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Effluent from biodigesters with different retention times for primary production and feed of Tilapia (*Oreochromis niloticus*)

San Thy and T R Preston

University of Tropical Agriculture Foundation
Chamcar Daung, PO Box 2423, Phnom Penh 3, Cambodia
santhy@utafoundation.org
regpreston@utafoundation.org

Abstract

A completely randomized design was used to study growth rate of Tilapia (*Oreochromis niloticus*) as influenced by pond fertilization (0.133g N/m^2/day) with effluents from biodigesters having hydraulic retention time of 10 (ERT10) and 30 (ERT30) days. There were three replications (ponds of 6 m^2 in area) of each treatment, applied over a period of 120 days.

Growth rate and net fish yield were higher with ERT30 (0.43g/day and 1363 kg /ha) than with ERT10 (0.27g/day and 899 kg/ ha) after 120 days. Mean values for BOD_5 were higher for the ERT10 treatment.

It is concluded that the improved fish productivity with effluent from biodigesters with 30 day, compared with 10 day, retention times was probably due to a combination of lower BOD in the pond water, and a higher proportion of ammonia-N in the effluent.

Keywords: Biodigester, effluent, Oreochromis niloticus, primary production, retention time, tilapia,

Introduction

Integrated aquaculture is the comprehensive utilization of natural resources and ecosystems for the artificial rearing of aquatic animals and plants (Lin et al 1999). The integration of livestock with trees, food crops and aquaculture is seen as the most appropriate technology to use the natural resources in a system that is productive and sustainable according to Preston (2000). In such a system the processing of the livestock manure by anaerobic digestion is a key component as it has many positive benefits such as reduction in emission of methane, which is a major actor in global warming (Preston and Leng 1989), decrease in pathogens, better health of people and animals, production of biogas for cooking (reduced pressure on forests for fuel wood; more comfortable working conditions in the kitchen for women) and improved nutrient recycling (reduced need for chemical fertilizer) (Preston and Rodriguez 1996).

In all countries, one objective of waste-water treatment should be the reduction, and if possible the removal, of parasites, bacteria and pathogenic viruses that cause endemic diseases. Ponds for water plant (Chará et al 1999) and for fish culture are technological options through which such objectives can be realized. If the only objective was to decontaminate water resources, most projects would not be financially feasible. However, if the excellent bacteriological quality of stabilized pond effluent is taken as an advantage, as well as the nutrients it contains, benefits are jointly obtained for agriculture, livestock, horticulture, aquaculture and forestation. The design of these systems should be adjusted according to the effluent quality required for the intended usage. The use of wastewater facilitates the efficient use of water, the provision of natural fertilizers and food, the creation of employment sources and economic income, and the expansion of agricultural frontiers in desert areas **(**Moscoso and Leon 2000).

The main products from the biodigester are biogas and effluent, which is a potential fertilizer because the anaerobic digestion process results in conversion of organic nitrogen from manure to ionized ammonia (NH_4^+) which can be used directly by plant roots (Forchhammer 1994). Thus it has been found in Vietnam that the effluent was a better fertilizer compared with raw manure for application to cassava and duckweed (Le Ha Chau 1998a,b), although there are few reports of trials to compare the two sources of plant nutrients. It is also important to note that biodigester effluent, as well as behaving as inorganic fertilizer, also contains the organic materials from the digestion of bacteria that fish can use as food to grow (Rakocy and Ginty 1989).

The objective of the present experiment was to obtain further evidence concerning the fertilizer value of biodigester effluent, and specifically to compare effluent produced by different retention times, when used in ponds for fish culture. The hypothesis underlying the design of the experiment was that increasing the retention time in the biodigester would produce effluent of superior nutritive value for use in fish ponds stocked with Tilapia.

Materials and Methods

Treatments and design

A completed randomized block design was used for allocation of two treatments to six ponds, arranged in three blocks (Table 1). The treatments were: effluent from biodigesters with 10 (ERT10) and 30 (ERT30) day retention times The experiment had a duration of 120 days from 1st July to 6th Nov 2002.

Table 1. Allocation of treatments

Block 1	Block 2	Block 3
ERT30	ERT10	ERT30
ERT10	ERT30	ERT10

Biodigester effluent

The design and management of the plastic plug-flow biodigesters were described by Santhy et al (2003). The influent was a mixture of pig manure and water with a solids (DM) concentration of 60 g/litre, which with hydraulic retention times of 10 and 30 days, was equivalent to a loading rate of 3.06 and 1.02 kg DM manure per m³ of liquid volume of the biodigester. The composition of the effluent for the hydraulic retention times of 10 and 30 days was: total N content, 1003 and 1066 mg N/litre, ammonia-N 486 and 636 mg/litre, and ammonia-N to total nitrogen ratio, 0.50 and 0.60.

Table 2. Quantities applied to the ponds of effluent, total N and NH_3-N, according to the source of the effluent (retention times of 10 and 30 days)

	Retention time, days	
	10	**30**
N, mg/litre effluent	1003	1066
Effluent, litres/m^2/day	0.26	0.24
N, g/m^2/day	0.133	0.133
NH_3-N, g/m^2/day	0.066	0.080

The fish ponds

The ponds were 2 x 3m and 1 m deep, and were lined with a cement and soil mixture to avoid water leakage through the sandy soil (Photo 1). Quick-lime (CaO) was applied to the bottoms of all ponds at the rate of 100 g/m², 10 days before stocking with fish. This liming was to eliminate parasites and pathogenic organisms and to increase the pH (Pich Sophin and Preston 2001). The ponds were filled with water 3 days after liming. The effluent was applied in quantities equivalent to 160 kg N/ha over the 120 days, equivalent to 0.133 g N /m^2 /day (Table 2). The effluent was taken from each biodigester immediately after charging with manure and water and was applied at intervals of three days. Each pond was stocked with Tilapia *(Oreochromis niloticus)* at a density of 2 fish/m². The fish were introduced as fingerlings about 3 to 7 cm length.

Photo 1: The ponds used during the experiment

Data collection and analyses

Samples of effluent were taken before application to the fishpond every three days for determination of pH, DM, OM, N and Ammonia-N. Details of the analytical methods employed appear elsewhere (San Thy et al 2003).

The growth rate of the fish was determined by recording the length and weight every 20 days in the morning at 8:00am before loading the ponds with effluent. The fish were caught with a seine net and put in a small basket to measure the length and weight. The length from the tip of the mouth to the caudal fin was measured with a graduate ruler. At the end of the experiment the total fish biomass and the weight and length of each fish were recorded.

The oxygen level of the pond water was measured every two days, two times during the day in the early morning at 6:00am and in the afternoon at 2:00pm by a DO_2 meter (Model 9150). Water samples were collected at the same place in each pond at 20 cm depth and analyzed for pH (every two days, two times a day, in the morning at 9:00am and in the afternoon at 4:00pm) using a digital pH Meter (Model 410A). Water temperatures was measured three days a week, three times a day at 6:00, 12:00 and 17:00 h at a water depth of 20 cm. It was measured by a thermometer submerged into the pond water and left for 5 minutes, after which the reading was taken with the thermometer still in the water. Water transparency was measured every 2 days at midday using a Secchi disk. BOD was measured every 20 days by the method of Winkler (Andrew et al 1995). COD was measured by the Open Reflux method (Andrew et al 1995).

Statistical analyses

The data were subjected to analysis of variance (ANOVA) by using the General Linear Model (GLM) of the MINITAB software (Release 13.3, 1998). The variables were treatment (retention time) and error.

Results

Growth of Tilapia

There were contrasting results for growth in length and in weight, the former favoured by short retention time in the biodigester, and the latter by the longer retention time (Table 3; Figure 1).

Table 3. Effect of effluent from biodigesters with 10 or 30 day retention times on growth and weight/length ratio of Tilapia

	ERT10	ERT30	SEM	Prob
Day of measurement	**Length, cm**			
0	8.33	10.15	0.417	0.037
20	10.08	10.58	0.197	0.146
40	11.30	11.17	0.376	0.814
60	12.24	12.69	0.610	0.630
80	13.01	13.34	0.525	0.679
100	13.41	13.89	0.318	0.343
120	13.84	14.86	0.325	0.090
Daily gain in length, cm	**0.044**	**0.041**	**0.0011**	**0.100**
	Weight, g			
0	13.3	17.4	1.53	0.132
20	19.4	21.5	1.50	0.376
40	26.8	28.5	2.77	0.678

60	34.7	39.4	4.83	0.528
80	38.4	47.0	3.71	0.175
100	42.6	55.6	3.17	0.044
120	44.9	68.2	2.67	0.004
Daily weight gain, g	**0.27**	**0.43**	**0.017**	**0.004**
	Weight/length, g/cm			
0	1.60	1.71	0.10	0.61
20	1.92	2.03	0.08	0.55
40	2.35	2.55	0.12	0.48
60	2.81	3.09	0.18	0.49
80	2.93	3.52	0.17	0.09
100	3.17	4.00	0.21	0.03
120	3.24	4.59	0.31	0.001

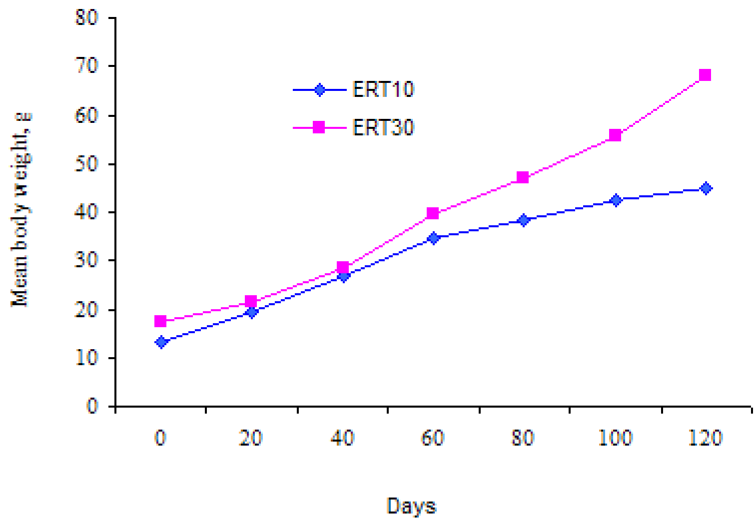

Figure 1: Growth curves of Tilapia in ponds fertilized
with effluent from biodigesters having 10 day and 30 day retention times

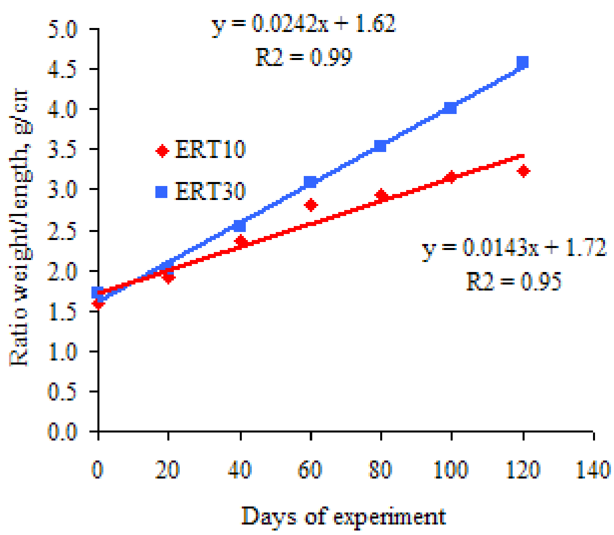

Figure 2: Development of Tilapia in terms of the ratio of weight/length, in ponds fertilized
with effluent from biodigesters having 10 day and 30 day retention times

Water quality in fishpond

The BOD values (biological oxygen demand) were higher for the pond receiving effluent from the biodigester with 10 day retention time compared with 30 days (Table 4).

Table 4: Mean values for water quality parameters

	ERT10	ERT30	SEM	Prob.
pH	8.63	9.01	0.38	0.347
Water transparency, cm	30.0	25.6	2.7	0.305
Water temperature, ^oC	30.1	30.1	0.78	0.999
BOD, mg/litre	7.10	4.74	0.97	0.022
Dissolved oxygen, mg/litre				
6:00am	2.89	2.81		
2:00pm	4.59	4.80		0.083 /0.001
SEM/Prob.	0.083/0.61			

Table 5: Reports in the literature on oxygen level of pond cultures growing tilapia

Types of culture	Feed and fertilizer	DO_2 mg/litre	Sources
Male tilapia (4.1 fish/m^2)	TSP, urea	2.40-3.52	Lin et al 1999
No details	Waste and supplement	above 3	Chapman 2000
Semi- intensive tilapia	Feed and inorganic fertilizer	2.2 -4.5	Veverica et al 1999
Sex reversed male tilapia (3 fish/m^2)	Urea and 30% crude protein feed	1- 10.6	Lin et al 2001
(2 fish/ m^2)	Chicken manure (500 kg/ha), urea and TSP	0.9-2.5	Lin et al 2000

Net fish yield

The net fish yield (total output weight minus the weight at the start) was 60% higher for the 30 day compared with the 10 day retention time (Table 6). The yields were at the low end of the results reported by a range of authors using a wide range of fertilizer management systems (Table 7).

Table 6: Initial and final weight and length of tilapia

	ERT10	ERT30
Total net fish yield, g/pond	1140	1828
Total net fish yield, kg/ ha	633	1015

Table 7: Literature reports of growth and yield of tilapia from different types of culture

Types of culture and fertilizer	Final weight fish, g	Net fish output, kg/ha	Reference
Semi-intensive tilapia (DAP and Urea)	nd#	1127- 2098	Veverica et al 1999
Mixed culture			
- Cool season	23.1-70.5	1015- 2510	Veverica et al 2000
- Warm season	106-168	1119 -1520	
Treated effluents from stabilization ponds (without adding artificial food)	250	4 400	Moscoso and Leon 2000
Chicken litter, urea-super phosphate and mixed feed	149	2970	Nagdi et al 1998
Tilapia with fertilization alone or subsequent addition of feed	314	5460	Diana et al 1996
Tilapia, chicken manure,(120 d)	nd	3660	Knud Hansen et al 1992
Effluent from 30 day retention in biodigester	68	1015	This experiment

#nd: no data

Discussion

Growth of Tilapia

It appears that, when growth conditions are limiting, Tilapia change their conformation, increasing more in length than in mass (Lowe-McConnell 1982). When the growth data were expressed as the ratio of weight/length, then the results were much superior for the longer retention time (Figure 2). The survival rates were high (100% on ERT10 and 99.7% on ERT30).

Water quality in fishpond

Higher BOD levels mean that more oxygen is needed for the oxidation of the carbon in the effluent and therefore there would be less oxygen for the fish. However, the differences in BOD between retention times did not seem to be reflected in the dissolved oxygen concentration, although as expected values were lower in the early morning than in the afternoon. There was a suggestion (SEM ±0.11; P=0.26) of an interaction between treatment and time of measurement, such that dissolved oxygen values were higher for 30 than 10 days retention time in the afternoon with no difference in the morning.

The dissolved oxygen is produced during photosynthesis carried out by aquatic plants and algae during daylight hours, declining during the night and is lowest just before daybreak. If DO is below 5 mg/litre, it may be harmful to fish (Swingle 1969; Floyd 1997), and piping (gulping air at the surface) may be observed when the DO falls below 2 mg/litre. A low level of DO is most frequently associated with hot, cloudy weather and algae die-offs (Floyd 1997). The values in our experiment were within the range reported by several groups of researchers (Table 4). The pH of the pond water between treatments was not different. This range of pH (8.63-9.01) is in the optimum range for growth of from 6.5 to 9, according to Swingle (1969) and from 6.0 to 8.5, according to Chapman (2000).

Net fish yield

The results of this experiment showed that the productivity of the ponds was relatively low, if compared with the potential when pond inputs are optimized. According to Knud-Hansen et al (1991) and Lin et al (1997) the optimum input of nitrogen for fish culture is 4 kg N/ha/day or 400 mg N/m^2 per day. The quantity of N recommended by these authors is almost 4 times higher than what was used in the present study (about 1 kg N/ha/day). Processing pig manure in an anaerobic biodigester, before using it as fertilizer for ponds stocked with a fish polyculture, resulted in a daily growth of tilapia of 0.5 g/day (Pich Sophin and Preston 2001). In research on integrated biogas technology, using biodigester effluent and different hydraulic retention times (50-70, 70 and 30-50 days), and a stocking density of 5 fish/m^2 and a supplement of commercial pellets, the final weight of tilapia was from 27.5 to 41.1 g in 6 months (daily weight gain of 0.15 to 0.23g) according to Edwards et al (1988). Thus the growth rates of the Tilapia were higher in our study but stocking rate, and hence overall productivity, was lower.

Conclusions

It is concluded that the improved fish productivity with effluent from biodigesters with 30 day, compared with 10 day, retention times was probably due to a combination of lower BOD in the pond water, and a higher proportion of ammonia-N in the effluent.

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