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EFFECT OF WATER TEMPERATURE ON THE GROWTH OF NILE TILAPIA FISHES AND ON SOME AFFECTING ENVIRONMENTAL FACTORS

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ABSTRACT

This research studied the effect of temperature on the weight and length growth of Nile tilapia fishes, and on dissolved oxygen concentration, ammonia concentration and pH value of water. The experiments were carried out using five treatments throw 91 days. These five treatments conditions comprised testing the effect of levels of temperature at 20,25,28,30 and 35 °C .The obtained data revealed that:

- The most positive results in the weight and length growth of Nile tilapia fishes, were at the temperature of 28 °C, especially for fishes having weight more than 50 g,while the treatments at temperature of 30 °C had the most positive results for fishes having weight less than 50 g.
- Increasing water temperature in aquarium caused in a continuous decrease in the dissolved oxygen and the change of its concentration was highly significant.
- Increasing water temperature in aquarium resulted in a modest increase in pH values.
- Increasing water temperature in aquarium caused in an increase in total ammonia concentrations.

This study was ended by deriving some mathematical relations describing the effect of water temperature on both, weight and length growth of Nile tilapia fishes, the dissolved oxygen concentration, ammonia concentration and pH value, Also, mathematical equation was derived for the relation between the weight and the length of Nile tilapia fishes.

1- INTRODUCTION

Environmental factors have critical effect on aquaculture. Many environmental factors influence pond aquaculture, but fortunately, only few normally have a decisive role (Rasmy and El-meseery,2003) .The Nile tilapia is one of the aquatic animals which has many characteristics, and is considered an easily farmed fish since it is easy to hold and breed in a captive environment ; tolerate crowding , relatively poor water quality and other stress factors; and is less susceptible to disease. Nile tilapia can grow in a wide variety of aquaculture systems, eats algae and detritus materials naturally produced in culture systems

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as well as manufactured feeds containing ingredients derived from plants. They reach typical market size (500-600g) in about 6-8 months under optimum temperature conditions for growth ranging from 30 to 35 °C (Lucas and Southgate, 2003). According to FAO (2001), the tilapia production in 1999 in Egypt was 103 988 ton.

The limited fresh water resources in Egypt and the Egyptian laws restricting the use of freshwater in aquaculture projects encourage sea or brackish water aquaculture. Anyhow, these water have variable conditions of salinity, pH, and temperature which are apt to affect- positively or negatively the growth rate of fish. So, as long as these environmental factors have critical effects on aquaculture, some thing has to be done to control these factors to increase the production from Nile tilapia.

The main objective of this research work was to study the effect of water temperature on the growth rate of Nile tilapia fishes (***Oreochromis Niloticus***) and its effect on pH degree, ammonia concentration and the dissolved oxygen concentration in water.

Temperature is a major or even decisive environmental factor in the sense that it governs the rate of metabolic reactions affecting all physiological processes in ectotherms, metabolism, food intake and nutritional efficiency (Burel et al., 1996). Increasing water temperature causes in a continuous decrease in dissolved oxygen concentration with high significance (Rasmy and El-meseery, 2003).

Parker (2002) mentioned that thermal stress or shock can occur when temperature change more than 2 to 3 °F (1 to 2 °C) in 24 hours. Zaghloul (1997) stated that the River Nile water quality is better in winter than in summer; nevertheless, he stated that the number of fish collected from the different studied sites in Nile in Cairo was greater in summer than in winter. This phenomenon may be due to the increase in water temperature in summer.

Parker (2002) mentioned that aquatic life requires dissolved oxygen; most aquatic animals need more than 1 ppm concentration for survival, depending on culture circumstances. Aquatic animal need 4 to 5 ppm to avoid stress, concentration considered typical for surface water and is influenced by temperature, but usually exceeds 7 to 8 mg/l (7- 8 ppm).
According to Rasmy and El-messery (2003), when the oxygen level drops below 0.3 mg/l, most fish will not grow and cause morality. Fish grow well at least through concentration of 3 mg/l of dissolved oxygen. The dissolved

oxygen concentration in water is correlated negatively with raising water temperature, and this relation within the range of 14-36 °C at water with salinity of 5000 ppm is expressed in the equation(1):

$$\mathbf{DO = 7.5 - 0.1313\ (T)} \qquad (1)$$

where:

DO = dissolved oxygen concentration in water (mg/l)

T = water temperature (°C)

Sharma and Ahlert, (1977) showed that "pH" is one of the most common water tests and it is a measure of hydrogen ions in the water. They found that pH value decreases continuously as a result of nitrate accumulation in a recycling system. Death points for fish are approximately at pH 4 and 11, acid and alkaline (basic). Growth and reproduction can be affected between pH 4 and 6 and between pH 9 and 10 for some fishes. Also pH affects the toxicity of other substances, such as ammonia and nitrite (Parker, 2002).

Ammonia is presented in slight amounts in some well and pond water. As fishes become more intensively cultured or confined, ammonia can reach harmful levels. Any amount is considered undesirable, but stress and some death loss occur at more than 2mg/l, and at more than 7 mg/l fish loss increases sharply. Ammonia is a waste product of proten metabolism by aquatic animals. In water, ammonia occurs either in the ionized (NH_3) or the un-ionized (NH_4) form, depending upon pH. Unionized ammonia is considerably more toxic to fish and occurs in greater proportion at high pH and warmer temperature.

2- MATERIAL AND METHODS

This study was carried out on Nile tilapia fish (***Oreochromis Niloticus***) at the bio-engineering unit, Agricultural Engineering Department, Faculty of Agriculture, Cairo University. Experiments were carried out through a period of three months from September to November 2004 (91 days were recorded). The study was conducted in fifteen glass aquaria, 60 liter water volume. Each aquarium was aerated with one air stone (air pump) with aeration rate of 23.7 cm^3 /s, and one thermo-automatic heater was used to provide and maintain the temperature at the desired level. For all experiments, each treatment was assigned to three replicate aquaria.

This study covered the changes in water quality such as the dissolved oxygen concentration, pH degree and ammonia concentration under the effect of different levels of temperature. Five levels of temperature (20, 25,28,30,35 °C) were tested. Nile tilapia fish (***Oreochromis Niloticus***) were used to study the growth rate of fish under these five different levels of temperature. The average fish weight used in this study at the beginning of the experimental work was almost the same, 30 ± 2 gm/fish. The stocking density was 4 fish / aquarium.

Cleaning the aquaria is very important in rearing fish, so, the daily routine work included the removal of excess organic matter resulting from digestion and feeding. Furthermore, the maintenance was conducted to replace the aquaria water with water of similar temperature each two days in each aquarium.

Fish feed was offered at a rate of 3% of fish weight per day. The dissolved oxygen, pH degree and ammonia concentration of water were measured daily using dissolved oxygen meter, pH meter and ammonia concentration meter, respectively.

The weight and length of each fish were weekly measured using digital balance and accurate scale of 30 cm, respectively.

Seven indicators for fish growth were used, equation (2) through (8). Experimental growth data were used to calculate the value of each growth indicator according to the following mathematical formulas:

A. Weight gain "WG_i".

$$\mathbf{WG_i = W2_i - W1_i} \qquad (2)$$

where:

WG_i = average weight gain per growth interval (g /fish)

$W2_i$ = average final weight per fish at each interval (g /fish)

$W1_i$ = average initial weight per fish at each interval (g /fish)

i = growth interval

B. Average daily gain in weight "DGW_i".

$$\mathbf{DGW_i = (W2_i - W1_i)/t} \qquad (3)$$

where:

DGW_i = average daily gain in weight at the end of the growth period. (g /fish. day)

t = growth interval within the growth period. (day)

C. Average daily gain in length "DGL_i"

$$\mathbf{DGL_i = (L2_i - L1_i)/t} \qquad (4)$$

where:

DGL_i = average daily gain in length at the end of the growth period. (cm/fish. day)

$L2_i$ = final total length at the end of growth period (cm)
$L1_i$ = initial total length at the beginning of growth period. (cm)

D. Specific growth rate in weight "$SGRW_i$"

SGRW was calculated according to (Jauncey and Ross, 1982) as:

$$\mathbf{SGRW_i = \{ (\ln W2_i - \ln W1_i) / t\} \times 100} \quad (5)$$

where:

$SGRW_i$ = specific growth rate in weight for fish (% weight / fish)
Ln = natural logarithm

E. Specific growth rate in length "$SGRL_i$"

$$\mathbf{SGRL_i = \{(\ln L2_i - \ln L1_i)/t\} \times 100} \quad (6)$$

where:

$SGRL_i$ = specific growth rate in length (% length / fish.day)

F. Percentage of average daily gain rate in weight "$GRWP_i$"

$$\mathbf{GRWP_i = \{(W2_i - W1_i)/W1_i\} \times (100/t)} \quad (7)$$

where:

$GRWP_i$ = Percentage of average daily gain rate in weight (% weight / fish .day)

G. Percentage of average daily gain rate in length "$GRLP_i$"

$$\mathbf{GRLP_i \ \% = \{(L2_i - L1_i)/L1_i\} \times (100/t)} \quad (8)$$

where:

$GRLP_i$ = percentage of average daily gain rate in length (% length / fish .day)

3- RESULTS AND DISCUSSION

3-1 Effect of water temperature on the growth of Nile tilapia fish

Table (1) and figure (1) show the weekly mean weight of the Nile tilapia fish for thirteen weeks (91 days) under different temperatures. The results showed that water temperature had remarkable effect on the fish growth rate since the average weight at the end of the experimental work ranged from 88 to 130 gram / fish. The treatment under 30 °C temperature gave the best results in the first six weeks, while the treatment under 28 °C was the best after that. Also, the results showed that the treatment under 35 °C gave the lowest growth rate since the final average weight of fish was only 88 gm, while the treatment at 25 °C was better than that at 35 °C or that at 20 °C. It is obvious from these data that a temperature deviation from 28 and 30 °C limits affects clearly fish growth rate.

Table (1) Average weight of Nile tilapia fishes (g) under different levels of temperature

Time (day)	20 C (±1)	25 C (±0.5)	28 C (±0.5)	30 C (±0.5)	35 C (±0.5)
0	30.55	30.50	29.6	30.40	29.80
7	34.82	35.06	34.98	35.90	34.18
14	39.69	40.70	41.35	42.20	39.20
21	44.41	46.68	48.10	49.50	44.22
28	49.69	53.55	55.06	56.00	49.80
35	53.86	59.73	61.81	62.12	54.33
42	58.38	65.59	69.16	69.90	59.27
49	63.12	71.50	78.36	78.27	64.25
56	68.42	76.78	89.33	86.50	69.65
63	73.22	81.62	100.00	94.00	73.55
70	77.83	85.93	109.00	101.90	77.67
77	82.73	89.90	117.30	109.00	81.67
84	86.87	94.09	124.00	115.00	85.40
91	91.03	98.13	130.00	119.90	88.00

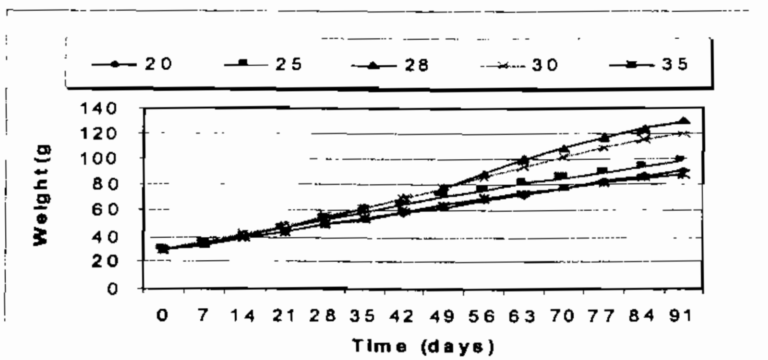


Fig. (1) Effect of the water temperature on fish growth in weight.

A mathematical equation was derived to show the relationship between the final mean weight of the Nile tilapia fish and water temperature within the experimental ranges, between 20 and 35 ˚C, with initial weight of 30 g/fish and a growth period of 13 weeks, and was expressed in equation (9). The coefficient of correlation (R^2) for equation was highly significant (0.9408).

$$\mathbf{W = 634.8 - 711.678\ T + 2.9113\ T^2 - 0.0381\ T^3} \qquad \mathbf{(9)}$$

Where:

W = final weight of the fish (g)

T = water temperature (C)

Table (2) shows the daily average percentages gain rate in weight (GRWP) at different temperatures levels. From table (1), it can be seen that the growth rates differ according to fish ages and weight. Applying equation (7) for five different weight classes shown in table (2) , the average percentages for each weight class can be computed. It is obvious from table (2) that the daily average growth rates for all temperature levels were higher for the weight class of 30-50 g than those of other weight classes. Since the weight increases by increasing fish age, the daily growth rate decreases by increasing fish age. Also, it can be seen the higher gain rate occurred for fishes under the treatment of 28°C water temperature. However, the high percentage of the daily growth rates at the young ages, were gradually decreased from 2.9% until it reached a small value of 0.77% at the last 3 weeks period of the experiment. These results are illustrated in figure (2).

Table (2) Daily average weight increasing rate with different weight classes.

Temperature C	Weight increasing rate percentage within different weight classes				
	30-50 g	50-70 g	70-90 g	90-110 g	110-130 g
20	2.23	1.34	0.88	-	-
25	2.59	1.60	0.92	0.61	-
28	2.97	1.88	1.99	1.28	0.77
30	3.08	1.77	1.50	1.31	0.6
35	2.39	1.34	0.70	-	-

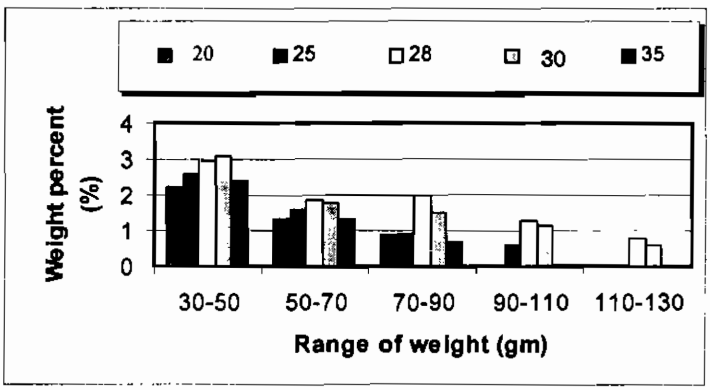


Fig. (2) Effect of water temperature on daily average rate of weight increase of Nile tilapia fishes.

Table (3) and figure (3) illustrate the mean lengths for Nile tilapia fishes, grown under different temperature levels . It is noticed that the maximum length at the end of the experiment was at 28°C water temperature, where the fish mean length reached 19.7 cm. The minimum length was 16.6 cm at 20 °C water temperature. Mean values of the length at each week during the experimental work for all treatments, are also shown in table (3) and from mean, an equation can be derived to predict directly the fish length as a function of time.

Table(3) Average length of Nile tilapia fishes (cm) under different levels of temperature

Time (day)	20 C (±1)	25 C (±0.5)	28 C (±0.5)	30 C (±0.5)	35 C (±0.5)	Mean length
0	12.1	12.0	11.9	12.0	12	12.00
7	12.3	12.4	12.5	12.5	12.3	12.40
14	12.9	13.0	13.1	13.2	13.0	13.04
21	13.3	13.4	13.7	13.8	13.5	13.54
28	13.7	13.8	14.2	14.3	13.9	13.98
35	14.0	14.2	14.8	14.8	14.3	14.42
42	14.4	14.6	15.3	15.4	14.6	14.86
49	14.8	15.1	15.9	16.0	15.0	15.36
56	15.1	15.4	16.7	16.6	15.4	15.84
63	15.5	15.8	17.6	17.2	15.7	16.36
70	15.8	16.1	18.2	17.9	16.0	16.80
77	16.1	16.6	18.7	18.4	16.3	17.22
84	16.4	16.9	19.2	18.8	16.6	17.58
91	16.6	17.2	19.7	19.2	16.8	17.90

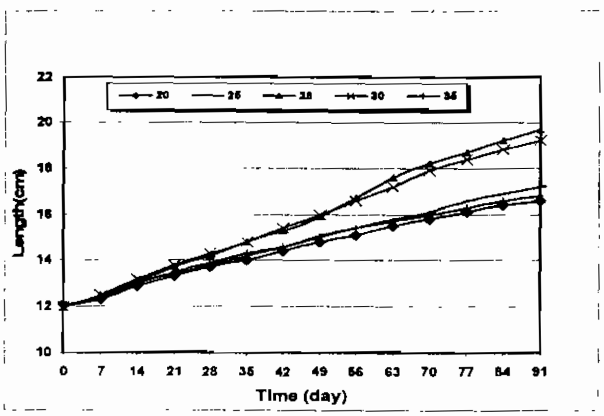


Fig. (3) Effect of water temperature on fish growth in length

Applying the data of table (3), a mathematical relationship was derived between the mean length of the Nile tilapia fish and water temperature within the ranges between 20 to 35 ˚ C, initial length of 12 cm and a growth period of 13 week. This relationship was expressed in equation (10). The coefficient of correlation (R^2) for that mathematical equation was highly significant (0.9388).

$$L = 77.673 - 7.6839\,T + 0.3037\,T^2 - 0.0039\,T^3 \qquad (10)$$

where:

L= final length of the fish (cm)

T = water temperature (°C)

Applying the data of table (1) and (3), a mathematical relation between the length (L) and the weight (W) was derived, equation (11). From this equation, the length of the fish can be predicted from its weight.

$$L = 0.077\,W + 9.8411 \qquad (11)$$

where:

L = final length of the fish (cm)

W = final weight of the fish (g)

Equation (2) through (8) were applied for the initial conditions of the experimental treatments, and the final results at the end of the experiment. The computed results are illustrated in table (4). It can be seen that the best treatment which gave the most positive results, was at 28 °C water temperature, while the lowest results was at 35 ° C water temperature, except for two computations of "DGL" and "SGRL" since the 20 ° C temperature was the minimum. This was due to the fact that these two temperatures were far away from the suitable range of temperature for fish growth.

Table (4) Effect of water temperatures on the computed indicator values for fish growth.

Evidence	Temperature (° C)				
	20	25	28	30	35
Weight gain "WG" (g/fish)	60.48	67.94	100.4	89.86	58.2
Average daily gain in weight "DGW" (g/fish. day)	0.664	0.746	1.103	0.987	0.639
Average daily gain in length "DGL" (cm/fish. day)	0.3	0.39	0.55	0.51	0.36
Specific growth rate in weight "SGRW" (% weight /fish. day)	1.19	1.285	1.479	1.38	1.18
Specific growth rate in length "SGRL" (% length /fish. day)	0.049	0.057	0.085	0.079	0.052
Percentage of daily gain rate in weight "GRWP" (% weight/fish. day)	2.17	2.47	3.72	3.2	2.14
Percentage of daily gain rate in length "GRLP" (%length/fish .day)	0.4	0.47	0.65	0.65	0.34

Figures (4) through (9) illustrate the computed values of each fish growth indicator.

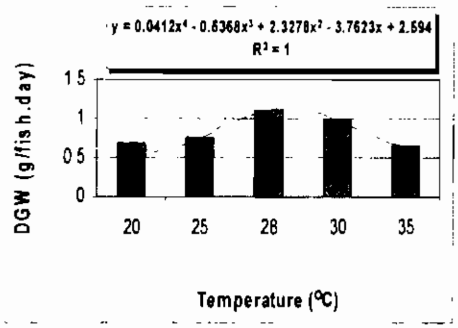
For each indicator, the experimental data were used to derive a mathematical equation to predict "y" the value of this indicator as a function of water temperature "x". To make the coefficient of correlation "R^2" for each equation very close to one "R^2=1", i.e,to make the computed results highly significant, an equation of the fourth degree was derived for each indicator. So, it is possible to compute the value of each indicator "y" as a function of water temperature "x" .Also, it will be possible to compute the final weight and length of the fish as long as its initial dimensions and growth period are close to those obtained from the experimental work.

3-2 Effect of water temperature on the dissolved oxygen concentration in aquarium water.

Table (5) and figure (10) show the weakly dissolved oxygen concentration for a period 13 week (91day) in the aquarium water, under different temperature levels, (20,25,28,30,35 ºC). The obtained results showed that the dissolved oxygen concentration during the experiment was between 4.25 - 10.0 mg/l, which is a suitable range for the growth and the activity of the Nile tilapia fishes. Also, it is noticed that the temperature had a significant effect on the dissolved oxygen concentration, where, the dissolved oxygen concentration decreased by increasing the water Temperature, and increased by decreasing the water temperature in the aquarium water.

Table (5) Effect of water temperature on the dissolved oxygen concentration as measured 24 hour after water change.

Time (day)	20 C (±1)	25 C (±0.5)	28 C (±0.5)	30 C (±0.5)	35 C (±0.5)
0	7.30	6.80	5.70	5.20	5.00
7	7.15	6.60	5.50	5.05	4.80
14	7.20	6.70	5.60	5.10	4.90
21	7.35	6.90	5.85	5.30	5.10
28	7.60	7.10	6.00	5.45	5.20
35	7.50	7.00	5.90	5.40	5.15
42	7.40	6.90	5.85	5.35	5.15
49	7.35	6.82	5.70	5.25	5.00
56	7.25	6.75	5.60	5.10	4.90
63	7.40	6.90	5.80	5.30	5.10
70	7.10	6.65	5.50	5.00	4.80
77	7.00	6.42	5.30	4.70	4.50
84	7.20	6.70	5.65	5.10	4.90
91	7.30	6.81	5.70	5.20	4.95



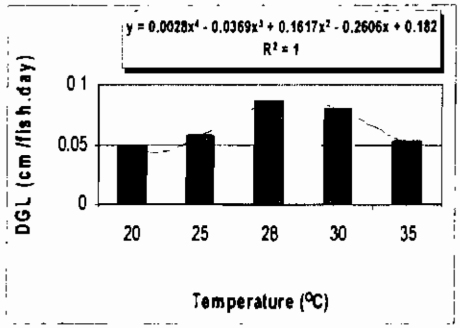
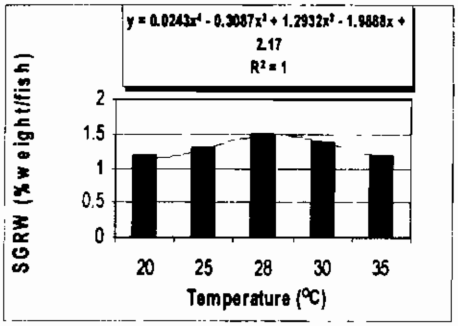


Fig Fig. (4)Daily average weight gain "DGW" under different temperature levels and its representive equation (12).

Fig. (5) Daily average length gain "DGL" under different temperature levels and its representive equation (13).



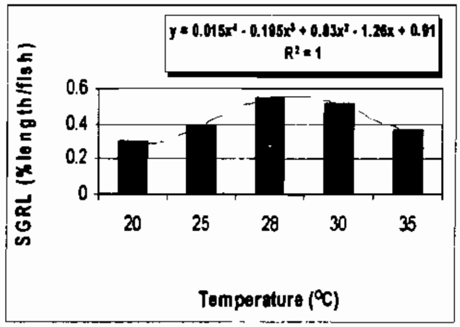
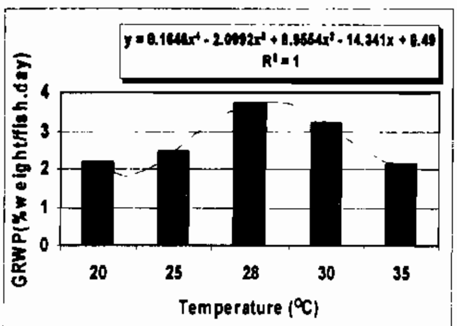


Fig.(6) Specific growth rate in weight "SGRW" under different temperature levels and its representive equation (14).

Fig (7) Specific growth rate in length "SGRL" under different temperature levels and its representive equation (15).



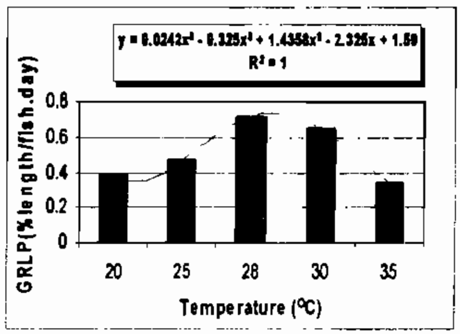


Fig Fig. (8) Percentage of daily average gain rate in weight "GRWP" under different temperature levels and its representive equation (16).

Fig. (9) Percentage of daily average gain rate in length "GRLP" under different temperature levels and its representive equation (17).

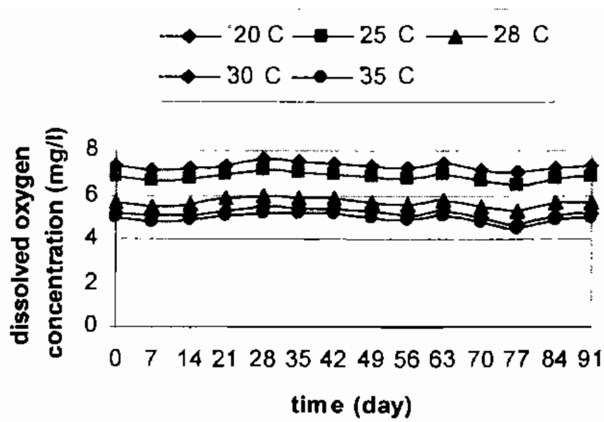


Fig. (10) Effect of water temperature on dissolved oxygen concentration measure after 24hours from the time of changing aquarium water.

Table (6) and figure (11) show the effect of water temperature and the consumption of oxygen on the dissolved oxygen in the aquarium at the time of water changing, after 24 hour and after 48 hour, just before the next water change. The reduction in oxygen concentration was due to both the effect of water temperature and the consumption of oxygen by fishes.

Table (6) Effect of water temperature and the consumption of oxygen on dissolved oxygen concentration.

Temperature C	Average oxygen concentration (mg/l)			Consumption rate (mg/l.h)
	After water change directly	After 24 hour	After 48 hour	
20	9	7.50	6.65	0.048
25	8.75	6.90	6.10	0.055
28	7.50	5.90	5.35	0.044
30	6.50	5.40	4.75	0.036
35	5.80	5.20	4.45	0.028

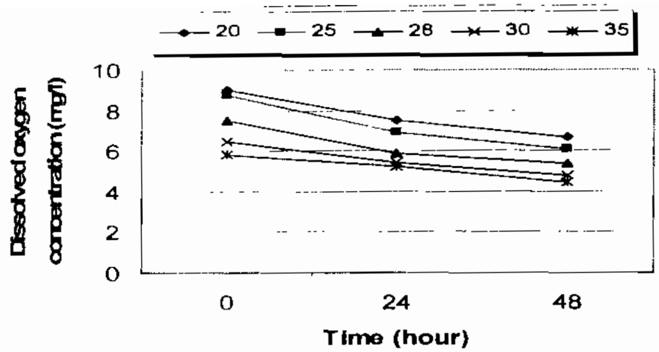


Fig. (11) Effect of temperature and the consumption of oxygen on the dissolved oxygen concentration within a period of 48 hours under different levels of temperature.

The results presented in the second column of table (6) and in figure (11) show the dissolved oxygen concentration in fresh water just at the time of water change. The concentration of oxygen differed according to water temperature. After that time, the dissolved oxygen started to be consumed as a result of fish, algae and other micro-organisms respiration in the aquarium. .Although the air pump helped in raising the dissolved oxygen concentration in the aquarium, the consumption of the dissolved oxygen was higher, so, the resultant of the dissolved oxygen concentration in the water reached low values, about 4.45 mg/l at the 35 °C water temperature.

Fig (11) shows the change in the dissolved oxygen concentration from the time of water changing until recharging it again after 48 hour. From that, oxygen concentration decreasing rate per hour for tilapia fishes can be computed as shown in the last column in table (6).This rate was higher at low temperature levels, and lower at high temperature levels.

A mathematical equation was derived for the relationship between the resultant state of dissolved oxygen concentration and water temperature, within the experiment temperature range, between 20 and 35 °C , and was expressed in equation (18). The coefficient of correlation (R^2) for this mathematical equation was highly significant (0.912).

$$\textbf{RC DO} = 14.545 - 0.4598\,T + 0.0052\,T^2 \qquad (18)$$

where:

RC DO= the resultant state of the dissolved oxygen concentration (mg/ l)

T = water temperature in aquarium (C)

Also, a mathematical equation was derived to assess the dissolved oxygen consumption rate at any given water temperature, equation (19). The coefficient of correlation (R^2)for this mathematical equation was highly significant (0.8411).

$$OCR = -0.0148 + 0.006\,T - 0.0001\,T^2 \qquad (19)$$

where:

OCR = dissolved oxygen concentration (mg/l)

T = water temperature (C)

A separate experiment was run to find out the standard curve illustrating the value of the dissolved oxygen concentration in the natural fresh water without any fishes, within water temperature ranging from 5°C to 48 °C. The date of this separate experiment are illustrated in fig. (12) and water used to derive a mathematical equation, equation (20), correlating in natural fresh water without any fishes and within this temperature range from 50 to 48 °C. The coefficient of correlation (R^2) for this equation was highly significant (0.9777).

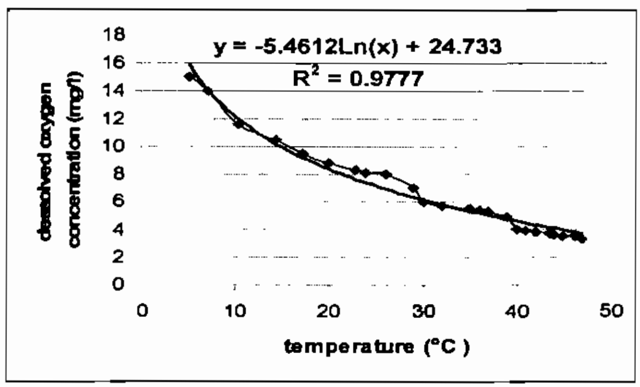


Fig.(12)The effect of water temperature on the dissolved oxygen concentration of natural fresh water without any fishes.

$$D.O = 24.733 - 5.4612\,Ln\,T_f \qquad (20)$$

where:

D.O = dissolved oxygen concentration (mg/l)

T_f = fresh water temperature (°C)

3-3 Effect of water temperature on the pH value

Table (7) and figure (13) show the weekly pH value in aquarium water for a period of 13 weeks (91day), under different temperature levels, (20, 25,28,30,35 °C).The results showed that the pH value during the experiment was ranging between 8.0 to 9.0 with a mean value of 8.5, which was a suitable range for the growth and activity of the Nile tilapia fishes. Also, it is noticed that the water temperature had a simple effect on the pH value, where the pH value slightly increased or decreased around the mean value by increasing or decreasing the water temperature.

Table (7) The value of pH under different water temperatures as measured after 24 hour from water change.

Time (day)	20 C (±1)	25 C (±0.5)	28 C (±0.5)	30 C (±0.5)	35 C (±0.5)
0	8.20	8.30	8.40	8.55	8.80
7	8.25	8.32	8.41	8.57	8.81
14	8.15	8.25	8.35	8.50	8.75
21	8.13	8.24	8.33	8.50	8.77
28	8.32	8.41	8.50	8.65	8.90
35	8.42	8.50	8.62	8.75	9.00
42	8.28	8.37	8.50	8.65	8.90
49	8.45	8.54	8.65	8.82	9.05
56	8.21	8.32	8.42	8.58	8.82
63	8.30	8.41	8.50	8.64	8.90
70	8.00	8.12	8.25	8.40	8.65
77	8.20	8.31	8.40	8.55	8.78
84	8.10	8.22	8.33	8.48	8.64
91	8.25	8.34	8.45	8.60	8.85

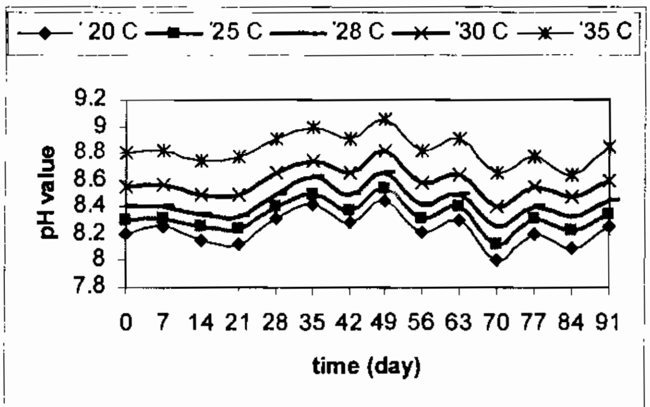


Fig. (13) Effect of water temperature on pH value as measured after 24 hour from the time of changing aquarium water.

A mathematical equation was derived to correlate the relationship between water temperature "T" and the value of pH, equation (21) the coefficient of correlation (R^2) for this equation was highly significant (0.9469).

$$pH = 7.3606 + 0.0407\,T \qquad (21)$$

Table (8) and figure (14) show the changes in the pH values for 48 hour under different temperature levels. It is noticed that pH had a maximum value at time 18.00 hour (6pm) and a minimum value at 6.00 hour (6am). The difference between the maximum and minimum value of pH during the 48 hour period under different temperature levels were computed and the results showed that this difference increased under higher temperature levels (35°C), while under lower temperature levels (25°C), this difference was decreased. This periodical fluctuation in the pH values was probably due to a fluctuation in the values of the carbonates and the bicarbonate. The increase in the bicarbonates content in the aquarium caused in raising pH value. During the 24 hour cycle, there is a solubilization of the existing carbonate at night and a transformation to bicarbonate. During the 24 hour cycle, there was a solubilization of the existing carbonate at night and a transformation to bicarbonate. During the day, in contrast, some portion of the carbon dioxide is used up, and part of the bicarbonates is transformed to carbonates and resulting in an increase in pH value, as noted at the end of the day.

Table (8) Changes in pH value during 2 days period under different water temperature.

Temperature C	6.00	12.00	18.00	24.00	6.00	12.00	18.00	24.00	Difference in pH value
20	7.95	8.2	9.10	8.10	8.00	8.30	9.10	8.10	1.10 -1.15
25	7.90	8.27	9.25	8.12	7.90	8.35	9.25	8.15	1.35
28	7.75	8.41	9.20	8.25	7.90	8.55	9.30	8.25	1.40 -1.45
30	8.00	8.55	9.40	8.32	7.90	8.65	9.40	8.35	1.40 -1.50
35	7.70	8.80	9.35	8.50	7.85	8.70	9.38	8.55	1.53 -1.65

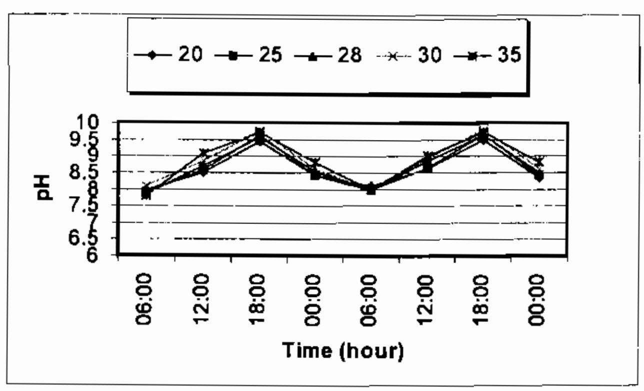


Fig. (14) Effect of water temperature on pH value during 2 days period.

3-4 Effect of water temperature on the concentration of the total ammonia in the aquarium.

Table (9) and figure (15) show the weekly total ammonia concentration in the aquarium water for a period of 13 weeks (91 day) under different water temperature levels. The results showed that the ammonia concentration during the experiment was between 1.50 to 3.05mg/l which was a suitable range for the growth and activity of the Nile tilapia fishes. Also, it is noticed that the temperature has a significant effect of the ammonia concentration, the ammonia concentration increased by increasing the water temperature, and vice versa.

Table (9) The effect of water temperature on the total ammonia concentration (mg/l) after 24 hour from the time of changing aquarium water.

Time (day)	20 C (±1)	25 C (±0.5)	28 C (±0.5)	30 C (±0.5)	35 C (±0.5)
0	1.70	1.82	2.50	2.72	2.95
7	1.65	1.72	2.45	2.65	2.85
14	1.85	2.00	2.65	2.90	3.05
21	1.65	1.74	2.40	2.62	2.80
28	1.78	1.87	2.55	2.75	2.97
35	1.75	1.82	2.50	2.71	2.92
42	1.55	1.73	2.44	2.49	2.65
49	1.50	1.69	2.40	2.65	2.85
56	1.58	1.79	2.50	2.72	2.90
63	1.60	1.91	2.60	2.83	3.00
70	1.65	1.85	2.50	2.75	2.95
77	1.60	1.79	2.50	2.72	2.90
84	1.65	1.84	2.55	2.75	2.95
91	1.64	1.74	2.45	2.65	2.85

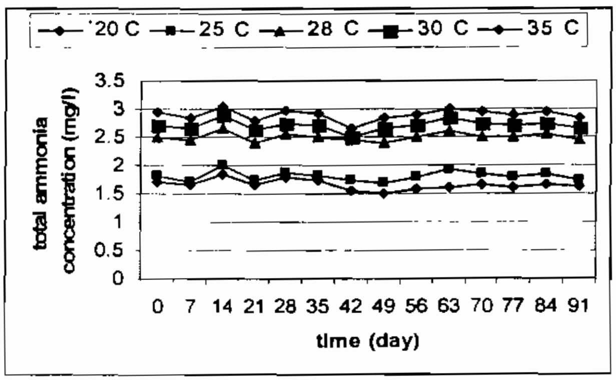


Fig. (15) Effect of water temperature on ammonia concentration as measured after 24 hour from the time of changing aquarium water.

The relationship between the total ammonia concentration and water temperatures between 20 to 35 C was derived, equation (12) and the coefficient of correlation (R^2) between these was significant (0.8908).

$$Am = -0.2625 + 0.933\ T \qquad (22)$$

where :

Am = total ammonia concentration (mg/l)

T = water temperature (C)

Table (10) and Figure (16) shows the effect of water temperature on the total ammonia concentration. Although, the fact that the temperature causes in an increase in the ammonia concentration in the water, it is noticed from the results that the ammonia concentration rate per hour (0.077 gm/l.h) was high at 28 °C water temperature, followed by 25°C , 30°C , 20 °C and 35 °C. This is attributed to the fact that the fish growth rate in the 28, 25, and 30 °C and 25 °C water temperature were greater than that at 20 °C and 20 °C. So, the higher metabolism rates caused in more production of ammonia.

Table (10) Effect of water temperature and time on total ammonia concentration (mg/l) and ammonia concentration rate (mg/l.h).

Temperature °C	After changing water directly	After 24 hour	After 48 hour	Ammonia concentration rate (mg/l.h)
	Total ammonia (mg/l)	Total ammonia (mg/l)	Total ammonia (mg/l)	
20	0.30	1.55	3.80	0.073
25	0.33	1.70	3.95	0.075
28	0.40	2.45	4.10	0.077
30	0.53	2.70	4.10	0.074
35	0.61	2.90	4.05	0.071

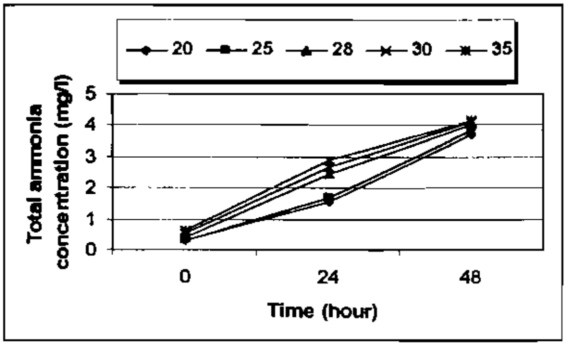


Fig. (16) Total ammonia concentration under different levels of water temperature through a 48 hour period.

In order to evaluate the ammonia amount produced from Nile tilapia in an accurate manner, an independent experiment was done for 60 hours without changing the water in an aquarium with same density. of fishes (4 g fish/ liter water), the pH value was between 8 to 9 and the temperature was 30 °C. The ammonia was estimated every 6 hours, and the results are illustrated in table (11) and figure (17). The obtained results showed that the ammonia accumulation increased along the time of the experiment period .It also revealed that the ammonia increasing rate per hour for the first 24 hour was 0.098 mg/ l.h, and that for the next 24 hour was 0.060 mg/l.h, while that for the next 12 hour was 0.15 mg/l.h. This shows the importance of changing aquarium water after 48 hour to avoid the higher increasing rate of ammonia after that time. And ammonia rate per hour for the last 12 hours was also very highly The total ammonia concentration of 60 hour, table (11) was (60 mg/l) which is considered very high concentration and a dangerous value for fish growth.

Table (11) Ammonia concentration during 60 hour experiment without any change an aquarium water under fish density of 4 gm fish / liter of water and 30 C

Time (h)	0	6	12	18	24	30	36	42	48	54	60
Ammonia concentration (mg/l)	0.40	0.70	1.50	2.30	2.75	3.10	3.70	4.00	4.20	5.10	6.00
Ammonia increasing rate (mg/l.h)					0.098				0.060		0.15

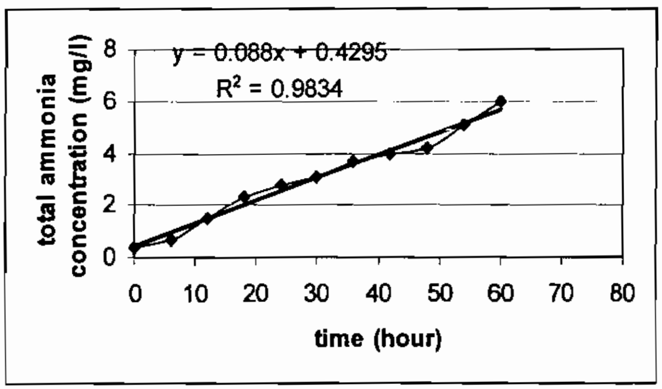


Figure (17) Ammonia concentration in aquarium water without changing the water for 60 hour

From the relation between the generation and the accumulation of ammonia as time passes, due to the growth and the activity of Nile tilapia fishes, equation (23) was derived for the prediction of the generated ammonia amount (Am) as a function of the period passed after water change in the aquarium, for a fish density of 4g/l, and water at temperature (t*) of 30 °C the coefficient of correlation (R^2) for this mathematical relation was highly significant (0.9834).

$$\mathbf{Am = 0.4295 + 0.088\, t^*} \quad (23)$$

where:

Am = ammonia concentration (mg/l)

t* = time after water changing (hour)

Other mathematical relations among each of: the average of dissolved oxygen concentration ,pH value and total ammonia concentration were suggested and were derived from the results in the table (5), (7) and (9). These relations expressed in the following, equations (24) through (29).These equations greatly help the researcher to any required value from other available values.

$$\mathbf{DO = 736.3 - 167.29\,(pH) + 9.5657\,(pH)^2} \quad (24)$$
$$R^2 = 0.9669$$

$$\mathbf{pH = 15.025 - 1.9819\,(DO) + 0.1449\,(DO)^2} \quad (25)$$
$$R^2 = 0.910$$

$$\mathbf{pH = 10.155 - 2.012\,(Am) + 0.5331\,(Am)^2} \quad (26)$$
$$R^2 = 0.954$$

$$\mathbf{Am = -319.22 + 73.222\,(pH) - 4.1609\,(pH)^2} \quad (27)$$
$$R^2 = 0.9485$$

$$\mathbf{Am = 5.5069 - 0.536\,(DO)} \quad (28)$$
$$R^2 = 0.9615$$

$$\mathbf{DO = 10.238 - 1.85\,(Am)} \quad (29)$$
$$R^2 = 0.9915$$

5-CONCLUSION

From the results of this research work the following conclusions were drawn:

1- The best growth (weight and length) of Nile tilapia fishes, was obtained at 28 °C water temperature , especially for fishes having a weight more than 50 g, and at 30 °C for fishes having a weight less than 50 g.

2- Increasing water temperature caused in a continues decrease in the dissolved oxygen concentration.

3- Increasing water temperature in aquarium caused in a slight increase in pH values.

4- Increasing water temperature caused in an increase in total ammonia concentrations.

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الملخص العربي

تأثير درجة الحرارة على نمو اسماك البلطي النيلى وعلى بعض العوامل البيئية المؤثرة عليه

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تعتبر الأسماك من الأغذية الهامة للإنسان، وتنمية الثروة السمكية تعتبر من العناصر الأساسية لحل أزمة نقص البروتين الحيواني في مصر وخاصة مع الزيادة السكانية السريعة، وتحتاج الأسماك كاى كائن حي إلى بيئة مناسبة لممارسة نشاطها الحيوي من نمو وتكاثر وغيره. ومن أهم المشاكل الرئيسية للاستزراع السمكي هو تحديد الظروف البيئية المناسبة لنمو وتكاثر الأسماك وتوفيرها لها. لذلك اهتم هذا البحث بدراسة تأثير درجة حرارة الماء بأحواض سمك البلطي النيلى على نمو الأسماك، وكذلك تأثيرها على عوامل جودة مياه الحوض مثل تركيز الأكسجين الذائب ونسبة تركيز الامونيا الكلية وقيمة الـ pH. كما اهتم البحث أيضا بإيضاح العلاقات الرياضية التي تربط بين العوامل السابقة مع درجات الحرارة المختلفة ومع بعضها البعض .

وقد اشتملت الدراسة التجريبية دراسة تأثير درجات الحرارة المختلفة على نمو اسماك البلطي النيلى ذات متوسط أوزان 30 جم داخل أحواض زجاجية لمدة 13 أسبوع (91 يوم) وتحت مستويات مختلفة من درجات الحرارة عند 20، 25، 28، 30، 35 درجة مئوية، وعند معدل تهوية ثابت (23.7 سم3 / دقيقة). وتم خلالها قياس كلا من الطول و الوزن للأسماك و تركيز الأكسجين الذائب وتركيز الامونيا و قيمة الـ pH للماء أسبوعيا.

وقد أوضحت النتائج مايلى:

1- تؤثر درجات الحرارة بشكل معنوي على نمو اسماك البلطي النيلى حيث يزداد الوزن والطول للأسماك ذات أوزان اقل من 50 جم بزيادة درجة الحرارة وكانت درجة الحرارة المثلي لذلك 30 درجة مئوية بينما كان أفضل درجة حرارة لنمو اسماك البلطي في الوزن والطول هي 28 درجة مئوية وذلك للأسماك ذات الأوزان الأكبر من 50 جم .

2- تؤثر درجات الحرارة بشكل معنوي على درجة تركيز الأكسجين الذائب في الماء، حيث يقل تركيز الأكسجين الذائب في الماء بزيادة درجة الحرارة، كما لوحظ أن درجة تركيز الأكسجين تتغير على المدى اليومي مع ثبات درجة الحرارة.

3- تؤثر درجات الحرارة على قيمة الـ pH للماء، فكلما زادت درجة الحرارة يزداد قيمة الـ pH ولكن بدرجة بسيطة كما لوحظ أن قيمة الـ pH تتغير على المدى اليومي مع ثبات درجة الحرارة.

4- تؤثر درجات الحرارة على نسبة تركيز الامونيا الكلية في الماء فكلما زادت درجة الحرارة زاد تركيز الامونيا الكلية في الماء وهذا يستدعى العمل على تغيير الماء كل 48 ساعة حتى لا يزداد تركيز الامونيا ويزداد تأثيرها السام على الأسماك ونموها.

كما تم استنتاج بعض العلاقات الرياضية التي تربط بين درجة الحرارة مع الطول والوزن وبعض مؤشرات النمو الأخرى ، وبين الطول والوزن، وكذلك بعض العلاقات الرياضية التي تربط بين القيم المتوسطة لكل من الأكسجين الذائب وقيمة الـ pH وتركيز الامونيا الكلية بالمياه مع درجة الحرارة ، ومع بعضهم البعض

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