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THE POTENTIAL OF WASTE REUSE FROM INTENSIVE AQUACULTURE IN INTEGRATED POND SYSTEMS

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ABSTRACT: The investigated combined intensive-extensive system (IES) as a production system operated in a close interaction of the intensive and extensive production units. The key element of the proper operation was the treatment capacity of the extensive unit; hence the investigations were focused on the periphyton application on the nutrient utilisation and water quality of the production system. Results proved that combination of intensive aquaculture with extensive fishponds enhances the nutrient utilisation efficiency and fish production in IES. The combined fish production resulted in higher protein utilisation by 26%; even this ratio can be increased by 40% with periphyton application.

Keywords: integrated aquaculture, fishpond, waste reusing, nutrient, SustainAqua

INTRODUCTION

Nutrient retention into fish biomass varies only between 20 and 30% of the introduced fish feed in various aquaculture practices. The combination of intensive fish production with extensive pond culture affords a possible solution to increase the nutrient utilisation of aquaculture. In the frame of the SustainAqua project two pilot scale experiments were implemented in the HAKI in order to investigate the potential of nutrient reusing capacity of integrated aquaculture:

- combined intensive-extensive aquaculture system (IES),
- constructed wetland system (ACS).

The IES as a production system operated in a close interaction of the intensive and extensive production units. The key element of the proper operation was the treatment capacity of the extensive unit; hence the investigations were focused on the periphyton application on the nutrient utilisation and water quality of the production system.

Nutrient retention into fish biomass varies only between 20 and 30% of the introduced fish feed in various aquaculture practices (Hargraves, 1998; Brune et al., 2003). For the sustainability of aquaculture necessary steps needed to reduce the nutrient input. To make further sustainable increase of aquaculture production possible higher efficiency of nutrient conversion of input nutrients is needed. The fishponds could be an effective tool for water treatment since they are able to retain high amount of nutrients (Knösche et al., 2000; Gál et al., 2008). The combination of the intensive fish production with extensive pond culture affords a possible solution for the improvement of the nutrient utilisation and for the diversification of fish species. The overall objective of the IES case study is helping for the traditional carp farmers to use their water more efficiently by producing valuable species in their reservoir or extensively used ponds in order to diversify their production and increase the economical performance of fish production.

The ACS was built for the water treatment of the effluents of an intensive flow-through African catfish production farm. This study focuses only the evaluation of waste reutilisation of the combined intensive-extensive fish production system. The nutrient retention capacity of the constructed wetland system is described in somewhere else (Kerepecki et al., 2010; Gál et al., 2009).

MATERIALS AND METHODS

The experiments of IES were carried out in three ponds (area 310m^2, depth 1m) served as extensive units, where to a cage was placed as an intensive unit (volume 10m^3) in each pond.

The ponds were filled up with natural water from a river before a week of fish stocking. The water level was maintained by supplying river water regularly. A paddlewheel aerator (0.5 kW) was applied in the pond to provide sufficient oxygen concentration and maintain the water circulation between the intensive and extensive units (Figure 1).

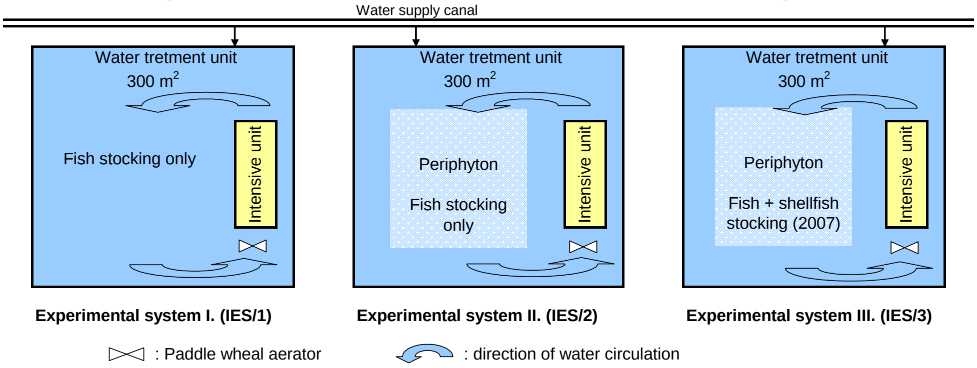

Fig. 1 Scheme of the IES

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Three different setups of extensive ponds were studied: additional area for periphyton development equalled about 0, 100 and 200% of the pond surface area. Artificial plastic substrate was used for periphyton. The operation lasted 16 weeks from 21 May to 10 September of 2008. In the intensive units African catfish (*Clarias gariepinus*) were cultured and fed with pellet – initial stocking biomass was 200kg (20 kg/m^3) –, while 200kg common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) were stocked in each extensive unit as well (in the ratio of 1:1) and were raised without any artificial feeding. All ponds were subjected to the same regime of feeding and fish stocking. A pelleted fish feed (45% crude protein, C:N ratio 6) was applied daily to the intensive ponds using an automatic feeder, but there was no feeding in the extensive fishponds. The only nutrient source of the system was the fish feed used in the intensive unit. The average feed loading was 0.9gN/m^2/day (maximum 1.8gN/m^2/day).

RESULTS AND DISCUSSION

The growth rate (SGR 1.0%) and feed conversion (FCR 1.6%) were similar in all intensive units. The fish yields and data of growth performances are summarised in Table 1. There was no significant difference in the fish growth performances between the intensive units. Therefore the net fish yield of the whole system (intensive and extensive unit together) was the highest in those ponds, where the periphyton area was 100% of the pond surface.

Table 1.
Fish growth performance in IES (SF: shellfish)

	IES/1	IES/2	IES/3
Intensive unit			
Stocked fish	African catfish	African catfish	African catfish
Stocked total weight	200 kg	200 kg	200 kg
Stocked avg. weight	612 g/ind	606 g/ind	618 g/ind
Added feed amount	613 kg	613 kg	613 kg
Average feeding rate	1.55%	1.57%	1.57%
Harvested total weight	613 kg	599 kg	600 kg
Harvested avg. weight	1890 g/ind	1872 g/ind	1916 g/ind
Specific growth rate	1.02%	1.00%	1.00%
Food conversion ratio	1.53	1.58	1.58
Mortality	2%	3%	5%
Net yield	13.2 t/ha	12.8 t/ha	12.8 t/ha
Extensive unit			
Stocking	C carp/Tilapia	C carp/Tilapia	C carp/Tilapia
Stocked total weight	100 kg/100 kg	100 kg/100 kg	100 kg/100 kg
Stocked avg. weight	140/500 g/ind	140/500 g/ind	140/500 g/ind
Feeding rate	no feeding	no feeding	no feeding
Harvested total weight	173/115 kg	206/152 kg	163/122 kg
Net yield	2.79 t/ha	5.05 t/ha	2.72 t/ha
Combined			
Food conversion ratio	0.90	0.83	0.92
Gross yield	28.9 t/ha	30.7 t/ha	28.4 t/ha
Net yield	16.0 t/ha	17.8 t/ha	15.5 t/ha

The total nutrient inputs (stocked fish, inlet water, fish feed) and outputs (harvested fish and drainage water) are summarised in Table 2. The main nutrient source was the fish feed, which represented 80% of the total input of nitrogen, 75% of phosphorus and 85% of carbon. The nutrient retention was 6,300 kg/ha for organic carbon, 1,000 kg/ha for nitrogen and 180 kg/ha for phosphorus. The retained nutrients represented 57% of the nitrogen and 58% of the phosphorus and 64% of the organic carbon introduced into the system in average. The combined system was able to process 1,400 kg/ha of fish feed-origin nitrogen.

Table 2.
Partial nutrient budget of the IES

	IES/1			IES/2			IES/3		
	N	P	C	N	P	C	N	P	C
Input (kg/ha)	1790	310	9700	1800	320	9700	1800	310	9700
Output (kg/ha)	760	130	3100	840	140	3900	720	130	3200
Retention (%)	58	60	67	53	55	59	60	60	67

Several data for nutrient budgets of freshwater fishponds operated in various climatic conditions and carp based ponds in the temperate zone (Oláh et al., 1994; Knösche et al., 2000) have been reported. According to Knösche et al. (2000), fishponds retain on average 78,5 kg N/year and 5.71 kg P/year. However, nitrogen retention of 93 kg N/ha/year was reported by Oláh et al. (1994), as a result of an analysis of nitrogen input and output data for semi-intensive fishpond system for a 20 year period. The average nutrient retention in German and Hungarian fishponds was 78.5 kg/ha/year for nitrogen and 5.1 kg/ha/year for phosphorus in a number of fishponds (Knösche et al., 2000). In a combined intensive extensive system with continuous water circulation 1935 kg/ha/year (81.5%) of organic carbon, 103 kg/ha/year (54.7%) of nitrogen and 25 kg/ha/year (72.2%) of phosphorus were retained during a three-year long experiment (Gál et al., 2003). Comparing the above results it can be stated that the efficiency of nutrient retention can be improved by the combination of the treatment pond and a fishpond unit with periphyton application.

The nutrient utilisation of fish production in IES expressed in the percentage of the total introduced nutrients is summarised in Table 3. There were only negligible differences in the nutrient accumulation between the intensive units. The nutrient reuse by the additional fish production in the extensive unit was the highest where the periphyton area was 100% of the pond surface. The combined fish production resulted in higher protein utilisation by 26%; with periphyton application this ratio can be increased by 40%. This indicates that the 100% periphyton ratio was sufficient to utilise the metabolites of the feed loading of 1.8 g N/m^2/day. The average FCR was 1.5 in the intensive unit. By the combined production the FCR was improved by 44% (to 1.6 and 0.9) due to the additional fish yield of the extensive unit.

Between the treatments there were no significant differences in the measured water quality parameters ($p>0.05$).

Table 3.

Nutrient accumulation in fish biomass in the percentage of the total input (%)

	PA 0%			PA 100%			PA 200%		
	N	P	C	N	P	C	N	P	C
Intensive	23	23	16	22	22	15	22	22	15
Extensive	6.1	3.3	4.4	10	8.9	7.3	5.9	3.3	4.2
Total	29	26	20	33	31	22	28	25	19

PA: Periphyton area

From the experimental ponds 2.6-5.8 g nitrogen, 0.20-0.53 g phosphorus and 16-46 g organic carbon were discharged during the production of 1 kg fish biomass. There was no effect of the periphyton application and feed loading on the nutrient content of effluents. Only the nitrogen concentration was lower in the effluent in case of 200% periphyton ratio.

In the operation of water treatment systems besides algae nutrient uptake and bacterial decomposition, consumption of heterotrophic organisms and denitrification processes have a significant role. Hence, the regulation of oxygen regime, to provide aerobic condition by artificial aeration is important for the efficient nutrient removal during water treatment.

The pilot scale experimental combination of an intensive fish production unit and an extensive fishpond proved the applicability of such systems. The combined system could process a significant part of surplus nutrients from the intensive fish production.

The efficiency of the extensive unit was improved by periphyton developed on artificial substrates, as the periphyton can provide special foods for fish. The dry matter content of periphyton developed on different layers was significantly higher in the samples, which were collected from the top parts of poles than samples were taken from lower parts. Comparing the annual average amounts of periphyton dry matter, there was no significant difference between the ponds. However, the higher amount of periphyton consumption by fish resulted in a higher fish yield in the extensive unit. By following the quantitative and qualitative changes of the periphyton, we get more detailed knowledge on functioning of the system, nutrient cycling and energy flow in the aquatic ecosystem and possibilities of increasing the system efficiency, which can then be applied to the operation and further development of the technology.

Investigations on the nutrient budget of the system demonstrated that an adequate size of the extensive fish pond could treat the effluent from intensive fish culture efficiently and make possible the reuse of water for intensive fish production.

Results proved that combination of intensive and extensive fish farming systems is an efficient tool to reduce environmental pollution of intensive fish farming and to increase extensive fish production as co-product. The general fish yields are around 1 t/ha in traditional ponds, but in combined systems it can be increased up to 20 t/ha. However, the nutrient discharge from the traditional fishponds is very low because of the improved nutrient utilisation efficiency.

CONCLUSIONS

Results of the study proved that combination of intensive aquaculture with extensive fishponds enhances the nutrient utilisation efficiency and fish production in IES. The combined fish production resulted in higher protein utilisation by 26%; even this ratio can be increased by 40% with periphyton application. The operation of the constructed wetland system was characterized by effective nutrient removal efficiency and additional revenue possibilities. Besides the adequate treatment capacity the constructed wetlands have a remarkable potential in energy crop production, as well.

The experimental work resulted in higher nutrient utilisation efficiency and reduced environmental emissions of fish production with increased production capacity. The application of the combined intensive-extensive pond fish production system could contribute to the sustainable use of natural resources (i.e. higher nutrient utilisation efficiency and reduced environmental emissions) and to the economical sustainability as well (i.e. increased production capacity).

The combined system is addressed to the traditional pond farmers who intend to diversify their income with predatory fish production. It helps for the carp farmers to use their water more efficiently by producing valuable species in their large reservoir ponds or extensively used ponds and increases the economical performance of fish production.

The combination of the intensive and extensive aquaculture exploits the advantages of traditional pond farming and intensive fish culture systems. Valuable predatory fish species can be produced in the intensive part of the system, whilst by the integration of extensive pond as a treatment unit resulting in decreased nutrient loading to the environment and increased nutrient recovery in fish production. The intensive rearing can be performed in cages or in in-pond floating tanks, which are placed in extensive pond environment. In the intensively managed part of the system valuable carnivorous fish can be cultured in controlled conditions and fed with artificial diets. The uneaten feed and the fish metabolic wastes can be utilised in the extensive part and can increase the fish yields. Compared to the nutrient utilization efficiency of about 20-25% in most intensive culture systems, it could be increased up to 30-35% in integrated pond systems, resulting in less nutrients discharge to the receiving waters. The application of the combined intensive-extensive pond fish production system could contribute to the better use of water resources and the sustainability of aquaculture.

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