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Influence of Water Temperature and Salinity on Rearing of Nile Tilapia Fry under Biofloc Culture System

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ABSTRACT

Nile tilapia fry (1.45 g each) were subjected to four salinity treatments (0.5‰, 5‰, 10‰, 15‰) under two temperature regimes (Statistical analysis: two-way ANOVA). Nile tilapia fry grew to harvest weights of 3.92 to 8.12 g/fingerling after 60 days of rearing. Tilapia fry reached higher harvest weights and daily weight gains when raised within 5-10 ‰ salinity range than those reared in 15 ‰ salinity. Among all treatments, there was an adverse effect of the highest salinity (15‰) on the growth performance of tilapia fry compared to other salinities. The better growth performance of Nile tilapia fry underwater salinity of 5-10% can be ascribed to the ease of osmoregulation under those salinities. Nile tilapia fry had better feed conversion ratio FCR performance when reared under high-temperature conditions (2.05-2.22) within the salinity range of 0.5-10% when compared to those of low temperature (3.04-5.38). Feed conversion ratios were deteriorated (4.01-5.74) when fry were raised in water salinity of 15 ‰ due to the adverse effect of increased salinity. The protein efficiency ratios were also better under high temperatures when fry were raised in 0.5-10 ‰ salinity range. Biofloc volumes were optimal and lower under high temperature and increased at low temperature due to the negative effect of low temperature on bacterial metabolism. Rearing Nile tilapia in biofloc system reduced ammonia and nitrite concentrations to recommended levels. Consequently, it is recommended to rear Nile tilapia fry under optimal range of salinity and temperature when reared in biofloc systems.

INTRODUCTION

The expected increase in aquaculture production in Egypt is limited by the shortage of land and inadequacy of fresh water needed for Nile tilapia culture, which can be solved by employment of intensive aquaculture **(Wasave *et al.*, 2020).** Biofloc technology is intensive aquaculture system that solve land costs, use minimum water in fish culture and reduce waste discharge such as ammonia and nitrite toxic metabolites **(Crab *et al.*, 2012& Garcia-Rios *et al.*, 2019).**

Research work on rearing tilapia in biofloc system for fry and fingerlings is scarce, since research on tilapia culture in biofloc focused only on juveniles and adult stages **(Azim and Little, 2008; Ekasari and Maryam, 2012; Pérez-Fuentes *et al.*, 2016 and García-Ríos *et al.*, 2019).**

Moreover, the expansion of Nile tilapia aquaculture in Egypt need further research on potential growth and production in brackish water systems to overcome the limited fresh water resources and land costs, especially during the early life stages, since scarce data were reported by several authors **(El-leithy *et al.*, 2019).** The current study was designed to define salinity limits in order to optimize rearing operations of tilapia in brackish water systems.

Inadequate research about the effect of different levels of water salinity and water temperature on Nile tilapia fry growth and feed performance when raised in biofloc systems has been given to date. Therefore, the present study was designed to examine the combined effect of different water salinity (0.5‰, 5‰, 10‰, and 15‰) and temperature (23 and 27 ºC) on growth performance and feed efficiency of Nile tilapia fry when raised in biofloc system. The current study was also planned to test the optimum salinity and temperature needed during rearing Nile tilapia fry under biofloc conditions.

MATERIALS AND METHODS

The study was conducted at the Fish Culture Research Unit, Faculty of Agriculture, Cairo University, Egypt during (November and December 2019).

Experimental design:

Tilapia fry were fed ground diet (30% crude protein), 7 days a week. Sucrose was dissolved in water and sprinkled over water surface in each biofloc tank at 50% of daily feed input (g/g) in order to develop biofloc and nourish heterotrophic bacteria. The experiment started in November 2019 and lasted for 60 days. The design of the experiment was as follows:

Nile tilapia fry, with average initial weight of 1.45 g/fry were distributed randomly among 24 glass aquaria (50 liter each), at stocking density of 28 fry per aquarium. The experiment consisted of four salinity treatments (using sodium chloride) under both low (23.0-24.0 ºC) and high (27.0-28.0 ºC) water temperature in two separate rooms (i.e. the cool room and the warm room) using air heater during winter time. The cool room contained 12 aquaria distributed randomly among four salinity treatments (0.5‰, 5‰, 10‰, and 15‰); with 3 replicate tanks per treatment. The warm room was supplied with air heater and contained 12 aquaria distributed randomly among the same salinity treatments, with 3 replicate tanks per treatment.

The manufactured fry diet was purchased from Aller-Aqua Company, 6th of October, Giza, Egypt, with proximate composition analysis of 9.0% moisture, 7.5% ash, 31.1% crude protein, 3.7% crude fiber, 4.0% crude fat, and 44.7% (NFE) Nitrogen Free Extract on as fed basis. The growing period of fry started 12/11/2019 and lasted for 60 days. When extrapolated_to water volume, the same feed input (g/tank/day) was applied to all treatments overtime, starting at 4 g diet/tank/day which was gradually increased to 7 g diet/tank/day overtime in match with the fry growth. These feed inputs are equivalent to

80-140 g diet/m^3/day when extrapolated to cubic meter of water. Initial feeding rate at the start of the experiment was adjusted to 10% of fry biomass.

Growth performances of fry were measured in terms of body weight, weight gain (WG), daily weight gain (DWG), SGR, and survival. Moreover, fry biomass and biomass gain during the experiment were calculated by multiplying fry density per aquarium by average fry weight. Biomass gain of fry population was obtained by subtracting initial and final biomasses. Feed performances were measured in terms of feed conversion ratio (FCR) and protein efficiency ratio (PER) values. Growth and feed performances were determined as follows:

Body weight of fry (BW) was measured using a digital balance

Weight gain= final body weight (W_T)-initial body weight (W_O)

Daily weight gain $= \frac{\text{final boby weight} - \text{initial body weight}}{\text{experimental period (t in days)}}$

Specific growth rate = $(L_nW_{t} - L_nW_o)*100/t$

Survival rate = (final fry count / initial fry count)*100

Biomass gain (g) = (final biomass – initial biomass)

Biomass (g) = fry count*average fry weight

FCR = feed input fed / biomass gain (g/g)

PER = fry biomass gain (g) / protein fed (g)

All determinations of water quality parameters in terms of water temperature, dissolved oxygen, biofloc volume, pH values, ammonia concentration (TAN), and nitrite levels (NO_2-N) were measured according to **Boyd and Tucker (1992).** Water quality parameters were measured as follows:

Total ammonia concentration (TAN) in tank water was measured using the phenate method and colorimeter. Nitrite – nitrogen was measured using the diazotizing method and colorimeter. Biofloc volume in each tank was measured using the Imhof cone where water loaded with biofloc was left to settle for 30 minutes. Temperature and dissolved oxygen were measured using Hanna instrument Cairo, Egypt (model 55) dissolved oxygen meter. pH was measured using digital pH meter (Hanna instruments) at the laboratory.

Statistical analysis

Growth performances of the cultured fry as well as water quality parameters in culture tanks were subjected to two-way analysis of variance to determine significant statistical differences among treatments. Statistical differences for different salinities were assessed by Duncan multiple rang test (Duncan, 1955), while those of water temperature were assessed by student *t*-test. Statistically significant differences were determined by setting type I error at 5% for each comparison.

RESULTS AND DISCUSSION

Growth performance data are shown in Table (1). Starting with average initial weights of 1.33-1.52 g/fry, Nile tilapia fry grew to harvest weights of 3.92 to 8.12 g/fingerling after 60 days of rearing. The high temperature treatments had higher harvest weights (5.17-8.12 g/fingerling) above that obtained with lower temperature treatments (3.92-5.86 g/fingerling), with significant differences among means. By the end of the experiment, Nile tilapias raised under high temperature were heavier than those raised under low temperature conditions. **Jun *et al.* (2012)** indicated that water temperature is considered a primary factor that control metabolic rate of Nile tilapia; therefore, affecting mobility of fish and its growth. Moreover, temperatures have a great influence on daily weight gain of fish **(Shackleton, 2012).** When water temperature is raised, metabolic rate of fish improves within the comfort range **(Likongwe *et al.*, 1996)**, which accordingly has a positive effect on both growth and feed intake according to **Ross (2000).**

By the end of experiment, Nile tilapia fry reared at high temperature were heavier than those raised at low temperature by 28-93%, indicating the positive effect of water temperature on growth performance, which resulted in better growth. Tilapia fry reared in the low temperature treatments attained lower harvest size due to the effect of lower water temperature on fry metabolism. Fish exposed to water temperature of 30 ºC exhibited best growth, however lowest growth was observed when water temperature was reduced to 22 ºC, with higher weight gain and harvest weight at 30 ºC **(El-Wahab *et al.*, 2020). Likongwe *et al.* (1996)** showed that low water temperature (24 ºC) had adverse outcome on metabolic rate of Nile tilapia.

Nile tilapia fry reached higher harvest weight (7.51-8.12 g/fingerling) when raised within 5‰-10‰ salinity range than those reared in 0.5‰ salinity (6.67 g/fingerling) or 15‰ salinity (5.17 g/fingerling) under high temperature conditions. This was due to the low energy cost of osmoregulation when fish are raised within 5‰-10‰ salinities since body fluids salinities are close to 12‰. Thus, adverse effects of water salinity on harvest weight were observed when fingerlings were reared at higher salinity (i.e.15‰).

Daily weight gain and body weight gain

The growth rate of tilapia fry in terms of daily weight gain was generally higher Table (1) when fry were raised in the higher water temperature treatments (0.062-0.11 g/fry/day) when compared to those reared under the lower temperature treatments (0.04-0.073 g/fry/day), with significant differences among means ($p<0.05$). Among all treatments, there was an adverse effect of the highest salinity (15‰) on growth performance of tilapia fry compared to other salinities that ranged 0.5-10‰ Table (1). The highest daily weight gains (0.1-0.11g/fry/day) were observed when tilapia fry were reared at 5-10‰ at high temperature table (1). When tilapia fry were reared under low temperature, best daily weight gain (0.073g/fry/day) was obtained under 10‰ salinity conditions compared to other low temperature treatments ($p<0.05$) Table (1). **Shaheen *et***

***al.* (2017)** reported that when water temperature is optimal, better growth performance of Nile tilapia could be obtained at salinity equivalent to 5 ppt. **Payne and Collinson (1983)** showed that optimal growth of Nile tilapia could be obtained at upper salinity range of 5-10 ppt range, **Sutthi and Thaimuangphol (2020)** demonstrated that Nile tilapia fingerlings could be raised within comfort salinity range of 0-10 ppt, with better growth Performance when fish are raised within 0-5 ppt range than higher salinity (10 ppt).

Table (1): Growth performance of Nile tilapia fry in biofloc culture under different levels of temperature and salinities.

Parameter		**Salinity**			
		0.5‰	**5‰**	**10‰**	**15‰**
Initial weight	LT	1.51	1.42	1.47	1.48
(g/fry)	HT	1.33	1.52	1.48	1.40
Final weight	LT	3.92^{cB}	4.20^{cB}	5.86^{bA}	3.92^{cA}
(g/fry)	HT	6.67^{abA}	8.12^{aA}	7.51^{aA}	5.17^{bcA}
Weight gain	LT	2.40^{dB}	2.78^{dB}	4.39^{bcA}	2.44^{dB}
(g/fry)	HT	5.33^{abA}	6.60^{aA}	6.02^{aA}	3.76^{cdA}
Daily weight gain	LT	0.04^{dB}	0.046^{dB}	0.073^{bcA}	0.040^{dB}
(g/fry/day)	HT	0.088^{abA}	0.110^{aA}	0.100^{aA}	0.062^{cdA}
Specific growth rate	LT	1.58^{cB}	1.79^{cB}	2.29^{bA}	1.61^{cA}
(% per day)	HT	2.67^{aA}	2.78^{aA}	2.67^{aA}	2.15^{bA}

*Means within the same row or vertically within the same column having different superscript letters are significantly differ ($p<0.05$). HT= high temperature and LT= low temperature. Row comparison= small letters and column comparison= capital letters.

The better growth performance of Nile tilapia fry under water salinity of 5-10% can be ascribed to the ease of osmoregulation under those salinities, since body fluids have a salinity of 12‰ in fresh water fishes. In this case tilapia fry will exert low osmoregulation efforts when reared under water salinity close to that of body fluids, allowing better growth rate.

The lowest daily weight gain of Nile tilapia fry under the 15‰ salinity could be explained by the deterioration of osmoregulation within body fluids at higher salinity when the water medium has salinity above that of body fluids. High water temperature treatments under moderate salinities (0.5-10‰) gave the best weight gains per individual fry (5.33-6.6 g/fry) and was significantly higher ($p<0.05$) in growth response compared to those of low water temperature treatments (2.4-4.39 g/fry). The lowest weight gains per individual fry were observed in the 15‰ salinity treatments due to the negative effect of high salinity on energy cost of osmoregulation when water salinity exceeds that of body fluids.

Within high temperature treatments, higher weight gains (5.33-6.6 g/fry) were attained when water salinities were lower than 10‰, consequently, it can be concluded that Nile tilapia fry should not be raised in water salinities above 10‰. **Villegas (1990)** revealed that Nile tilapia grew optimally at 0-10 ppt comfort salinity range, furthermore, **Nandlal and Pickering (2004)** showed that water salinity lower than 10 ppt is favored by Nile tilapia, with higher mortality rate when salinity is raised more than 14ppt. Regarding the metabolic cost of osmoregulation, Nile tilapia had least oxygen consumption when raised at 10 ppt salinity, being nearly 50 % compared with that of fresh water **(Awal *et al.* 2012).**

Specific growth rates

The results in Table (1) confirmed that the best growth of (*Oreochromis niloticus)* was obtained in the high temperature treatments when compared to those of the low temperature treatments. Growth performances were lower due to the Q-10 effect of water temperature on fry growth and metabolism during the course of the experiment. **Likongwe *et al* (1996)** indicated that water salinity more than 8 ppt reduced growth rate of Nile tilapia over a wide range of water temperature (24-33 ºC), while growth rate was greater when water temperature was increased within that range. Moreover, tilapia fry grew optimally when water temperature ranged 25-29 ºC, while growth rate was reduced when water temperature was decreased to 22 ºC **(Faruk *et al.*, 2012),** Consequently, water temperature within a comfort zone (25-29 ºC) improved fry growth rate.

Increasing water temperature in rearing tanks did improve SGR performance, indicating that high water temperature should be adopted when rearing Nile tilapia fry. Lower growth pattern of fish when water temperature was reduced support the Q-$_{10}$ effect of water temperature on growth rates. **Dawood *et al.* (2019)** indicated that raising Nile tilapia in suboptimal temperature reduced feeding rate, while optimum temperature for growth ranged around 28 ºC **(Azaza *et al.*, 2008).** When water temperature was reduced to suboptimal levels, growth performance was significantly reduced, despite Nile tilapia ability to acclimate to a wide range of growing conditions **(Nobrega *et al.*, 2017). Pandit and Nakamura (2010)** reported that feed intake and maximum growth as well as improved FCR were observed when water temperature ranged 27-32 ºC in rearing units.

Fry survival

Survival rates in the low temperature treatments (90.6-96.0%) were similar to those of the high temperature treatments (85.7-100%), with no significant differences among means ($p>0.05$). Although non-significant, survival rates were lowest in the 15‰ salinity treatments (85.7-90.6%) due to the stress induced by the effect of high salinity on osmoregulation and osmoregulation costs. Nile tilapia fry experienced low mortality rates when water salinity ranged 0.5-10‰, which indicated favorable conditions during the current experiment Table (2).

When Nile tilapia at the fingerling stage were reared within a salinity range of 0-7 ppt **(Lawson and Anetekhai, 2011)** or 0-7.5 ppt **(Shaheen *et al.*, 2017),** optimum survival of 100% were attained, while survival rate was reduced to 81.67% when fish were exposed to 15 ppt **(Basuki and Rejeki, 2015). Sutthi and ThaimulangPhol (2020)** pointed out that growth of Nile tilapia as well as their blood chemistry were optimal when fish were raised within 0-5 ppt range, although good survival was obtained within 0-10 ppt range. **Villegas (1990)** observed that Nile tilapia grew optimally at wide salinity of 0-l0 ppt, while survival rate decreased when water salinity extended above 15 ppt **(Basiao *et al*., 2005).**

Fry biomass harvest

Starting with initial fry biomass of 39.9-42.4 g/aquarium in the low temperature treatments, final biomass harvest per aquarium reached 99.3-149.2 g/aquarium, with significant differences among salinity treatments ($p<0.05$). The lowest biomass harvest was observed in the 15‰ salinity treatment (99.3 g/aquarium). Starting with initial fry biomass of 37.3-42.5 g per aquarium in the high temperature treatments, final biomass harvest per aquarium ranged 122.8-204.0 g/aquarium among different salinity treatments, with significant differences among means ($p<0.05$) (Table 2).

Moreover, the 15‰ salinity treatment had significantly the lowest biomass harvest (122.8 g/aquarium). The biomass harvest in the 15‰ salinity treatments followed the same trend under both the low and high temperature conditions. This may be explained by the adverse effect of excessive salinity on growth performance of Nile tilapia fry when water salinity exceeded 10‰. Final biomass harvest within the 0.5-10‰ salinity range at higher temperature had similar final biomass harvest per aquarium (186.7-204.0 g/aquarium), with no significant differences among means, indicating favorable salinity conditions regarding growth performance of Nile tilapia fry.

Warm water conditions in the high temperature treatments within 0.5-10‰ salinity range had higher final biomass harvest (186.7-204.0 g/aquarium) than those of the low temperature treatments (104.5-149.2 g/aquarium), with significant differences among means. This can be explained by the positive effect of warm water temperature on growth of Nile tilapia fry as justified by the $Q\text{-}_{10}$ principle. The optimal biomass harvest of fry in high temperature treatments was equivalent to 3.7-4.0 kg fry/m^3 when extrapolated to cubic meter of water in biofloc system.

Biomass Gain

The biomass gain per aquarium in the low temperature treatments ranged 57.7-108.0 g, with the 15‰ salinity treatment being lowest in terms of biomass gain (57.7 g/aquarium). The biomass gain in the high temperature treatments varied from 83.4 to 161.4 g/aquarium, with the 15‰ salinity treatment being significantly least in terms of biomass gain. The lowest biomass gain observed in the 15‰ salinity treatments under both the low and high temperature conditions can be ascribed to salinity stress on Nile tilapia fry under salinities above 10‰ as observed in the current experiment Table (2).

Body fluid salinities in Nile tilapia are close to 10‰ salinity where fish do not experience salinity stress. The biomass gains under the high temperature conditions within the 0.5-10‰ salinity range (149.4-161.4 g/aquarium) were significantly higher than those of the low temperature treatments (62.0-108.0 g/aquarium), indicating the positive effect of warm water temperature on growth performance of Nile tilapia fry when water temperature were 4.0 ºC higher than the low temperature conditions ($p<0.05$).

Low water temperature had adverse effect on growth and metabolism of Nile tilapia fry in general due to the positive effect of warm water temperature on growth and feed intake of the poikilothermic Nile tilapia. By the end of the experiment, Nile tilapia fry subjected to warm temperature had higher growth performance than those under low water temperature within 0.5-10‰ salinity range; moreover, the current experiment indicated that Nile tilapia fry cannot normally grow under the 15‰ salinity conditions.

Feed performance parameters

Feed conversion

Feed performance data of Nile tilapia fry are shown in Table (2). Under all water temperature treatments, Nile tilapia fry had better FCR performances when fry were reared under high temperature conditions (2.05-2.22:1) within salinity range of 0.5-10‰ when compared to those of low temperature treatments (3.04-5.38:1),with significant differences among means ($p<0.05$).

Feed efficiency in terms of FCR and PER had positive relationships with water temperature, while both parameters were adversely affected by higher salinity **(Likongwe *et al.*, 1996).** Feed efficiencies as well as growth performances were maximum when Nile tilapia were reared under 32 ºC and 8 ppt combination, moreover, lower water temperature (24 ºC) had inferior growth rates compared with higher temperature within 28-32 ºC range **(Likongwe *et al.*, 1996). Kawanna (2008)** indicated that growth and feed efficiency were optimal when tilapia fry were raised at water temperature (28 ºC), while both Parameters showed inferior performances with reduced water temperature. **Azaza *et al.* (2008)** showed that feed intake of Nile tilapia Fry was higher when water temperature increased within a 22-30 ºC range, while FCR improved at higher temperature (1.96) and deteriorated (2.85) at lower temperature. **El-Sayed and Kawanna (2008)** reported that the best feed efficiency in terms of FCR was observed at water temperature 28 ºC, while FCR was significantly inferior at 24 ºC. The deterioration of Nile tilapia growth under lower temperature was due to the increase of energy cost needed for maintenance, along with its negative effect on appetite **(Azaza *et al*., 2008).**

Feed conversion ratios were deteriorated (4.01-5.74:1) when fry were raised in water salinity of 15‰ due to the adverse effect of increased salinity on growth rates. The deterioration in feed conversion ratios were due to the slow growth rate of Nile tilapia fry under higher salinity conditions. **Likongwe *et al.* (1996)** showed that FCR value was deteriorated in Nile tilapia fry when water salinity increased above comfort levels.

Feed conversion ratios and daily weight gain were significantly improved when Nile tilapia fry were raised under warm water conditions within a salinity range of 10‰, or less indicating better environment of those treatments which improved treatment performance in terms of growth and feed conversion. Nile tilapia fry were more efficient in transforming dietary protein into fish growth under these conditions. This in accordance with **Jun *et al*. (2012)** who reported that warm water temperature and lower salinity combination increased growth rate of Nile tilapia fry during rearing cycle.

Slow growth of Nile tilapia fry under low temperature and high salinity conditions could be ascribed to both the Q_{-10} principle where growth is reduced under low temperature and the cost of osmoregulation which had adverse effect on daily growth and feed conversion. It is concluded that appropriate water temperature (27.0 ºC) and salinity (0.5‰-10‰) should be used in formulating rearing conditions of Nile tilapia fry in order to accomplish better growth rates and feed conversion when rearing Nile tilapia fry during early life stages.

Lower maintenance energy cost was needed for osmoregulation when Nile tilapia were reared in iso-osmotic water which was reflected in improved growth rate of tilapia under water salinity (12ppt) compared to that reared in fresh water **(Ulotu *et al.*, 2016).** Moreover, **Martinez- Palacios *et al.* (1990)** indicated that rearing of Nile tilapia under appropriate temperature, reduced energy cost required for osmoregulation when water salinity is near isosmotic level.

The better environment improved treatment performance in terms of daily weight gain, feed conversion ratio and protein efficiency ratio, improving protein retention during fry growth when acceptable environment are maintained in rearing tanks. Feed efficiencies by fish fry were low under low temperature and high salinity conditions which can be explained by the loss of appetite, as a result environmental stress and optimization should be employed in order to avoid reduced growth and feed efficiency. Although survival rate was not affected at low suboptimal temperature, feed consumption of Nile tilapia as well as weight gain were decreased by 40% and 60%, respectively **(Corrêa *et al.*, 2018).**

Protein efficiency ratio (PER)

The protein efficiency ratios (PER) were better under high temperature conditions (1.51-1.63) when Nile tilapia fry were raised in the 0.5-10‰ salinity range compared to those of low temperature (0.62-1.09) at similar salinities conditions ($p<0.05$). Within high temperature treatments, PER values were better under all salinities except for the higher 15‰ treatment. Consequently, the highest water salinity neither improved growth, nor enhanced protein efficiency ratios Table (2).

Table (2). Feed efficiency and biomass performance of Nile tilapia fry in biofloc culture under different levels of temperature and salinities.

Parameter		Salinity			
		0.5‰	**5‰**	**10‰**	**15‰**
FCR	LT	5.38^{abA}	4.54^{bcA}	3.04^{cA}	5.74^{aA}
	HT	2.22 ^{dB}	2.05^{dB}	2.15^{dA}	4.01^{cB}
PER	LT	0.629^{cB}	0.745^{bcB}	1.09^{bA}	0.585^{cB}
	HT	1.51^{aA}	1.63^{aA}	1.63^{aA}	0.845^{bcA}
Feed input (g/tank)	LT	329	329	329	329
	HT	329	329	329	329
Initial feeding rate	LT	10%	10%	10%	10%
	HT	10%	10%	10%	10%
Initial biomass (g/tank)	LT	42.42	39.93	41.20	41.58
	HT	37.35	42.56	41.66	39.45
Final biomass (g/tank)	LT	104.51^{cB}	113.50^{bcB}	149.26^{bA}	99.33^{cA}
	HT	186.76^{aA}	204.04^{aA}	202.86^{aA}	122.89^{bcA}
Biomass gain (g/tank/60 days)	LT	62.08^{cB}	73.56^{bcB}	108.06^{bA}	57.75^{cB}
	HT	149.40^{aA}	161.47^{aA}	161.19^{aA}	83.43^{bcA}
Survival (%)	LT	95%	96%	91.64%	90.64%
	HT	100%	90.46%	96.42%	85.71%

*Means within the same row or vertically within the same column having different superscript letters are significantly differ ($p<0.05$). HT= high temperature and LT= low temperature. Row comparison= small letters and column comparison= capital letters.

The better FCR and PER performances obtained when water salinities were 10‰ or less indicated better environment in those treatments which improved treatments performance in terms of feed efficiency. The data suggested that Nile tilapia fry should not be reared in salinities above 10‰ in order to achieve better growth and feed efficiencies. Both FCR and PER values were deteriorated when fry were reared above water salinity 10‰, indicating adverse environment at higher salinity conditions. The use of appropriate water salinity is important during fry rearing in order to reduce salinity stress on fish fry during the secondary rearing in biofloc medium.

Water quality parameters

Water quality parameter observed in biofloc tanks during the study period are shown in Table (3).

Water temperature

Water temperature ranged from 23.3 to 24.0 ºC among treatments under low temperature conditions, while high temperature treatments had a temperature range of 27.5-27.7 ºC. No significant differences were detected among treatments in terms of water temperature within both the low and high temperature conditions ($p>0.05$).

The high temperature treatments had optimal temperature conditions for fry growth**.** The low temperature treatments had suboptimal temperature conditions for growth since tilapias are known to increase their growth rates when water temperature is above 25 ºC **(Boyd, 1990).** Variations in water temperature among treatments were the primary factor that affected growth performance of Nile tilapia fry since there is a direct relationship between water temperature and fish growth **(Farrell *et` al.,* 2011).**

The observed growth of Nile tilapia fry under the low temperature conditions reflected the adverse effect of suboptimal water temperature on growth performance of Nile tilapia. The increase in fry growth was linked to the thermal pattern in rearing tanks.

Oxygen concentration

Dissolved oxygen concentrations ranged 4.8-5.14 mg/l among the low temperature treatments and 4.3-4.5 mg/l among the high temperature treatments, with no significant differences among means ($p>0.05$). There was a narrow range of variations among treatments in terms of dissolved oxygen since artificial aeration supplied dissolved oxygen in water for all rearing tanks. The dissolved oxygen was maintained above acceptable levels recommended for Nile tilapia rearing during the study period.

The pH values

The pH values in water in culture tanks were slightly higher ($p<0.05$) in the low temperature treatments (8.06-8.2 units), than those of the high temperature treatments (7.7-8.2 units), with significant differences observed between the low and high temperature conditions. The minor increase in water pH in the cold water treatments may be explained by the decrease in metabolic activities and respiration of fish and aquatic bacteria under low temperature conditions.

The decrease in respiration rate of aquatic organisms and fish under low temperature, results in the decrease of CO_2 production which increases water pH values. Higher respiration rate of aquatic organisms induced by optimal temperature increased the rate of CO_2 production which resulted in a slight decrease of water pH, since CO_2 is acidic in nature.

Similar pH readings were observed among treatments within the low temperature treatments, except for 15‰ salinity treatment. The same pattern was also observed within the high temperature treatments, with significant differences among means ($p<0.05$). The slightly higher pH values observed in the 15‰ treatments under both high and low temperature conditions can be explained by the salinity stress on fry during the culture period, which decreased feed intake and metabolic excretion of CO_2. Low water temperature normally decreases the metabolic activities and CO_2 production of fish fry and bacteria living in the biofloc system. Warm water temperature increases metabolic activities and CO_2 production in aquatic systems, reducing pH values.

Biofloc volume and Imhoff readings.

In biofloc systems, dense bacterial growth was developed in water as a result of high feed inputs. This process results in the excretion of excessive amounts of ammonia in culture water. The metabolic excretion of ammonia and phosphorus by fish fry leads to the development of excessive biofloc densities and bacterial biomass utilizing carbon sources in sucrose applied along with dietary inputs.

The biofloc volume within the low temperature treatments ranged 49.5-112.1 ml/l, while those of the high temperature treatments varied at 25.2-47.5 ml/l. No significant differences were observed among most treatments ($p>0.05$). Although non-significant, biofloc volumes within the high temperature treatments (25.2-47.5 ml/l), were lower than those of the low temperature treatments (49.5-112.1ml/l) (Table 3). This may be attributed to the slow rate of biofloc intake by fish fry as a food source under the low temperature conditions since feeding activities have a positive relationship with water temperature. Similarly, decomposition cycle of biofloc material during rearing is slow under low temperature conditions.

Feed inputs in rearing tanks increased from 80 to 140 g/m^3/day during the study period (i.e. 4.0-7.0 g diet/aquarium/day), consequently, the biofloc treatments had higher feed inputs during the current experiment. In Practice, biofloc is produced through continuous aeration and carbohydrate addition that permit heterotrophic bacteria development and continual absorption of toxic metabolic as ammonia from the aquatic medium **(Hargreaves, 2013).** Complete water exchange in rearing tanks was adopted once every month to reduce toxic effects of accumulated organic nitrogen and dilute biofloc concentration in water according to **Gao *et al.* (2012).**

During several experiments conducted in the Fish Culture Unit (Cairo university), it was noticed that biofloc volume often exceeds 80 ml/l, without water renewal. Consequently, the design of the current study included complete renewal of water in rearing aquaria once every month. Water in culture tanks was completely renewed once each month in order to overcome excessive biofloc density in water. Old water in rearing tanks could be used in the irrigation of plant crops, annexed to fish culture units. **Boyd (2000)** showed that approximately 75% of nitrogen and phosphorus nutrients in diet are excreted into water by fish, which supports bacterial growth and abundance in terms of biofloc volume.

Ammonia and Nitrite concentrations

Feeding rates in biofloc tanks adopted in the current study, ranged from 80 to 140 g diet per cubic meter of water per day. These feeding rates are equivalent to the excretion of 2.4-4.2 mg ammonia/liter/day in water of rearing tanks. However, the observed ammonia (TAN) concentrations ranged 0.45-0.6 mg/l in water in rearing aquaria (Table 3). The abrupt decrease in TAN concentrations was due to the absorption and transformation of the excreted ammonia into biofloc biomass by bacterial activities.

Furthermore, heterotrophic bacteria make use of carbohydrate source (such as sucrose) in producing suspended bioflocs that absorb metabolic ammonia excreted by fish as a result of protein metabolism **(Ebling and Timmons, 2010).** The concentrations of TAN in the biofloc aquaria were reduced as a result of supplying sucrose at 50% of ration inputs per day during the rearing study. Bacterial absorption of ammonia resulted in the reduction of TAN concentrations in water, resulting in total ammonia nitrogen being within the normal range which considered optimal for rearing of Nile tilapia fry (0.45-0.6 mg/l), with no significant differences among treatments ($p>0.05$). Total ammonia concentrations remained under 0.6 mg/l level during most of the experiment, although fish fry should have excreted 2.4-4.2 mg TAN/l/day. TAN concentrations within the low temperature treatments ranged 0.45-0.57 mg/l, while those of the high temperature treatments varied from 0.41-0.6 mg/l, with no significant differences detected among the low and high temperature treatments ($p>0.05$). Nitrozomonas bacteria which oxidize ammonia into nitrite are slow growing bacteria that have a doubling time (26 hours), while nitrobacter bacteria that oxidize nitrite into nitrate are extremely slow growing bacteria that have a doubling time (72 hours) **(Ebling and Timmons, 2010).** Normal aquatic bacteria doubling rate ranges from 2-6 hours to develop.

Table (3). Water quality dynamics in biofloc culture under different levels of temperature and salinities.

Parameter		Salinity			
		0.5‰	**5‰**	**10‰**	**15‰**
Temperature	LT	23.32^{bB}	23.62^{bB}	23.89^{bB}	24.08^{bB}
	HT	27.5^{aA}	27.5^{aA}	27.6^{aA}	27.7^{aA}
Oxygen	LT	4.8^{aA}	5.0^{aA}	5.06^{aA}	5.14^{aA}
	HT	4.31^{aB}	4.5^{aB}	4.4^{aB}	4.3^{aB}
PH	LT	8.1^{abA}	8.06^{bcA}	8.09^{abcA}	8.2^{Aa}
	HT	7.8^{dB}	7.9^{dB}	7.7^{cdB}	8.2^{abB}
Immhof	LT	49.5^{bA}	112.1^{aA}	50.3^{bA}	59.7^{bA}
	HT	25.2^{bA}	28.8^{bA}	32.85^{bB}	47.5^{bA}
NH_3	LT	0.45^{aA}	0.53^{aA}	0.56^{aA}	0.57^{aA}
	HT	0.58^{aA}	0.49^{aA}	0.60^{aA}	0.41^{aA}
NO_2	LT	0.18^{aA}	0.25^{aA}	0.24^{aA}	0.20^{aA}
	HT	0.29^{aA}	0.25^{aA}	0.20^{aA}	0.26^{aA}

*Means within the same row or vertically within the same column having different superscript letters are significantly differ ($p<0.05$). HT= high temperature and LT= low temperature. Row comparison= small letters and column comparison= capital letters.

Nitrite concentrations in water in rearing aquaria ranged 0.2-0.29 mg NO_2-N/l in the high temperature treatments, being significantly similar to those of the low temperature treatments (0.18-0.25 mg NO_2-N/l), with no significant differences among treatments ($p>0.05$). Nitrite bacteria worked in the process of transformation of nitrite into non-toxic nitrate, reducing nitrite content in water. This showed that Nitrobacter and Nitrozomonas bacteria were very effective in converting ammonia into nitrite and nitrate **(Ebling and Timmons, 2010)**

CONCLUSION

Feed conversion ratios and daily weight gains were significantly improved when Nile tilapia fry were raised under warm water conditions within a salinity range of 0.5-10 ‰, indicating better environment. The observed growth of Nile tilapia fry under the low temperature conditions reflected the adverse effect of suboptimal water temperature on growth performance of Nile tilapia fry. Furthermore, feed conversion ratios and growth were deteriorated when water salinity increased to 15 ‰. Water salinity of 10 ‰ or less is considered within optimal range, while water salinity 15 ‰ denoted adverse conditions. The data suggested that Nile tilapia fry should not be reared in salinities above 10‰ in order to achieve better growth and feed efficiencies. The decrease in feed efficiencies under low temperature and high salinity conditions, which can be explained by the loss of appetite, as a result of environmental stress. It is concluded that appropriate water temperature (27.0 ºC) and salinity (0.5‰-10‰) should be used in formulating rearing conditions of Nile tilapia fry in order to accomplish better growth rates and feed conversion ratios.

REFERENCES

Awal, A.; Kundri, K.C. and Sarker, S. (2012). Effect of Salinity on the Oxygen Consumption of Tilapia Fingerlings. Daffodil International University Journal of Science and Technology, 7(1): 12-14.

Azaza, M.S.; Dhraief, M.N. and Kriem, M.M. (2008). Effects of water temperature on growth and sex ratio of juvenile Nile tilapia *Oreochromis niloticus (Linnaeus)* reared in geothermal waters in southern Tunisia. Journal of thermal Biology, 33(2): 98-105.

Azim, M.E. and Little, D.C. (2008). The biofloc technology (BFT) in indoor tanks: water quality, biofloc composition, and growth and welfare of Nile tilapia *(Oreochromis niloticus)*. Aquaculture, 283(1-4): 29-35.

Basiao, Z.U.; Eguia, R.V. and Doyle, R.W. (2005). Growth response of Nile tilapia fry to salinity stress in the presence of an ‘internal reference fish. Aquaculture Research, 36(7): 712-720.

Basuki, F. and Rejeki, S. (2015). Analysis on the survival rate and growth of Larasati tilapia (*Oreochromis niloticus*) F5 seed in Saline Media. Procedia Environmental Sciences, 23: 142-147.

Boyd, C. E. (1990). Water quality in ponds for aquaculture. Alabama Agricultural Experiment station, Auburn University, 462 pp.

Boyd, C.E. and Tucker, C.S. (1992). Water quality and pond soil analyses for aquaculture. Water quality and pond soil analyses for aquaculture. Alabama Agricultural Experiment Station, Auburn University, 188 pp.

Boyd, C.E.; Queiroz, J.; Lee, J.; Rowan, M.; Whitis, G.N. and Gross, A. (2000). Environmental assessment of channel catfish *Ictalurus punctatus* farming in Alabama. Journal of the World Aquaculture Society, 31(4): 511-544.

Corrêa, C.F.; Nobrega, R.O.; Block, J.M. and Fracalossi, D.M. (2018). Mixes of plant oils as fish oil substitutes for Nile tilapia at optimal and cold suboptimal temperature. Aquaculture, 497: 82-90.

Crab R.; Defoirdt, T.; Bossier, P., and Verstraete, W. (2012). Biofloc technology in aquaculture: Beneficial effects and future challenges. Aquaculture, 356: 351-356.

Dawood, M.A.; Shukry, M.; Zayed, M.M.; Omar, A.A.; Zaineldin, A.I. and El Basuini, M.F. (2019). Digestive enzymes, immunity and oxidative status of Nile tilapia (*Oreochromis niloticus*) reared in intensive conditions. Slovenian Veterinary Research, 56(22): 99-108.

Ebeling, J. M. and Timmons, M. B. (2010). Recirculating Aquaculture. Cayuga Aqua ventures, Ithaca, New York,USA.

Ekasari, J. and Maryam, S. (2012). Evaluation of biofloc technology application on water quality and production performance of red tilapia *Oreochromis sp*. cultured at different stocking densities. HAYATI Journal of Biosciences, 19(2): 73–80.

El-Leithy, A.A.; Hemeda, S.A.; Abd El Naby, W.S.; El Nahas, A.F.; Hassan, S.A.; Awad, S.T.; El-Deeb, S.I. and Helmy, Z.A. (2019). Optimum salinity for Nile tilapia (*Oreochromis niloticus*) growth and mRNA transcripts of ion-regulation, inflammatory, stress-and immune-related genes. Fish physiology and biochemistry, 45(4): 1217-1232.

El-Sayed, A.F. and Kawanna, M. (2008). Optimum water temperature boosts the growth performance of Nile tilapia (*Oreochromis niloticus*) fry reared in a recycling system. Aquaculture Research, 39(6): 670-672.

El- Wahab, A.A.; Visscher, C.; Teitge, F. and Steinhagen, D. (2020). Choice preference of diets with different protein levels depending on water temperature in Nile tilapia. Journal of the World Aquaculture Society, 51(2): 512-526.

Farrell, A.P. (2011). Encyclopedia of fish physiology: from genom to environment. Academic press, pp. 321-329.

Faruk, M.A.R.; Mausumi, M.I.; Anka, I.Z.; Hasan, M.M. and Mausumi, M.I. (2012). Effects of temperature on the egg production and growth of monosex Nile tilapia *Oreochromis niloticus* Fry. Bangladesh Research Publication Journal, 7: 367-377.

Gao, L.; Shan, H. W.; Zhang, T.W.; Bao w. y. and Ma, S. (2012). Effects of Carbohydrate addition on *litopenaeus vannamei* intensive culture in a zero-water exchange systems. Aquaculture, 342: 89-96.

García-Ríos, L.; Miranda-Baeza, A.; Coelho-Emerenciano, M.G.; Huerta-Rábago, J.A. and Osuna-Amarillas, P. (2019). Biofloc technology (BFT) applied to tilapia fingerlings production using different carbon sources: Emphasis on commercial applications. Aquaculture, 502: 26-31.

Hargreaves, J.A. (2013). Biofloc production systems for aquaculture. Southern Regional Aquaculture Center (SRAC). Missisipi, Puplication NO. 4503, pp. 1-11.

Jun, Q.; Pao, X.; Haizhen, W.; Ruiwei, L. and Hui, W. (2012). Combined effect of temperature, salinity and density on the growth and feed utilization of Nile tilapia juveniles (*Oreochromis niloticus*). Aquaculture Research, 43(9): 1344-1356.

Lawson, E.O. and Anetekhai, M.A. (2011). Salinity tolerance and preference of hatchery reared Nile tilapia, *Oreochromis niloticus* (Linneaus 1758). Asian Journal of Agricultural Sciences, 3(2): 104-110.

Linkongwe, J.S.; Stecko, T.D.; Stauffer, J.R.; and Carline, R.F. (1996). Combined effects of water temperature and salinity on growth and feed utilization of juvenile Nile tilapia, *Oreochronis niloticus* (*Linneaus*). Aquaculture, 146(1-2): 37-46.

Martinez-Palacios C.A.; Rossb L.G. and Rosado-Vallado M. (1990). The effects of salinity on the survival and growth of juvenile *Cichlasoma urophthalmus*. Aquaculture, 91(1-2): 65–75.

Nandlal, S. and Pickering, T. (2004). Tilapia fish farming in Pacific Island countries. Volume 1. Tilapia hatchery operation. Noumea, New Caledonia: Secretariat of the Pacific Community, 41pp.

Nobrega, R.O.; Corrêa, C.F.; Mattioni, B. and Fracalossi, D.M. (2017). Dietary α-linolenic for juvenile Nile tilapia at cold suboptimal temperature. Aquaculture, 471: 66-71.

Pandit, N. P. and Nakamura, M. (2010). Effect of high temperature on survival, growth and feed conversion ratio of Nile tilapia, *Oreochromis niloticus*. Our Nature, 8(1): 219- 224.

Payne, A.I. and Collinson, R.I. (1983). A comparison of the biological characteristics of *Sarotherodon niloticus (L.)* with those of *Surotherodon nureus (Steindachner)* and other tilapia of the Delta and lower Nile. Aquaculture, 30(1-4): 335–351.

Pérez-Fuentes, J.A.; Hernández-Vergara, M.P.; Pérez-Rostro, C.I. and Fogel, I. (2016). C: N ratios affect nitrogen removal and production of Nile tilapia *Oreochromis niloticus* raised in a biofloc system under high density cultivation. Aquaculture, 452: 247-251.

Ross, L. G. (2000). Environmental physiology and energetics. In M. C. M. Beveridge & B. J. McAndrew (Eds.), Tilapias: Biology and exploitation London, England: Kluwer Academic Publishers, pp. 89–128.

Shackleton, E. (2012). Effects of temperature and terrestrial carbon on fish growth and pelagic food web efficiency. Department of Ecology and Environmental Science Umeå University. Lefébure; 28pp.

Shaheen, F.; Kousar, R.; Raza, I.S,; Mahmood, T. and Hassan, S.W. (2017). Effects of salinity and hardness on the growth of Nile Tilapia (*Oreochromis niloticus*) in Northern Punjab Region of Pakistan.International Journal of Fisheries and Aquaculture Research, 3(1): 21-32.

Sutthi, N. and Thaimuangphol, W. (2020). Effects of yeast (*Saccharomyces cerevisiae*) on growth performances, body composition and blood chemistry of Nile tilapia (*Oreochromis niloticus Linnaeus*, 1758), under different salinity conditions. Iranian Journal of Fisheries Sciences, 19(3): 1428-1446.

Ulotu, E.E.; Mmochi, A.J. and Lamtane, H.A. (2016). Effect of salinity on the survival and growth of Rufiji Tilapia (*Oreochromis urolepis urolepis*) fry. Western Indian Ocean Journal of Marine Science, 15(2): 31-37.

Villegas, C.T. (1990). Evaluation of the salinity tolerance of *Oreochromis mossambicus*, *O. niloticus* and their F1 hybrids. Aquaculture, 85(1-4): 281-292.

Wasave, S.S.; Chavan, B.R.; Pawase, A.S.; Shirdhankar, M.M.; Mohite, A.S.; Pai, R. and Wasave, S.M. (2020). Effect of carbon sources and water requirement in rearing of genetically improved farmed tilapia (*Oreochromis niloticus*) fry in biofloc system. Jornal of Entomology and Zoology Studies, 8(5): 1361-1365.