Asian Fisheries Science **13**(2000): 251-261
Asian Fisheries Society, Manila, Philippines
https://doi.org/10.33997/j.afs.2000.13.3.007

Annual Yield of Tilapia (*Oreochromis niloticus* L.) in a Semi-recycling Integrated System in Kuwait

A.A. AL-AMEERI, E.M. CRUZ, A.A. AL-AHMAD and M. RIDHA

Mariculture and Fisheries Department
Kuwait Institute for Scientific Research
PO Box 1638, 22017 Salmiya
Kuwait

Abstract

A simple small-scale tilapia culture system suitable for integration in existing agricultural farms in Kuwait was studied. Nile tilapia (*Oreochromis niloticus* L.) fingerlings (2-7 g) were cultured sequentially in raceways inside a greenhouse. Well water flowed through the fish tanks during irrigation time and was recycled during non-irrigation time. The system was tested from January 1995 to August 1998.

Results revealed that the system was capable of producing 2,340 kg fish per year and market size fish (>250 g) may be produced within 227 days. The partial water recycling system provided optimum environmental conditions for optimum fish growth. Problems identified during the trial were low DO of well water, power cut-off, leaking and bending of air supply pipes and very big size variation of fish at harvest. Measures to solve the problems are discussed in this paper.

Introduction

As water is Kuwait's most limited resource for crop production, integrating aquaculture with agriculture should not lead to increased demand on precious underground water. Therefore, only water utilized for crop production is considered as potentially available for integration with fish culture within the existing farming system.

Presently, there are more than 40 agricultural farms in Kuwait (Al-Ahmad 1998) that culture tilapia in tanks. Water exchange in the fish tanks is coupled with an irrigation schedule that takes place only during the day. At night, water is kept stagnant in fish tanks. Although this system is simple, inexpensive and commonly used by farmers, production rate is limited to 5-10 $kg \cdot m^3$. In addition, the small farm size in Kuwait (5 ha) limits fish production as fish effluents have to be used within the farm itself. The current approach to increase fish production is to increase the number and size of fish tanks. However, this approach will subsequently lead to increased water pumping in already overexploited aquifers. Therefore, with such small-scale farms, the challenge is to increase the productivity per unit area, per unit time, and per unit of capital input.

Currently, recirculating system is not considered as a viable fish production system for Kuwait. In view of its sophisticated set up, this system requires close monitoring. Highly trained technicians are therefore needed to operate them, a precondition that is not easily obtainable in Kuwait. Furthermore, high capital and operating costs are still the major constraints to making the recirculating system economically feasible (Muir 1982). The relatively low market prices of tilapia in Kuwait further restrain their economical feasibility.

Alternatively, a flow-through simple recycling system is presumed to be the most promising as a potential practical technology for fish production in existing agricultural farms in Kuwait. The system is based on three concepts. First, well water flows through the fish tanks, and then discharged to agricultural crops during irrigation time. During non-irrigation time, water in fish tanks is recycled. Hence water exchange is based on crop irrigation schedule. Second, fish production tanks are placed inside a greenhouse to minimize fluctuation during changes in environmental conditions. Third, fish are cultured in a sequential manner, so that fish grown in one tank are transferred after a certain period of time to the next bigger tank to efficiently utilize the area devoted for rearing the fish at different growth stages.

The objective of this study was to determine the annual yield, feed conversion ratio and water quality parameters of a fully loaded semi-recycling tilapia production system under modified management conditions.

Materials and Methods

Set up of experimental facilities

A greenhouse measuring 20 x 5 x 3 m (LxWxH), covered with corrugated fiberglass sheets and shade nets (TILNET, 60%), was constructed at Al-Wafra, an agricultural area located about 100 km south of Kuwait City. Two exhaust fans were installed at one end of the greenhouse to maintain cool air inside the greenhouse during summer. A concrete slab (10 cm thick) with a central drain canal covered the floor of the greenhouse. Inside the greenhouse, two identical raceways were installed (Fig. 1). Each raceway consisted of three fish tanks of different sizes and a sand filter.

All tanks were made of fiberglass. The first, second and third fish tanks in each raceway had water volumes of 1.5, 4.5 and 6.0 m^3, respectively. The height and width of all the tanks were 1.2 and 1.0 m, whereas the length of the first, second and third tanks were 1.5, 4.0 and 6.0 m, respectively. The tanks were elevated and arranged in tiers. The first and second fish tanks stood on 40 cm and 20 cm legs, respectively. The third fish tank was placed

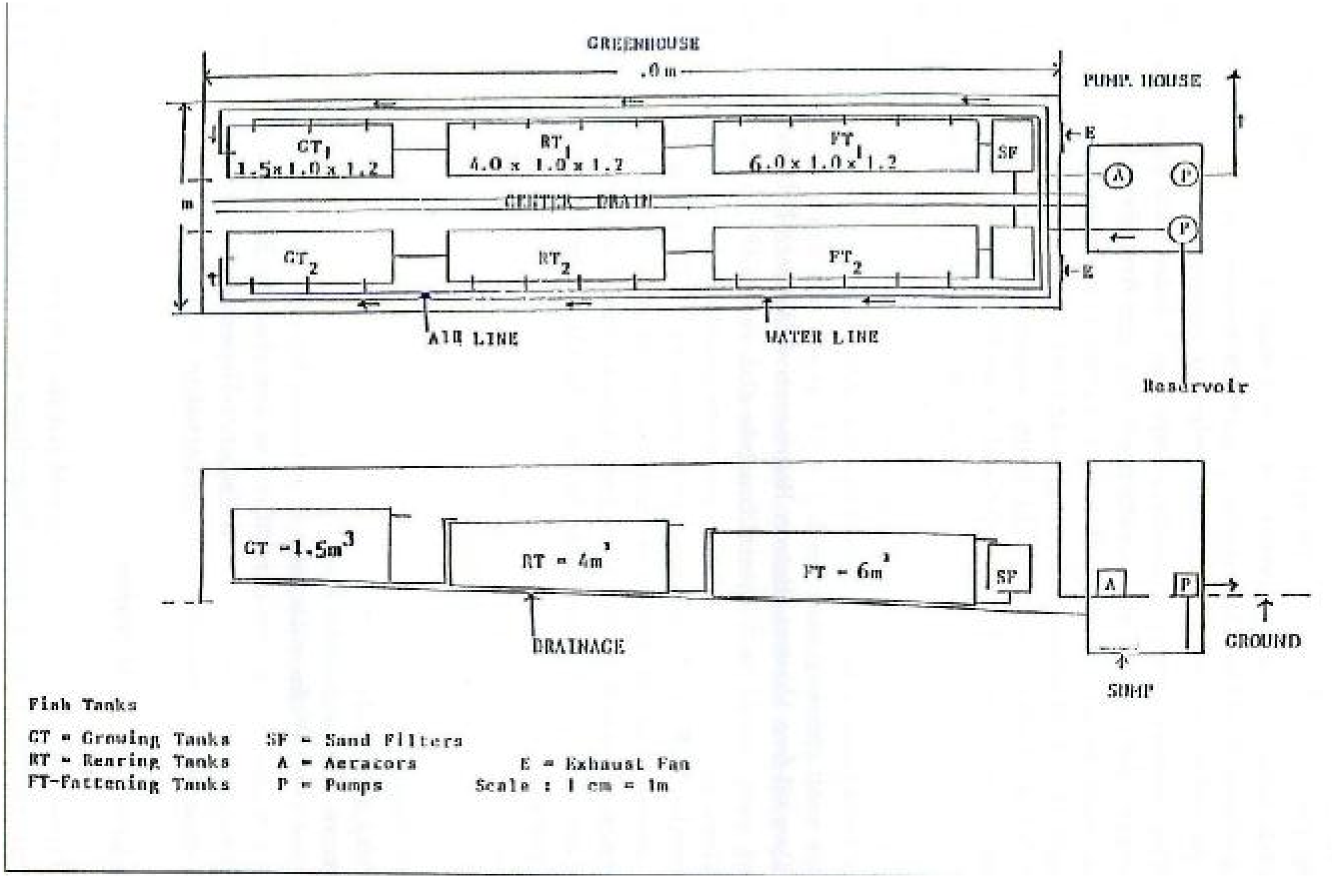

Fig. 1. Layout of the greenhouse sharing in two raceways.

on the ground. At the outlet of the third tank, a sand filter was installed. The sand filter tank which measured 2.0 x 1.0 x 0.6 m was built with a false bottom at 15 cm above the tank bottom with slots (1 x 10 cm), which could withstand a load of 0.6 m^3 of sand, gravel and water. The filter tank stood on legs, 20 cm high.

A small pump house made of corrugated steel and measuring 3 x 3 x 3 m was also constructed near the greenhouse to shelter the sump tanks, submersible pumps, and air blowers. A sump made of concrete was likewise constructed. Two fiberglass water reservoirs measuring 1.5 x 2.0 x 1.5 m were placed in the sump. Each reservoir was assigned to a raceway.

The raceways received freshly pumped well water through a 3-inch PVC waterline. Well water was discharged into the first fish tanks (growing tank), then by gravity flowed to the second tanks (rearing tank), then through the third tanks (fattening tank), and ultimately through the sand filter before it finally went to the sump, where water was collected. From the sump, water was either delivered to irrigate the alfalfa, from 8:00 to 16:00 hr or recycled from 16:00 to 8:00 hr the next day, using a low-pressure submersible pump placed inside the reservoir. A waterline made of 2-inch PVC pipes was installed from the sump tanks to the first fish tanks. Two submersible water pumps (Grundfos KP-300, 2 m head; flow = 250 l·min), one for each raceway were used.

Two oil-free blowers (Rotron Regenerative Blowers DR6D5, 5HP, single phase) were placed on a special concrete slab inside the pump house. Aeration lines made of 2-inch PVC pipes were installed from the blowers to the fish tanks. Diffusers (air stones) connected by PVC tubing to the air line were installed at the bottom of the tanks at intervals of one meter. Aeration was made in such a way that each blower could supply air to the two raceways. The two blowers were run alternately. Each blower was run for a 12 h period.

Spawning and fry production

A pure stock of Nile tilapia *Oreochromis niloticus* (Linneaus) of the Ismailia strain imported from Aquasafra Inc., Florida, USA were used as spawners. Fry production was carried out continuously to supply the grow-out facilities at Al-Wafra with 2500 *O. niloticus* fry at a size of 2 to 7 g every 70 days. Fry production was carried out as described by Ridha et al. (1998). Fry produced at the Mariculture and Fisheries Department were packed in plastic bags with oxygen infusion and transported to Al-Wafra by car.

Fish grow-out at Al-Wafra

Grow-out production was carried out on a year-round basis with stocking and harvesting every 70 days. Fingerlings were transferred to Al-Wafra and stocked in two identical raceways (A and B). Each raceway consisted of three sequential tanks (1.5, 4.0, and 6.0 m^3). Each raceway received a flow rate of 250 l·min. Water delivery time was from 8:00 to 16:00 hr. Water was recycled when no new water was delivered. Only one pump was used to deliver water to the alfalfa, drawing effluents from two compartments of the sump.

Two low-pressure pumps (Grundfos KP-300, 2 m head; flow = 250 l·min), one for each raceway, were used for recycling. The pump delivering new water to the fish tanks from the reservoir operated only during irrigation time. The tanks were continuously aerated by diffused air situated at the bottom of the fish tanks.

The production schedule started with stocking 1,250 fingerlings of 2 to 7 g in the first tanks (A1 and B1) of each raceway. Every 70 days, the fish were transferred to the next tanks and the first two tanks were restocked with a new batch of fingerlings. After 210 days, the fish were harvested from the third tanks (A3 and B3). With harvesting and stocking done every 70 days, five crops were possible during a normal production year, i.e. starting from the date all the fish tanks were stocked with fish or 140 days after the first stocking.

The fish were fed with 2.0 mm crumbles until the fish reached an average weight of 10 g; with 2.0 mm pellets from 10 to 50 g; with 3.2 mm pellets from 50 to 100 g and with 4.5 mm pellets for fish bigger than 100 g. Commercially prepared tilapia feed (32% CP) by Provimi, Holland was given. The fish were fed at a satiation rate determined every Saturday of the week. The fish were fed seven days a week using automatic feeders (Sweeney Corp., USA). Feeder model AF-48 was used for tanks A1 and B1 while feeder model AF3-A was used for the other four tanks. The feeders were set to discard feed every two hours during day time. Feeding was stopped a day before the fish transfer and harvest.

The fish were anesthetized every time they were transferred from one tank to another. Quinaldine mixed in equal amount with acetone and ethyl alcohol was mixed with water at 2 mg·l quinaldine prior to transfer. Fish were counted and weighed at stocking, transfer and harvest. At harvest, samples were taken for sex determination. Water temperature and dissolved oxygen (DO) from the well and the fish tanks were recorded daily. Ammonia, nitrite, nitrate and pH were measured biweekly. On sampling day, two water samples were taken at 7:30 am and 11:30 am. Data on mean daily growth, fish yield, feed conversion ratio (FCR) and survival rates were analyzed statistically.

This study was conducted from June 17, 1996 to June 23, 1998. Six batches were conducted during this period. Stocking dates are presented in table 1. The first two batches were conducted to test the system and make the necessary modifications to ensure successful production of the succeeding fish batches (four batches)

Results

The system ran smoothly during the first two weeks. Problems related to facilities and their solutions are as follows: a) clogging of sand filter - its use was stopped so that water from each raceway flowed directly to the sump tank, b) air leak and pipe (PVC) believed to be due to high temperature - the first 3 m of the aeration system was replaced with galvanized pipes, c) power cut off during the culture of the second fish batch caused heavy mortality - a standby generator was purchased, and d) incoming water contains low oxygen levels (2 to 3 mg·l) - jet agitators were introduced in addition to air blowers to improve aeration.

Results of fish batches 1 and 2 are presented in table 1. The average survival rate of batch 2 after 161 days of culture was 65.0%. This survival rate was lower than that of batch 1 (84.1%). Unfortunately, an electrical failure due to main power cut off contributed to this low survival rate. Fish mortality also affected the amount of total fish harvested from batch 2, which was 351.3 kg compared with 483.9 kg for batch 1. On the other hand, fish daily gain in weight and FCR obtained in batch 2 were 1.25 and 1.9 g, respectively. Higher mean daily gain in weight (1.41 g·d) and better FCR (1.22 g) were obtained in fish batch 1. However, there were no significant differences ($P > 0.05$) in growth rate and FCR between batches 1 and 2.

Problems encountered during the rearing of the fish were: a) big differences in size among the harvested fish, grading was introduced to reduce fish size variation at harvest, b) desired market size of 250 g was not achieved, grading was resorted to, c) laborers worked up to 1400 hr only resulting to underfeeding of fish, thus automatic feeders were introduced to allow feeding beyond 1400 hr.

Table 1. Average gain in weight, feed conversion ratio and survival rate of six batches of *O. niloticus* grown at Al-Wafra (data are mean of two replicates).

Batch (Date)	1 (17/06/96)	2 (24/09/96)	3 (12/03/97)	4 (21/05/97)	5 (9/08/97)	6 (4/11/97)	Mean*
Stocking data							
Mean wt, g fish^{-1}	2.9	3.4	2.1	1.9	7.0	3.3	3.6
Total wt, kg	7.4	8.6	5.3	4.8	17.4	8.2	8.9
Number	2574	2532	2500	2500	2500	2500	2500
Harvest data							
Mean wt, g fish^{-1}	224.1 ± 6.9	209.6 ± 8.5	280.4 ± 33.6	246.6 ± 62.8	257.5 ± 52.0	233.3 ± 44.9	254.5
Total wt, kg	483.9 ± 10.7	351.3 ± 55.6	553.2 ± 6.0	461.2 ± 36.9	565.6 ± 6.70	411.0 ± 11.5	497.8
Number	2165	1700	1996	2082	2246	1810	2034
Survival, %	84.1 ± 6.3	67.1 ± 23.7	79.9 ± 7.8	83.3 ± 33.1	89.9 ± 9.8	72.4 ± 10.0	81.4
Daily wt gain, g fish^{-1}	1.41 ± 0.1	1.28 ± 0.1	1.30 ± 0.21	1.11 ± 0.3	1.05 ± 0.2	1.50 ± 0.2	1.2
Feed conversion ratio	1.22 ± 0.1	1.89 ± 0.6	1.85 ± 0.1	2.0 ± 0.3	1.8 ± 0.6	2.2 ± 0.2	2.0
Male population (%)			77	55	61	52	61.2
Duration, d	169	161	215	222	238	231	227

*Mean is for batches 3-6 only.

Results of the four batches produced from the grow-out system are likewise presented in table 1. The data revealed that the objective of this study of producing 500 kg fish/batch with an average market size of 250 g was achieved only in batches 3 and 5 and not in batches 4 and 6 although the differences were not significant ($P > 0.05$). In batches 4 and 6, only 25-30% of the harvested fish met the expected market size of 250 g body weight. Actual hand sexing of fish samples in batches 4 and 6, revealed that male ratio was about 54.3 and 52.1%, respectively.

On the other hand, harvest weight of batches 3 and 5 revealed that about 55% of the harvested fish were about the market size of 250 g body weight whereas the other 45% exceeded 300 g body weight. With such a size ratio, it was possible to exceed the project's objective of producing 500 kg fish/batch. Actual hand sexing of the final harvest of batches 4 and 6 showed that the male ratio was 77.0 and 61.2%, respectively.

Average total production per batch was 497.8 kg. On the average, harvest was done every 78 days, giving a total of 4.7 cycles per year. Thus, the average annual production of the system was 101.7 kg·m^3 of the total system volume.

To define optimum male ratio, figures 2, 3 and 4 show the relationship of male ratio with harvest fish size, survival rate and production rate, respectively. The relationship between male ratio and fish size was linear; i.e., the higher male ratio, the bigger the size of harvested fish (Fig. 2). However, the effect of male ratio on survival rate and production rate was curvilinear. The relationship was linear up to a male ratio of 62%. At a higher male ratio, there seems to be a reduction in survival rate (Fig. 3) and a plateau in production rate (Fig. 4). These results suggest that the optimum male ratio for maximum production in the system is about 62%.

The lowest recorded temperature was 25.5°C in February 1998, whereas the highest recorded temperature was 31.3°C in September 1997. However, these two records were also occasional. During the study, the temperature fluctuated between 27 and 30°C. The lowest DO level in well water was 1.88 mg·l, whereas the highest was 4.31 mg·l; however, these two records were occasional. Generally, well water DO fluctuated between 2.0 and 2.5 mg·l. The lowest DO level recorded in fish tanks was 0.90 ppm, whereas the highest value was 3.76 mg·l. There is a declining trend in each raceway, where DO was highest in the first tanks (tanks A1 and B1) of each raceway and lowest in the last two tanks (tanks A3 and B3); however this is not generally true. Variation of air pressure in the aeration piping system sometimes changes. This trend resulted in higher DO levels in the last two tanks (closer to air blower) than the middle tanks. Generally, addition of agitators did not increase DO levels in fish tanks over values recorded earlier by Al-Ameeri et al. (1999), but were successfully maintained at an acceptable level in a fully loaded system with fish.

Ammonia level in the inlets' well water was not detectable. Nitrite level ranged from 0.099 to 0.132 mg·l, whereas nitrate level ranged from 4.4 to 8.8 mg·l. In fish tanks generally, there was an increasing trend in ammonia and nitrite levels in each raceway, but not of nitrate. The lowest recorded

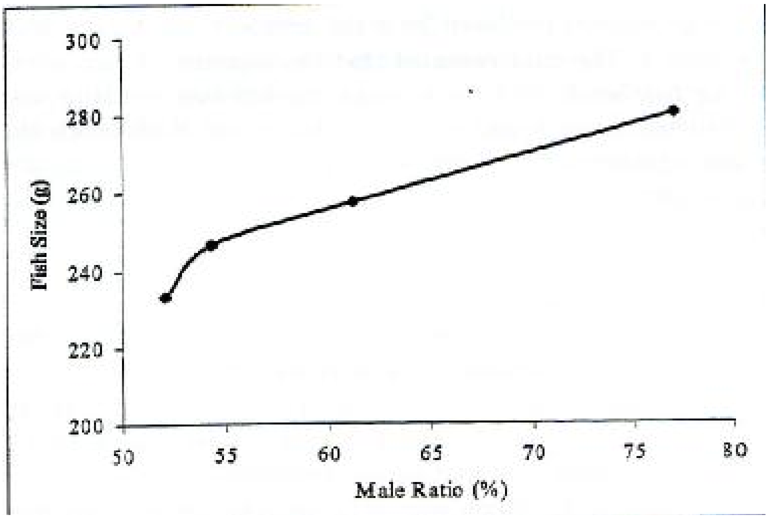

Fig. 2. Relationship between male ratio and fish size of *O. niloticus* grown in Al-Wafra.

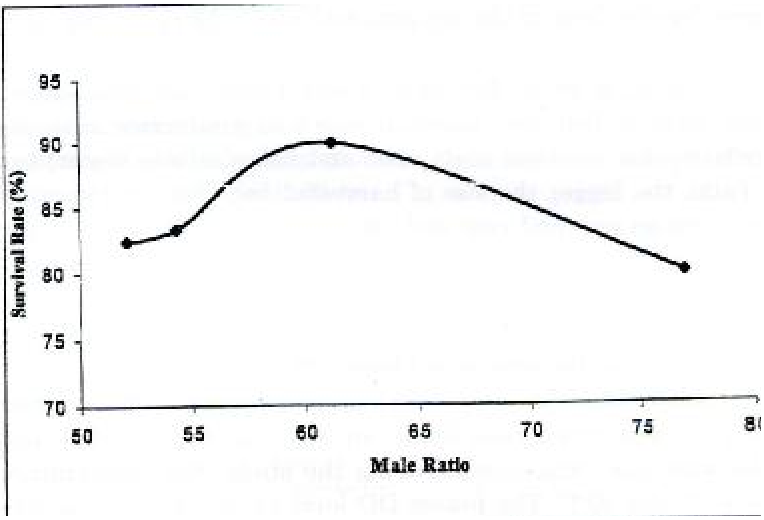

Fig. 3. Relationship between male ratio and survival rate of *O. niloticus* grown in Al-Wafra.

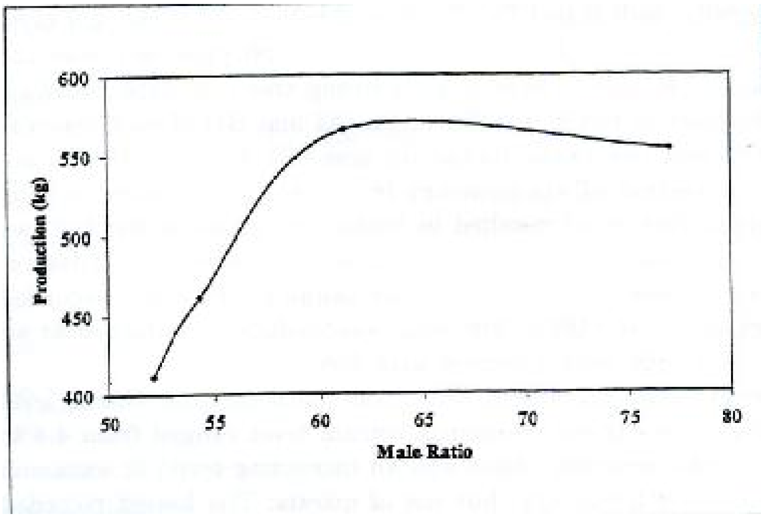

Fig. 4. Relationship between male ratio and production of *O. niloticus* grown in Al-Wafra.

total ammonia level was 0.128 mg·l NH_4.N, whereas the highest level was 2.19 mg·l NH_4.N. Early in the morning, before new water is pumped, unionized ammonia level, ranged from 0.08 to 0.11 mg·l. Nitrite level in fish tanks ranged from 0.099 to 0.759 mg·l NO_2.N, whereas nitrate level in fish tanks ranged from 8.8 to 13.2 mg·l; pH ranged from 7.31 to 7.33.

Discussion

Generally, the semi-recycling system tested in this study compares very well with the model used by Balarin and Haller (1982) for intensive tilapia production in continuous flow-through tanks. Fish in both systems were grown and transferred in three growing units during production cycle. Average survival rate of four production cycles in this study was 81.4%, whereas it was 82.5% in the continuous flow-through tank model. In this study, market-size fish of 250 g average body weight was produced within 227 days on the average, whereas Balarin and Haller (1982) suggested a total production cycle duration of 205 days (195-215 days) to produce the same size of fish. It should be noted, however, that Balarin and Haller (1982) used hormonally sex reversed tilapia, whereas no hormone treatment was applied in this study. This could probably explain the slightly longer duration needed to achieve the 250 g fish. However, the two systems differ greatly in the total annual harvests. Following the sequential stocking-harvest technique, 4.7 harvests/year were possible, whereas only two harvests/year were possible with the selective grading technique as suggested by Balarin and Haller (1982).

The maximum densities accomplished from this study (47.3 kg·m^3 culture tank) is substantial but lower than the tilapia densities of 63-78 kg·m^3 culture tank attained by Leclercq and Hopkins (1985) in aerated circular tanks under Kuwaiti conditions. However, total annual production is equivalent to that obtained by Leclercq and Hopkins (1985) due to sequential harvest. Average annual production rate obtained from this system was 101.7 kg·m^3 of the total fish tank volume. This value is equivalent to production rates obtained by Leclercq and Hopkins (1985) with the aerated tank system that ranged from 72 to 120 kg·m^3 (mean = 100 kg·m^3). It should be noted, however, that this system produced larger fish (average harvest size = 254.5 g) than the aerated tank system (calculated harvest size = 140 g from Leclercq and Hopkins 1985). This demonstrates the advantageous effect of the sequential production technique in maintaining high production rate and at the same time producing larger fish.

Better space utilization was evident from fish condition at harvest. Fish appearance at harvest was generally good. Very few fish with abrasions were noticed indicating the good health condition of the cultured fish. This is in contrast with the result of Leclercq and Hopkins (1985) who observed abrasions of the pelvic, pectoral, and tail fins of the fish in the aerated tank system. It's worth noting that higher initial stocking density (833 fish·m^3) was used in this study than that implemented in the aerated tank system

(555 fish·m^3). The higher initial stocking density with better harvest fish condition highlights the advantageous effect of the use of different tank sizes in sequential production technique in utilizing tank space.

Water utilization on the other hand was much higher in this system than in the aerated tank system. The average water utilization for the four fish batches produced in this study was 109.4 m^3·kg·fish. This value is much higher than that obtained by Leclercq and Hopkins (1985) which ranged from 14 to 20 m^3·kg·fish. Melard and Philippart (1980) reported more comparable results for the production of *O. niloticus* in an intensive semi-closed recirculatory system, that was 85 m^3 of heated water to produce 1 kg·fish.

It should be noted, that the amount of water used for fish production in this study does not represent any additional demand on the existing water pumping rate in Kuwait. This water is currently pumped on a daily basis even without fish production. The amount of fish produced in this system must be considered as an additional crop to the other agricultural crops being currently produced in Kuwait.

In addition, the water quality parameters gathered from this study revealed that fish growth was not impaired by the metabolites level in fish culture tanks. Maximum unionized ammonia level (0.08- 0.11 mg·l) was lower than the 0.6-0.7 mg·l recorded by Leclercq and Hopkins (1985). These values are well below the effective ammonia concentration that reduces the growth by 50% (EC-50). Al-Ameeri (1988) found that the EC-50 for *O. spilurus* was 0.55-0.65 mg·l NH_3N. Thus, water quality parameters suggest that sand filter is not essential at this production level and that fish production probably may be doubled without demanding more water. Increasing fish production can be achieved by increasing fish raceways from two to four. Further research is needed to define whether to use the same water pumping rate and reduce pumping time for each raceway from 8 to 4 hours a day or reduce pumping rate and maintain pumping time. Both scenarios will reduce daily water exchanges for each raceway from 10.4 to 5.2 exchanges per day.

Variation in fish size at harvest was evident in all fish batches. This contrasts with the results of Paessun and Allison (1984) who reported that sequential rearing, grading, and restocking produce fish of uniform size for market. It is worth noting that Paessun and Allison (1984) aimed to produce a market size fish of 167 g, whereas in this study a larger market-size fish was targeted. At a larger size, differences in growth rates between males and females became more pronounced.

Optimum male ratio defined in this system was about 62%. Further increase in male ratio did not lead to significant increase in total yield. Such a result, however, contradicts with most available literature on the positive relationship between male ratio and total yield (Mair and Van Dam, 1996; Macintosh et al. 1988; Lovshin et al. 1990). This result suggests that the system might reach its maximum carrying capacity and also demonstrates its efficiency in producing market-size fish without the need for a special hatchery production technique. Any increase in male ratio, however, will very likely shorten the production period.

References

Al-Ahmad, A.A. 1998. Survey of fish farms in Al-Wafra. Kuwait Institute for Scientific Research. Technical Report. KISR 5253.

Al-Ameeri, A.A. 1988. Protein intake, ammonia excretion and growth of *Oreochromis spilurus* in sea water. Ph.D. thesis. University of Stirling. 207p.

Al-Ameeri, A.A, E.M. Cruz, A.A. Al-Ahmad, T.A. Madou, M.T. Ridha, A.H. Jamal, and S.A. Al-Kayat. 1999. Integration of tilapia (*Oreochromis niloticus*) culture with alfalfa (*Medicago sativa* L.) production. Kuwait Institute for Scientific Research. Final Report No. KISR 5499.

Balarin, J.D. and J. Hatton. 1979. Tilapia a guide to their biology and culture in Africa. University of Stirling.174p.

Balarin, J.D. and R.D. Haller. 1979. Africa tilapia farm shows the profit potential. Fish Farming International. 6 (2): 16-18.

Balarin, J.D. and R.D. Haller. 1982. The intensive culture of tilapia in tanks, raceways and cages. In: Recent Advances in Aquaculture. (eds. J. Muir and R.D. Roberts). pp. 265-355. Croom Helm, London.

Granoth, G. and D. Porath. 1983. An attempt to optimize feed utilization by tilapia in a flow-through aquaculture. In: Proceedings of the First International Symposium. on Tilapia in Aquaculture. (comps. L. Fishelson and Z.Yaron). May 8-13; Nazareth (Israel).

Hopkins, M.L., K.D. Hopkins, and A.A. Al-Ameeri. 1984. Tilapia market introductions in Kuwait 1982 and 1983. Kuwait Institute for Scientific Research. Interim Report No. KISR 1459.

Jauncey, K. and B. Ross. 1982. A guide to tilapia feeds and feedings. Institute of Aquaculture, University of Stirling, Stirling, Scotland. 111pp.

Leclercq, D.I. and K.D. Hopkins. 1985. Preliminary tests of an aerated tank system for tilapia culture. Aquaculture Engineering 4: 299-304.

Lovshin, L.L. and A.B. de Silva, A. Carneiro-Sobrinho and F.R. Melo. 1990. Effects of *Oreochromis niloticus* females on the growth and yield of male hybrids (*O. niloticus* female x *O. hornorum* male) cultured in earthen ponds. Aquaculture 88: 55-60.

Macintosh, D.J., T.B. Singh, D.C. Little and P. Edwards. 1988. Growth and sexual development of 17 a methyltestosterone- and progesterone-treated Nile tilapia (*Oreochromis niloticus*) reared in earthen ponds. In: The Second International Symposium on Tilapia in Aquaculture. ICLARM Conf. Proc. 15. (eds. R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean). p. 457-463.

Mair, G.C. and A.A. Van Dam. 1996. The effect of sex ratio at stocking on growth and recruitment in Nile tilapia (*Oreochromis niloticus*) ponds. In: The Third International Symposium on Tilapia in Aquaculture. ICLARM Conf. Proc. 41. (eds. R.S.V. Pullin, J. Lazard, M. Legendre, J.B. Amon Kothias and D. Pauly). p. 100-107.

Melard, C. and J.C. Philippart. 1980. Intensive culture of *Sarotherodon niloticus* in Belgium. EIFAC Sympo. on New Dev. In: Utilization. Of Heated Effluents and of Recirc. Systems for Ints. Aquacult. (EIFAC/80/Symp.-E/11),11: 28pp. (Fr.edn.)

Muir, J.E. 1982. Recirculated water systems in aquaculture. In: Recent Advances in Aquaculture. (eds. Muir, J.E. and Roberts, R.D.). pp 358-446. Croom Helm, London.

Paessun, M.A. and R. Allison. 1984. Maximizing tilapia production in recirculating systems by sequential rearing. Aquaculture 42: 185-189.

Ridha, M.T. and E.M. Cruz. 1998. Observations on the seed production of the tilapia *Oreochromis spilurus* (Günther) under different spawning conditions and sex ratios. Asian Fisheries Science 10: 199-208.

Ridha, M.T., E.M. Cruz, A. A. Al-Ameeri and A.A. Al-Ahmad. 1998. Effects of controlling temperature and light duration on seed production in tilapia, *Oreochromis spilurus* (Günther). Aquaculture Research 29: 403-410.

Uchida, R.N. and J.E. King.1962. Tank culture of tilapia. US Fish Wildlife Services, Fisheries Bulletin. 62: 21-52.

Manuscript received 20 August 1999; Accepted 08 March 2000.