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The commercial intensive culture of tilapias in Belgium

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Abstract

The paper reports on some of the final results of a 6 year (1977-1983) research project dealing with the intensive culture of the Nile tilapia, *Oreochromis niloticus* in the heated effluent of the Tihange nuclear power plant on the River Meuse. It also gives an outline of the commercial tilapia rearing operations by the fish farm Piscimeuse SA on the Tihange site.In experimental male monosex culture, a market size 300-350g tilapia is produced in 8-9 months starting from the egg stage. The commercial development of the research programme took place in 1984 when the fish farm Piscimeuse SA started operating, utilizing the heated effluent at the rate of 1 800m^3.h^{-1}. This fish farm rears two species of tilapias (*O. niloticus* and *O. aureus*) and also other warm water fishes such as catfishes (*Clarias lazera, Silurus glanis*, and *Ictalurus punctatus*), carps (*Cyprinus carpio*) and goldfish (*Carassius auratus*). In 1986, the yield of tilapias amounted to 136t.

KEYWORDS: *O. niloticus, O. aureus*, Tilapias, Heated effluent, Fish culture.

Introduction

In 1977, the University of Liège (Belgium) undertook a research programme dealing with the utilization of industrially heated water for the culture of the tilapias *O. niloticus* and *O. aureus*, two species of great potential for aquaculture in the world (Balarin and Haller, 1982; Pullin and Lowe-McConnell, 1982). The research was conducted in a experimental fish-culture station (CERER, Research Centre for Waste Heat Utilization) supplied with a part of the heated effluent of the Tihange nuclear power plant on the River Meuse (Philippart and Mélard, 1980). The good results obtained in this research station (Mélard and Philippart, 1981ab; Mélard, 1986) led to the development of the commercial production of tilapias by the Piscimeuse SA company which started operating in June 1984.

The present paper reports on some experimental results achieved by the research centre under optimal rearing conditions at a pilot scale and gives a first outline of the commercial culturing operations carried out by Piscimeuse SA.

Material and methods

The two main species of tilapias which have been studied are *O. niloticus* from a stock belonging to the aquarium of the University of Liège (Belgium) and from a crop harvested in March 1977 on a fish farm in Kinshasa (Zaïre), and *O. aureus* supplied by the Dor fish farm (Israel).

Water temperature

The water used to rear the fish comes from the cooling system of the nuclear power plants of Tihange 1 (since 1977), 2 (since 1984), and 3 (since 1985). The water temperature is increased by 12°C (open cooling system) to 20°C (closed cooling system) in comparison with the temperature of River Meuse. The water supplied by the power plants (temperature 20°C-45°C) is sent without being previously filtered towards the ponds and production tanks. An automatic (research centre) or manual (Piscimeuse Company) control system makes it possible to maintain the water temperatures between 20°C and 28°C by adding cold water from the River Meuse (0°C-22°C) or from a well (14°C).

Feeding

The fish are fed prepared diets (pellets) with a protein content decreasing from 50 to 30% as the fish grow larger. For fishes up to 30-40g, automatic feeders are used, then demand feeders for larger fishes.

Facilities

Experimental unit

The infrastructure necessary to carry out the reproduction operations consists of two 150m^2 ponds and a number of 4m^2 (1.5m^3) fiber-glass tanks. The infrastructure used for the growth-production experiments is made up of one 150m^2 (200m^3)earthen pond, two 8m^3 circular tanks, and one 6.5m^3 longitudinal D-ended tank with a water recirculating system. All these tanks and ponds are equipped with complementary aeration systems (compressed air, emulsifiers).

Piscimeuse Company

The commercial production is carried out in concrete tanks (two 400m^2 raceways, ten 30m^3 and ten 6m^3 D-ended tanks, five 8m^3 square tanks, and fifteen 5m^3 tanks) or in polyester tanks (twenty four 4m^2 tanks) the total capacity of which is 1 200m^3. These are equipped with reoxygenation systems (floating aerators or pulsed air). The fry are produced in earthen ponds with a total surface of 2 000m^2.

Results

Experimental unit

Production of fry

In order to obtain synchronized reproductions, the ponds and tanks are stocked with females which have reached an advanced maturity stage. In order to limit the spawning frequency, the spawners and the fry are harvested 2 months after the first spawning. This method of fry production in ponds or tanks makes it possible to produce (Table I) large amounts of fry in reduced areas (up to 72 000 fry in 2 months in a 150m^2 pond). The fry production varies from 1.8 to 36.2m^{-2}.d^{-1} depending upon the body weight of the females, the stocking density of the broodstock, and the sex ratio (Table I).

Growth and production

In 1982, intensive growth-production experiments were undertaken on a pilot scale in large tanks and in ponds respecting the optimal growth conditions (stocking density, temperature, oxygenation, feeding) which had been determined in previous experiments on a smaller scale as reported by Mélard and Philippart (1981ab; 1983) and Mélard (1986).

In tank

Starting from fry of 10g (produced in 2.5 to 3 months starting from the egg), 5.5 months are needed to obtain a 300g marketable size in monosex male high density culture (1 300-300 fish.m^{-3}) (Fig. 1). This represents an absolute growth of 1.6-1.8g per fish per day (Table II). After 60 days under experimentation, the fish are sorted according to their sex which makes it possible to eliminate slow growing females (51.3% of the whole group, 48g average body weight). Another 60 days later, the males are sorted according to their size, the small sized fishes (47% of the whole group, 134g average body weight) are removed and the biomass readjusted.

Table II shows that the productions expressed as kg.m^{-3} of tank.d^{-1} are very similar in circular tanks (0.95) and in D-ended tanks (0.91). On the contrary the productions per water flow unit are more important in D-ended tanks (25.8g.m^{-3}.h^{-1}) than in circular tanks; the high efficiency of the aerators in D-ended tanks indeed makes it possible to maintain a satisfying oxygenation rate while using a reduced quantity of water. The food conversion ratio (1.6) shows the food is absorbed in a very satisfying way in both systems.

Table I. Results of *O. niloticus* fry production in different breeding systems

Surface (m^2)	Density of spawners ($fish.m^{-2}$)	Sex-ratio female/male	Fry prod. ($fish.m^{-2}.d^{-1}$)	Fry prod. (kg^{-1} $female.d^{-1}$)	Total fry production
4	3.0-8.3	3.0-10.0	5.6-36.2	3.6-46.5	2 000- 7 300
10	3.0-4.3	2.8- 4.4	16.7-35.0	35.7-64.9	9 000-14 000
150	0.6-2.5	2.1- 4.6	1.8- 9.5	7.9-39.0	23 100-71 600

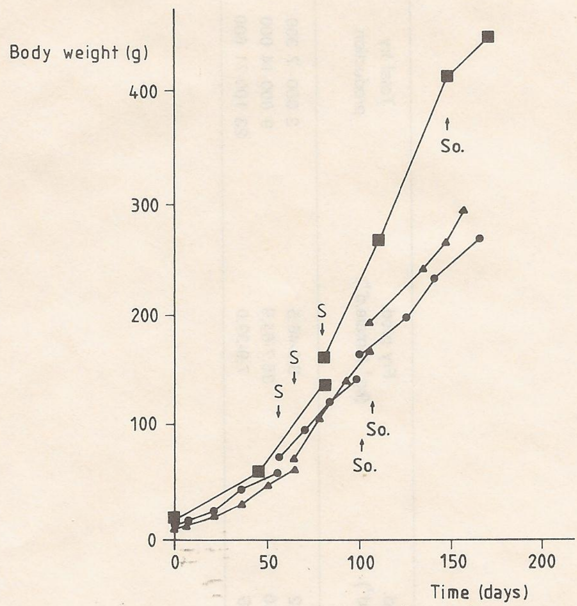

Fig. 1. Ponderal growth of *O. niloticus* in different rearing systems (pilot scale operation). (●) D-ended tank, (▲) circular tank; (■) earthen pond; (S) sexing; (So.) sorting.

In earthen pond

Concurrently with the two experiments reported above, an experiment of semi-intensive pond production was undertaken for comparison (Fig. 1, Table II).

Thanks to the low stocking density (8-9 fish.m^{-2}) and the very good oxygenation level (6.9ppm dissolved oxygen) and temperature conditions (average temperature of 26.4°C) the absolute growth in weight is high (2.5g per fish.d^{-1}), and after 120 days the fish are already marketable (300g). This method requires, however, large water volumes (60 times larger) to obtain a total production similar to that reached in the tanks.

Piscimeuse SA Company

Production

The productions obtained by Piscimeuse (from 1984 to 1986) are shown in Table III. A growing dominance of the original or difficult-to-rear species (tilapias *O. niloticus* and *O. aureus*, catfishes, Koi carps, and barbel) can be noticed in comparison with the traditional species (carp, trout, tench).

Table IV summarizes the main rearing parameters. In 1985-86, the production was 160t.yr^{-1}, i.e. 0.34kg.m^{-3} of tank.d^{-1}. When stocking densities increase as in 1986, the food conversion ratio increases whereas the feeding ratio decreases. Momentary market difficulties, which led to an overcrowding and a slowing down of the growth rates, account for these results. On the other hand when the stocking density remains low (1984) the conversion ratio is better but the production m^{-3} of tank.d^{-1} is insufficient and non-profitable according to the local economic situation.

Table V shows that high stocking densities (1986) lead to an important increase in electricity expenses (more than 20% in 1986). The volume of water required to produce 1kg of fish is about 87m^3. Moreover the metabolization of 1kg of food requires 1kWh.

High temperature is an important growth increase factor. Nevertheless as the DO content

Table II. Growth and production of *O. niloticus* in different rearing systems at pilot scale

	Circular tank	Oval D-ended tank	Earthen pond 150 m^2
Volume of water	8.0 m^3	6.5 m^3	200 m^3
Duration (d)	157	165	168
Initial number	10 460	9 000	2 427
Inital fish density (fish.m^3)	1 308	1 385	12
Initial mean body weight (g)	8.9	10.8	19.9
Initial biomass (kg)	92	98	48
Final number (marketable fishes)	2 678	1 980	1 089
Final fish density (fish.m^3)	335.0	305.0	5.5
Final mean body weight (g)	291	269	442
Final biomass (marketable fishes) (kg)	780	530	481
Mean loading ($kg.l^{-1}.min^{-1}$)	1.5	2.5	0.5
Total production ($kg.m^{-3}$ $volume.d^{-1}$)	0.95	0.91	0.02
Total production ($g.m^{-3}$ water $supply.h^{-1}$)	14.0	25.8	3.4
Relative growth rate Gw (%.d^{-1})	2.22	1.95	1.85
Absolute growth ($g.fish.^{-1}.d^{-1}$)	1.80	1.56	2.51
Food conversion	1.52	1.63	1.56
Mean water temperature (°C)	27.2	27.9	26.4
Mean dissolved oxygen (ppm)	4.7	3.9	6.9

$$Gw = \frac{\ln Wi - \ln Wf}{t\ (d)} \times 100$$

Table III. Fish production by Piscimeuse SA (1984-1986). Production figures are in t (percentage in parentheses)

Year	Tilapias	Carp	Catfishes (*S. glanis* *C. lazera* *I. punctatus*)	Tench	Trout	Koï	Barbel	All species
1984	23.1	48.2	2.3	8.2	1.9	0.4	-	84.0
(260 d)	(27.5)	(57.4)	(2.7)	(9.7)	(2.3)	(0.5)		
1985	104.4	46.0	3.4	0.8	9.3	2.1	-	166.0
	(63.0)	(27.0)	(2.1)	(0.5)	(5.6)	(1.3)		
1986	136.0	14.4	7.6	0.2	-	2.4	0.1	
	(84.0)	(8.0)	(4.8)	(0.1)		(1.5)	(0.1)	
Total	263.5	108.6	13.3	9.2	11.2	4.8	0.1	410.7
	(64.0)	(26.3)	(3.2)	(2.2)	(2.7)	(1.1)	-	

Table IV. Evolution of the fish produced by Piscimeuse SA during the first 3 years of operation (± 60% of tilapias)

Year	Mean temperature (°C)	Amount of food given (t)	Food conversion	Daily production ($kg.m^{-3}.d^{-1}$)	Average stock in tanks ($kg.m^{-3}$)	Rate of feeding (% body $wt.d^{-1}$)	Total production (t)
1984 (260 d)	24.0	111.4	2.04	0.22	22.0	2.4	54.4
1985	24.5	360.8	2.42	0.34	54.3	1.6	166.0
1986	24.3	463.3	3.20	0.33	97.2	1.1	160.7

Table V. Evolution of the energy consumption by Piscimeuse fish farm during the first 3 years of operation

Year	Total electricity consumption $kw.h^{-1}$ (m^3 tank)	Electricity consumption per kg of fish produced ($kw.h^{-1}$)	Electricity consumption per kg of food ($kw.h^{-1}$)	Total water supply (warm water + cold water) ($m^3 \times 10^3$)	Rate of water renewal in the tanks per h	Volume of water used per kg of fish produced (m^3)
1984 (260 d)	129 900 (0.4)	2.4	1.2	6 953	0.9	127.8
1985	378 633 (0.9)	2.6	1.1	12 934	1.2	87.4
1986	503 247 (1.2)	3.1	1.1	14 256	1.4	88.7

at saturation in heated water is maximum 8ppm, reoxygenation (surface aerators) does not make it possible to get the same oxygen transfer efficiency as in trout culture (2ppm DO are lost on the average with equal power and stocking), and is proportionally more expensive.

Pathology

The temperature range is too high to allow classical viral cold-water diseases. For the different fish species reared at Piscimeuse, five kinds of mortality are observed, some of which fairly specific for this kind of fish farm and should therefore be named "technopathology". Tilapias are very resistant to any diseases. The only troubles that may occur are those mentioned in further points 2, 3, and 4 which are common to all the species reared.

1) In the pregrowing and growing phases at high stocking density: ectoparasites (*Trichodina*, *Gyrodactylus*), Columnariosis, gill diseases, *Aeromonas* infection.

2) In winter, when the water temperature accidentally becomes too low (< 15°C): gill disease with branchiomycosis (tilapias), saprolegnosis, and mortality caused by anemia in carps (under 8°C, even if the thermal adaptation is long). This problem prevents all trade of living carps in winter.

3) In winter: gas bubble disease resulting from strong variations of gas supersaturation. A computer program is used to analyze this phenomenon and to improve the transfer of animals.

4) When animals are transferred from extensive to intensive culture systems, they are very weak and sometimes parasited.

5) Accidentally: mortality caused by chlorine or chemicals used by the power plant for cleaning its cooling system.

Conclusions

The production results obtained on a pilot scale in the experimental fish culture unit could not be achieved on an industrial scale (2-3 times less important production per volume unit). Problems connected with the commercial management of the stock (e.g. sorting of the fish according to their sex), the commercialization (new market, size of the fish), and the economic constraints (electricity consumption, water needs) have prevented the optimal growth-production conditions, defined under experimental conditions, from being respected in the commercial operation.

Increasing productivity and profitability of intensive tilapia rearing depends on: 1) an improvement of the stock management; 2) the design of facilities better adapted to the final growing stage of the fish; and 3) the development of monosex male culture allowing a growth increase of the stock by elimination of the females.

Relating to these problems, two methods are currently being studied: hormonal sex reversal at a large scale in ponds and production of sex-reversed females (genotypic males) to be crossed with males in order to produce 100% genotypical males (Mair et al., 1986).

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