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Small crumbled diet versus powdered diet in restricted feeding management of juvenile Nile tilapia

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ABSTRACT. The pellet size of the diet can affect both fish growth performance and the water quality of the rearing units. The present work assessed the effects of feeding juvenile Nile tilapia, *Oreochromis niloticus* (L.) a small crumbled diet (SCD; 0.8 mm) on water quality and growth performance. Fish were reared for six weeks in twenty 250-L polyethylene outdoor tanks at a density of 10 juveniles tank^{-1} (40 fish m^{-3}). There were two feeding rates (standard and restricted) and two types of artificial fish diet (powdered and SCD). The standard feeding rates were reduced by 30% for restricted feeding. The concentrations of free CO_2, reactive phosphorus, total ammonia nitrogen (TAN) and nitrite were higher in the full-fed tanks relative to the restricted-fed tanks. In the standard feeding rate groups, those tanks fed SCD had lower TAN and nitrite concentrations than tanks fed a powdered diet. The final body weight and specific growth rate of fish fed a restricted SCD were higher than the full-fed tanks. The higher levels of food waste in the powdered-diet tanks lead to impairment of fish growth performance.

Keywords: unpelleted diet, crumble, particle size, restricted feeding, water quality, *Oreochromis niloticus.*

Ração farelada versus ração desintegrada no manejo alimentar restritivo de juvenis de tilápia do Nilo

RESUMO. O tamanho do pélete da ração pode afetar tanto o desempenho zootécnico dos peixes como a qualidade da água das unidades de cultivo. O presente trabalho avaliou os efeitos do arraçoamento de juvenis de tilápia do Nilo, *Oreochromis niloticus* (L.) com ração desintegrada de 0,8 mm, sobre a qualidade da água e crescimento dos peixes. Os peixes foram cultivados por seis semanas em 20 tanques externos de polietileno de 250 L, na densidade de dez juvenis tanque^{-1} (40 peixes m^{-3}). Havia duas taxas alimentares (padrão e restritiva) e dois tipos de dietas artificiais (farelada e desintegrada). As taxas padronizadas de alimentação foram reduzidas em 30% no manejo restritivo. As concentrações de CO_2 livre, fósforo reativo, nitrogênio amoniacal total (NAT) e de nitrito foram maiores nos tanques com manejo alimentar regular em relação aos tanques com alimentação restritiva. Nos grupos alimentados segundo a tabela-padrão, aqueles tanques que receberam a ração desintegrada apresentaram menor concentração de NAT e nitrito que os tanques arraçoados com a dieta farelada. O peso corporal final e a taxa de crescimento específico dos peixes alimentados restritivamente com a ração desintegrada foram maiores que o observado nos tanques alimentados regularmente. O grande desperdício de ração nos tanques alimentados com ração farelada comprometeu o desempenho zootécnico dos peixes.

Palavras-chave: ração farelada, ração desintegrada, tamanho de partícula, restrição alimentar, qualidade de água, *Oreochromis niloticus.*

Introduction

The feeding management during second phase culture of tilapia, after sexual reversion, significantly affects fish growth, survival and feeding efficiency. The use of good quality artificial rations is as important as natural food for achieving desired growth performance (BAMBA et al., 2007). In addition, the amount of feed delivered to the animals should be matched to their appetite to avoid under- and overfeeding (KAMLER et al., 2006). Underfeeding may impair growth due to nutritional deficiencies, whereas overfeeding is associated with economic loss from wasted feed. Excessive feeding also deteriorates water quality and releases high polluting effluents to the environment (YOKOYAMA et al., 2009).

Optimum pellet size is one aspect of feeding management strategies that requires further research (BAILEY et al., 2003). Santiago et al. (1987) recommended the use of small granular feed called crumble instead of unpelleted feed for tilapia from the fry stage and beyond. Nevertheless, fish producers generally feed tilapia a powdered diet until they reach

5-g body weight and then change to a pelleted diet (RICHE; GARLING, 2003). One reason for a delayed switch to a crumbled diet is that small crumbled diets (particle size < 1.0 mm) are not easily found in the market and they are more expensive than powdered diets with similar chemical composition. However, if the use of small crumbled diets (SCD) is shown to be advantageous it may become more commonly used among tilapia producers.

The present study assessed the effects of feeding juvenile Nile tilapia, *Oreochromis niloticus* (L.) a restricted SCD on water quality and growth performance.

Material and methods

The study was carried out at the Fortaleza, Ceará, Brazil. All-male sex-reversed Nile tilapia juveniles between 1 - 2 g were obtained from *Centro de Pesquisa em Aquicultura do Departamento Nacional de Obras Contra as Secas* (Dnocs; Pentecoste, Ceará State) and transported by road to the laboratory facilities. In the lab, fish were acclimatized for four days in one 1,000-L tank (dechlorinated tap water; temperature = 27.5 ± 0.5°C, pH = 7.2 ± 0.3, dissolved O_2 saturation > 60%; natural photoperiod). Over the acclimatization period, fish were fed a high-protein commercial diet four times per day at 8.00, 11:00 a.m., 2:00 and 5:00 p.m. The daily feeding rate was equal to 10% of stock biomass. Next, fish were reared for six weeks in twenty 250-L polyethylene tanks at a density of 10 juveniles tank^{-1} (40 fish m^{-3}). The experimental system was located outdoors and allowed the development of plankton in water (green water culture).

A completely randomized design arranged in a 2 x 2 factorial was used in the present study. There were two feeding rates (standard and restricted) associated with two types of artificial fish diet (powdered and SCD). The standard feeding rate was based on feeding rates prescribed by the *Laboratório de Ciência e Tecnologia Aquícola* (Universidade Federal do Ceará, Fortaleza, Ceará, Brazil) - LCTA's feeding table and the manufacturer's recommendations. The standard feeding rates were reduced by 30% for the restricted feeding rate (Table 1). The SCD was delivered as is (particle size = 0.8 mm) in the SCD group or it was finely powdered with mortar and pestle in the powdered-diet group. Every two weeks fish were weighed to adjust the feeding rates delivered to the tanks and obtain their growth curve.

Table 1. Feeding management for the growth trial.

Fish body weight (g)	Feeding rate (% live weight day^{-1})		Feeding meals day^{-1}
	Standard	Restricted (standard-30%)	
1.0 - 1.5	17.0	11.9	6
1.5 - 2.0	15.0	10.5	6
2.0 - 2.5	14.0	9.8	5
2.5 - 3.0	13.0	9.1	5
3.0 - 3.5	12.0	8.4	5
3.5 - 4.5	11.0	7.7	4
4.5 - 5.5	10.0	7.0	4
5.5 - 7.0	9.0	6.3	4
7.0 - 9.0	8.0	5.6	4
9.0 - 16.0	7.5	5.3	4
16.0 - 20.0	7.0	4.9	4

Water quality was monitored throughout the growth trial as follows: water temperature, daily at 8:00 a.m. and 4:00 p.m.; pH and electrical conductivity, daily at 16h00; optical transmittance at 670 nm, total alkalinity, free CO_2, dissolved oxygen (Winkler's method), total ammonia nitrogen (TAN; Nessler's method), nitrite (diazotizing and coupling method) and reactive phosphorus (ammonium molybdate method), weekly between 9:00 and 10:00 a.m. All water quality assessments followed the standard methodologies described by APHA (1999). Final body weight, survival, specific growth rate (ln final body weight - ln initial body weight/no. of days x 100), tank yield and feed conversion ratio (feed allowance/fish weight gain) were also recorded. No artificial aeration was provided to the experimental tanks, and the water replacement was done only to replenish water loss through evaporation.

Water quality and growth performance variables were analyzed by two-way ANOVA with feeding rate (standard and restricted) and type of artificial fish diet (powdered or SCD) as the main factors. The assumptions of normality and homogeneity of variances were checked before analysis. Percentage and ratio data were analyzed using arcsine-transformed data. All ANOVA analyses were carried out at 5% level of significance using SigmaStat for Windows 2.0 (Jandel Statistics).

Results and discussion

The restricted diet affected all water quality variables except pH, temperature and dissolved oxygen. The 0.8-mm SCD only had a significant effect on the concentration of total ammonia nitrogen (TAN) and nitrite ($p \leq 0.05$). Significant interactions between feeding rate and pellet size were also seen for TAN and nitrite concentrations in the water (Table 2).

Table 2. Water quality of 250-L polyethylene round tanks stocked with Nile tilapia juveniles subjected to different feeding rates and either a powdered or small crumbled diet (SCD; particle size = 0.8 mm). Ten tilapia juveniles were stocked per tank for six weeks. Initial body weight = 1.95 ± 0.10 g (mean ± standard deviation; n = 5)

Variable	Pellet size	Feeding rate[1] Standard	Feeding rate[1] Restricted (-30%)
pH	Powder	7.39 ± 0.04[2]	7.40 ± 0.07
	0.8 mm	7.40 ± 0.03	7.37 ± 0.04
Electrical conductivity (μS cm^{-1})	Powder	723 ± 7.8 a	699 ± 7.7 b
	0.8 mm	728 ± 8.8 a	695 ± 5.9 b
Optical transmittance at 670 nm[4] (%)	Powder	73.0 ± 4.0 a	90.4 ± 1.1 b
	0.8 mm	71.3 ± 3.6 a	90.6 ± 1.3 b
Dissolved oxygen (mg L^{-1})	Powder	4.44 ± 0.13	4.68 ± 0.31
	0.8 mm	4.62 ± 0.37	4.55 ± 0.21
Free CO_2 (mg L^{-1})	Powder	26.5 ± 1.6 a	19.1 ± 1.7 b
	0.8 mm	26.5 ± 2.5 a	17.7 ± 1.7 b
Total ammonia N (mg L^{-1})	Powder	0.778 ± 0.02 Aa	0.650 ± 0.05 Ab
	0.8 mm	0.647 ± 0.03 Ba	0.634 ± 0.05 Aa
Nitrite (mg L^{-1})	Powder	0.595 ± 0.02 Aa	0.496 ± 0.01 Ab
	0.8 mm	0.543 ± 0.02 Ba	0.483 ± 0.02 Ab
Reactive phosphorus (mg L^{-1})	Powder	0.510 ± 0.02 a	0.330 ± 0.04 b
	0.8 mm	0.492 ± 0.01 a	0.339 ± 0.02 b

Two-way *ANOVA P* Factor	pH	EC	Opt tr	DO_2	CO_2	TAN	NO_2^-	React P
Feeding rate	ns[3]	< 0.01	< 0.01	ns	< 0.01	< 0.01	< 0.01	< 0.01
Pellet size	ns	ns	ns	ns	ns	< 0.01	< 0.01	ns
Rate vs. Pellet size	ns	ns	ns	ns	ns	< 0.01	0.03	ns

[1]Standard: the feeding rates prescribed by the laboratory's feeding table were fully adopted, according to the manufacturer's recommendations; restricted: the standard feeding rates were reduced by 30%. [2]For each variable, means in the same row or column that do not share the same lower case or capital letter, respectively, are statistically different (Tukey's test; p < 0.05). [3]Not significant (p > 0.05).

Water temperatures in the tanks were 27.0 ± 0.36°C and 29.3 ± 1.02°C at 8:00 a.m., and 4:00 p.m., respectively. The minimum and maximum values recorded were 25.6 and 27.7°C at 8:00 a.m.; 26.5 and 30.8°C at 4:00 p.m., respectively. These values fell within the range considered as appropriate for normal tilapia growth (AZAZA et al., 2008).

Electrical conductivity (EC) of water in full-fed tanks was higher than in the restricted-fed tanks ($p \leq 0.05$). As organic matter decomposes, inorganic salts are released to water thereby increasing EC. In fact, water EC can be used as a subsidiary eutrophication index in limnology (ZHANG et al., 2010). In aquaculture tanks and ponds, readings of water EC up to 1000 μS cm^{-1} are considered suitable. Above that level the culture environment can be considered hypereutrophic and, as a consequence, susceptible to filamentous alga blooms and anoxia (BOYD; TUCKER, 1998). Therefore, it is wise to restrict feeding rates as much as possible to avoid these water quality problems.

The concentrations of free CO_2 and reactive phosphorus in the full-fed tanks were higher than the restricted-fed tanks ($p \leq 0.05$). Higher CO_2 is associated with higher acidity whereas more reactive phosphorus can lead to dangerous algal blooms (LIU et al., 2011). The present study indicated that the water quality in the full-fed tanks was lower than in the restricted-fed tanks. The optical transmittance at 670 nm, which indirectly points to the phytoplankton abundance in water, was lower in the full-fed tanks than in the restricted-fed tanks. That supports the theory that there was a greater availability of inorganic nutrient for algal growth in the full-fed tanks (Table 2).

The most interesting results for water quality were TAN and nitrite concentrations. Overall, these values were higher in the full-fed tanks than in the restricted-fed tanks ($p \leq 0.05$), but TAN did not differ when the fish were fed SCD instead of the powdered diet ($p > 0.05$). The main source of TAN and nitrites in intensive aquaculture systems is the dietary allowance to fish (TNG et al., 2008). Since a large amount of food is wasted at high feeding levels (AMIRKOLAIE, 2011) there is a direct relationship between the feeding rate and water eutrophication. Sun and Chen (2009) observed an increase in nitrogenous excretions (TAN) in proportion to ration size for cultured cobia (*Rachycentron canadum*). Therefore, the optimum feeding rate would be the one that allows for good growth rates at the lowest feeding rate possible.

In the standard feeding rate groups, those tanks fed SCD had lower TAN and nitrite concentrations than the ones fed the powdered diet ($p < 0.05$). As soon as the powdered diet entered the water it rapidly dispersed and leached into the water. In contrast, the SCD was more stable in the water and maintained its physical integrity for some time (PIEDECAUSA et al., 2010). The interaction between the feed pellet and water is higher for lower size pellets (CHEN et al., 1999). Thus, the TAN and nitrite values measured in the present work indicated that a higher amount of powdered diet was wasted in the water relative to SCD. The higher amount of powdered diet in water caused an increased release of TAN and nitrite after decomposition.

Stewart and Grant (2002) examined the role of physical and biological variables on the amount of material lost from waste feed in salmonid diets and found that smaller pellets eroded faster than larger ones. Likewise, Sutherland et al. (2006) observed a strong positive correlation between pellet dimensions and erosion thresholds; increased pellet size makes pellet erosion (leaching) more difficult. Piedecausa et al. (2009) examined the physicochemical characteristics of *Sparus aurata* and *Dicentrarchus labrax* feed and fecal pellets and also found that smaller pellets have higher leaching rates and, subsequently, higher TAN production. In contrast, the present study detected no reductions in TAN and nitrite between the SCD tanks and the powdered-diet tanks in the restricted-fed groups ($p > 0.05$; Table 2). This suggests that the positive effect of SCD on water quality is magnified at higher feeding rates.

Feeding rate and pellet size had no effect on fish survival (Table 3; $p > 0.05$). Nevertheless, it is noteworthy that 100% survival was attained only in the restricted-fed groups. The restricted-fed powdered diet had no effect on final body weight, SGR and tank yield ($p > 0.05$). This suggests that the dietary allowances in the full-fed tanks surpassed the feeding requirements of Nile tilapia.

Table 3. Growth performance of Nile tilapia juveniles subjected to different feeding rates and either a powdered or small crumbled diet (SCD; particle size = 0.8 mm). Ten tilapia juveniles were stocked in 250-L polyethylene round tanks for six weeks. Initial body weight = 1.95 ± 0.10 g (mean ± standard deviation; n = 5).

Variable	Pellet size	Feeding rate[1]	
		Standard	Restricted (-30%)
Final body weight (g)	Powder	9.8 ± 0.39 Aa[2]	10.8 ± 0.67 Aa
	0.8 mm	11.8 ± 0.61 Ba	14.2 ± 1.05 Bb
Survival (%)	Powder	92 ± 18.0	100 ± 0.0
	0.8 mm	88 ± 22.0	100 ± 0.0
SGR[3] (% BW day^{-1})	Powder	3.88 ± 0.18 Aa	4.06 ± 0.26 Aa
	0.8 mm	4.31 ± 0.12 Ba	4.69 ± 0.24 Bb
Yield ($g\ m^{-3}$)	Powder	396.4 ± 13.7 Aa	431.6 ± 26.9 Aa
	0.8 mm	474.5 ± 23.6 Ba	597.0 ± 75.4 Bb
FCR[4]	Powder	2.13 ± 0.24 Aa	1.42 ± 0.14 Ab
	0.8 mm	1.66 ± 0.10 Ba	1.07 ± 0.19 Bb

Two-way ANOVA P					
Factor	BW	Surv	SGR	Yield	FCR
Feeding rate	< 0.01	ns[5]	0.01	< 0.01	< 0.01
Pellet size	< 0.01	ns	<0.01	< 0.01	< 0.01
Rate vs. Pellet size	0.03	ns	0.03	0.03	ns

[1]Standard: the feeding rates prescribed by the laboratory's feeding table were fully adopted, according to the manufacturer's recommendations; restricted: the standard feeding rates were reduced by 30%. [2]For each variable, means in the same row or column that do not share the same lower case or capital letter, respectively, are statistically different (Tukey's test; $p < 0.05$). [3]Specific growth rate (% body weight per day) = [(ln final body weight - ln initial body weight)/rearing days] x 100. [4]Food conversion ratio = weight of feed offered (g)/fish weight gain (g). [5]Not significant ($p > 0.05$).

The capacity of fish to thrive on limited feeding resources varies among species (RASMUSSEN; OSTENFELD, 2010), and Nile tilapia is known to have a high tolerance for low food resources.

The final body weight, yield and SGR of fish on the restricted-fed SCD were higher than the full-fed tanks ($p > 0.05$). The greater amount of feed waste in the powdered-diet tanks caused a decrease in fish growth performance. There were lower concentrations of stressful compounds (TAN and nitrite) in the SCD tanks than in the powdered-diet tanks. The feeding restriction in the present work produced better FCR for both the powdered diet and the SCD diet groups (Table 3); therefore, the feeding restriction did not reduce weight gain. Our laboratory will now use the restricted feeding table as the new standard feeding table for the green water tanks.

Irrespective of the feeding rates adopted, fish fed a SCD had better growth performance indicators (final body weight, SGR, yield and FCR) than those fed on a powdered diet ($p \leq 0.05$; Table 3). This was likely due to a combination of higher water quality and reduced feed waste in the SCD tanks compared to the powdered-diet tanks.

Conclusion

The 0.8-mm crumbled diet has impacted less the water quality in tilapia tanks than the powdered diet. The better water quality attained in the former tanks has allowed faster tilapia growth. That result was magnified by the restriction of the feeding allowance to the tanks.

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