Effects of stocking density and water exchange rates on growth performances, production traits, feed utilization and body composition of mono-sex male Nile tilapia, *Oreochromis niloticus* (L.) cultured in concrete tanks

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Abstract A 44-week randomized factorial design 2 x 3 x 2 (two water exchange rates, three stocking density and two replicates) rearing trial was conducted in concrete tanks with average initial weight and length of 7.5 ± 1.2 g/fish and of 8.9 ± 0.5 cm/fish of mono-sex male Nile tilapia, *Oreochromis niloticus*, to examine the effects of two water exchange rates and three stocking density on growth performances, production traits, feed utilization and body composition. Twelve concrete tanks 4 m³ each were stocked with either 200, 300 and 400 fish for each tank to give a stocking rate of 50, 75 and 100 fish/m³, respectively and mentioned at 8L/min. or 12 L/min. water exchange rates. The results revealed that, growth performance and feed utilization parameters were significantly (Ps ≤ 0.01) the best at the lowest stocking density. No significant differences (P > 0.05) were found between water exchange rates in terms of growth performance, feed utilization and all production traits. The lowest stocking density (50fish/m³) had significantly the best feed utilization parameters. There were no significant differences between it and the stocking density of 75fish/m³. Whole fish body composition % of protein, fat and ash contents were significantly (P ≤ 0.05) influenced by stocking density but did not influenced by water exchange rates. From the above results it can be concluded that, stocking density of 50 fish /m³ of mono-sex male Nile tilapia reared at either 8L/min or 12L/min. water exchange rates exhibited the highest net profit and would seem to be the most desirable density under this system conditions.

Keywords Nile tilapia; Stocking density; Water exchange rates; Growth performances

Introduction

Tilapias can become the worlds most important warm water cultured fishes (FAO, 1980). Among all cultured tilapia species, Nile tilapia, *Oreochromis niloticus* has emerged as the single most important species. The attributes, which make Nile tilapia so suitable for fish farming, is its general hardness, ease of breeding, rapid growth rate, ability to efficiently convert organic and domestic wastes into high quality protein, and good taste. (Yi et al. 1996). For optimizing production from a system, a number of factors which are directly related to the stocking density must be considered. These factors are the physio-chemical condition of water, the production system, the types and the size of rearing tanks, the water exchange rate, the size of the fish and the quantity of the ration have been particularly emphasized (Trzebiatowski et al. 1981).

Studies on the relation between stocking density and growth of tilapia have been numerous (Youssif 2002). The optimal stocking density of certain species for obtaining the highest possible yield depends on the amount and the quality of food available (Zonneveld and Fadholi, 1991). The increases in stocking density become possible by the introduction of oxygen depletion (El-Saidy and Gaber 2002b). High-density culture of tilapia has been successful (Youssif 2002), but comparing results is difficult because individual studies do not address the full complex of parameters. Honer et al. (1987, a & b), indicated that high density fostered faster growth but, with slightly greater variance than low-density culture in juvenile and adult tilapia. Wallace et al. (1988) found that rearing fingerling salmonids at very high densities reduced the phenotype variance while Bagley et al. (1994) observed more rapid growth, increased genetic variance and reduced environmental variance.
Stocking density is a major factor that affects fish growth under farmed conditions (Hengsawat et al. 1997; Maragoudaki et al. 1999). Stocking density and therefore, the volume of water per fish is a significantly factor in determining production in concrete tanks. Increasing stocking density results in stress (Leatherland and Cho, 1985) which leads to enhanced energy requirements causing reduced growth and food utilization. Consequently, identifying the optimum stocking density for a species may be a critical factor in affecting growth and feed intake in concrete tanks.

Studies have shown that aquaculture systems with recycle water not only enabled water conversion but also reduced pollution of receiving waters and facilitated increased fish production when properly designed and managed because of controlled environment (El-Saidy et al., 2009). Little information is available concerning the effects of stocking density and water exchange rates under the concrete tanks rearing system conditions.

The major objective of this study was to investigate the effects of stocking density and water exchange rates on growth performances, production traits, feed utilization, body composition and finally the economic feasibility of mono-sex male Nile tilapia (Oreochromis niloticus) reared in concrete tanks recirculation systems.

1 Materials and Methods
This study was carried out at the outdoor installations of the fish research laboratory, faculty of Agriculture, Minufiya university, Egypt, in order to investigate the effect of stocking density and water exchange rates on growth performances, production traits and feed utilization of mono-sex male Nile tilapia cultured in concrete tanks.

1.1 Description of tank system used
The experimental system consisted of a series of twelve concrete tanks; each of them was 2 m long, 2 m-wide and 1.25-m height. Water level in the concrete tanks was kept at one-meter depth to maintain the water volume at 4 m$^3$. The concrete tanks were supplied with fresh water at a rate of 8 or 12 L/min. The tanks were provided with continuous aeration through an air compressor. The walls and bottoms of the tanks were scraped and cleaned weekly. Also, all tanks were drained and cleaned every 4 weeks during sampling.

1.2 Experimental fish
A number of 4 males and 8 females (1:2) of Nile tilapia, was stocked in concrete tank of 2 m long, 2 m wide and 1.25 m height. Supplied with fresh water kept at 1 m depth, in the summer of 2003 the fries were collected from the tank and transported to another tank and fed on a diet containing 48.5 % crude protein supplemented with 17-α methyltestosterone (Sigma company) at a rate of 60 mg/kg diet. Hormone was dissolved in ethylalkhol and supplemented to the diet and dried at 105 C in oven.

Fry was fed at a rate of 20 % of body weight daily for 28 days to obtain mono sex male. After that the fishes were fed on a diet without hormone containing 47 % crude protein (artificial food) at a rate of 10 % of body weight daily in the second month, and then we fed on a diet containing 33.8 % crude protein at a rate of 6% of body weight daily. The daily amount of food was divided into four times.

1.3 Stocking rates
A set of 3600 mono-sex Nile tilapia were of an average initial weight of 7.5 (g) and average initial length of 8.9 (cm/fish) were distributing in densities of 200, 300 and 400 fish per tank (4m$^3$) to give a stocking density of 50, 75 and 100 fish/ m$^3$ with duplicate tanks per treatment for either 8L/min. or 12 L/min. water exchange rate as follows:

| Treatments | Tank #  | Water exchange rate | Stocking density (fish/tank 4m$^3$) |
|------------|--------|---------------------|-------------------------------------|
| 1          | 1,2    | 8L/min.             | 200 (50fish/m$^3$)                  |
| 2          | 3,4    | 8L/min.             | 300 (75fish/m$^3$)                  |
| 3          | 5,6    | 8L/min.             | 400 (100fish/m$^3$)                 |
| 4          | 7,8    | 12L/min.            | 200 (50fish/m$^3$)                  |
| 5          | 9,10   | 12L/min.            | 300 (75fish/m$^3$)                  |
| 6          | 11,12  | 12L/min.            | 400 (100fish/m$^3$)                 |
1.4 Feeding
Composition and proximate analysis of the practical diet used in the present study are presented in Table 1. The practical diet formulated to contain 33.8 % crude protein and 4.5 kcal/g diet gross energy and covering all nutrient requirements of Nile tilapia. In preparing the diet, dry ingredients were first ground to a small particle size (approximately 250µm) in a wiley mill. Ingredients were thoroughly mixed and then thoroughly added water to obtain a 40 % moisture level. Diet was passed through a mincer with die into 2.5-mm diameter spaghetti-like strands and was dried under sun for 8 h. After drying the diet was broken up into small strands and sieved into appropriate pellet sizes. Diet was stored at –20 C in plastic-lined bags until fish were fed. The fish were fed with a daily quantity of food equivalent to 5% of fish biomass in each tank during the first 12 weeks, then gradually reduced to 2% during the second 12 weeks, then reduced to 1.5 % until the end of the experiment. Fish in each treatment were fed manually their daily amount of food three times daily at 0800, 1300 and 1600, six days per week for 44 weeks. About 20% of fish in each tank were randomly sampled and measured at 4 weeks intervals for total length (L) (cm) and body weight (Wt) to the nearest 0.1g.

1.5 Water quality analysis
Water temperature and dissolved oxygen were measured every day using YSI model 58 oxygen meter (Yellow Springs Instrument Company, Yellow Springs, OH, USA). Total ammonia and nitrite were measured once weekly using a DREL 2000 spectrophotometer (Hach Co., Loveland, CO). Total alkalinity and chloride were monitored once a week using the titration method, and pH was monitored twice weekly using an electronic pH meter (pH pen, Fisher Scientific, Cincinnati, OH). During the 44-week rearing trial, the average water quality parameters (± SD) were: water temperature, 26.9 ± 1.2°C; dissolved oxygen, 5.4 ± 0.6 mg l⁻¹; total ammonia 0.2 ± 0.1 mg l⁻¹; nitrite, 0.04 ± 0.03 mg l⁻¹; total alkalinity, 185 ± 47 mg l⁻¹; chlorides, 554 ± 122 mg l⁻¹; pH, 7.7 ± 0.18.

1.6 Growth performance parameters
Growth response, production and feed utilization parameters were calculated as follows: SGR (% day⁻¹) = 100 (Ln final weight - Ln initial weight)/ days; Net production = final biomass - initial biomass (kg/tank); Gain in weight (g/fish)= mean final body weight - mean initial body weight; Gain in total length = mean final body total length -mean initial total length (cm/fish) ; Condition factor (K) = 100(Wt/L²), where Wt is fish body weight (g), L is total length (cm); Feed conversion ratio (FCR) = total dry feed fed (g)/total wet weight gain (g); Protein efficiency ratio (PER) = total wet weight gain (g)/ total dry protein fed (g); Feed intake (g/fish) was recorded daily and calculated at the end of the experiment. Net income was determined by the difference between the sale price of the fish after harvest and the costs of fingerlings and food according to Hengsawat, Ward & Jaruratjamorn (1997).

Table 1 Major ingredients and proximate analysis of the diet fed to mono-sex Nile tilapia O. niloticus intensively reared in concrete tanks at different stocking density and water exchange. All values on a dry matter basis%.

| Ingredients % | Diet |
|---------------|------|
| Fish meal (60% C.P) | 8.0  |
| Soybean meal (44 % C.P.) | 62.0 |
| Wheat bran | 8.0  |
| Yellow corn meal | 10.0 |
| Soybean oil | 5.0  |
| Vitamins and minerals premix 1 | 1.5  |
| Calcium di-basic phosphate | 2.0  |
| Molasses | 2.0  |
| L-methionine | 1.0  |
| L-lysine HCl | 0.5  |
| Proximate analysis2 |
| Moisture | 9.8  |
| Crude protein | 33.8 |
| Crude fat | 10.4 |
| Ash | 7.9  |
| Crude fiber | 6.7  |
| NFE 3 | 31.4 |
| Gross Energy (kcal/g diet) 4 | 4.5  |

Note: 1. Premix supplied the following vitamins and minerals(mg or IU)/ kg of diet, vit. A, 8000 I.U.; vit. D3, 4000 I.U.; vit. E: 50 I.U.; vit. K3, 19 I.U.; vit. B2, 25 mg; vit. B3, 69 mg; vit. B6, 20 mg; Nicotinic acid, 125 mg; Thiamin, 10 mg; Folic acid, 7 mg; Biotin, 7 mg; Pantothenate, 15 mg; vit. B12, 75 mg; Choline, 900 mg; vit. C, 500 mg; Manganese, 350 mg; Zinc, 325 mg; Iron, 30 mg; Iodine, 0.4 mg; Cobalt 2 mg; Copper, 7 mg; Selenium, 0.7 mg and 0.7 mg B.H.T. according to Xie, et al., (1997). 2. Values represent the mean of three sample replicates. 3. Nitrogen free extract (NFE) = (100 - (moisture + crude protein + crude fat + ash + crude fiber)) 4. Gross energy was calculated using the gross energy values for the macronutrients (5.6 kcal/g protein, 9.5 kcal/g fat and 4.1 kcal/g carbohydrate) according to Sanz, et al., (1994).
1.7 Body composition analysis
For body composition analysis, 6 fish from each tank at harvest were randomly sampled and stored at −20 C for subsequent chemical analysis. Analysis of samples were made as follows, dry matter after desiccation in an oven (105 C for 24 h.), ash incineration at 550 C for 12 h., crude protein (microkjeldahl, N x 6.25), crude fat (ether extraction by Soxlhet method) and crude fiber, according to the methods of AOAC, (1995).

1.8 Statistical analysis
Data were analyzed by two-way analysis of variance using the SAS General Linear Models procedure (Statistical Analysis Systems 1993). Significance between stocking density, between water exchange rates, and their interaction were determined using Duncan’s multiple range test (Duncan’s, 1955). Treatments effects were considered significant at P ≤ 0.05. All percentage and ratio data were transformed to arcsin values prior to analysis (Zar 1984).

2 Results
2.1 Water quality
Throughout the duration of the study, water quality parameters were not significantly different (P > 0.05) among treatments and were averaged ± SE: water temperature, 26.6 ± 0.05 C; dissolved oxygen, 4.5 ± 0.3 mg/L; pH, 7.9 ± 0.5; total ammonia, 0.3 ± 0.1mg/L; nitrate, 1.52 ± 0.3 mg/L; alkalinity, 189 ± 43mg/L. Water quality parameters were within the acceptable range for tilapia growth.

2.2 Fish growth and production
Effects of stocking density and water exchange rate on mono-sex Nile tilapia, O. niloticus initial weight (g), final weight (g), initial length (cm/fish), and final length (cm/fish) after 44 weeks of rearing in concrete tanks in the present study are presented in Table 2. It is evident from this table that, there were no significant differences in the initial weight and length of fish at the beginning of the experiment. At the end of the trial average final weight and length were affected significantly by stocking density but not influenced by water exchange rate. The highest average final weight and length of fish were recorded with the lowest stocking density (50fish/m3) and the lowest were recorded in the highest stocking density (100fish/m3). There were no significant interaction between stocking density and water exchange rate. There were a correlation between stocking density and final average weight and length of fish. When the stocking density was increased the final average body weight and length of fish was decreased.

| Classification | Average body weight (g) | Average body length (cm) |
|----------------|-------------------------|-------------------------|
|                | Initial | Final | Initial | Final |
| Stocking density |         |       |         |       |
| N.S. | 7.5 ± 1.15 | 218.9 ± 10.9a | 8.9 ± 0.1 | 22.0 ± 0.64 |
| 50 fish/m3 | 7.5 ± 1.15 | 163.5 ± 7.9b | 8.9 ± 0.1 | 20.8 ± 0.3b |
| 75 fish/m3 | 7.5 ± 1.15 | 132.3 ± 6.5c | 8.9 ± 0.1 | 19.0 ± 0.3c |
| 100 fish/m3 | 7.5 ± 1.15 | 116.9 ± 8.1 | 8.9 ± 0.1 | 20.8 ± 0.3 |
| Water exchange |         |       |         |       |
| N.S. | 7.5 ± 1.15 | 176.3 ± 8.7 | 8.9 ± 0.1 | 20.4 ± 0.4 |
| 8 liter/min. | 7.5 ± 1.15 | 166.9 ± 8.1 | 8.9 ± 0.1 | 20.8 ± 0.3 |
| 12 liter/min. | 7.5 ± 1.15 | 132.3 ± 6.5c | 8.9 ± 0.1 | 19.0 ± 0.3c |
| SD x WE | N.S. | N.S. | N.S. | N.S. |
| R^2 | 0.39 | 0.31 | 0.29 | 0.20 |

Note: 1. Significant level: N.S. = P > 0.05, ** = P ≤ 0.01. 2. Means that have the same superscript letters within each classification column are not; significantly different from each other. 3. SD = Stocking density; WE = water exchange
Changes in average body weight (g/fish) of Nile tilapia reared in concrete tanks for 44 weeks at different stocking density and water exchange rate are shown in Figure 1. It is evident from this figure that at the beginning of the experiment, average initial weight (g/fish) was not significantly different among the densities at two water exchange rates (P > 0.05). The overall average ± SE of mono-sex Nile tilapia was 7.5 ± 1.2 g/fish. At the termination of the experiment, the mean body weight ranged between 220.9 ±10.9 and 130.0 ± 6.5 g/fish for the lowest (50 fish/m³ at 8 L/min.) and the highest (100 fish/m³ at 8 L/min.) stocking density, respectively (Figure 1).

Changes in average body length (cm/fish) of Nile tilapia reared in concrete tanks for 44 weeks at different stocking density and water exchange rate are shown in Figure 2. It is evident from this figure that at the beginning of the experiment, average initial length (cm/fish) was not significantly different among the densities at two water exchange rates (P > 0.05). The overall average ± SE of mono-sex Nile tilapia body length was 8.9 ± 0.1 cm/fish. At the termination of the experiment, the mean body length ranged between 22.6 ± 0.6 and 19.0 ± 0.3 cm/fish for the lowest (50 fish/m³ at 12 L/min.) and the highest (100 fish/m³ at 12 L/min.) stocking density, respectively (Figure 2).

Effects of stocking density and water exchange rate on mono-sex Nile tilapia, O. niloticus gain in weight (g/fish), gain in weight (%), gain in length (cm/fish), gain in length (%) after 44 weeks of rearing in concrete tanks in the present study are presented in Figure 2. Changes in average body length (cm/fish) of Nile tilapia reared in concrete tanks for 44 weeks at different stocking density and water exchange rates

Table 3. It is evident from this table that, average gain in weight (g/fish), average gain in weight (%), average gain in length (cm/fish) and average gain in length (%) were affected significantly (P ≤ 0.01) by stocking density but not influenced by water exchange rate. The highest average gain in weight (g) and gain in length (cm) of fish were recorded with the lowest stocking density (50fish/m³) and the lowest were recorded in the highest stocking density (100fish/m³).

Effects of stocking density and water exchange rate on mono-sex Nile tilapia, O. niloticus average daily gain (g/fish/day), specific growth rate (%/day) and condition factor (K) after 44 weeks of rearing in concrete tanks are presented in Table 4. It is evident from this table that, average daily gain (g/fish/day) and specific growth rate (%/day) were affected significantly (P ≤ 0.01) by stocking density but not influenced by water exchange rate. The highest average daily gain (g/fish/day) and specific growth rate (%/day) were recorded with the lowest stocking density (50fish/m³) and the lowest were recorded in the highest stocking density (100fish/m³). The lowest
Effects of stocking density and water exchange rates on mono-sex Nile tilapia, *O. niloticus* total production and net production (kg/m$^3$) after 44 weeks of rearing in concrete tanks. Values are means ± SE

Table 3 Effects of stocking density and water exchange rate on mono-sex Nile tilapia, *O. niloticus* gain in weight (g), gain in length (cm/fish), and specific growth rate (%/day) after 44 weeks of rearing in concrete tanks. Values are means ± SE

| Classification | Average gain in weight (g/fish) | Average body length (cm/fish) | Average daily gain (g/fish/day) | Specific growth rate (%/day) | Condition factor (K) |
|----------------|---------------------------------|------------------------------|---------------------------------|-----------------------------|---------------------|
| Stocking density |                                |                              |   |                              |                     |
| 50 fish/m$^3$ | **211.4 ± 10.9** | **2817.8 ± 145.3 $^a$** | **13.6 ± 0.4 $^a$** | **0.68** | **1.95 ± 0.3** |
| 75 fish/m$^3$ | **156.0 ± 7.9** | **2080.3 ± 105.2 $^b$** | **11.9 ± 0.3 $^b$** | **0.98** | **1.82 ± 0.2** |
| 100 fish/m$^3$ | **124.8 ± 6.5** | **1664.3 ± 86.2 $^c$** | **10.1 ± 0.3 $^c$** | **0.91** | **1.88 ± 0.3** |
| Water exchange | N.S. | N.S. | N.S. | N.S. | N.S. |
| 8 liter/min. | **168.8 ± 8.7** | **2250.3 ± 116.0** | **11.8 ± 0.3** | **0.98** | **1.95 ± 0.3** |
| 12 liter/min. | **159.4 ± 8.1** | **2124.7 ± 107.6** | **11.9 ± 0.3** | **0.98** | **1.95 ± 0.3** |
| SD x WE | N.S. | N.S. | N.S. | N.S. | N.S. |
| $R^2$ | 0.31 | 0.31 | 0.33 | 0.25 | 0.25 |

Note: 1. Significant level: N.S. = P > 0.05, * = P ≤ 0.05, ** = P ≤ 0.01. 2. Means that have the same superscript letters within each classification column are not significantly different from each other. 3. SD = Stocking density; WE = water exchange

stocking density grows faster and had a daily gain and specific growth rate of 0.68 (g/fish) and 1.08 (%/day), respectively, while the highest stocking density grows slower and had a daily gain and specific growth rate of 0.41 (g/fish) and 0.91, respectively. Condition factor (K) was not influenced significantly by either stocking density or water exchange rate. The means of condition factor were 1.86, 1.90 and 1.88 for stocking density of 50fish/m$^3$, 75 fish/m$^3$ and 100 fish/m$^3$, respectively. The means of condition factor were 1.95 and 1.82 for water exchange rates of 8L/min. and 12 L/min., respectively. There were no significant interaction between stocking density and water exchange rate in terms of average daily gain, specific growth rate and condition factor. There were a correlation between stocking density and average daily gain (g/fish) and specific growth rate (SGR %/day). When the stocking density were increased the average daily gain and specific growth rate of fish were decreased.

Notes: 1. Significant level: N.S. = P > 0.05, * = P ≤ 0.05, ** = P ≤ 0.01. 2. Means that have the same superscript letters within each classification column are not significantly different from each other. 3. SD = Stocking density; WE = water exchange

Table 4 Effects of stocking density and water exchange rate on mono-sex Nile tilapia, *O. niloticus* average daily gain (g/fish/day), specific growth rate (%/day) and condition factor (K) after 44 weeks of rearing in concrete tanks. Values are means ± SE

| Classification | Average daily gain (g/fish/day) | Specific growth rate (%/day) | Condition factor (K) |
|----------------|---------------------------------|-----------------------------|---------------------|
| Stocking density |                                |                             |                     |
| 50 fish/m$^3$ | **0.68 ± 0.04 $^a$** | **1.08 ± 0.02 $^a$** | **1.08 ± 0.02** |
| 75 fish/m$^3$ | **0.51 ± 0.03 $^b$** | **0.98 ± 0.02 $^b$** | **1.90 ± 0.11** |
| 100 fish/m$^3$ | **0.41 ± 0.02 $^c$** | **0.91 ± 0.02 $^c$** | **1.88 ± 0.03** |
| Water exchange | N.S. | N.S. | N.S. |
| 8 liter/min. | **0.55 ± 0.03** | **1.00 ± 0.02** | **1.95 ± 0.06** |
| 12 liter/min. | **0.52 ± 0.03** | **0.98 ± 0.02** | **1.82 ± 0.05** |
| SD x WE | N.S. | N.S. | N.S. |
| $R^2$ | 0.31 | 0.28 | 0.25 |

Notes: 1. Significant level: N.S. = P > 0.05, * = P ≤ 0.05, ** = P ≤ 0.01. 2. Means that have the same superscript letters within each classification column are not significantly different from each other. 3. SD = Stocking density; WE = water exchange
while total production increased with increasing stocking density (Figure 4). Stocking density showed significant (P ≤ 0.01) effect on net production and total production, while there was no significant effect of water exchange rates and interaction (Table 5).

2.3 Feed utilization
Effects of stocking density and water exchange rates on mono-sex Nile tilapia, *O. niloticus* feed conversion ratio (FCR), feed efficiency ratio (FER), protein efficiency ratio (PER) and feed intake (g/fish) after 44 weeks of rearing in concrete tanks are presented in Table 6. From this table the results of feed conversion ratio, feed efficiency ratio, protein efficiency ratio and total feed intake were significantly (P ≤ 0.01) affected by stocking density. But not affected significantly by water exchange rates. The best results of FCR, FER and PER were obtained at the lowest stocking density 50 fish/m$^3$. There were no significant differences between fish stocked at 50/m$^3$ and 75/m$^3$ in terms of FCR, FER and PER. The lowest feed intake (g/fish) was obtained at the highest stocking density of 100 fish/m$^3$ and there were no significant differences between it and fish stocked at 75 fish/m$^3$. The highest food intake was achieved at lowest stocking density of 50 fish/m$^3$. There was a significant interaction between stocking density and water exchange rates in terms of all feed utilization parameters except feed intake.

2.4 Body composition
The effects of stocking density and water exchange rates on mono-sex male Nile tilapia, *O. niloticus* whole fish body proximate composition (%) of Moisture, crude protein, crude fat and crude ash after 44 weeks of rearing in concrete tanks are presented in Table 7. It
Table 6 Effects of stocking density and water exchange rate on mono-sex Nile tilapia, *O. niloticus* feed conversion ratio (FCR), feed efficiency ratio (FER), protein efficiency ratio (PER) and feed intake (g/fish) after 44 weeks of rearing in concrete tanks. Values are means ± SE.

| Classification | FCR       | FER       | PER       | Feed intake (g/fish) |
|----------------|-----------|-----------|-----------|----------------------|
| Stocking density | **       | **       | **       | **                   |
| 50 fish/m³       | 2.33 ± 0.05 a | 0.44 ± 0.01 a | 1.29 ± 0.02 a | 492.0 ± 29.3 a       |
| 75 fish/m³       | 2.46 ± 0.06 a | 0.42 ± 0.01 b | 1.23 ± 0.04 b | 388.3 ± 22.8 b       |
| 100 fish/m³      | 2.67 ± 0.04 b | 0.38 ± 0.01 b | 1.12 ± 0.02 b | 337.7 ± 18.1 b       |
| Water exchange | N.S.      | N.S.      | N.S.      | N.S.                 |
| 8 liter/min.     | 2.46 ± 0.04 | 0.42 ± 0.01 | 1.23 ± 0.03 | 410.3 ± 20.2         |
| 12 liter/min.    | 2.51 ± 0.04 | 0.40 ± 0.01 | 1.20 ± 0.02 | 397.0 ± 22.2         |
| SD x WE **       | **       | **       | N.S.      | 0.17                 |
| R²              | 0.20      | 0.17      | 0.17      | 0.17                 |

Note: 1. Significant level: N.S. = P > 0.05, * = P ≤ 0.05, ** = P ≤ 0.01. 2. Means that have the same superscript letters within each classification column are not significantly different from each other. 3. SD = Stocking density; WE = water exchange.

Table 7 Effects of stocking density and water exchange rates on mono-sex male Nile tilapia, *O. niloticus* whole fish body composition (%) of moisture, crude protein, crude fat and crude ash after 44 weeks of rearing in concrete tanks. Values are means ± SE.

| Classification | Moisture | Crude protein | Crude fat | Crude ash |
|----------------|----------|---------------|-----------|-----------|
| Stocking density | N.S.    | *             | **        | **        |
| 50 fish/m³       | 71.4±0.33 | 53.7±0.39 ab | 22.8±0.88 ab | 18.2±0.32 a   |
| 75 fish/m³       | 71.9±0.38 | 54.3±0.47 a   | 23.4±0.45 ab | 16.4±0.39 b   |
| 100 fish/m³      | 71.7±0.65 | 52.7±0.30 b   | 24.9±0.46 a | 17.7±0.52 ab  |
| Water exchange | N.S.    | N.S.          | N.S.      | N.S.      |
| 8 liter/min.     | 71.7±0.43 | 53.2±0.35     | 23.4±0.66  | 17.4±0.56    |
| 12 liter/min.    | 71.6±0.34 | 53.9±0.34     | 24.0±0.40  | 17.5±0.24    |
| SD x WE  **       | N.S.    | **            | **        | **        |
| R²              | 0.20      | 0.17          | 0.17      | 0.17       |

Note: 1. Significant level: N.S. = P > 0.05, * = P ≤ 0.05, ** = P ≤ 0.01. 2. Means that have the same superscript letters within each classification column are not significantly different from each other. 3. SD = Stocking density; WE = water exchange.

is evident from this table that, whole body moisture content did not significantly (P ≥ 0.05) influenced by either stocking density or water exchange rate. Whole body protein, fat and ash contents were not influenced by water exchange rate, but these means were significantly (P ≤ 0.05) influenced by stocking density. The highest whole body protein content was recorded with fish stocked at 75 fish/m³, but the lowest was at 50 fish/m³. The lowest whole body fat was achieved with fish stocked at 50 fish/m³, but the highest was at stocking density of 100 fish/m³. The highest whole body ash was resulted with fish stocked at 50 fish/m³, but the lowest was at stocking density of 75 fish/m³.

2.5 Economic information

The Economic information for mono sex Nile tilapia reared in concrete tanks for 44 weeks at three stocking density at two water exchange rates are presented in Table 8. From this table the net profits were directly related to stocking density and water exchange rates. The fingerling cost (Lever Egyptian) increase by increasing stocking density. Also, the food cost and total cost (Lever Egyptian) increases by increasing stocking density. From the economic information it can be concluded that the highest net profit (Lever Egyptian) was achieved at stocking density of 75 fish /m³ at 12 liter/min. water exchange rate in concrete tanks.

3 Discussion

There are several factors supporting the use of intensive fish culture in recalculating systems. Increasing land costs and decreasing freshwater supplies are the main reason for intensification of fish farming in Egypt, though additional advantages include savings in manpower and easier stock management. Increased fish yields in conventional, static ponds or reservoirs was accomplished by a combination of management procedures, the most...
important among them being the use of supplementary feed, polyculture, and auxiliary aeration during the night (Sarig 1989). Higher yields were obtained in specially designed smaller units, 50-1000m3 (Zohar et al. 1985; Van Rijn et al. 1986), which differ from conventional ponds in design. These are made of concrete or are plastic-lined, and their configuration allows periodical removal of organic matter from the bottom. Most of these units are operated in a semi-closed mode, allowing optimal use of water and hence, minimal water discharges. Due to their reduced environmental impact, national and regional authorities support their development. Pollution control is, therefore, another factor underlying the development of intensive systems. Finally, culture of fingerlings (mainly tilapia) during off-season in heated, indoor systems is rapidly expanding, and so, heat conservation can be counted as an additional factor promoting the use of intensive recirculating systems.

Besides genetics and environmental condition, water exchange rates and stocking density are important factors affecting growth and maturation of cultured fish (Huang and Chiu 1997). As stocking density increases, competition for food and living space usually intensifies providing one of the most effective controls on animal production (Huang and Chiu 1997). The effects of density may be divided into two categories: the density dependent and the density-independent. The stocking density that significantly negatively affects the growth of fish was considered as the density dependent category, such as the cases found for blue gill, *Lepomis macrochirus* Rafinesque (Wiener and Hanneman, 1982), chinook salmon, *Oncorhynchus tsawytscha* (Martin and Wertherimer 1989), Nile tilapia, *Oreochromis niloticus* (L.) (Siddiqui et al. 1989). In the present study the similar case of negative curvilinear relationship was found between stocking density and growth weight of Nile tilapia (Figure 4).

The changes in growth of fingerlings are physiological response to environmental condition (Wootton 1990). Water quality has complex side effect on high stocking density. Miao (1992) found that higher stocking density was accompanied by lower pH and dissolved oxygen and suggested that the resulting changes in water quality might play an important role in affecting growth and survival of fish. Chen et al. (1997) indicated that metabolic wastes, which are directly proportional to stocking density, have been implicated in inhibiting the growth of fish and to be toxic to fish. Moreover, fish need oxygen for aerobic generation of energy for body maintenance, locomotion, feeding and biosynthesis. A minimum dissolved oxygen level of 3.0 PPM was recommended during cage culture of tilapia in freshwater (Coche 1982). The water flow system in the present study provided fairly good water quality consistently throughout the experimental period at all tanks. There were no evidences of large physiochemical fluctuations, occurrence of disease and handling stress,

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### Table 8 Economic information for mono-sex male Nile tilapia intensively reared in concrete tanks for 44 weeks at three stocking density and two water exchange rates

| Parameters                  | Water exchange 8 L/min. | Water exchange 12 L/min. |
|-----------------------------|-------------------------|--------------------------|
|                             | Stocking density 50 /m³ | Stocking density 75 /m³  |
|                             | 100 /m³                 | 100 /m³                  |
| No. fish stocked / tank (4m³) | 200                     | 300                      |
| No. fish harvested          | 200                     | 300                      |
| Survival rate (%)           | 100                     | 100                      |
| Initial wt. stocked (kg/tank)| 1.50                    | 2.25                     |
| Total production (Kg/tank 4m³) | 44.18                   | 54.96                    |
| Net production (Kg/tank 4m³) | 42.68                   | 52.71                    |
| Food used (kg/tank 4m³)     | 98.64                   | 121.12                   |
| Fingerling cost (0.20 LE./fish) | 40.00                  | 60.00                    |
| Food cost (1.7 LE./kg diet) | 167.69                  | 205.90                   |
| Total cost (LE.)            | 207.69                  | 250.23                   |
| Value of harvest (9 LE./kg) | 397.62                  | 402.30                   |
| Net profit (LE.)            | 189.93                  | 152.07                   |

Note: LE. = Lever Egyptian (about 0.18 Dollar). Fingerlings cost calculated as 200 L.E./1000 fingerlings
and deterioration of water quality in the experimental tanks during the course of the experiment. This is in agreement with that of El-Saidy and Gaber, 2002b. Siddiqui et al. (1991) reported that effects of water exchange on water quality in out door concrete tanks stocked with Nile tilapia fingerlings were with respect to dissolved concentrations and unionized ammonia levels deteriorated with batch flow. In tanks with flow through system, oxygen concentrations above 3.9 mg/L were maintained, as the metabolites, excreta and left over more continuously removed and incoming water was rich in oxygen, however, the ammonia levels for different water exchange rates were not significantly different from each other. Ng. et al. (1992) found that the quality of water supplied to the fish rearing areas, even without filtration to be acceptable at the present fish stocking levels. The discontinuous operation of pumps for 9h a day, which resulted in only 8% exchange of water through the fish rearing volume, seemed to be adequate for the existing fish population.

Besides water quality, the effect of stocking density on tilapia fingerlings might be dependent upon the biological characteristics of fish, such as, tolerance to environmental change, life stage, sex, social interaction and behavior, so that the density effect on growth and production might be explainable by their competition for territories, with similar case found for African catfish (Haylor 1991). Behavioral studies on red tilapia indicating that growth inhibiting antagonistic behavioral patterns was generally unabated even at the highest stocking density (Suressh and Lin 1992). The stress on fish caused by the crowdedness may be the other explanation for the effect of stocking density. Hogendoorn and Koops (1983) also found that the highest biomass (Harvest) was achieved at the highest stocking density for African catfish cultured in ponds. Culture of Nile tilapia, O. niloticus in cages showed that the highest stocking density (100 fish /m³) achieved the highest biomass after five and half months (Daungsawasdi et al. 1986). In our experiment, the highest biomass was achieved at stocking density of 100 fish /m³ at either 8L/min. or 12 L/min. water exchange rates.

It has been found that the growth of Nile tilapia was affected significantly by the stocking density not by the water exchange rates. Fish reared at low density grow better than those reared at high density (Table 2), and the differences were highly significant. Final mean weight were inversely proportional to stocking density, which was particularly evident when average weight of fish reared at the lowest stocking density was significantly different from weight of fish reared at the higher densities. Youssif (2002) studied the effects of stocking density and water exchange rate on size variation of juvenile O. niloticus. He found that the fish subjected to the lowest stocking and highest water exchange rate achieved the best final body weight. Also, he reported that manipulation of water exchange rates and hence water quality was found to be an effective approach for minimizing the adverse effects of high stocking densities of juvenile O. niloticus. Baker and Ayles (1990) resulted that it is a generally accepted principal that increasing the number of fish or reducing water turn over (lowering water quality) will adversely affect fish growth. Stocking density also affected the growth of C. macrocephalus x C. gariepinus hybrids cultured in concrete ponds at three different densities (Jarimopas et al. 1999). Fish reared at the highest density had the lowest final mean weight. These results may be attributed to the fish at low density consume maximum amount of food available and growing fast (Essa and Nour, 1988). Also, Hepher et al. (1989) reported that slow growth of fish at high density was probably due to that the individuals disturbing each other during feeding and normal activity. Holm et al. (1990) attributed the decrease in growth rate with increasing density to the reduced food consumption and thereby the feed efficiency ratio. The data on feed conversion ratio given in Table (6) confirm this finding, whereas the fish reared at low density and at either 8 L/min. or 12 L/min. water exchange rates possessed the better feed conversion (the fish used less feed to produce one unit of gain in body weight) than those reared at high density and at either 8 L/min. or 12 L/min. water exchange rates.

While final harvest and production values were directly related to stocking density, there must be some density at which mortality is severe for a variety of causes and growth rate is reduced. When this occurs, production will be reduced. This critical level was not reached in our experiment although the stocking density of 100 fish/m³ was high. One reason for the ability of Nile tilapia to maintain high
production levels when available oxygen present and unionized ammonia is reduced. Rearing densities of 75 fish/m³ for fingerling would seem to be the most desirable in the system studied. There was a strong trend for both production and final harvest to increase with increasing stocking density (Figure 3). These results are in agreement with those of Cruz and Ridha (1989) from studies on tilapia (Oreochromis spilurus) reared in cages. Our results also agree with Al Jerian (1998) who reported that production of fish culture are generally depended on the stocking density, water exchange, daily feed consumption rate and feeding frequency. Therefore, the results of the present study showed that stocking density was positively correlated with total production per unit area (r = 0.987) and negatively correlated with individual weight gain (r = −0.997).

Water exchange in aquaculture ponds in thought to improve water quality by providing oxygen enriched water by diluting excessive concentrations of toxic metabolites nutrients and plankton (Boyd, 1982). Mc Gee and Boyd (1983) pointed out that the pond manager use water exchange in two ways: during an oxygen depletion, fresh oxygenated water is supplied to provide oxygen enriched zones near in flow pipes, which are sough out by fish. Water also, may be exchanged at intervals in attempts to remove excess nutrients and plankton resulting from feed applications.

The carrying capacity of fish in an intensive culture system is determined by the quality of dissolved oxygen available to fish. Because the amount of oxygen available is directly proportional to the volume of water flowing past the fish an increase in flow rate leads to a proportional increase in carrying capacity (Piper et al., 1982). In the present study, water exchange rates had no significant effects on growth performances of mono-sex male Nile tilapia reared in concrete tanks. This is in agreement with that of Diana and Fast (1989) who reported that water flow rate had no significant effects on growth and yield of Clarias fuscus. In contrast to our results, Siddiqui et al. (1991) resulted that the growth rate was found to be directly related to the rate of water flow, and the amount of water was the limiting factor. They found the best growth with a continuous flow rate of 1 L/min per kg biomass. Paspatis et al. (2003) pointed out that in channel catfish (Ictalurus punctatus) culture, the relation of stocking density and fish growth is changeable and depends on water exchange rate.

In the present study water exchange rates had no significant effect on feed conversion ratio. But the lowest values were achieved at the lowest water exchange rate. This is in agreement with that of Siddiqui et al. (1991) who reported that the feed conversion ratios increased with decreasing rate of water flow (water exchange) at O. niloticus fingerlings where stocked in 3.75 m³ out door concrete tanks for 98 days. An experiment was conducted by (Cole, et al. 1994) to determine the effect of 5% daily water exchange and no water exchange on tilapia production. They found that mean growth, yields, survival and feed conversion were 3.5 kg / day, 6.8 kg / m³, 97 % and 1.8 for water exchange tanks and 3.4 kg/d, 6.5 kg / m³, 95 % and 1.9 for tanks without water exchange. Also, they pointed out that 5 % daily water exchange did not significantly improve any of the production parameters.

In the present study, the whole body fat and energy contents were not significantly affected by stocking density or water exchange rates. Al Hafedh (1999) and El-Saidy et al. 1999 reported similar results. Whole-body protein and ash contents were not significantly affected by water exchange rates, but significantly affected by stocking density. Fish stocked at 50fish/m³ had a higher percentage of protein, but lower lipid than fish stocked at 100 fish/m³. These results were reported also by El-Saidy and Gaber (2002a)

Finally, from the above results and the economic evaluation it can be concluded that a stocking density of 75 fish/m³ at either 8L/min. or 12L/min. water exchange rates is recommended for mono-sex male Nile tilapia. These fish showed no significant increase in weight gain with increasing water exchange rates, but exhibited a significant increase with decreasing stocking density. Thus a stocking density of 75 fish/m³ at 8L/min. water exchange rate is cost effective, highest profit and maintained adequate growth and production of mono-sex male Nile tilapia in concrete tanks under the experimental condition.

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