

Full Length Research Paper

Effects of salinity on growth and metabolism in blue tilapia (*Oreochromis aureus*)

Semra Küçük^{1*}, Aslihan Karul², Şükrü Yildirim³ and Kutsal Gamsiz³

¹Department of Fisheries, Faculty of Agriculture, Adnan Menderes University, 09100, Aydın, Turkey.

²Department of Biochemistry, Faculty of Medicine, Adnan Menderes University, 09100, Aydın, Turkey.

³Department of Aquaculture, Faculty of Fisheries, Aegean University, 35100, Bornova, İzmir, Turkey.

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Tilapia were acclimated to the water source which had 8 ppt of salinity in the experimental unit before the experiment started and then, they were transferred to five different saltwater (SW) treatments: SW (8 ppt), 50% SW (12 ppt), 100% SW (16 ppt), 150% SW (20 ppt), and 200% SW (24 ppt). The objectives of this study were; to investigate the effects of five different salinities on specific growth rate (SGR), weight gain (WG), food intake (FI) and survival of tilapia in the long term trial (30 days) and find out how salinity affects muscle water content, hematocrit index (HSI), and blood chemistry (sodium, chloride, potassium, glucose, total protein and triglycerides) in the short term trial (6 to 12 h). In the long-term trial, six fish were stocked in each aquarium. They were fed with commercial feed (Bagcı trout) to satiation twice a day and individually weighed at ten-days interval. Growth rate was highest in the 50% SW (SGR $0.95 \pm 0.18\%$ per day); there was no significant difference among the first three treatments. Growth rate was lowest in 200% SW (SGR $0.23 \pm 0.08\%$ per day). Weight gain and food intake showed identical results as SGR. Survival was high in the first three groups (72.2 ± 9.2 to 100.0 ± 0.0) but it was lowest in the 200% SW treatment ($22.2 \pm 19.2\%$). In the short-term trial, six tilapia were placed per aquarium. They were exposed to SW, 50, 100, 150 and 200% SW treatments and the fish were gradually acclimated to salt water. Blood samples were taken to analyse plasma sodium, chloride, potassium, total protein and triglycerides. Liver and muscle samples were collected for HSI and moisture values. Plasma sodium chloride increased in parallel with salinity rise. Total protein and triglycerides significantly reduced as salinity increased. Glucose and potassium were not altered significantly. HSI and muscle water content decreased when salinity concentration was elevated. Blood chemistry demonstrated that isosmotic water concentration was between 8 and 12 ppt. Salinity did not affect HSI and moisture until it reached as much as 16 ppt (100% SW). The results show that the optimum condition for farming blue tilapia, *Oreochromis aureus*, both with respect to growth rate and metabolic parameters is at salinities lower than 12 ppt. This is an important finding for the tilapia industry.

Key words: Tilapia, salinity, growth, survival, metabolism.

INTRODUCTION

Tilapia is a fresh water species most widely cultured in the world. Production of tilapia is 2.5 million tons (FAO, 2007). The first five orders of the most produced countries are China, Egypt, Indonesia, Thailand and Philippines, respectively. The first three orders of the

most imported countries are USA, European Union and Japan, respectively. Tilapia is the general name of cichlids. They are taxonomically classified in the family of Cichlidae of order Perciformes. Its origin is Africa. There are three genera, *Oreochromis*, *Sarotherodon* and *Tilapia*

*Corresponding author. E-mail: semrakucuk03@yahoo.com.

Table 1. Water quality parameters of source.

Parameter	Value
EC ($\mu\text{s}/\text{cm}$)	842.2
Total hardness (mg/L CaCO_3)	732.5
Alkalinity (mg/l CaCO_3)	600.0
Bicarbonat (mg/L)	348.9
Calcium (mg/L)	89.8
Magnesium (mg/L)	12.4
Ammonia (mg/L)	0.22
Nitrite (mg/L)	0.007

in this family. The most distinguishable characteristic in them is reproductive behavior. Tilapia species are nest builders. *Oreochromis* and *Sarotherodon* are mouth brooders.

Since approximately 60 years, tilapia has been cultured in the tropical and subtropical regions. Nowadays, the most commercially cultured genus of tilapia is *Oreochromis* and more than 90% of all is Nile tilapia in the world. The most farmed species of them are Nile tilapia (*Oreochromis niloticus*), Blue tilapia (*Oreochromis aureus*), Mozambique tilapia (*Oreochromis mossambicus*) and Zanzibar tilapia (*Oreochromis hornorum*) (Popma and Masser, 1999). Salinity is described as the sum of all ions in water. It consists of not only sodium and chloride, but also calcium, magnesium, potassium, bicarbonate, and sulfate ions. If salinity is so low (for example, fresh water), it can be expressed in milligram per liter (ppm). If it is so high (for example, brackish water and sea), it can be defined as parts per thousand (ppt) (Boyd, 1990; Boyd and Tucker, 1998).

In aquaculture, not only quality and quantity of feed are important, but also adequate environmental conditions is vital for fish production. Salinity is one of the important abiotic environmental factors (temperature, dissolved oxygen) that direct fish growth (Mommssen, 1998). When fish are forced to deal with different salinities, depending on marine or fresh water fish, they spend more energy to hold their homeostasis and grow less. Because osmoregulation break down, fish spends more energy to hold sodium and chloride ions in their bodies or take off them. The aim of this study was to assess the influences of five different salinity treatments (SW, 50, 100, 150, and 200% SW) on growth (specific growth rate, weight gain, food intake and survival), blood chemistry (sodium, chloride, potassium, glucose, total protein and triglycerides) and metabolic parameters (hematosomatic index, and muscle water content).

MATERIALS AND METHODS

Long-term effects of salinity on fish

Tilapia ($n = 90$, 26.04 ± 3.70 g bw and 118.13 ± 6.90 mm bl) were

provided commercially and acclimated to laboratory conditions (8 ppt water source and about 25°C) for one month before the experiment started. Salinity was gradually raised to the desired salinity levels (2 ppt per day). Laboratory condition was climatized for 24 h a day to constrict water temperature to around 25 to 26°C . Water quality parameters [pH, temperature, electrical conductivity (EC), total hardness, alkalinity, bicarbonate, calcium, magnesium, ammonia and nitrite] were measured and are given in Table 1. The osmolarity of each salinity treatment was measured by osmometer (Model 3250 Advanced Instruments, Inc). Six fishes were placed in the 20 L aquariums for each salinity treatment. Fish were not fed for 24 h before stocking each aquarium. Fish was fed *ad libitum* with commercial feed (Bagcı trout, 45% protein, 21% fat) twice a day for 30 days. There were three replicates per salinity level. In each aquarium, water was renewed every morning at the rate of 50% with fresh water having similar salinities. Fish were weighed individually on day 0, 10, 20 and 30. Fish growth (specific growth rate, weight gain, food intake) and survival were calculated (Kangombe and Brown, 2008).

Specific growth rate (SGR) ($\% \text{ day}^{-1}$) = $[(\log_e W_f - \log_e W_i) / \text{day}] \times 100$

Food intake (FI) (g) = total feed consumption

Weight gain (WG) (g) = $W_f - W_i$

Survival (S) (%) = $((N_f - N_i) / N_i) \times 100$

Where, W_i and W_f are the initial and final mean body weights and N_f , N_i are the numbers of harvested and stocked fish.

Short-term effects of salinity on fish

Tilapia ($n = 60$, 47.53 ± 6.54 g bw and 147.03 ± 8.53 mm bl) were exposed to five different salinities (SW, 50, 100, 150 and 200% SW). Fish were separately placed in the 20 L aquariums (6 fish per aquarium) for each treatment. Two replicates were used for each treatment. They were fed *ad libitum* with commercial feed (Bagcı trout, 45% protein, 21% fat) twice a day. Salinity was gradually raised to 2 ppt per day until desired salinity levels were reached. Three fishes were removed from each aquarium for blood sampling (six samples for each salinity treatments). Fish total length (the nearest mm) and fresh weight (to the nearest mg) were measured, and blood samples (1 to 2 ml) were immediately taken from caudal vein by vacutainer tubes (2 ml, without anticoagulant, BD brand) and needles (0.7 x 38 mm, BD brand). Samples were kept on ice before being centrifuged for 5 min at 6000 rpm. Plasma was stored at -80°C until analysis was performed. Plasma sodium, chloride, potassium, glucose, total protein and triglycerides were analysed in blood by autoanalyzer machine (Architect C8000). For muscle tissue samples (1 to 2 g) without skin, scan were taken from the dorsal region to determine water content. They were weighed to the nearest milligram immediately after removal. They were dried at 80°C for 24 h and reweighed every 24 h until constant weight was found. Total liver was removed and freshly weighed for hepatosomatic index. Muscle water content and hematosomatic index were verified (Luz et al., 2008; Overton et al., 2008).

Muscle moisture (%) = $[(\text{wet weight} - \text{dry weight}) / \text{wet weight}] \times 100$

Hepatosomatic index (HSI) (%) = $(\text{wet liver weight} / \text{body weight}) \times 100$

Differences in mean values of SGR, WG, FI, survival, HSI, muscle moisture and blood parameters among each treatment were analyzed by SSPS (18.0). Differences between the means were

Table 2. Water pH, temperature and osmolality at five different salinities (mean±SD).

Salinity	SW	50% SW	100% SW	150% SW	200% SW
pH	7.72 ± 0.26 ^a	7.69 ± 0.24 ^a	7.71 ± 0.22 ^a	7.66 ± 0.20 ^a	7.60 ± 0.19 ^a
Temperature (°C)	26.13 ± 0.73 ^a	25.78 ± 0.95 ^a	25.70 ± 0.69 ^a	25.80 ± 0.58 ^a	26.13 ± 0.38 ^a
Osmolarity (mOsm/kg)	24.50 ± 1.00 ^a	149.00 ± 0.82 ^b	275.75 ± 1.26 ^c	401.50 ± 0.58 ^d	535.34 ± 0.77 ^e

Table 3. The effect of salinity on specific growth rate (SGR), weight gain, food intake and survival of tilapia (mean±SD) for 30 days.

Salinity	SGR (%/day)	Weight gain (g)	Food intake (g)	Survival (%)
SW	0.70 ± 0.01 ^a	6.02 ± 0.44 ^a	13.76 ± 2.65 ^b	94.4 ± 9.6 ^a
50% SW	0.95 ± 0.18 ^a	8.35 ± 0.85 ^a	20.82 ± 2.78 ^a	100.0 ± 0.0 ^a
100% SW	0.84 ± 0.09 ^a	7.46 ± 1.16 ^a	14.30 ± 5.29 ^b	72.2 ± 19.2 ^a
150% SW	0.81 ± 0.30 ^a	7.49 ± 3.39 ^a	14.38 ± 0.98 ^b	72.2 ± 19.2 ^a
200% SW	0.23 ± 0.08 ^b	1.86 ± 0.69 ^b	3.14 ± 2.52 ^c	22.2 ± 19.2 ^b

compared by using one way-ANOVA and Duncan's multiple range test with $p < 0.05$.

RESULTS

Long-term effects of salinity on fish

Water pH, temperature and osmolality values are given in Table 2. pH and temperature were not changed during the experiment, but osmolality was significantly increased with salinity increase in five treatment groups. Tilapia growth performance is shown in Table 3. Specific growth rate (SGR 0.95 ± 0.18% per day) was the highest in 50% SW; there were no significant differences among the first three groups. However, fish growth was significantly affected in the 200% SW (SGR 0.23% per day). SGR was lowered after 20 and 30 days in this treatment as seen in Figure 1. Weight gain and food intake were also the lowest in 200% SW (Table 3 and Figure 2). Weight gain decreased by 75% and food intake reduced by 78%. Survival was high in the first four treatments (72.2 ± 19.2 to 100.0 ± 0.0%). There were no significant differences among them. Mortality was highest in the 200% SW treatment (22.2 ± 19.2%).

Short-term effects of salinity on fish

Blood parameters of tilapia exposed to SW, 50, 100, 150 and 200% SW treatments are given in Table 4. Sodium began to increase in the 100% SW (158.5 ± 8.5 mM) and elevated to 179.5 ± 10.6 and 184.0 ± 13.9 mM in 150 and 200% SW, respectively. Chloride increased from 100% SW (139.5 ± 8.0 mM) and reached 149.8 ± 0.4 and 149.7 ± 0.8 mM in the 150 and 200% SW, respectively. However, potassium was unchanged (higher than 10 mM). Glucose (5.5 ± 0.7 to 7.1 ± 2.4 mM) and total protein (35.6 ± 8.9 to 50.4 ± 5.3) also did not change.

Triglycerides declined from 2.7 ± 0.7 mM in SW to 1.9 ± 0.3 mM in 50% SW and dropped to 1.1 ± 0.3 mM in 200% SW. Hematosomatic index and muscle water content values are presented in Table 5. HSI was lower in 150% SW (1.08 ± 0.04%) and 200% SW (0.99%) than SW (1.35 ± 0.11%), 50% SW (1.24 ± 0.06%) and 100% SW (1.24 ± 0.04%). Moisture decreased in 150% SW (80.85 ± 0.60%) and 200% SW (80.19 ± 0.64%); it was 81.68 ± 0.02% in SW.

DISCUSSION

Many authors found that fishes grew better in brackish water than fresh water and sea water (or salt water) (Vonck et al., 1998; Imsland et al., 2001; Rubio et al., 2005; Resley et al., 2006; Arjona et al., 2009; Imsland et al., 2008; Kangombe and Brown, 2008; Kearney et al., 2008; Luz et al., 2008; Overton et al., 2008; Mylonas et al., 2009). Two earlier studies showed that fishes growth rate was higher in fresh water than salt water (Wang et al., 1997; Altinok and Grizzle, 2001). Some studies presented the growth and physiology of Mozambique tilapia acclimated to salt water (Morgan et al., 1997; Vonck et al., 1998; Fiess et al., 2007) but there is limited information about blue tilapia exposed to salt water.

Scientists have been trying to understand how salinity affects fish growth and metabolism and whether it changes fish energetics or not. There is an accepted hypothesis that isosmotic water decreases use of energy for osmoregulation compared to fresh water and salt water. This saved energy is used for growth. Some studies indicates that rising salinity in fresh water increases growth rate in tilapia; (from 5 to 10 ppt) (Kangombe and Brown, 2008) (from 8 to 24 ppt) (Vonck et al., 1998) and some show that lowering salinity in marine enhances growth in turbot (from 32 to 15 ppt)

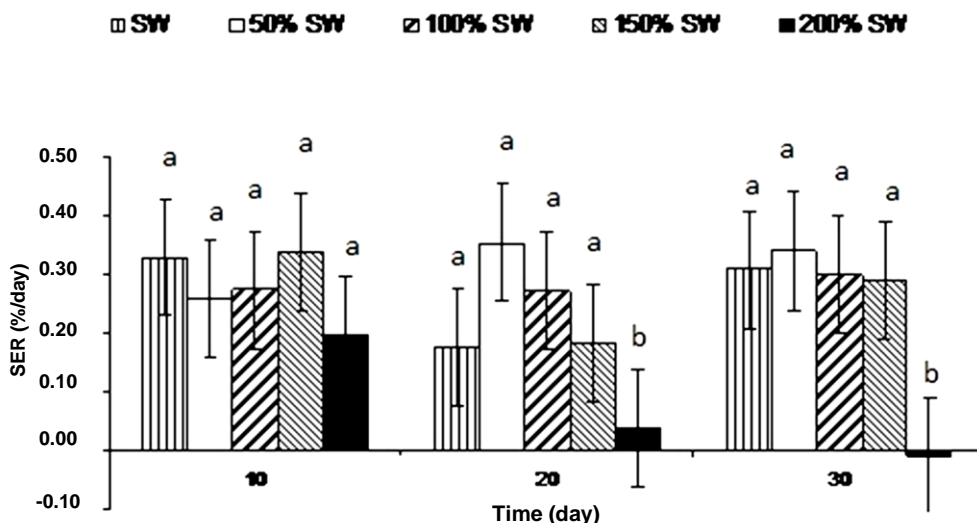


Figure 1. Tilapia specific growth rate (SGR) at five different salinities in 30 days.

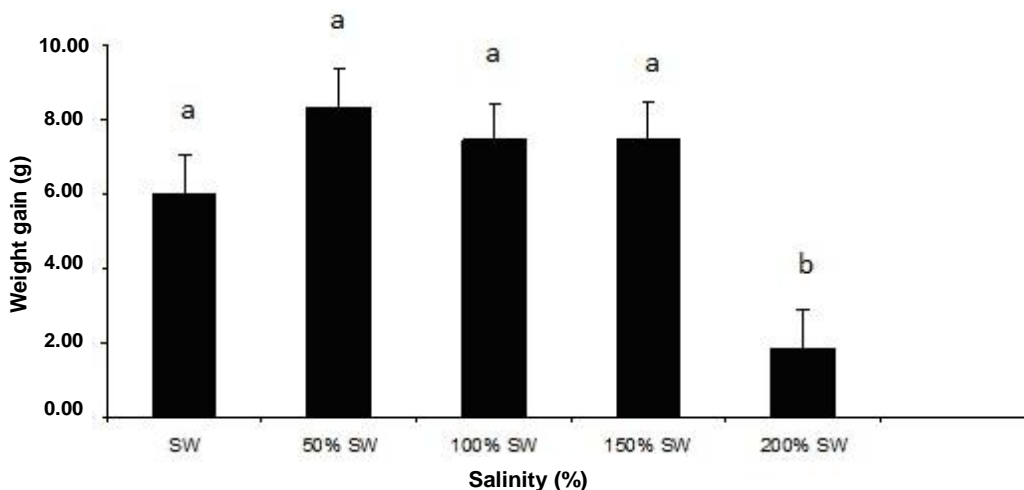


Figure 2. Tilapia weight gain at five different salinities in 30 days.

Table 4. Plasma sodium, chloride, potassium, glucose, total protein and triglycerides of tilapia in five different salinities (mean±SD) for 6 to 12 h.

Salinity	Sodium (mM)	Chloride (mM)	Potassium (mM)	Glucose (mM)	Total Protein (mM)	Triglycerides (mM)
SW	144.2 ± 6.4 ^a	124.5 ± 9.8 ^a	>10	6.1 ± 3.1 ^a	44.8 ± 5.8 ^{ab}	2.7 ± 0.7 ^a
50% SW	146.0 ± 6.2 ^a	124.8 ± 6.7 ^a	>10	7.0 ± 0.7 ^a	50.4 ± 5.3 ^a	1.9 ± 0.3 ^b
100% SW	158.5 ± 8.5 ^b	139.5 ± 8.0 ^b	>10	7.1 ± 2.4 ^a	40.0 ± 7.9 ^b	1.0 ± 0.5 ^c
150% SW	179.5 ± 10.6 ^c	149.8 ± 0.4 ^c	>10	6.8 ± 1.3 ^a	35.6 ± 8.9 ^b	1.1 ± 0.5 ^c
200% SW	184.0 ± 13.9 ^c	149.7 ± 0.8 ^c	>10	5.5 ± 0.7 ^a	35.7 ± 6.0 ^b	1.1 ± 0.3 ^c

(Imsland et al., 2008), in solea (39 to 15 ppt) (Arjona et al., 2009), in sea bass (from 25 to 0 ppt) (Rubio et al., 2005), and in cobia (from 30 to 5 ppt) (Resley et al., 2006). Although a numbers of studies has been done on this area, there is a confusion to determine or calculate

the cost of ion regulation. Earlier, energetic cost of osmoregulation was found very high (approximately 20 to 30%) in rainbow trout and tilapia (Rao, 1968; Farmer and Beamis, 1969) and in catfish (50%) (Furspan et al., 1984) in fresh water and salt water than in isosmotic waters.

Table 5. Hematosomatic index and moisture of of tilapia in the five different salinities (mean±SD) for 6 to 12 h.

Salinity	HSI (%)	Moisture (%)
SW	1.35 ± 0.11 ^a	81.68 ± 0.02 ^a
50% SW	1.24 ± 0.06 ^a	81.05 ± 0.49 ^a
100% SW	1.24 ± 0.04 ^a	80.85 ± 0.60 ^a
150% SW	1.08 ± 0.04 ^b	80.19 ± 0.64 ^b
200% SW	0.99 ± 0.01 ^b	80.52 ± 0.83 ^b

Energy expenditures for osmoregulation were supposed to be zero in isosmotic environments. However, latter on, required energy for ion regulation were found as 5.7% in rainbow trout and 12% (standard metabolism) in flounder in SW (Kirschner, 1993; Imsland et al., 2003) and <4% (total energy) in cutthroat (Morgan and Iwama, 1999) in FW and SW. Febry and Lutz (1987) indicated that methodology to estimate cost of osmoregulation should be controlled again. Further studies are needed to evaluate the accurate energy of osmoregulation in different salinities and determine optimal point for grow for the other species.

When environmental salinity changes, fish encounter morphological, biochemical and endocrinological alterations in the acclimation time. These variations result in modifications in oxygen consumption and energy demands (Morgan and Iwama, 1991) although both marine fish (<5 ppt) and fresh water fish (10 to 15 ppt) demonstrated high growth performance in intermediate salinities (Boeuf and Payan, 2001). Every fish species has its special optimum salinity ranges for growth. For instance, grass could be reared at salinities up to 9 ppt (Maceina and Shireman, 1980). Tilapia grew optimum in the range of 10 to 20 ppt (Suresh and Kwei-Lin, 1992). Turbot (*Scophthalmus maximus*) grew well at 18.5 ppt and 21.8°C (Imsland et al., 2001). Shortfin glass eels (*Anguilla australis*) were reared well at 17.5 ppt and 17.5 °C or 0 to 17.5 ppt and 26.5°C (Kearney et al., 2008). Eurasian perch (*Perca fluviatilis*) showed optimum of growth rate at 0 to 8 ppt salinities (Overton et al., 2008). Shi drum (*Umbrina cirrosa*) had high growth rate at 10 ppt salinity (Mylonas et al., 2009). This study showed that optimum (point for blue tilapia was 12 ppt of salinity).

Two studies indicate that tilapia grow better in brackish water and sea water than fresh water (Liao and Chang, 1983; Watanabe et al., 1988). Kangombe and Brown (2008) reported that tilapia, *Tilapia rendalli* had a high growth rate at 5 to 10 ppt. Vonck et al. (1998) determined that tilapia, *Oreochromis mossambicus* growth rate increased at 8 to 24 ppt. In our study, blue tilapia grew best in 50% SW (12 ppt) (SGR 0.95 ± 0.18% per day). Growth rate was lowest in the 200% SW (24 ppt) (SGR 0.23 ± 0.08% per day). Fish tolerate high level of salinity somehow but survival decreases as salinity increases. Kangombe and Brown (2008) reported that survival

reduced with salinity increase. In the present study, survival was high in SW (8 ppt) and 50% SW (12 ppt) treatments (94.4 ± 9.6 to 100 ± 0.0%). It decreased to 72.2 ± 19.2% in 100% (16 ppt) and 150% SW (20 ppt) treatments. It was surprisingly low in 200% SW (24 ppt) treatment.

Salinity increase influences blood chemistry (sodium, potassium, chloride, glucose, total protein, triglycerides) as well. Sodium concentration was 144.2, 146.0, 158.5, 179.5 and 184.0 mM in SW (8 ppt), 50% SW (12 ppt), 100% SW (16 ppt), 150% SW (20 ppt) and 200% SW (24 ppt), respectively. Chloride concentration was 124.5, 124.8, 139.5, 149.8 and 149.7 mM in SW (8 ppt), 50% SW (12 ppt), 100% SW (16 ppt), 150% SW (20 ppt) and 200% SW (24 ppt), respectively. Sodium and chloride concentrations instantly increased in 100% SW (16 ppt) and continued to increase in the upper salinities.

Morgan et al. (1997) reported that sodium and chloride ions showed similar patterns in mozambique tilapia. Sodium was about 136 mM in the FW and rised to about 155 mM and 170 mM in ISO (12 ppt) and 75% SW (25 ppt), respectively. Chloride increased around 165 mM in the 75% SW while it was about 140 mM in FW and ISO. Overton et al. (2008) also indicated that sodium and chloride concentrations increased at higher than 8 ppt. We found that potassium concentration remained unchanged in the fish exposed to the five different salinities. Potassium did not change significantly in mozambique tilapia, *O. mossambicus* (Morgan et al., 1997) in FW, ISO (12 ppt) and 75% SW (25 ppt), in perch, *Perca fluviatilis* (Overton et al., 2008) at 0 to 10 ppt and in shi drum, *Umbrina cirrosa* (Mylonas et al., 2009) at 4, 10, 40 ppt of salinity. Total protein and triglycerides and glucose in plasma are related to fish energy metabolism.

In the present study, there were no significant differences in the mean of plasma glucose concentration (around 5 to 7 mM) among the fish reared at all treatments. It may be due to the acclimatization of the fish to SW before the experiment started. Other studies (Morgan et al., 1997; Mylonas et al., 2009; Arjona et al., 2009) also found that glucose did not change during the salinity exposure. In this study, plasma triglycerides (2.7 ± 0.7 mM at 8 ppt) significantly decreased in parallel with increase in salinity (1.1 mM at 24 ppt). Mylonas et al.

(2009) found that triglycerides increased in shi drum at between 4 and 10 ppt (3.1 to 7.1 mM, respectively), but it decreased at 40 ppt (4.7 mM). On the contrary, Arjona et al. (2009) reported that plasma triglycerides increased in sole, *Solea senegalensis*. It reached from 2.8 to 10.7 mM at between 15 and 39 ppt.

Our findings show that high salinity caused alterations in muscle tissues, also. Hepatosomatic index and muscle moisture were significantly decreased in 150% SW and 200% SW. It reduced by 1.08 and 0.99% in 150% SW (20 ppt) and 200% SW (24 ppt), respectively, while it was by 1.35% in SW. On the other hand, HSI (mean 1.1%) did not change in sole (Arjona et al., 2009) at 15, 25, 39 ppt and in goldfish (Luz et al., 2008) at 0 to 10 ppt. Muscle water content showed a similar trend with HSI. It was 81.68% in the SW, but declined by 80.19 and 80.52% in 150 and 200% SW, respectively. Muscle moisture reduced in grass carp (Maceina and Shireman, 1979), in Mozambique tilapia at 10 to 20 ppt (Lee et al., 2005), in goldfish (Luz et al., 2008) at 10 ppt of salinity. However, muscle moisture (around 79 to 82%) did not change at 0 to 10 ppt of salinity (Overton et al., 2008).

Vertebrates have 9 g/L salt and pH 7.4 in their blood. About 77% of this salt consists of sodium and chloride ions. The remainder (23%) is composed of bicarbonate, potassium and calcium ions. Especially, sodium and potassium have an important role in heart, nerve and muscle functions. When fish starts losing salt from blood, higher energy is needed to replace it. It causes heart failure, nerve and muscle spasms. If the water has high bicarbonate alkalinity and calcium hardness, fish can be transferred easily from freshwater to seawater or from seawater to freshwater. It is reported that the ideal water condition for fish transportation is 100 to 200 mg/L as CaCO₃ of bicarbonate alkalinity, 125 to 250 mg/L as CaCO₃ of calcium hardness, pH of 7 to 8, and 8 g/L salt (Wurts, 1995). It also indicates that water having high calcium concentration sedates fish by decreasing ion loss (Wurts, 1998).

These values show that our water source has a characteristic ideal water condition for fish transport. The water source had high level of monovalent and divalent ions. It may be an ideal water at the level of isosmotic salinity for transport. Nowadays, brackish water is encouraged to be use in aquaculture because of the competitions between land and water use in agriculture. There are some fish species that have high potential for culturing because of high salinity tolerance capacity such as sea bream, sea bass, mullet, turbot, and tilapia. Especially, most of the tilapia species have high salinity tolerance capacity. Mozambique tilapia, *O. mossambicus* (42 ppt) (Stickney, 1986; Wang et al., 1997) has higher salinity tolerance for growth than blue tilapia, *Oreochromis aureus* and Nile tilapia, *Oreochromis niloticus* (20 ppt) (Nugon, 2003). Hybrids (20 to 30 ppt) (Avella and Doudet, 1996) that occurred by

crossbreeding between different tilapia species have high tolerance to salinity than their parents.

Conclusion

The present results show that environmental salinity influence the growth and metabolism of tilapia, *O. aureus* for 30 days. Optimum condition for farming tilapia is 12 ppt (isosmotic environments). Fishes exposed to 24 ppt of salinity were sturdily affected. The ability of tilapia to use environments at low salinities, up to isosmotic levels, makes it to be the candidate for growth in lagoons and estuaries. Thus, tilapia, *O. aureus* can be an alternative species in marine aquaculture.

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