Changes in some water quality conditions in recycling water using three types of biofiltration systems during the production of the sharptooth catfish *Clarias gariepinus* (Burchell)

Part II: Growth and production of sharptooth catfish over a period of 78 days

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Abstract

An investigation into the growth and production of the sharptooth catfish *Clarias gariepinus* (Burchell) was conducted over a period of 75 d in recirculating water, using three types of biofiltration systems. Yields fluctuating between 195.2 kg and 242.1 kg were obtained with the mean fish mass per m^3 of water ranging between 19.5 and 22.5 kg. A biofilter system using PVC shavings was not only found to be the most efficient in the transformation of nitrogenous wastes, but also produced the highest growth and production of catfish as well as the best feed conversion ratio of the three biofiltration systems used.

Introduction

Factors which may affect water quality conditions and consequently the growth performance of fish in recirculating water and steps which can be taken to neutralise or eliminate potentially harmful metabolic wastes from such systems, have been investigated in recent years by a number of research workers (Paller and Lewis, 1982; Miller and Libey, 1984; Watten and Busch, 1984; Van Rijn, 1996). Attention was also given to the intensive culture of the African sharptooth catfish *Clarias gariepinus* in recirculation water (Hogendoorn et al., 1983; Bovendeur et al., 1987). In South Africa the pond fish farming of *Clarias gariepinus* only commenced in 1984 (Bok and Jongbloed, 1984). Prinsloo and Schoonbee (1987a) used chicken offal to obtain yields of *Clarias gariepinus* of more than 2 t/ha over a period of 75 d. Using the sharptooth catfish in polyculture with the European common carp *Cyprinus carpio* L., Prinsloo et al. (1989a) obtained yields of 4.55 t over a period of 100d with the catfish comprising 35.9% (1.6 t/ha). Prinsloo and Schoonbee (1992) achieved a yield of 2.824 t/ha for the sharptooth catfish in final effluent water from sewage maturation ponds over a period of 126 d commencing during the second half of summer (February) and ending during the beginning of June (early winter) when mean water temperatures were 16.3 °C with a fluctuation of 14.7°C to 18.0°C. Using a combination of minced fish and bakery floor sweepings as well as a formulated diet, a yield of 7.64 t/ha was recorded for *C. gariepinus* over a summer production period of 140 d. In this case, the mean feed conversion ratio (FCR) was 1.9 (Prinsloo et al., 1989b).

The present exploratory production investigation on the *C. gariepinus* in recirculating water using three types of biofiltration systems must be considered the first serious attempt in South Africa to produce the sharptooth catfish under such conditions. This paper forms **Part 2** of two papers investigating the efficiency of three types of biofiltration units on the oxidation of nitrogenous metabolic wastes in water recirculation systems for the intensive production of the sharptooth catfish.

Material and methods

As mentioned in Part 1 (Prinsloo et al., 1999), each biofiltration system consisted of five aquadams of which each dam, holding 5 m^3 of water, was stocked at the onset of the investigation with 520 young catfish with a mean individual mass at stocking of 83 g. These fish were all pre-treated prophylactically for possible ecto-parasites.

Where some initial fish mortalities occurred, they were replaced by similar sized fish. Water quality conditions were regularly evaluated. The food applied and feeding programme followed, are briefly reported upon in **Part 1** (Prinsloo et al., 1999).

Mass determinations of fish

Because of practical considerations and the fact that subsampling of catfish in such holding tanks did not provide a representative sample of the fish in a specific tank as a result of the specific avoidance behaviour of the catfish, individual aquadams in each system were drained weekly on a rotational basis. All fish were then removed and the individual length and biomass of fish determined. The total fish biomass in the remaining four aquadams of each system was then calculated using the percentage increase in biomass of the fish sampled in one tank compared to the biomass determined the previous week.

Fish growth and feed conversion ratio

Fish growth based on determined fish biomass was calculated on a weekly basis. From these data the amount of feed to be given

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TABLE 1
TOTAL WATER EXCHANGE, TOTAL MASS OF FISH REPLACED, INITIAL AND ESTIMATED NUMBERS AND CALCULATED MASS OF FISH, MEAN FISH MASS, CALCULATED WEEKLY YIELDS, FISH DENSITY PER m³ WATER, TOTAL FEED GIVEN AND THE FCR FOR SYSTEM 1

Period (week)	No of days	Date	Mean temp °C	Total water exchange m³/week	Total mass of fish replaced in kg	Initial (I), estimated (E) and final (F) number of fish total	Mean fish mass in g	Initial (I), estimated (E) final (F) fish mass in kg	Mean weekly yield in kg	Mean fish mass in kg/m³ water	Total feed given in kg/system/ period	FCR*
1	5	17/1-21/1	29			2 600 (I)	83.0	215.7 (I)		8.6	18.3	
2	7	22/1-28/1	28	34		2 585 (E)	102.2	264.2 (E)		10.6	25.93	
3	7	29/1-04/2	29.5	70	28.06	2 600 (E)	107.6	278.1 (E)		11.1	20.14	
4	7	05/2-11/2	29.5	29		2 571 (E)	124.3	319.2 (E)		12.8	36.11	
5	7	12/2-18/2	29	39		2 566 (E)	135.5	347.4 (E)	28.2	13.9	45.44	1.3
6	7	19/2-25/2	30	55		2 558 (E)	147.9	378.2 (E)	30.8	15.1	41.67	1.5
7	7	26/2-03/3	28	55		2 550 (E)	163.4	416.5 (E)	38.3	16.7	46.12	1.1
8	7	04/3-10/3	28.5	55		2 541 (E)	177.8	453.0 (E)	36.5	18.1	45.75	1.3
9	7	11/3-17/3	27	55		2 540 (E)	190.1	484.2 (E)	31.2	19.4	49.83	1.5
10	7	18/3-24/3	27	55		2 531 (E)	203.1	514.0 (E)	29.8	20.6	42.46	1.7
11	7	25/3-31/3	28	55		2 518 (F)	222.3	561.3 (F)	47.3	22.5	54.17	0.9
								Total	242.1		Mean	1.33

* FCR: Feed conversion ratio expressed as dry feed mass/fish mass gain

daily for that week was based on 2% of the total fish biomass. This was calculated for each individual system. The feed conversion ratio was also calculated for each system by dividing the total amount of fish feed administered per week by the weekly fish yield.

The entire project lasted for 78 d at the end of which biomass determinations were made of all surviving fish in the three systems.

Results

Fish growth and production

Results on the fish production with the associated parameters such as fish mass and density, yields, feed given as well as feed conversion ratio, are summarised in Tables 1, 2 and 3 for the three recirculation systems. A factor which seriously affected the initial data on fish growth was fish mortalities which occurred during the second to third week of the investigation in Systems 1 and 2 when the nitrogen removal efficiency of the biofiltration systems had not yet become functional (Prinsloo et al., 1999: Fig. 2). This particularly applies to ammonia and nitrite concentrations accumulating in the recirculating water (Prinsloo et al., 1999: Tables 6 and 7). The efficiency in ammonia and nitrite "removal" was dramatic when these biological filters eventually became operational. Ammonia was the first of the nitrogen compounds which showed a drastic decline in concentrations as from Day 20 with efficient nitrite "removal" following approximately 2 d later. With the stabilisation in the efficiency of ammonia and nitrite "removal" by the filters, it was decided to replace the fish lost with similar sized specimens. Because of this, the calculations of parameters such as weekly yields and feed conversion ratio only commenced as from Week 5 (Tables 1 to 3). No further problems were experienced with the growth of fish.

From Tables 1, 2 and 3 it can be seen that the mean fish densities (in terms of biomass) increased from 8.6 kg to 22.5 kg/m³ of water (System 1), 8.9 kg to 22.5 kg/m³ of water (System 2) and 8.8 kg to 19.5 kg/m³ of water (System 3). Total yields for the three systems over a period of 54 d were 242.1 kg (System 1), 195.2 kg (System 2) and 218.7 kg (System 3), respectively.

The mean weekly fish yields over the period of Weeks 5 to 11, showed System 1 to produce the best results namely an overall mean of 34.5 kg compared to 27.9 kg and 27.3 kg for Systems 2 and 3. The total fish yields for the three systems for the 11 week production period amounted to 242.1 kg (System 1), 195.2 kg (System 2) and 218.7 kg (System 3). The final mean fish mass per m³ of water per system over the entire period was 22.5 kg, 22.5 kg and 19.5 kg for Systems 1, 2 and 3, respectively. The mean feed conversion ratio for the 11 week period was the best in System 1 (1.33) followed by those of System 2 (1.67) and System 3 (1.73).

Discussion

At this stage only limited published information is available on the intensive production of *C. gariepinus* in water recirculating systems. Miller and Libey (1984) evaluated a trickling biofilter in a recirculating

TABLE 2
TOTAL WATER EXCHANGE, TOTAL MASS OF FISH REPLACED, INITIAL AND ESTIMATED NUMBERS AND CALCULATED MASS OF FISH, MEAN FISH MASS, CALCULATED WEEKLY YIELDS, FISH DENSITY PER m³ WATER, TOTAL FEED GIVEN AND THE FCR FOR SYSTEM 2

Period (week)	No of days	Date	Mean temp °C	Total water exchange m³/week	Total mass of fish replaced in kg	Initial (I), estimated (E) and final (F) number of fish total	Mean fish mass in g	Initial (I), estimated (E) final (F) fish mass in kg	Mean weekly yield in kg	Mean fish mass in kg/m³ water	Total feed given in kg/system/ period	FCR*
1	5	17/1-21/1	29			2 600 (I)	85.7	222.8 (I)		8.9	18.3	
2	7	22/1-28/1	28	34		2 593 (E)	104.8	271.8 (E)		10.9	25.93	
3	7	29/1-04/2	29.5	62	111.24	2 600 (E)	124.7	323.2 (E)		12.9	12.24	
4	7	05/2-11/2	29.5	29		2 588 (E)	141.8	366.9 (E)		14.7	38.82	
5	7	12/2-18/2	29	39		2 583 (E)	153.3	395.9 (E)	29.0	15.8	47.39	1.3
6	7	19/2-25/2	30	55		2 560 (E)	160.3	410.5 (E)	14.6	16.4	47.52	3.2
7	7	26/2-03/3	28	55		2 545 (E)	179.5	456.8 (E)	46.3	18.3	49.83	1.03
8	7	04/3-10/3	28.5	55		2 528 (E)	200.4	510.2 (E)	53.4	20.4	50.38	0.9
9	7	11/3-17/3	27	55		2 530 (E)	200.1	509.6 (E)	-0.6	20.4	56.15	
10	7	18/3-24/3	27	55		2 525 (E)	222.1	536.0 (E)	26.4	21.4	38.02	2.1
11	7	25/3-31/3	28	55		2 521 (F)	221.3	562.1 (F)	26.1	22.5	44.48	1.5
								Total	195.2		Mean	1.67

* FCR: Feed conversion ratio expressed as dry feed mass/fish mass gain

aquaculture system using the channel catfish *Ictalurus punctatus* at an initial stocking biomass of 45.4 kg/m³ water. After a production period of 15 weeks, minimum and maximum mean yields of 1.71 and 2.98 kg/m³·week were obtained. Using the data on *C. gariepinus* during the present study for a production period of 11 weeks mean yields, despite a comparatively low initial stocking density of 8.9 kg/m³ water, varied between 1.77 to 2.04 kg/m³·week.

Hogendoorn et al. (1983) found *C. gariepinus* a highly suitable candidate for high density intensive aquaculture on the basis of its rapid growth and efficient feed utilisation. They found, however, the specific growth rate of this fish to decrease from a maximum of 11%/d for small fish at 30°C to a maximum of 2%/d for the larger size fish at 25°C. They also found feed conversion efficiency to decline dramatically with growth in size.

Certain problems which were encountered and which may well have affected the yields obtained for *C. gariepinus* during the present study, included the question of water replacement, feed quality, as well as the manual removal of settled solids, but certainly the most important aspect was the considerable fluctuation and comparatively low levels which prevailed in pH and alkalinity coupled with fluctuations in ammonia and nitrite concentrations (Prinsloo et al., 1999). Although all three biofilters were calculated to be extremely efficient in the oxidation of nitrogenous wastes at final maximum densities of 100 fish and maximum biomass of 22.5 kg/m³ water respectively, certain problems were encountered when, if eliminated, could well lead to much higher yields. This included ample water replacement, improved feed quality, continuous removal of settled solids in the recirculating systems, but most importantly, the control of the considerable fluctuation and comparatively low levels experienced in pH and alkalinity.

Should the densities of *C. gariepinus* and consequently the fish biomass per m³ of water be increased, it may be essential to introduce larger or, alternatively, auxiliary mechanical and/or biofilter systems which will increase the nitrogen oxidation capacity of these filters at specific stages, especially during the daily feeding cycle. This will enable the system to cope with the elevated levels of nitrogenous metabolic wastes released into the recirculating water. It is therefore proposed that an adjustment to this effect be made in any future high-density fish production programmes under local conditions. The incorporation of an anaerobic digester (Van Rijn, 1996) may further facilitate the intensive production of warm-water fish in water-recirculating systems.

As mentioned earlier, the production capacity of water recirculating systems can further be improved by increasing the volume of replacement water from the present 12%/d to 20%/d or even more. These relatively large volumes of nutrient-rich wastewater need not be discarded but can be used profitably in integrated aquaculture-agriculture projects which had been successfully demonstrated by Prinsloo and Schoonbee (1987b).

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TABLE 3
TOTAL WATER EXCHANGE, TOTAL MASS OF FISH REPLACED, INITIAL AND ESTIMATED NUMBERS AND CALCULATED MASS OF FISH, MEAN FISH MASS, CALCULATED WEEKLY YIELDS, FISH DENSITY PER m³ WATER, TOTAL FEED GIVEN AND THE FCR FOR SYSTEM 3

Period (week)	No of days	Date	Mean temp °C	Total water exchange m³/week	Total mass of fish replaced in kg	Initial (I), estimated (E) and final (F) number of fish total	Mean fish mass in g	Initial (I), estimated (E) final (F) fish mass in kg	Mean weekly yield in kg	Mean fish mass in kg/m³ water	Total feed given in kg/system/period	FCR*
1	5	17/1-21/1	29			2 600 (I)	84.8	220.7 (I)		8.8	18.3	
2	7	22/1-28/1	28	34		2 588 (E)	103.7	268.5 (E)		10.7	25.93	
3	7	29/1-04/2	29.5	30	none	2 588 (E)					20.64	
4	7	05/2-11/2	29.5	29		2 576 (E)	116.6	300.0 (E)	31.5	12.0	31.32	
5	7	12/2-18/2	29	39		2 568 (E)	126.3	324.4 (E)	24.4	13.0	34.77	1.3
6	7	19/2-25/2	30	55		2 555 (E)	138.1	352.9 (E)	28.5	14.1	38.93	1.2
7	7	26/2-03/3	28	55		2 543 (E)	150.8	383.4 (E)	30.5	15.3	42.97	1.3
8	7	04/3-10/3	28.5	55		2 530 (E)	165.9	421.7 (E)	38.3	16.9	42.21	1.1
9	7	11/3-17/3	27	55		2 529 (E)	174.7	439.5 (E)	17.8	17.6	46.34	2.4
10	7	18/3-24/3	27	55		2 521 (E)	189.6	478.1 (E)	38.6	19.1	32.93	1.2
11	7	25/3-31/3	28	55		2 518 (F)	199.0	487.2 (F)	9.1	19.5	48.3	3.6
								Total	218.7		Mean	1.73

* FCR: Feed conversion ratio expressed as dry feed mass/fish mass gain

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