprivation and refeeding) and D (5-days feed deprivation and 7 days refeeding) were not significantly different from the control group, while that of group C (5-days feed deprivation and 5-days refeeding) were significantly higher than that of the group A (control group); this agrees with the report of[24], that the condition factor of the feed deprived Asian sea bass (*Lates calcarifer*) were not significantly different from the control group and concluded

this was a result of compensatory growth exhibited by the fish in the feed deprivation regimens. The implication of this finding is that *Clarias gariepinus* juvenile catfish exposed to a feeding regimen of 5-days feed deprivation and 5-days refeeding exhibit a superior condition factor score compared to fish in other feeding regimens.

Hepatosomatic index refers to the weight of the liver in relation to the total body weight. It is associated with the liver energetic reserves and metabolic activities [25, 26]. A high hepatosomatic index indicates a large liver size and a lower HIS indicates a low liver size. The present study shows, the hepatosomatic index of fish subjected to a 3-days feed deprivation and 3-days refeeding regimen was not significantly different from the HSI of fish on a continuous feeding regimen. The HSI of fish subjected to a 5-days feed deprivation and 7-days refeeding regimen was significantly lower than that of the HSI of fish on a continuous feeding regimen. This in indicative of the fact that the fish on the 5-days feed deprivation and 7-days refeeding regimen were unable to restore the used-up energy sources that were *apriori* stored in the hepatic tissue; regardless of an additional 2-days of feeding after the 5 days period of feed deprivation.

This finding agrees with the reports of [27], who observed that metabolic pathways such as fat digestion and absorption, and glycolysis and or gluconeogenesis are assessed during fasting periods and that, the decrease in the HSI is directly related to the use of the fish's energy reserves. The HSI of fish subjected to the 5-days feed deprivation and refeeding regimen was however significantly higher than the HSI of the fish fed continuously appears to be indicative of the sourcing of the energy requirements from other sources probably from the abdominal fat or from the gastrointestinal sources. This would only occur if there were sufficient reserves in these locations as reported by [28, 29].

The decrease in the HSI of group B (3-days feed deprivation and 3-days refeeding) which is lower than that of the control group agrees with the report by Naghshpour *et al*. (2021), which showed that there was a decrease in the HSI of starved juvenile beluga (*Huso huso*) and is indicative of the inability of the test fish to achieve its energy requirements from the consumed feed following the periods of feed deprivation.

Gastro-somatic index refers to the weight of the stomach in relation to the total body weight. A high gastro-somatic index indicates a large stomach size and vice versa. The gastro-somatic index of the feed deprived groups B (3-days feed deprivation and 3-days refeeding), C (5-days feed deprivation and 5-days refeeding) and group D (5-days feed deprivation and 7-days refeeding) were not significantly different from that of the control group at sample days 0 and 63. At day 98, the GSI of groups B (3-days feed deprivation and 3-days refeeding) and C (5-days feed deprivation and 5-days refeeding) were not significantly different from that of the control group but the GSI of group D (5-days feed deprivation and 7-days refeeding) was significantly higher than that of the control group. The significant increase is different from the report by [30] which showed a decrease in the GSI of starved juvenile beluga (*Huso huso*). Though the fish were deprived of feed on the sample day, the increase in the GSI of the fish in group D (5-days feed deprivation and 7-days refeeding) could be as a result of hyperphagia in the fish which could have occurred during feeding a day prior to the sample day.

Conclusion

Juvenile African catfish, *Clarias gariepinus* subjected to 5-days feed deprivation and 5-days re-feeding regimen exhibited 'over compensatory' growth. The result of the present study indicates that juvenile *Clarias gariepinus* can produced in farm settings following a feed deprivation and refeeding regime, without significantly affecting its

growth and production performance. The economic implication of this strategy is that production can be maximized while significantly reducing the cost of feed. From the results obtained from this study, it recommended that the 5-days feed deprivation and 5-days refeeding regimen should be employed by the farmers as this results in high weight gain at a reduced cost

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