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BIOLOGICAL AND ECONOMICAL EVALUATION OF AFRICAN AND EUROPEAN CATFISH REARING IN WATER RECIRCULATION SYSTEMS

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ABSTRACT. The possibility of rearing African and European catfish in water recirculation systems was analysed. African catfish showed higher growth rate, but feed conversion rate was similar in the two species. Fish losses due to cannibalism was lower in European catfish. Water quality in the rearing tanks met the demands of both species. Economical results were better for European catfish.

Key words: AFRICAN CATFISH, EUROPEAN CATFISH, WATER RECIRCULATION SYSTEM

INTRODUCTION

In Poland, catfish (*Siluroidei*) rearing is limited to two species – autochthonic European catfish (*Silurus glanis*), and African catfish (*Clarias gariepinus*) introduced to Europe in the '70. The latter was brought to Poland in 1988, from Agriculture University in Wageningen, the Netherlands, to the Institute of Ichthyobiology and Aquaculture of PAS in Gołysz. In Europe this species may be reared on a commercial scale in heated waters only, contrary to the European catfish which is usually reared in ponds or cages.

The aim of the present study was to compare biologic and economic aspects of African and European catfish rearing in water recirculation systems.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse, in seven recirculation systems of 4.15 m^3 each. The systems consisted of a rearing tank, a vertical sedimentation tank, a well equipped with water pump, and a biofilter (Fig. 1). Two types of biofilter substrates were applied in the experiment. In four systems, plastic packages were used, the same as in biological sewage treatment plants, and in the three remaining systems – PCV chips placed in polypropylene boxes.

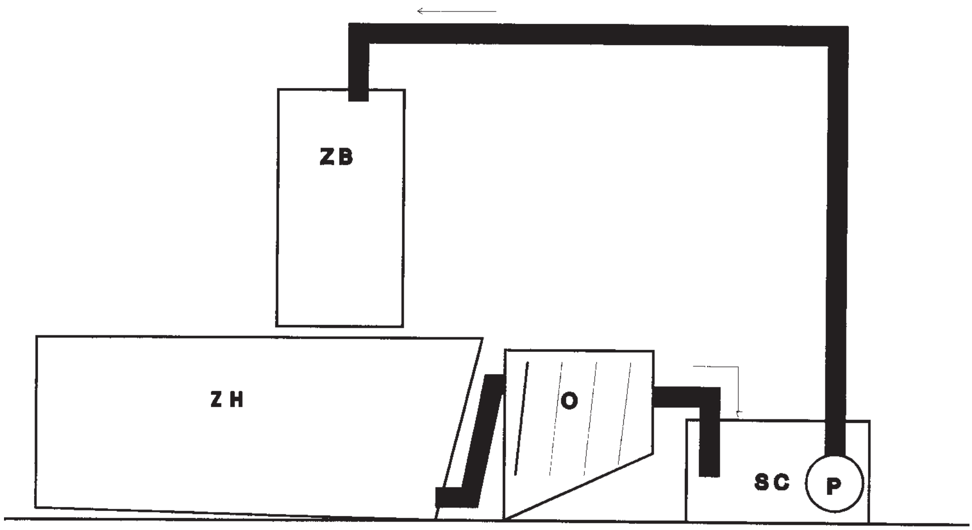

Fig. 1. Experimental water recirculation system. ZB – biofilter, ZH – rearing tank, O – vertical sedimentation tank, SC – well, P – pump. The arrows indicate water flow direction

Basic physico-chemical water parameters were monitored during the experiment to control environmental conditions of rearing and evaluate water purification efficiency.

The tanks were stocked with fish according to Tab. 1. The fish were fed the diet produced in the Department (Tab. 2). Feed was supplied for 24 hours a day, using automatic feeders, Schorfling type. Feeding rates were changed every 7-10 days, according to fish body weight.

Specific growth rate (SGR), and feed conversion rate (FCR) were calculated from the final results.

Significance of the differences in rearing parameters among the experimental groups were calculated using the least significant difference (LSD) test, at the level $p \leq 0.05$. Values described in the tables with the same letters do not differ significantly.

RESULTS

EUROPEAN CATFISH

Final fish body weight in all systems was a little over 14 g. Periodical measurements revealed gradual decrease of specific growth rate from 16% in the initial phase of rearing to about 2.5% at the end of the experiment. Mean values ranged from 4.99 to

TABLE 1

The results of the experiment

Water recir-cula-tion	Biofilter filling Species	Experiment duration	Num-ber of days	Fish stock (pcs.)	Fish losses (pcs.)	Total weight (kg)		Individual weight (g)		Weight increment		Amo-unt of feeds (kg)	SGR (%)	FCR	aNPU (%)	ER (%)	FR (%)	Caniba-lism (%)
						initial	final	initial	final	total (kg)	indyvi-dual (%)							
	Packages																	
I	European catfish	30.07-4.091997	36	1600	5	3.80	18.83	2.38	14.32	15.03	503	17.00	4.99	1.13	32.45	28.38	53.27	18
II	European catfish	13.07-20.08.97	38	1480	98	2.31	16.51	1.56	14.58	14.20	834	12.10	5.88	0.85	42.54	37.25	70.08	24
	PCV chips																	
III	European catfish	23.07-4.09.1997	43	1900	12	1.75	16.70	0.92	14.57	14.95	1482	17.90	6.42	1.20	30.09	26.36	49.65	40
IV	European catfish	23.07-4.09.1997	43	1900	27	1.75	20.34	0.92	14.60	18.59	1485	17.90	6.43	0.96	37.30	32.68	61.60	27
Mean						2.40	18.10	1.44	14.52	15.69	1076	16.23	5.93b	1.04a	35.59a	31.17a	58.65b	27
	Packages																	
V	African catfish	13.07-4.09.1997	53	3800	45	3.23	53.00	0.85	54.58	49.77	6321	50.05	7.85	1.01	35.47	35.24	88.72	73
VI	African catfish	13.07-4.09.1997	53	4000	6	3.40	56.45	0.85	46.04	53.05	5316	50.05	7.53	0.94	37.80	37.56	94.56	69
	PCV chips																	
VII	African catfis	13.07-4.09.1997	53	3700	311	3.15	46.01	0.85	85.52	42.87	9961	50.05	8.70	1.17	30.57	30.38	76.44	77
Mean						3.26	51.82	0.85	62.05	48.56	7200	50.05	8,03a	1.04a	34.61a	34.40a	86.57a	73

Values in the columns having the same letter do not differ in a significant way ($p = 0.05$)

TABLE 2

Chemical composition of the feed and fish body

	Component					Gross energy
	dry weight (%)	protein (%)	fat (%)	ash(%)	non-nitrogen extract (%)	(kcal/g)
Feed	92.70	51.46	6.57	11.25	23.42	4.489
European catfish						
Beginning of experiment	21.57	15.69	3.47	2.38	–	1.214
End of experiment	24.58	18.24	3.86	2.52	–	1.395
African catfish						
Beginning of experiment	24.34	16.33	5.51	2.59	–	1.443
End of experiment	26.75	18.23	5.84	2.53	–	1.582

TABLE 3

Water quality parameters in the rearing tanks

Parameter	Unit	European catfish		African catfish	
		mean	range	mean	range
Temperature	^{o}C	24.1	19.5-27.5	24.5	20.5-29.5
pH	pH	7.53	7.03-8.15	7.00	5.65-7.91
Oxygen content	mg/dm^3	4.34	0.78-7.21	3.37	0.0-6.90
Conductivity	mS/cm	0.282	0.055-0.422	0.33	0.078-0.524
Ammonia	mg/dm^3	1.69	0.88-6.73	5.87	1.06-15.29
Nitrates	mg/dm^3	0.510	0.039-3.412	2.028	0.167-5.977
Nitrites	mg/dm^3	2.374	0.130-4.996	2.758	0.302-9.254
BOD_5	$mg\ O_2/dm^3$	8.28	1.02-46.74	17.20	2.10-49.24
Phosphates	mg/dm^3	0.754	0.054-2.114	0.566	0.115-1.983

6.43% in various experimental groups (Tab. 1). Feed conversion rate showed considerable fluctuations during the experiment, mainly due to temperature changes. The lowest FCR values (0.4-0.7), caused by strong cannibalism, were observed on the first days of the experiment. At the end of rearing, FCR values ranged from 0.85 to 1.20, indicating good utilization of feed by the fish. This was confirmed by the results of chemical analyses. Retention of protein (aNPU), and energy (ER) exceeded 30%, and fat retention (FR) was 58%. No considerable mortality occured during the rearing. Only some dead fish were observed, up to 5%. However, strong cannibalism considerably reduced the fish stock, by from 18 to 40%. It was observed that cannibalism decreased with fish body weight.

Water temperature during the experiment ranged from 19.5 to 27.5^{o}C (Tab. 3), mainly due to the greenhouse effect. No water heating was applied. Water pH was 7.03-8.15. During the first days of rearing pH dropped due to an increase of nitrite and nitrate concentrations. Electric conductivity was related to feeding rate and water exchange, and increased gradually from 0.055 to 0.422 mS/cm. Dissolved oxygen concentrations were low, and gradually decreased. They ranged from 7.21 mgO_2/dm^3 on the first days of rearing to 0.78 mgO_2/dm^3 at the end of the experiment. Content of organic carbon was measured as BOD_5.It ranged from 1.0 to 46.7 mgO_2/dm^3. Concentrations of inorganic nitrogen showed considerable fluctuations. In the initial phase of rearing (up to day 8) ammonium nitrogen prevailed, reaching 6.73 mg N-NH_4/dm^3 in one of the systems. Later on, concentration of ammonia decreased, and beginning from day 12-13 it stabilized at the level of 1-2 N-NH_4/dm^3 (Fig. 2). Such values did not affect fish growth. The effect of other toxic nitrogen form – nitrites was much stronger. On day 8 of rearing maximum nitrite concentration was observed – 3.412 mg N-NO_2/dm^3. It inhibited feeding and caused general weakening of fish. After replacement of 20% of water in all systems, nitrite concentrations decreased, and no more dangerous nitrite buildup was observed until the end of the experiment. This was probably related to an increase of nitrate levels, indicating efficient nitrification. Nitrate levels ranged from 0.13 to 5.00 mg N-NO_3/dm^3 (Tab. 3).

AFRICAN CATFISH

African catfish growth rate was much higher compared to European catfish. Average final body weight ranged from 46.0 to 85.5 g. Body weight of individual fish varied within a very wide range – from 20 to 200 g, considerably affecting fish survival. Dead fish were observed only at the beginning of the study, and their number did not exceed 10% of the stock. At the end of rearing, however, fish losses reached 70%. They must have resulted from cannibalism, stronger than in European catfish. At the beginning of the experiment, growth rate of the fish was slightly lower than in the European species, and ranged from 10 to 16%. At the end of rearing, it decreased to about 5%. Nevertheless, average growth rate was higher compared to European catfish, and ranged from 7.5 to 8.7%. Final values of feed conversion rate were 0.94-1.17, similar to those observed for European catfish. Also the indices of feed utilization were similar - aNPU and ER exceeded 34%, FR reached 86% (Tab. 1).

Water temperature in African catfish tanks was similar to that for the European species, and fluctuated within the range 20.5-29.5^{o}C (Tab. 3). Water pH was lower,

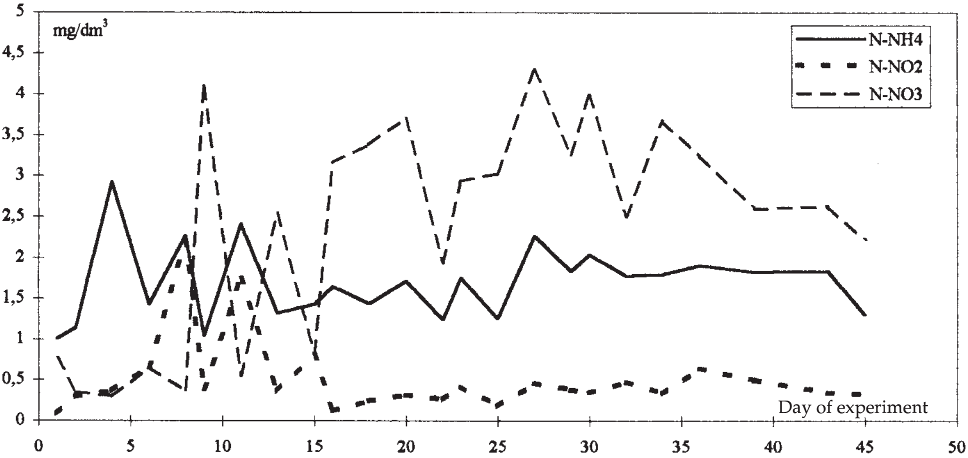

Fig. 2. Dynamics of inorganic nitrogen concentrations during European catfish rearing

and ranged from 5.65 to 7.91. Low pH was increased applying calcium carbonate ($CaCO_3$). In African catfish tanks, electrolytic conductivity of water was higher compared to the values observed in European catfish rearing. This was related to higher feeding rate, thus – higher concentration of inorganic nitrogen and phosphorus. Dissolved oxygen levels were fairly high only at the beginning of the experiment (6.79-6.90 mgO_2/dm^3), and then gradually decreased to 0-1 mgO_2/dm^3 at the end of rearing. BOD_5 fluctuated within a wide range, similarly as in European catfish tanks. Concentrations of inorganic nitrogen were about twice higher compared to those observed in European catfish rearing. At the beginning of the experiment, ammonium, nitrite and nitrate concentrations slightly increased, but later on gradual ammonium buildup was observed, up to 15.29 mg $N\text{-}NH_4/dm^3$ (Fig. 3). Maximum nitrite concentration (5.977 mg $N\text{-}NO_2/dm^3$) was noted on the fourth day of the study. On the following days its concentration decreased to 0.50-2.0 $N\text{-}NO_2/dm^3$ and remained at that level; only between days 35 and 45 nitrite concentration increased again to about 4.00 $N\text{-}NO_2/dm^3$. Nitrate level ranged from 0.302 to 9.254 mg $N\text{-}NO_3/dm^3$ (Tab. 3).

EVALUATION OF ECONOMIC RESULTS

Total construction cost of particular recirculation systems ranged from 4500 to 4800 PLN. Stocking material was most expensive, European catfish fry being more expensive due to difficult breeding and pre-rearing and to high demand for this species which is an attractive game fish. In African catfish rearing, electric energy was used only to maintain water exchange and heating, and in European catfish tanks – also to aerate water. Cost of experimental feed produced in the Department of Ichthyobiology and Aquaculture was 2.11 PLN per kg (commercial feed – ca 3.00 PLN/kg). All production costs are shown in Tab. 4.

TABLE 4

Fish production costs

Species	Costs								Incomes			Gross profit (PLN)
	Energy (PLN)		Feed			Stocking material			Fish			
	pumps	aeration	(kg)	unit price	value	number	unit price	value	number	unit price	value	
African catfish	337	0	150	2.11	317	11500	0.10	1150	2735	1.20	3282	1478
European catfish	372	340	65	2.11	137	6880	0.25	1720	4986	1.00	4986	2417

DISCUSSION

Water temperature in all water recirculation systems was near the optimum range for both species. According to Hogendoorn et al. (1983), successful African catfish rearing may be carried out at 20-30°C, and 25°C is an optimum. In our experiments average water temperature was 0.5-1.5°C lower than this value. Muller and Varadi (1980) stated that optimum range for European catfish was 20-24°C.

Dissolved oxygen concentration plays a less important role in case of African catfish. Even long-term hypoxia does not adversely affect this species thanks to its ability to breathe air. European catfish lacks such possibility, thus it requires an appropriate level of dissolved oxygen, but occasional drops of oxygen concentration under 1 mg/dm^3 do not cause serious disturbances (Filipiak et al. 1993c). In order to avoid long-term hypoxia, and the necessity to reduce feeding, water in European catfish tanks was continually aerated.

The highest daily individual weight increment (SGR), reaching on the average 8.03%, was observed in African catfish. European catfish showed slower growth, and average SGR was 5.93%. Degani et al. (1989) obtained 1.04-1.90% for African catfish of 10-12 g, and Filipiak et al. (1993a, b, c) – 2.37-2.51% for larger fish. Thus, the results obtained in the present study considerably exceeded SGR values observed by other authors.

Feed conversion rate (FCR) is another important parameter in fish rearing. Average FCR value was equal to 1.04 for both species. Efficient feed utilization was also in-

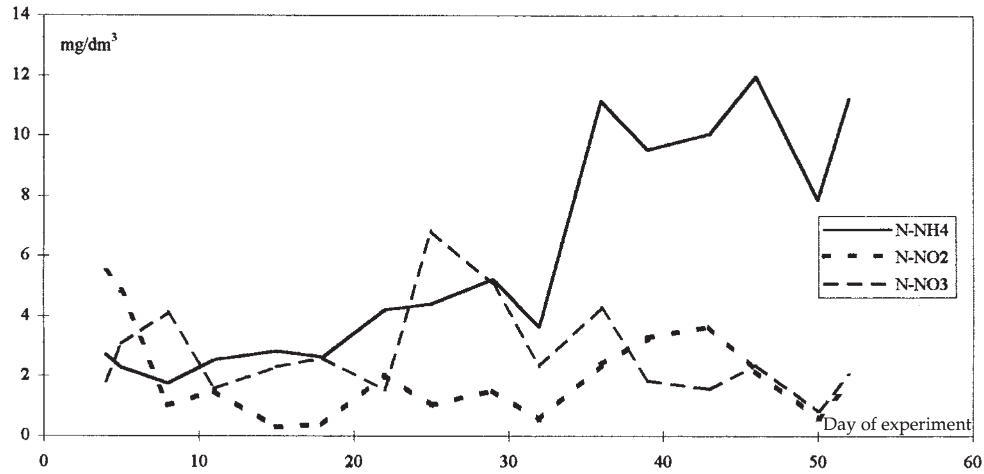

Fig. 3. Dynamics of inorganic nitrogen concentrations during African catfish rearing

dicated by the values of aNPU (35%), ER (31-34%), and FR (58-86%). These results are much better then those obtained by Filipiak et al. (1993a, c) in heated effluents.

Recirculation systems worked well. Two types of biofilters were tested during the experiment. Volume of the biofilter filled with PCV chips was about 3 times lesser, so its substrate and hydraulic loading were higher. Water quality, however, was not worse from that observed in the systems with plastic packages, and in some cases it was even better. In European catfish tanks (except tank II), ammonia levels were low, and beginning from day 5 nitrite concentration increased, later on being nitrified to nitrate. Concentration of the latter was fairly high until the end of the experiment, this resulted from high rate of nitrification despite low dissolved oxygen level. In African catfish tanks, the situation was different. Initial strong increase of nitrite level was followed by a gradual increase of nitrate concentration. Beginning from 30 day of rearing, second phase of nitrification (oxidation of nitrites to nitrates) collapsed, and nitrites started to build up again. Several days later also the first phase of nitrification failed (oxidation of ammonia to nitrites), and concentration of ammonia gradually increased. Nitrification collapse was caused by excessive loading of the biofilters, related to high feeding rate and oxygen depletion. Somewhat worse results obtained in the systems with package biofilters might have resulted partly from the difficulties in supplying water to entire filters.

CONCLUSIONS

European catfish is more susceptible to adverse environmental conditions. Ammonia nitrogen concenrations over 2 mg/dm^3, and nitrites over 1 mg/dm^3 should be avoided in rearing this species. Dissolved oxygen level should not drop below 2 mg/dm^3 , but short-term depletion below 1 mg/dm^3 does not cause serious disturbances. Water quality in water recirculation systems should be improved with aeration or pure oxygen supply.

African catfish confirmed its high resistance to oxygen depletion and high concentration of metabolites. Continuous monitoring of environmental conditions is, however, necessary in order to avoid excessive accumulation of ammonia and nitrites. Also appropriate water pH must be maintained using calcium carbonate, while aeration enhances nitrification processes. In case of temperature drop, water heating becomes necessary, which, of course, increases costs of rearing.

Reduction of cannibalism is an important issue, and may be done by frequent sizing of the fish. Feed conversion rates confirmed usefulness of the feed for the two catfish species, and growth rate was good.

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STRESZCZENIE

ANALIZA BIOLOGICZNYCH I EKONOMICZNYCH ASPEKTÓW CHOWU SUMA AFRYKAŃSKIEGO I SUMA EUROPEJSKIEGO W OBIEGU ZAMKNIĘTYM

W pracy przedstawiono wyniki doświadczeń nad chowem suma afrykańskiego i suma europejskiego w zamkniętych obiegach wody. Wyższe tempo wzrostu (SGR), sięgające 8,03% stwierdzono u suma afiykańskiego, natomiast nie było różnic w wykorzystaniu paszy. Współczynniki pokarmowe były równe dla obu gatunków i wyniosły 1,04. Znacznie niższy kanibalizmn był u suma europejskiego (27%), w porównaniu do 73% u drugiego gatunku. Jakość wody w basenach hodowlanych była odpowiednia dla obu gatunków. Średnia temperatura wody nieznacznie przekroczyła 24^{o}C a odczyn zbliżony był do obojętnego (7,00- 7,53 pH). Spośród badanych parametrów chemicznych jedynie stężenie azotynów przekraczało w niektórych okresach wartości dopuszczalne osiągając wartość 5,977 mg/dm^3. Pozostałe wskaźniki nie wykraczały poza dopuszczalne granice. Lepsze efekty ekonomiczne dał chów suma europejskiego, głównie ze względu na słabszy kanibalizm.

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