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Characterization and Evaluation of the Impact of Feed Management on the Effluents of Nile Tilapia (*Oreochromis niloticus*) Culture

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ABSTRACT

The objective of this study was to evaluate the effect of different feed management on the quality of effluent water generated in Nile tilapia (Oreochromis niloticus) culture ponds. Feed was supplied as follows: natural food, and pelleted, extruded or minced ration. The study was conducted during 19 weeks in 12 continuous water exchange ponds of 300 m^2 each, with a population of male Nile tilapia juveniles, in a density equal to 1.7 fish m^{-2}. Feeds contained 30% crude protein, 3,000 kcal digestible energy, and were supplied twice a day. Natural food consisted of chicken manure. Temperature, dissolved oxygen, pH, total phosphorus, total nitrogen, chlorophyll a and suspended solids were monitored weekly in the supplying and effluent water. Water residence time was also determined for the ponds. In general, effluent water quality decreased in all treatments.

Key words: Fish culture, environmental impact, feed management, effluent

INTRODUCTION

Water quality is a constant concern in fish culture. When its quality is low, fish may present impaired productive performance and increased mortality, leading to lower production and profit. Many times, lack of basic knowledge on water quality makes producers themselves contribute to this decrease in quality.

In fish culture, it is common to use pour quality feed and inadequate strategies, such as the use of high volumes of feed without considering the load capacity of the culture systems. This leads to an excessive accumulation of organic residues from feed leftovers, and fish excrement, what causes a reduction in the levels of oxygen and increases the concentration of toxic substances (Tovar et al., 2000). In order to minimize the impact of these problems, producers should have minimum protocol to assure safety, respecting the maximum fish load in a given area, improving feed management techniques, minimizing waste by using good quality, highly digestible feed (Rosenthal, 1994), with lower concentrations of nitrogen and phosphorus, without reducing its nutritive value (Boyd, 1999).

Besides the effects on the culture system, environmental impact is also a concern, once these systems produce effluents and bad quality water that are released to the environment. When compared with domestic effluents, fish culture effluent water presents greater volume and lower concentration of nutrients (Folke et al., 1994). However, its continuous release in aquatic

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ecosystems may lead to artificial eutrophization, with negative impacts on local biodiversity (Iwama, 1991; Beardmore et al., 1997). At present, concerns related to environmental impacts of aquaculture, such as sedimentation and destruction of watercourses, hypernutrification and eutrophization, release of effluents from culture system and pollution caused by chemical residues used in different phases of the system may lead to the establishment of new limits for this activity (Boyd, 1999).
Therefore, the use of water with good quality is a competitive differential, because it is increasing consumers demand in relation to culture systems that do not have any sanitary and environmental control.
Eutrophization of the water from ponds leads to social and economical problems that are more and more evident, mainly in developing countries, where generally there are no specific regulations and the producers themselves are not sensitive to the problems resulted from fish culture. Thus, although it is impossible to breed animals without producing environmental changes, the impact may be mitigated or reduced to a minimum, such that there is no reduction in biodiversity, no draining or negative impact on any environmental resource, or no significant changes in ecosystem structure or functioning (Valenti, 2000).
The objectives of the present study were to evaluate the effect of different feed management – natural food, pelleted, extruded and minced ration – on the effluent water from Nile tilapia culture ponds specifically evaluating possible environmental impacts and nutrient loads.

MATERIAL AND METHODS

Fish, feeding and experimental conditions

Nile tilapia (*Oreochromis niloticus*) juveniles, sexually reverted, with initial mean weight equal to 13.35 ± 0.59g were placed in twelve ponds (three for treatment) of 300 m^2 each, in a density equal to 1.7 fish m^{-2}. Ponds presented independent input and output water flows, and fish were kept in the ponds for 19 weeks (November/99 to April/00). Animals were submitted to the following treatments: natural food (chicken manure), pelleted ration (California Pellet Mill Co), extruded ration (Extrucenter - mod: US 200R), and minced ration (Vertical grinder/mixer). Isoproteic (30% crude protein) and isocaloric ration experimental (3,000 kcal digestible energy) were supplied twice a day (10 am and 5 pm) in a proportion equal to 5% total fish weight per day, until fish reached an average weight of 100g. Then feed was supplied in a proportion equal to 3% of their body weight. Ponds with natural food treatments were fertilized with chicken manure added according to the primary productivity, indexed by the Secchi depth. In the first fertilization, 250 g of manure m^{-2} where placed in each pond, and then, 150g of manure m^{-2}, in 20-day intervals.
Individual weighting in 10% of the fish was performed of each pond, in the beginning of the study, to the 16 days and about 28 days (in order to adjust the feeding rate). The fish were captured with cast nets and anesthetized with 2-Phenol Ethanol.

Water sampling

During 19 weeks, input and output water samples were collected from the ponds at 9 am. Temperature and pH were measured using a multi-sensor (HORIBA U-10). Dissolved oxygen was determined with an oxymeter (YSI Model 57). Total nitrogen was determined according to Mackereth *et al*. (1978). Total phosphorus was obtained according to Golterman et al. (1978). Chlorophyll *a* was determined according to Nush (1980). Suspended solids were determined according to Mudroch and Macknight (1991). Water residence time of the ponds was determined by the register of the input water, and dividing the volume of the ponds by the output water value.

Statistical analysis

Experiment was completely randomized design with three replicates in a split plot in time scheme, with four treatments in the plots and nineteen samples times (weekly samples) in the subplots. Differences among means were tested through analysis of variance (ANOVA). When significant differences were found the Tukey test a posteriori was applied. Significant differences imply in $P<0.05$.

RESULTS AND DISCUSSION

Changes in bodies weights of the fishes is shown in Fig. 1. Similar increase occurred during the 44 days of the study, in all treatments. After this period fishes that received pelleted and extruded ration presented increase in weight. Total quantities of ration and organic manure (in kg) supplied to the fishes in the experimental treatments are presented in Table 1.

It could be observed that there was an increase in the quantities of ration supplied throughout the experimental period, which was higher for pelleted ration.

Table 1 - Monthly amount of feed and organic manure (kg) consumed in each experimental treatment.

Treatment	Amount of feed and organic manure (kg)				
	1st month	2nd month	3rd month	4th month	5th month
Pelleted	16.56	77.75	109.20	195.44	280.00
Extruded	14.95	62.85	94.64	163.24	262.50
Minced	15.87	67.43	90.72	136.84	185.00
Natural food	135.00	135.00	270.00	135.00	135.00

Table 2 - F value and coefficient of variation (CV) of residence time (RT), temperature (T), dissolved oxygen (DO), pH, suspended solids (SS), chlorophyll *a* (Chlo *a*), total nitrogen (TN) and total phosphorus (TP) in effluent water from Nile tilapia (*O. niloticus*) culture ponds.

Statistic parameter	Variable							
	RT (days)	T (ºC)	DO (mg L^{-1})	pH	SS (mg L^{-1})	Chlo *a* (µg L^{-1})	TN (mg L^{-1})	TP (µg L^{-1})
Treatments (T)	0.52^{NS}	3.42^{NS}	0.79^{NS}	0.08^{NS}	3.19^{NS}	0.17^{NS}	1.01^{NS}	51.57**
Samples (S)	221.13**	242.06**	26.01**	297.97**	8.66**	9.46**	2.00*	3.19**
Interaction T x C	1.85**	0.88^{NS}	3.63**	0.78^{NS}	1.14^{NS}	1.80**	1.41^{NS}	3.38**
CV (treatment)	17.67	1.91	28.87	10.57	53.55	40.59	40.66	38.93
CV (samples)	8.55	1.09	14.74	3.13	33.51	46.31	32.98	42.89

Values with asterisks are significantly different (*P<0.05; **P<0.01).

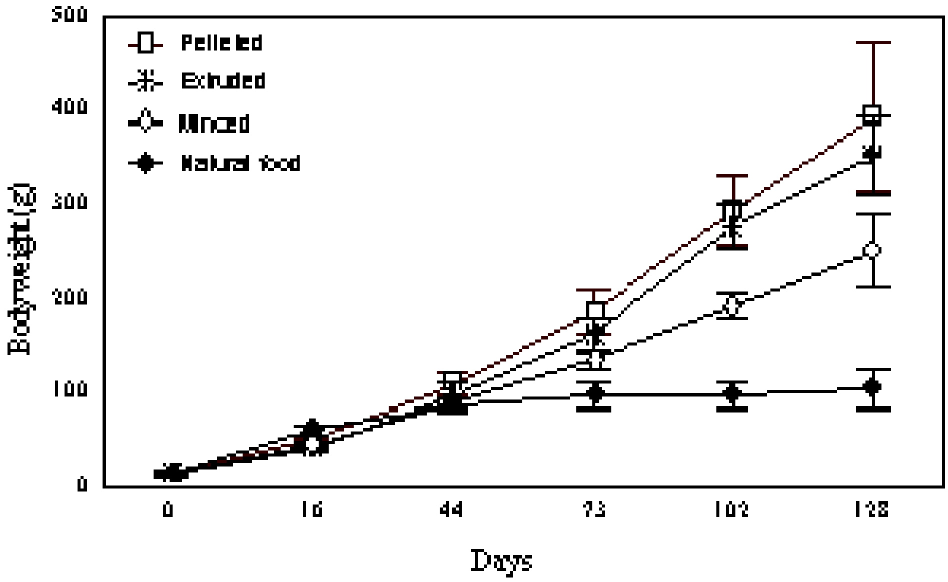

Figure 1 - Growth (in weight) of Nile tilapia (*O. niloticus*) submitted to different feed management, during the experimental period.

As for the residence time (Table 2), there was interaction ($P<0.01$) between the experimental treatments and samples. It was interpreted that differences of residence time along the samples depended on the treatment considered. In fact, residence time for the water ranged from 1.96 to 4.01 days, except in samples 5 and 6, when it was significantly higher in the ponds of the treatment with extruded ration whit residence time of 7.48 days in both the samples (Fig. 2).

Effluent temperature (Table 2) varied in different samples ($P<0.01$). The lowest mean values were recorded in the third samples (24.77ºC) and the highest, in the fourteenth samples (28.63ºC). During the whole experimental period, temperature of effluent water was higher to that of input water (Fig. 3). This was probably due to the incidence of sunlight that heated the water in the ponds and consequently, heated the effluent water. Difference in temperature was sometimes a very important pollutant factor. Gas solubility decreases with increases in temperatures, and biochemical activity doubles every 10ºC of temperature increase (Arana, 1997). Thus, this kind of heating may cause a thermal impact on receiving water bodies and may influence the whole native community.

Dissolved oxygen concentrations (Table 2) during the experimental period also presented significant interaction between treatment and samples ($P<0.01$). In the treatment with pelleted ration, dissolved oxygen concentrations varied from 2.00 to 5.50 mg L^{-1}; in the extruded ration treatment, from 1.33 to 5.93 mg L^{-1}; in the treatment with minced ration, from 2.30 to 5.23 mg L^{-1} and in the natural food, from 3.00 to 5.10 mg L^{-1}. Although there were differenced between the samples, the natural food was the treatment that presented less variation throughout the experimental period, and in the four last samples, it was significantly greater ($P<0.01$) than the other treatments (Fig. 4).

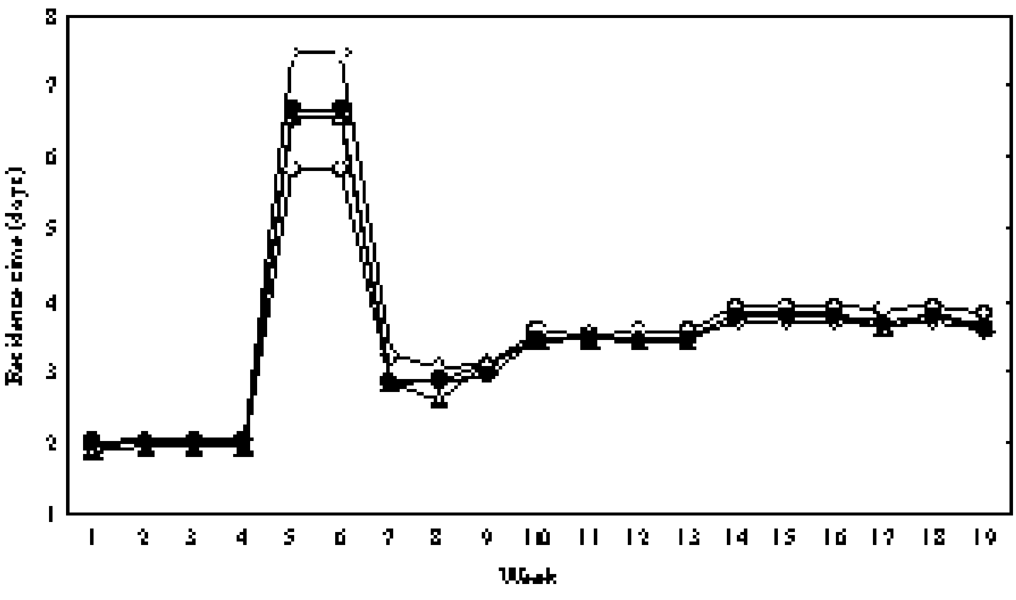

Figure 2 - Residence time in supplying water (□) and effluent water from Nile tilapia (*O. niloticus*) culture ponds with ration pelleted (Δ), extruded (◊), minced (O) and natural food (●).

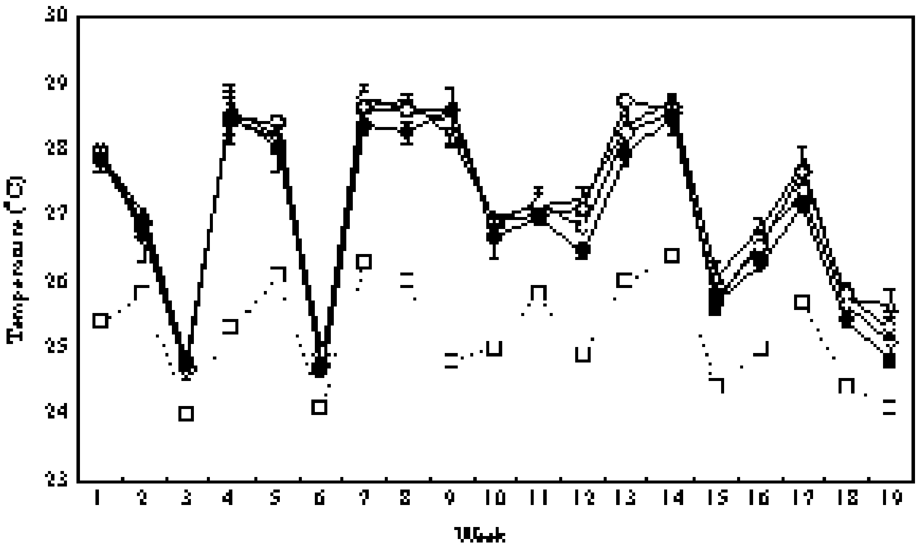

Figure 3 - Temperature variation in supplying water (□) and effluent water from Nile tilapia (*O. niloticus*) culture ponds with ration pelleted (Δ), extruded (◊), minced (○) and natural food (●).

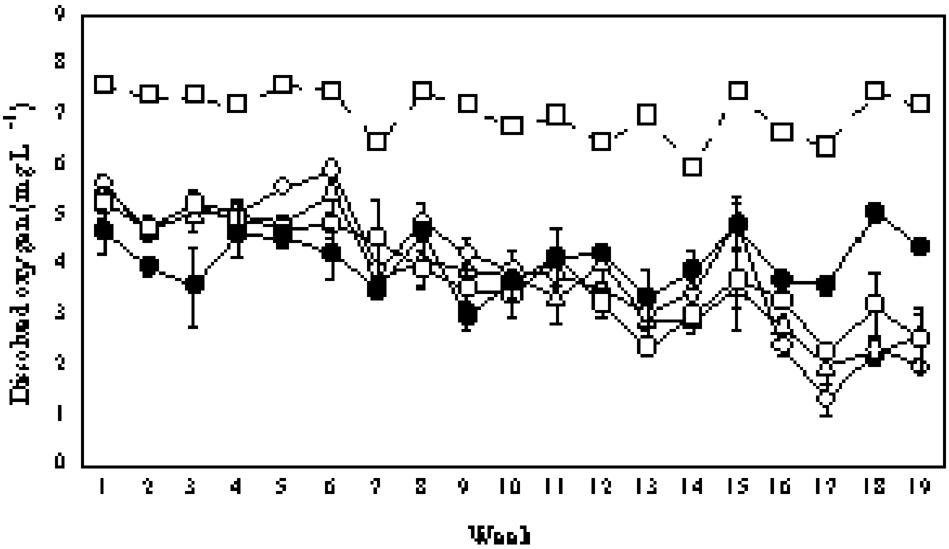

Figure 4 - Oxygen variation in supplying water (□) and effluent water from Nile tilapia (*O. niloticus*) culture ponds with ration pelleted (Δ), extruded (◊), minced (○) and natural food (●).

Concentration of dissolved oxygen was higher in the input water (6.00 to 7.6 mg L^{-1}) throughout the study. Input water has characteristics that may be altered in processes that normally occur in culture systems such as the reduction in the levels of dissolved oxygen due to the action of bacteria on organic matter available by the feed. The same occurrence was described by Boaventura et al., (1997) in rainbow trout culture systems.

Means values of suspended solids did not present differences between treatments throughout the experimental period (Table 2). It could be observed that, in general, there was an average increase from 6.80 to 12.46mg L^{-1} between samples, what corresponded to a mean increase of 83.24% in all treatments (P<0.01). From the tenth to the fourteenth week (Fig. 5), values for suspended solids in effluent water from the fertilized ponds were significantly greater, with a peak value equal to 28.35 mg L^{-1}.

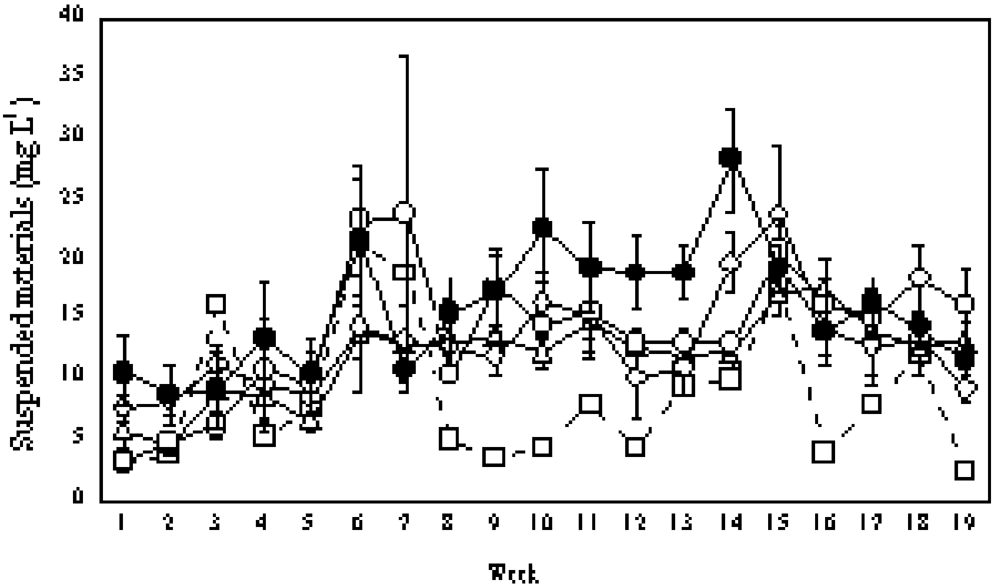

Figure 5 - Variation in suspended solids in supplying water (□) and effluent water from Nile tilapia (*O. niloticus*) culture ponds with ration pelleted (Δ), extruded (◊), minced (○) and natural food (●).

With the increase in biomass (Fig. 1), it could be observed that there was a gradual reduction in dissolved oxygen concentrations (Fig. 4) from 5.5 to 2.53mg L^{-1}, and an increase in suspended solids (Fig. 5) from 5.51 to 12.38mg L^{-1} in the effluent water of the ponds, probably due to the increase in the quantity of feed supplied to the fish, to the increase in the production of organic waste and to the decomposition of organic material. In fact, in the present study, the final quantity of feed (Table 1) was, in average, 15 times greater than the initial one, and fish biomass increased from 7.03 to 179.66kg in the treatment with pelleted ration; from 6.40 to 162.87kg in the treatment with extruded ration and from 6.78 to 110.75kg in the treatment with minced ration. Sipaúba-Tavares et al., (2000) studying Nile tilapia culture systems in ponds with continuous water renewal, also observed an increase in suspended solids from 1.28 to 105.52 mg L^{-1}, and reduction in the levels of dissolved oxygen, from 3.75 to 1.19 mg L^{-1}, at the end of the period. According to the authors, if the continuous organic matter input - as feed – was not controlled, it could lead to inadequate water quality.

Mean pH values in the treatments were around 5.36 and 8.06 during the experimental period (Fig. 6). Although there was no variation between treatments (Table 2), as the study went on there was an increase in pH values in input water, from 6.78 in the first collection, to 7.86 in the last one, what influenced values in the effluent water of all treatments (Fig. 6). According to Esteves (1998) aquatic communities may increase pH values by means of CO_2 assimilation during photosynthesis, what is especially frequent in low alkalinity water, as is this case of the input water in this experiment with total alkalinity value of 5.0 mg L^{-1}.

As for the concentrations of chlorophyll *a* there were significant interaction (P<0.01) between treatment and samples (Table 2). There was an increase from 10.04 to 20.69 µg L^{-1}, 7.94 to 15.64 µg L^{-1} and 7.79 to 18.58 µg L^{-1} for the treatments pelleted, extruded and minced ration, respectively (Fig. 6). In effluent water from the natural food, this tendency was not observed.

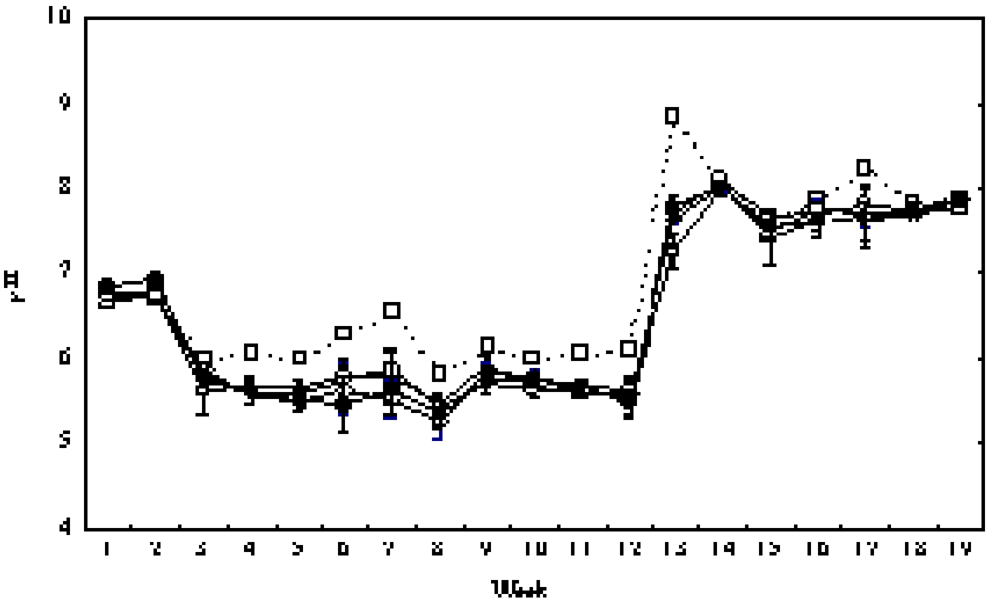

Figure 6 - pH variation in supplying water (□) and effluent water from Nile tilapia (*O. niloticus*) culture ponds with ration pelleted (Δ), extruded (◊), minced (O) and natural food (●).

Generally higher concentration of chlorophyll *a* could be expected in the natural food ponds where organic manure was used. Nile tilapia is an omnivorous fish that has a great ability in filtering plankton particles (Hassan et al, 1997). According to Perschbacher and Lorio (1993), tilapia densities over 5,000 fish ha^{-1} produced an effective biological control on phytoplankton. Thus, it could be probable that phytoplankton consumption by fish in the present study did not allow higher development of this community.

Concentrations of total nitrogen did not present any significant differences as function of the feed management (Table 2). Although significant differences were detected between sample collections, there was no clear increasing or decreasing tendency in the final concentration of this element (Fig. 8). Water bodies with relatively short residence times (similar to the case of the ponds in this experiment) do not enable the transformation of nitrogen by bacteria in the systems, and all nutrients are eliminated in the effluent water (Mires, 1995). Great water flow may carry nitrifying bacteria (Hargreaves, 1998).

Total phosphorus values during the experimental period presented significant interaction between treatment and samples (P<0.01). The values in the effluent water of fertilized ponds were superior to those of the other treatments up to the tenth samples (Fig. 9), probably due to the release of these compounds by the decomposition of organic matter accumulated in the ponds. Organic matter in the sediment was easily degraded in the presence of oxygen. This oxidation could lead to a deficit in the concentration of oxygen dissolved in the sediment, and produces changes in the chemical conditions of the water column, increasing the speed of the eutrophization process (Mires, 1995).

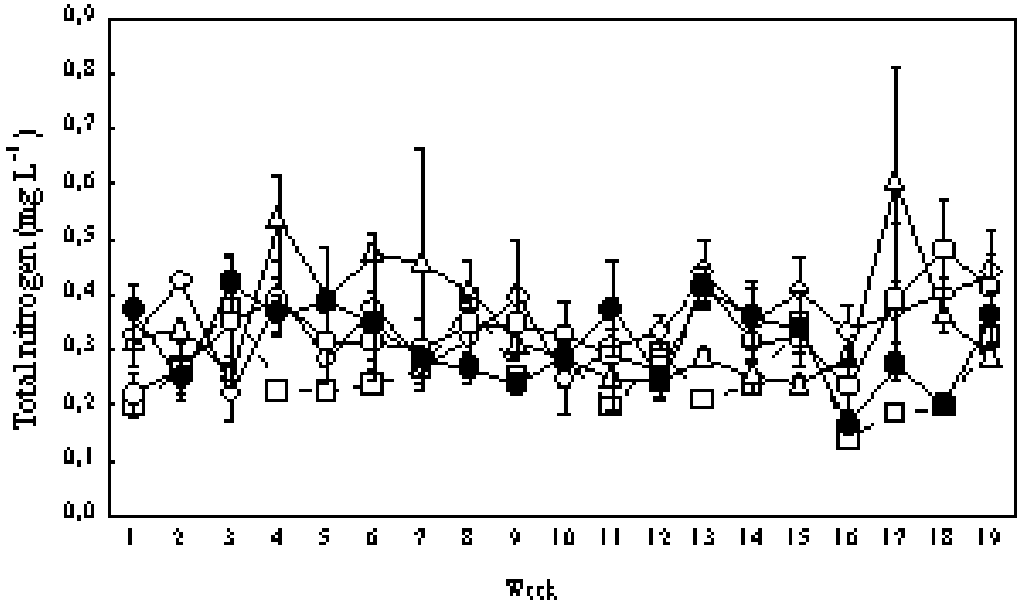

Figure 7 - Chlorophyll *a* variation in supplying water (□) and effluent water from Nile tilapia (*O. niloticus*) culture ponds with ration pelleted (Δ), extruded (◊), minced (○) and natural food (●).

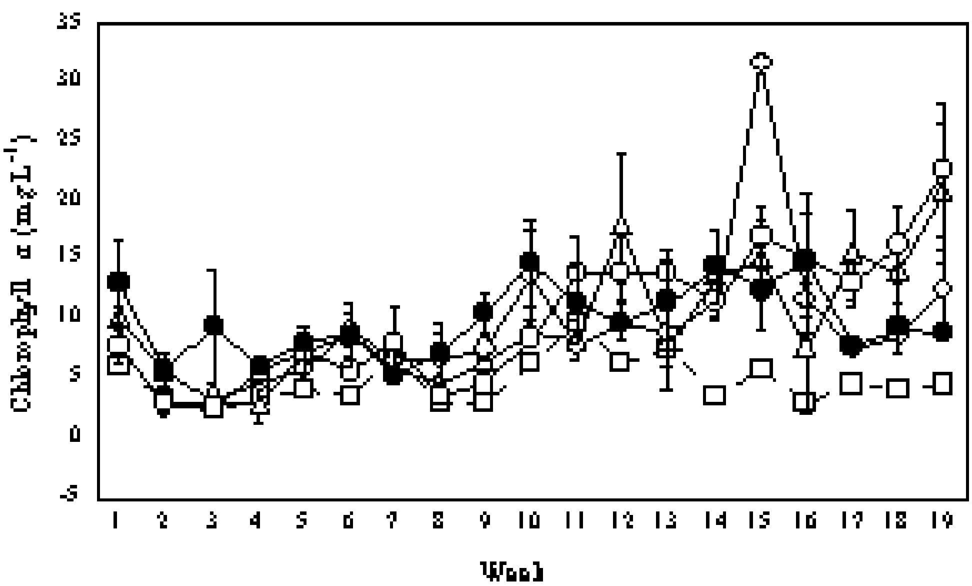

Figure 8 - Total nitrogen variation in supplying water (□) and effluent water from Nile tilapia (*O. niloticus*) culture ponds with ration pelleted (Δ), extruded (◊), minced (○) and natural food (●).

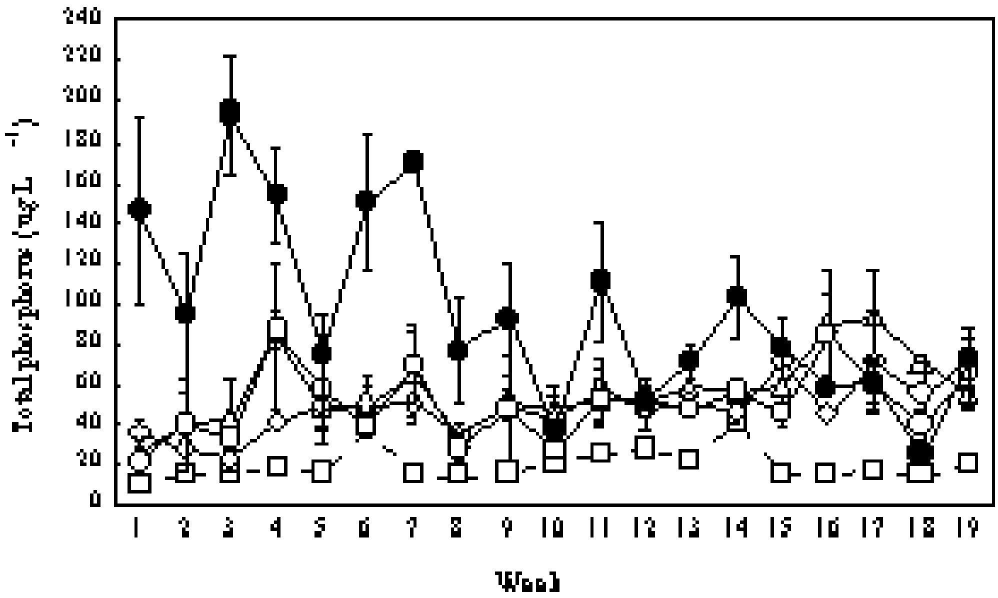

Figure 9 - Total phosphorus variation in supplying water (□) and effluent water from Nile tilapia (*O. niloticus*) culture ponds with ration pelleted (Δ), extruded (◊), minced (○) and natural food (●).

Although the quantity of organic manure added did not chang throughout the experimental period (Table 1), significant decreases in total phosphorus values were recorded (P<0.01) in fertilized ponds. This was probably due to the increase in organic material assimilation and recycling capacity in these systems, when the phytoplankton and bacterial communities became stable.

Opposite tendency was observed in the feed treatments. They presented a mean 39.06 $\mu g\ L^{-1}$ increase in total phosphorus at the end of the experimental period. The increase in the productivity of fish culture basically depends on feed supplementation. However, the introduction of feed in the ponds affects the quality of water, as observed in the present study, and these conditions could decrease the productive performance of the fish, leading to serious economic and ecological losses, once these systems produce effluents and bad quality water that are sent back to the environment (Bureau and Cho, 1999).

The quality of the effluent depends on the initial water quality and on the amount of feed supplied to fish, on the strategy of effluent emission, and on the residence time of the water in the ponds (Mires, 1995). Decreases in water quality were more evident at the end of the experimental period in the ponds that received feed, whereas in the natural food ponds this decrease occurred in greater proportion at the beginning of the experimental period. These differences in the quality of the effluents throughout the experimental period may make their treatment difficult, once the amount of residues in not constant, leading to an under use of the treatment system.

Input water presented, in this study, characteristics that were different from those of the effluent water. Therefore, feed management used in this study influenced the quality of the effluent water, once the quality of the input water was better than that of the effluent water. This fact showed the environmental impact of this practice, leading to possible eutrophization of receiving watercourses.

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RESUMO

O objetivo deste trabalho foi avaliar o efeito da utilização de diferentes manejos alimentares: alimento natural, ração peletizada, extrusada ou farelada, sobre a qualidade da água dos efluentes gerados em uma criação de tilápia do Nilo (*Oreochromis niloticus*). O experimento foi desenvolvido durante 19 semanas em doze viveiros de 300 m^2, com renovação contínua de água, povoados com juvenis machos de tilápia do Nilo na densidade de 1,7 peixes m^{-2}. As rações isoproteícas (30% de proteína bruta) e isoenergéticas (3.000kcal de energia digestível) foram fornecidas duas vezes ao dia. Quanto ao tratamento alimento natural, foi utilizado esterco de galinha poedeira. Semanalmente, foram aferidos na água de abastecimento e nos efluentes, temperatura, oxigênio dissolvido, pH, fósforo total, nitrogênio total, clorofila *a* e material em suspensão. De maneira geral, houve piora na qualidade da água dos efluentes de todos os tratamentos estudados, em comparação a água de abastecimento, evidenciando o impacto ambiental desta atividade produtiva, podendo levar a eutrofização dos corpos d'água receptores.

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