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Full Length Research paper

Compensatory growth effects on previously starved fingerlings and juveniles of African catfish (*Clarias gariepinus,* Burchell 1822)

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Compensatory growth in fingerlings and juveniles of *Clarias gariepinus* was examined after various feeding frequencies. Fish were first fed once, twice, thrice and four times daily over a period of 8 weeks before satiation feeding resumed for 9 weeks. Weekly changes in weight gain, feed intake, nutrient utilization and economy of production were monitored. No significant difference was observed in the feed conversion ratio and voluntary feed intake both at the juvenile and fingerling stages. Fish fed thrice a day recorded the highest mean weight gain but no significant difference was observed across the different feeding frequencies in the juvenile fish. The specific growth rate value of 0.57 and 0.53%/day, observed for the fingerlings and juveniles had the least value in fish fed four times a day. While no significant difference was observed in all economic parameters measured for the juveniles across the feeding levels, on the contrary fingerlings fed once were significantly different having the lowest values from those fed with other feeding levels in the investment cost analysis and gross profit. It can be concluded that at once a day feeding for a period of 8 weeks, a fish can still catch-up with others fed at higher feeding frequencies when returned to satiation feeding.

Key words: Compensatory growth, nutrient utilization, economy of production, feeding frequency.

INTRODUCTION

African catfish exhibits considerable growth variation both under aquaculture and in the wild (Van der Waal, 1998). The causes of such variation are still not clear, although it has been suggested that inherent differences in feeding behaviour may contribute to this variation (Valente et al., 2001; Sundström et al., 2003; Martins et al., 2005). The African catfish is especially known to exhibit sophisticated forms of social feeding behaviour, where the dominant fish are observed to exclude the subordinates from getting a relatively greater proportion of the food (Hecht and Uys, 1997). This phenomenon is thought to be a major cause for the feeding growth variations among individuals (Rad et al., 2004).

According to Thornton et al. (1979), animals subjected to a period of under nutrition often exhibit very high growth during subsequent re-alimentation. This phenomenon is known as compensatory growth. In manipulative feeding experiments, food available to an individual fish can be restricted in two different ways: (1) by decreasing the amount of food within a feeding period or (2) by decreasing the number of times of feeding. The latter case is adopted in this experiment.

The theory underlying compensatory growth is that an animal that has experienced a period of feed restriction will exhibit a hyperphagic response upon satiation feeding, resulting in faster growth (Russell and Wootton, 1992). Compensatory growth is of interest in aquaculture because an understanding of its dynamics may allow for the design of feeding schedules that could further improve growth rates (Hayward et al., 1997).

Feed and feeding practices can have significant effects on catfish production cost and hence the profitability of catfish farming. Under normal conditions catfish should typically be fed daily as much feed as they will consume without adversely affecting water quality. However,

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Table 1. Nutrient composition of Coppens (% DM).

Content	%
Crude protein	42
Carbohydrate	13
Crude fibre	1.50
Ash	9.00
Calcium	1.60
Phosphorus	1.10
Lysine	2.80
Methionine	0.90
$CUSO_4$	5 mg/kg
Selenium	0.3 mg/kg

depending on water temperature, other water quality parameters and the health of the fish, it may be prudent to restrict the daily feed allowance or to feed less frequently. How much to feed and the frequency of feeding are decisions that must be made daily by catfish producers based on each fish pond.

The objectives of this study were to examine the effect of compensatory growth on the growth performance, nutrient utilization and economic analysis of previously starved catfish fingerlings and juveniles that were later subjected to satiation feeding.

MATERIALS AND METHODS

Experimental fish, diet and husbandry conditions

This experiment was carried out at the Aquaculture Research Unit of University of Lagos, Akoka-Lagos, Nigeria. Prior to the commencement of this experiment, African Catfish, *Clarias gariepinus* fingerlings and juveniles (with average weight of 8.5 ± 0.1 and 34.3 ± 0.1 g respectively) were obtained from a local hatchery and transported in aerated polyethylene bags and left to acclimatize to laboratory conditions for two weeks in a 3,000-L capacity canvas tank fitted to a flow-through system. Fish (fingerlings and juveniles) were transferred into plastic tanks (52 × 33.5 × 21 cm) containing 30 L of borehole water. They were kept under natural photoperiod of approximately 12/12 h light/dark cycle and fed a popular commercial catfish feed (Coppens®, Holland) (Table1) of size 3.0 to 4.5 mm, subjecting them to four different feeding frequencies: Fed once (at 11:00 h), twice (at 9:00 and 16:00 h), thrice (at 9:00, 13:00 and 16:00 h) and four times (9:00, 11:00, 13:00 and 16:00 h) daily respectively to apparent satiation with each feeding frequency in triplicates for 8 weeks after which they were all fed *ad libitum* thrice daily (9:00, 13:00 and 17:00 h) to apparent satiation for another 9 weeks before the commencement of the experiment.

The treatments were designated F1, F2, F3, F4, J1, J2, J3 and J4, respectively based on fish size (fingerlings, F and juveniles, J) and feeding frequencies (1 - 4) accordingly. Feed remains were measured for each tank every other week to determine the actual quantity of feed taken using a digital scale (Camry EK5055 Max 5 kg/11lb d = 1 g/0.05 oz) and recorded. All Fish were also weighed individually at the beginning and end of the experiment, while batch weighing per tank was performed weekly using a digital scale to monitor growth performance.

Fish tanks were cleaned daily by siphoning out residual feed and faecal matter, water in the tanks were changed twice weekly depending on how dirty the water gets and mortalities were removed and recorded. Water quality parameters (temperature, dissolved oxygen and pH) were monitored twice weekly; temperature with Mercury-in-glass thermometer calibrated in degree centigrade (°C), dissolved oxygen (DO) was determined by using the Winkler's solution and pH was determined with a pH meter, to ensure they were within tolerant limits expected for the studied species. During the experiment, water temperature, pH and dissolved oxygen (DO) were kept within 26 - 29°C, 5.4 - 8.0 and 4.5 - 4.8 mgL^{-1} respectively. This was achieved from the source of water used for the experiment which was from a borehole source and preserved in big plastic storex tanks to maintain the temperature as well as the pH level but the DO was maintained at that level by regular water change as well as aeration.

Calculations

For this study, growth was expressed as mean weight gain (g), relative weight gain, and specific growth rate. Nutrient utilization indices were expressed as voluntary feed intake, feed conversion ratio and protein efficiency ratio as follows:

Mean weight gain (MWG) (g) = $W_f - W_i$,

Relative growth rate (RGR) = (Weight gain / Initial body weight) × 100

Specific growth rate (SGR) (g) = (Log w – Log w_l/ t) ×100

Voluntary feed intake (VFI) (%) = 100 x FI / [($W_i + W_f$) × t]

Where:
W_f refers to the mean final weight;
W_i is the mean initial weight of fish, and
T is the feeding trial period in days.

Feed conversion ratio (FCR) = Feed Intake (FI) (dry weight in g) /Fish wet weight gain (g)

Protein efficiency ratio (PER) = Mean weight gain / Total Protein intake

Where: Protein Intake = Total feed intake / Protein content of feed.

Economic analysis

The economic analysis was performed to estimate the cost of feed required to raise a kilogram of fish (for both fingerlings and juveniles) fed the popular commercial feed while being cultured under controlled conditions. The cost of feed and fish were the only economic criteria under consideration in this case and were based on the current market cost of the commercial feed and market value of a kilogram of fresh fish in Nigeria at the time of the experiment. The economic evaluations in terms of gross profit (GP), net profit value (NPV), investment cost analysis (ICA) and incidence cost (IC) were calculated based on the method of New (1989) as follows:

Gross profit (GP) = Net profit value (N) – Investment cost analysis (N)

Net profit value (NPV) = Mean weight gain of fish cropped (g) × Total no of the survival (n) x cost per kg

Investment cost analysis (ICA) = Cost of feed (N) + Cost of fish

Table 2. Summary of growth performance, nutrient utilization and economic indices of *Clarias gariepinus* fingerlings stage of previously starved fish now fed to satiation thrice daily.

Parameters	Experimental treatment				
	1	**2**	**3**	**4**	**±SE**
Mean initial weight (g/fish)	32.91[b]	62.12[a]	74.73[a]	77.6[a]	± 132.98
Mean final weight (g/fish)	155.03[c]	258.35[ab]	290.22[a]	194.08[bc]	± 1694.83
Mean weight gain (g/fish)	105.17[a]	224.3[b]	195.55[ab]	102.23[a]	± 21.37
Relative weight gain (%/fish)	48.75	44.99	37.92	17.5	± 5.69
Specific growth rate (%/day)	0.97[b]	1.04[b]	0.89[ab]	0.57[a]	± 0.07
Average feed intake (g/fish)	144.86	157.50	165.19	127.19	± 606.29
Feed conversion ratio	1.64	0.76	0.89	1.46	± 0.20
Voluntary feed intake (g/fish)	12.66	6.21	6.84	7.80	± 1.21
Protein intake	6084.2	6615.0	6937.9	5342.2	± 312.98
Protein efficiency ratio	0.02	0.03	0.03	0.02	± 0.003
Net profit value (N/kg)	13.35	12.3	29.03	24.18	± 3.77
Investment cost analysis (N)	163.46[a]	220.58[b]	236.22[b]	224.83[b]	± 10.46
Incidence cost	0.02	0.01	0.01	0.02	± 0.001
Gross profit/loss (N)	150.11[a]	208.28[b]	207.2[b]	200.65[b]	± 8.78

All values on the same row with the different superscripts are significantly difference (P < 0.05).

Table 3. Summary of growth performance, nutrient utilization and economic indices of *Clarias gariepinus* juvenile stage fed same type of feed.

Parameters	Experimental treatment				
	1	**2**	**3**	**4**	**± SE**
Mean initial weight (g/fish)	81.63[b]	116.37[a]	149.73[a]	143.75[a]	± 132.98
Mean final weight (g/fish)	263.67	315.1	391	329.81	± 1694.83
Mean weight gain (g/fish)	193.2	226.23	240.62	190.25	± 26.61
Relative weight gain (%/fish)	33.85[b]	23.6[ab]	16.15[a]	18.95[a]	± 2.56
Specific growth rate (%/day)	0.83[a]	0.74[ab]	0.63[ab]	0.53[b]	± 0.05
Average feed intake (g/fish)	156.42[b]	153.17[b]	192.12[a]	179.89[ab]	± 606.30
Feed conversion ratio	0.87	0.69	0.99	1.38	± 0.17
Voluntary feed intake (g/fish)	6.36	4.85	5.72	6.52	± 0.52
Protein intake	6569.0[b]	6433.0[b]	8069.4[a]	7555.4[ab]	± 292.35
Protein efficiency ratio	0.03	0.04	0.03	0.03	± 0.01
Net profit value (N/kg)	27.57	45.3	39.68	14.81	± 8.06
Investment cost analysis (N)	306.93	325.95	337.64	293.97	± 8.94
Incidence cost	0.01	0.01	0.01	0.01	± 0.001
Gross profit/loss (N)	279.36	280.65	297.96	279.15	± 10.50

stocked (N)

Incidence of cost (IC) = Cost of feed (N)/mean weight gain of fish produced (g)

Statistical analyses

The experimental design was a complete randomised design. All data collected were subjected to analysis of variance (ANOVA). Data are reported as mean ± standard error (n = 5). Comparisons among treatment means were carried out by Duncan Multiple Range test (Duncan, 1955) at a significance level of $P < 0.05$. All computations were performed by the statistical package SPSS 15.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

The mean growth performance, nutrient utilization and economic analyses of the fingerlings and juveniles stages of fish on four different feeding frequencies now fed to apparent satiation are shown in Tables 2 and 3, respectively.

The initial weight of the fish at the point of commencement of this trial for the fingerlings and

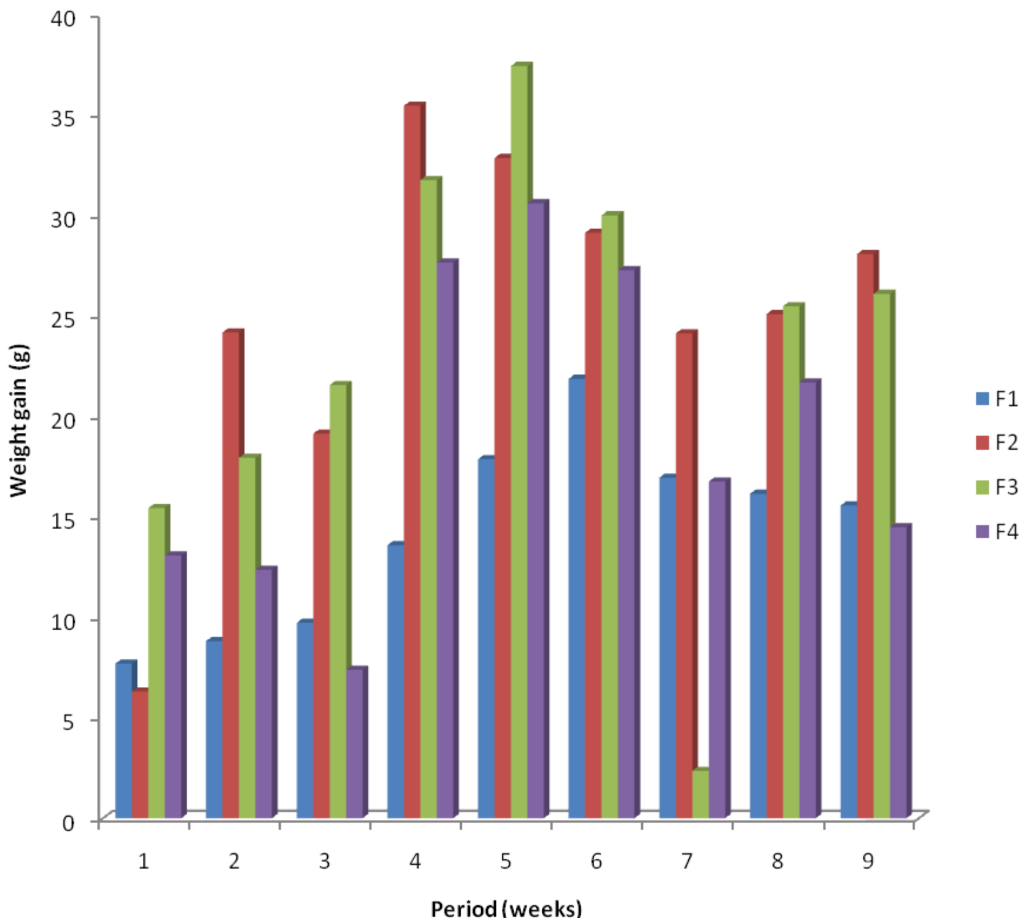

Figure 1. Weekly changes in weight gain of fingerlings for four feeding groups (Fed once daily, fed twice daily, fed thrice daily, and fed four times daily) over experimental period.

juveniles stages ranged from 32.91 - 77.60 and 81.63 - 149.73 g respectively while the final weight of the fingerlings and juveniles stages ranged from 155.03 - 290.22 and 263.67 - 391.00 g, respectively at the end of the trial (Tables 2 and 3, respectively). It means the mean live weight of all groups increased over the period they underwent apparent satiation (9 weeks). There was a significant difference ($P < 0.05$) in both initial and final weight of both the fingerlings and juveniles groups.

A gradual increase in mean weight was obvious for each treatment per period over the period of 9 weeks of apparent satiation feeding (Figures 1 and 2). The highest weight gain was achieved in both the fingerlings and juvenile groups between the 4^{th} and 5^{th} week of *ad libitum* feeding. This could be as a result of adaptation of fish to change in feeding frequency.

Specific growth gate (SGR) exhibited clear fluctuations ranging from 0.41 to 1.20 with overall mean values of 0.97, 1.04, 0.89, and 0.57% in diets 1, 2, 3 and 4 respectively for the fingerlings stage, while for the juveniles stage were from 0.83, 0.74, 0.63, and 0.53% in diets 1, 2, 3, and 4, respectively (Tables 2 and 3). The growth data clearly indicated that the final live weight values of the third treatment for the fingerlings and juveniles stages, F3 and J3, were significantly higher than those of other treatments ($P < 0.05$) but it varied in the SGR, as the second treatment for fingerlings stage, F2, was significantly higher than those of other treatments (Table 2).

Feed conversion rate (FCR) was presented in Table 2. The best (the lowest mean) FCR was obtained from fed twice (F2) in the fingerlings and juveniles stages (Tables 2 and 3).

Considering the economic analysis, in the fingerlings group, there was a significant difference with the feeding frequency in the fish fed once (F1) from the other treatments in the investment cost analysis (ICA) and the gross profit (GP).

DISCUSSION

African Catfish (*C. gariepinus*) fingerlings and juveniles fish were subjected to different daily feeding frequencies and brought to thrice daily feeding frequency to check their recovery. The highest weight gain was obtained

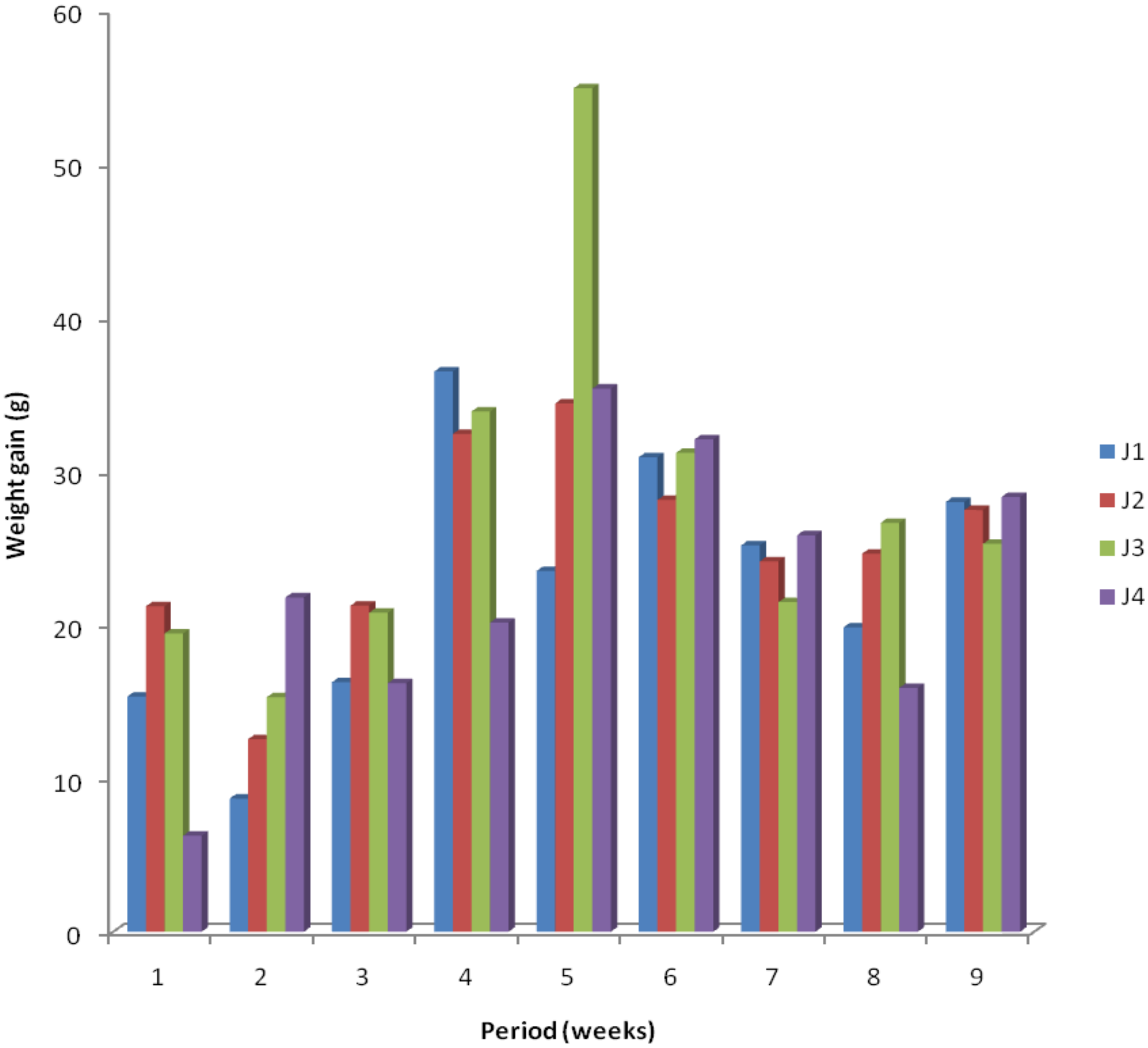

Figure 2. Weekly changes in weight gain of juveniles for four feeding groups (Fed once daily, fed twice daily, fed thrice daily, and fed four times daily) over experimental period.

($P < 0.05$) by feeding the fingerlings fish (twice daily) and the juvenile fish (thrice daily), thus providing more feed. It is evident that a higher growth rate depends on both higher and more frequent daily feed uptake. Studies conducted on other fish species have shown that feed consumption and growth generally increased with feeding frequency up to a given limit (Wang et al .,1998; Başçinar et al., 2007). This is in agreement with our findings in this study that feeding frequency had a significant effect on feed consumption and growth in the African catfish.

Food conversion ratio was best in twice daily feeding frequency because of its lowest food conversion ratio (0.76 and 0.69) value when compared to other treatments for the fingerlings and juvenile stages, respectively. Once daily feeding frequency with the highest food conversion ratio value (1.64) for the fingerlings stage and four times daily with the highest food conversion ratio value (1.38) for the juveniles stage were the poorest in food conversion. This may have been responsible for the best growth performances observed in the fish fed twice daily for both stages. According to De Silva and Anderson (1995), when these fish are fed to satiation, they do not tend to eat again until the stomach is almost completely evacuated. Therefore, a feeding frequency of twice daily is often more than sufficient.

The ability of an organism to utilize nutrients especially protein will positively influence its growth rate (Sogbesan and Ugwumba, 2008). This is justified by the highest PER and low FCR in the treatments fed twice daily in the fingerlings and juveniles fish stage. This suggested that fish must have efficiently converted feed consumed to growth.

The economical analysis of the feed for the fish fed once daily, twice daily, thrice daily and four times daily to satiation showed that both the cost of the feed and gross profit in treatment fed twice daily at the fingerling stage and treatment fed thrice daily were the best. In this situation, it is recommended that the treatment fed twice and thrice daily were the best economically for catfish.

Knowledge of how feed restriction affects the growth rate of catfish under different production conditions could be of practical value to producers seeking to develop feeding strategies that provide greater economic flexibility in an environment of changing feed costs and fluctuating fish prices.

This research study has shown that all the different feeding frequencies experimented upon can be used to feed *C. gariepinus* juvenile stage. Feed restriction should be avoided in the fingerlings stage of *C. gariepinus* growth because fish recovery rate was better in the juvenile stage compared to the fingerlings stage when exposed to satiation feeding.

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