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Water quality and Nile tilapia growth performance under different feeding schedules

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ABSTRACT. The present study investigated the effects of different feeding schedules on certain variables of water quality and growth performance of Nile tilapia juveniles. Fifteen 25-L aquaria were used to hold the experimental fish population for six weeks. Five fingerlings (1.86 ± 0.13 g) were stocked in each aquarium (200 fish m^{-3}; n = 5). The diet provided to fish and the feeding rates adopted were the same for all fish. The daily ration was divided in four meals (8, 11, 13 and 16h). In the positive control group (25/25/25/25), the daily ration was equally divided in the four meals; in the negative control group (40/30/20/10), the daily ration was unevenly divided in a progressively decreasing fashion (40, 30, 20 and 10%) throughout the day; in the experimental group (10/20/30/40), the daily ration was unevenly divided in a progressively increasing fashion (10, 20, 30 and 40%) throughout the day. The feed conversion ratio results were better for 10/20/30/40 than for the other groups. The 10/20/30/40 feeding schedule probably best combined the dietary allowance for fish with the increase in water temperature during the day.

Keywords: aquaculture, daily ration, feeding management.

RESUMO. Qualidade de água e desempenho produtivo da tilápia do Nilo submetida a diferentes programas alimentares. O presente trabalho investigou os efeitos de diferentes programas alimentares sobre algumas variáveis de qualidade de água e de desempenho zootécnico da tilápia do Nilo. Foram utilizados 15 aquários de 25 L para manter a população experimental por seis semanas. Foram estocados cinco alevinos ($1,86 \pm 0,13$ g) em cada aquário (200 peixes m^{-3}; n = 5). A dieta fornecida aos peixes e as taxas de arraçoamento adotadas foram as mesmas para todos os peixes. A ração diária foi dividida em quatro refeições (8, 11, 13 e 16h). No controle-positivo (25/25/25/25), a ração diária foi igualmente dividida nas quatro refeições; no controle-negativo (40/30/20/10), a ração diária foi desigualmente dividida de modo progressivamente decrescente (40, 30, 20 e 10%) ao longo do dia; no grupo experimental (10/20/30/40), a ração diária foi desigualmente dividida de modo progressivamente crescente (10, 20, 30 e 40%) ao longo do dia. Os resultados do fator de conversão alimentar foram melhores para 10/20/30/40 que para os outros grupos. O programa alimentar 10/20/30/40 foi aquele que provavelmente melhor combinou a oferta de dieta aos peixes cultivados com o aumento na temperatura da água durante o dia.

Palavras-chave: aquicultura, manejo alimentar, ração diária.

Introduction

The quality of the diet and feeding management adopted by producers can significantly affect growth, survival and feed conversion of culture tilapia. Generally, feed is delivered in equal amounts throughout the day (TACON; DE SILVA, 1997). However, as a cold-blooded animal, fish appetite varies throughout the day, mainly in function of water temperature. Up to a certain degree, an increase is expected in fish feed intake as water temperature rises during the day (HANDELAND et al., 2008). It is hypothesized that if the meals are equally divided, there would a waste of diet during lower-temperature hours and a lack of diet in the higher-temperature hours of the day. Diet waste means deteriorated water quality and economical losses (ALI et al., 2010); lack of diet for fish represents impaired growth performance (GANDRA et al., 2007).

Therefore, adjusting meal size to fish appetite has practical importance, because it can improve feed conversion. This could be carried out by allowing more diet in the hottest hours of the day and less diet in the colder periods. The main objective of the present study was to investigate the effects of different feeding schedules on certain variables of water quality and growth performance of Nile tilapia juveniles.

Material and methods

Fish and experimental system

One thousand male sex-reversed fingerlings of Nile tilapia, *Oreochromis niloticus* were obtained from a commercial supplier located 60 km from the laboratory (LCTA, DEP/CCA/UFC, Fortaleza, Ceará State, Brazil). Initially, fish stayed in the 1,000-L reception tank for one week for acclimation to laboratory conditions. Over the adjustment period, fish were fed a high-protein commercial diet (Aquaxcel™ 4512 0.8 mm, Cargill Animal Nutrition) in four daily meals at 8, 11, 13 and 16h. The daily feeding rate was 10% of stocked biomass.

Fifteen 25-L polyethylene outdoor green-water aquaria were used in the present work to hold the experiment fish. The aquaria had a cotton mesh cover to prevent fish from escaping. At the onset of the experiment, five fingerlings (1.86 ± 0.13 g) were stocked in each aquarium (200 fish m^{-3}). No artificial aeration was provided to the aquaria. Fish were maintained in the experimental system for six weeks.

Experimental design and husbandry

The daily ration was divided in four meals (at 8, 11, 13 and 16h). There was one positive standard control group (25% of the daily ration in each meal), one negative control group (40, 30, 20 and 10% of the daily ration) and one experimental group (10, 20, 30 and 40% of the daily ration), each with five replications arranged in a completely randomized design. The diet provided to fish (Aquaxcel™ 4512 0.8 mm, Cargill Animal Nutrition) and feeding rates adopted were the same for all fish (Table 1). The feeding rates employed in the present work were recommended by the manufacturer. Every two weeks, the fish were weighed to adjust the dietary allowance for each tank.

Table 1. Feeding rates based on tilapia body weight applied in the present work.

Fish body weight (g)	Daily ration (% biomass day^{-1})
1.5 - 2.0	15.0
2.0 - 2.5	14.0
2.5 - 3.0	13.0
3.0 - 3.5	12.0
3.5 - 4.5	11.0
4.5 - 5.5	10.0
5.5 - 7.0	9.0
7.0 - 9.0	8.0

Water pH and electric conductivity were determined daily at 8 and 16h using portable devices; water temperature was monitored daily at 8, 11, 13 and 16h. Total ammonia, nitrite and reactive phosphorus concentrations, as well as optical transmittance at 670 nm, were monitored weekly in all aquaria. The analytical assessments of total ammonia nitrogen (Nessler's method), nitrite (diazotization-coupling method) and reactive phosphorus (molybdenum blue method) were carried out according to the guidelines presented by APHA (1999); optical transmittance followed Silva-Neto et al. (2008). Fish final body weight, final body length, survival, specific growth rate (ln final body weight – ln initial body weight/no. of days) x 100 and feed conversion rate (feed allowance/fish weight gain) were observed in all replications.

Statistical analyses

Water quality and growth performance results were submitted to one-way ANOVA to detect whether there were significant differences between the controls and the experimental group. Whenever the differences were significant, the means were compared using Tukey's test. The statistical analyses were performed with the aid of SigmaStat 2.0 (Jandel Statistics) and Microsoft Excel 2007 (Microsoft Corporation). The level of significance of 5% was adopted in all statistical analyses.

Results and discussion

Water temperature in the aquaria increased progressively throughout the day (Figure 1). Therefore, the metabolic rate of fish possibly rose from the first to the last daily meal, as the highest water temperature observed (around 32°C) did not reach a harmful level for Nile tilapia. Azaza et al. (2008) observed growth impairment in Nile tilapia juveniles only when water temperature reached 34°C. As fish feed intake directly follows the metabolic rate (IMSLAND et al., 2006), it probably increased between 8h00 and 16h00 in the present work.

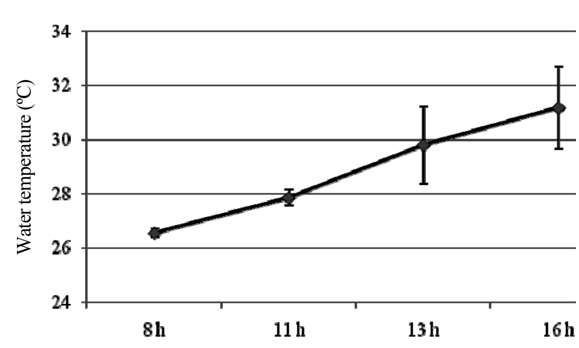

Figure 1. Water temperature throughout the day in 25-L outdoor polyethylene aquaria stocked with Nile tilapia juveniles for six weeks (mean ± S.D.; n = 40).

There were effects of the different feeding schedules (FS) on optical transmittance at 670 nm, total ammonia nitrogen (TAN) and reactive phosphorus. Conversely, no effect of FS was observed between the controls (25/25/25/25 and 40/30/20/10) and experimental group (10/20/30/40) on water pH (7.37 ± 0.15) and nitrite concentration (0.66 ± 0.02 mg L^{-1}; Table 2).

Water showed lower optical transmittance at 670 nm for 10/20/30/40 than that observed for 40/30/20/10. No difference was seen between the optical transmittance at 670 nm of 25/25/25/25 and 40/30/20/10 (Table 2). Optical transmittance at 670 nm is an index used to indirectly estimate phytoplankton abundance in water (CAVALCANTE; SÁ, 2010), and indicated there was greater phytoplankton density at 10/20/30/40 than at 40/30/20/10. It can be difficult to explain these differences between treatments for phytoplankton density. One possibility is that fish submitted to 10/20/30/40 had greater feed intake than the fish in 40/30/20/10 and, consequently, produced and released more feces in water than the latter. It is known that fish feces act as an excellent water fertilizer and may cause eutrophication due to its richness in nitrogen and phosphorus (SALAZAR; SALDANA, 2007).

The concentration of TAN in 10/20/30/40 was lower than those found for 25/25/25/25 and 40/30/20/10. The mean concentrations of TAN for 25/25/25/25 and 40/30/20/10 were very similar and their difference had no statistical significance. It is speculated that diet waste (diet not ingested by fish) in 25/25/25/25 and 40/30/20/10 were probably higher than for 10/20/30/40. At the former groups, the improved rate of organic matter decomposition by bacteria could have released more ammonia to water than 10/20/30/40 (HAI; YAKUPITIYAGE, 2005). Conversely, the better feed efficiency observed for 10/20/30/40 in comparison with the other groups produced fewer dietary remains and consequently released less ammonia in water.

The concentrations of reactive phosphorus for 40/30/20/10 and 10/20/30/40 were lower than for 25/25/25/25. The difference between 40/30/20/10 and 10/20/30/40 for reactive phosphorus was not significant (Table 2). In the present work's experimental system, the main source of phosphorus to water was the embedded phosphorus in the artificial diet of fish. Moreover, only a minor rate of the phosphorus that enters the aquatic system via feeding is retained in fish biomass (CYRINO et al., 2010). Therefore, the results of reactive phosphorus suggest that greater dietary allowance or lower phosphorus immobilization in fish biomass occurred in 25/25/25/25 when compared to 10/20/30/40 and 40/30/20/10.

The different FS employed in the present work had an effect on fish survival, final body weight, specific growth rate (SGR) and feed conversion ratio (FCR). On the other hand, fish final body length was not affected by FS (Table 3).

Very high survival rates were observed for 10/20/30/40 and 25/25/25/25, and no difference was detected between them in this regard. The survival for 40/30/20/10 was lower than for the other groups. The fish growth rate, expressed by final body weight and SGR, was lower for 40/30/20/10 than for 25/25/25/25 and 10/20/30/40. The differences between 25/25/25/25 and 10/20/30/40 for final body weight and SGR were not significant. FCR results were better for 10/20/30/40 than for the other groups. The significantly worst FCR was seen for 40/30/20/10 (Table 3). The growth performance results of the present work suggest that the FS 10/20/30/40 allowed a better feed utilization by fish than the FS 25/25/25/25 and 40/30/20/10. FS 10/20/30/40 was the one that probably best combined the dietary allowance for fish with the increase in water temperature throughout the day. Therefore, the present work's results confirm those of Handeland et al. (2008), who stated that fish feed intake increases up to a certain degree with water temperature.

Table 2. Water quality of 25-L outdoor aquaria stocked with Nile tilapia juveniles for six weeks (200 fish m^{-3}; initial body weight = 1.86 ± 0.13 g). The feeding rates adopted were the same for all fish, but the amount of diet in each of the four daily meals (8, 11, 13 and 16h) varied among treatments (mean ± S.D.; n = 5 fish $aquaria^{-1}$).

Feeding schedule (%)[1]	Opt transmit 670 nm[2] (%)	pH at 8h	TAN[5] (mg L^{-1})	Nitrite (mg L^{-1})	Reactive phosphorus (mg L^{-1})
25/25/25/25	28.6 ± 4.3 ab[3]	7.39 ± 0.16	2.79 ± 0.27 a	0.68 ± 0.05	0.65 ± 0.04 a
40/30/20/10	33.4 ± 5.0 a	7.36 ± 0.16	2.78 ± 0.30 a	0.66 ± 0.05	0.59 ± 0.03 b
10/20/30/40	23.2 ± 3.5 b	7.36 ± 0.14	2.45 ± 0.29 b	0.64 ± 0.05	0.59 ± 0.03 b
ANOVA P	< 0.05	ns[4]	< 0.05	ns	< 0.05

[1]25/25/25/25: the daily ration was equally divided in four meals (positive control group); 40/30/20/10: the daily ration was unevenly divided in four meals in a progressively decreasing fashion (40, 30, 20 and 10%) throughout the day (negative control group); 10/20/30/40: the daily ration was unevenly divided in four meal in a progressively increasing fashion (10, 20, 30 and 40%) throughout the day (experimental group); [2]Optical transmittance at 670 nm (%);[3] In each column, means not sharing the same letter are significantly different among themselves by Tukey's test; [4] Not significant (p > 0.05); [5] Total ammonia nitrogen.

Table 3. Growth performance of Nile tilapia juveniles reared for six weeks in 25-L outdoor aquaria (200 fish m^{-3}). The feeding rates adopted were the same for all fish, but the amount of diet in each of the four daily meals (8, 11, 13 and 16h) varied among the treatments. Initial fish body weight and length: 1.86 ± 0.13 g and 5.14 ± 0.27 cm, respectively (mean ± S.D.; n = 5 fish $aquaria^{-1}$).

Feeding schedule (%)[1]	Survival (%)	Final body weight (g $fish^{-1}$)	Final body length (cm $fish^{-1}$)	SGR[4] (% day^{-1})	FCR[5]
25/25/25/25	96.0 ± 8.9 a[2]	6.3 ± 0.3 a	7.0 ± 0.6	2.94 ± 0.17 a	2.19 ± 0.09 b
40/30/20/10	84.0 ± 16.7 b	5.5 ± 0.1 b	7.2 ± 0.5	2.50 ± 0.23 b	2.58 ± 0.15 c
10/20/30/40	100.0 ± 0.0 a	6.5 ± 0.5 a	7.3 ± 0.4	2.88 ± 0.25 a	1.77 ± 0.11 a
ANOVA P	< 0.05	< 0.05	ns[3]	< 0.05	< 0.05

[1]25/25/25/25: the daily ration was equally divided in four meals (positive control group); 40/30/20/10: the daily ration was unevenly divided in four meals in a decreasing fashion (40, 30, 20 and 10%) throughout the day (negative control group); 10/20/30/40: the daily ration was unevenly divided in four meal in an increasing fashion (10, 20, 30 and 40%) throughout the day (experimental group); [2]In each column, means not sharing the same letter are significantly different among themselves by Tukey's test; [3]Not significant (p > 0.05); [4]Specific growth rate = [(ln final body weight - ln initial body weight)/no. of days] x 100; [5]Feed conversion ratio = feed allowed (g)/fish weight gain (g).

There is some concern regarding the suitability of the feeding schedule employed in aquaculture, particularly in shrimp culture. It is suggested, for example, that the greatest amount of feed be allowed to shrimp at the night meals, due to the more active behavior of those animals during that period (GODDARD, 1996). Thus, the present work's results suggest that a similar concern would also be valid for finfish culture.

Conclusion

The adoption of the feeding schedule 10/20/30/40 (10% at 8h; 20% at 11h; 30% at 13h and 40% at 1h) when compared to the standard feeding schedule 25/25/25/25 (25, 25, 25 and 25% at the same times) can produce better water quality in Nile tilapia rearing units, expressed by a lower concentration of ammonia in water. The feed efficiency of Nile tilapia juveniles can be improved by adopting the feeding schedule 10/20/30/40 when compared to the standard feeding schedule 25/25/25/25.

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