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Impact of Different Salinity Levels on Growing Performance, Food Conversion and Meat Quality of Red Tilapia (*Oreochromis* sp.) Reared in Seawater Tanks

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Authors' Contribution
GA conceived the idea, designed the study and wrote the manuscript. AM did the experimental work. AG prepared the blood slides. SF analysed the data and LG edited the manuscript.

Key words
Red tilapia, Oreochromis, Growth, Feed efficiency, Salinity level, Adaptation.

ABSTRACT

The effect of varying salinity levels (15‰ to 40‰ with 5‰ increment) on growth, feed efficiency and meat quality of red tilapia, *Oreochromis* sp. (mean body weight 5±0.07g) were investigated. Juveniles of red tilapia were randomly distributed into seawater tanks (60 cm × 30 cm × 45 cm each). Ten fish were stocked in each tank with 2 replications. Fish were fed with commercial floating pellet (35% protein) at 3% body weight per day for 40 days. Results showed that fish growth was significantly ($P<0.05$) higher in term of weight gain, WG % of initial weight, mean daily WG, SGR, feed conversion and survival rate from 15‰ to 30‰ salinity than those reared in 35‰ and 40‰ salinity. Condition factor was found to be significantly higher on 40‰ salinity than 15‰ to 35‰ salinity. Feed conversion ratio remained non-significant in all salinity levels. Present study proves that red tilapia can be reared up to 30‰ salinity to get optimum growth and maximum survival rate. Biochemical analysis of fish meat showed that moisture, protein, lipid, ash and crude fiber were not significantly ($P>0.05$) affected by salinity level. The hematological parameters like hematocrit, cholesterol and plasma triglycerides were similar among fish fed on different salinity level ($P < 0.05$).

INTRODUCTION

Salt concentration (salinity) is considered as the most important environmental factor which affects the growth performance of numerous fish species cultured in seawater ponds and cages (Cruz *et al.*, 1990; Watanabe *et al.*, 1990; Naylor *et al.*, 2000; Cressey, 2009; Ferreira *et al.*, 2009; Martins *et al.*, 2010; FAO, 2014; Cao *et al.*, 2015). Salt control in these culture systems is a serious task for maintaining life in all higher organisms like bony fish including tilapia or cichlids. Cichlid have shown acceptance for rearing and spawning in brackish or seawater environment (Lim and Webster, 2008). Due to shortage of freshwater in the biosphere, it would be helpful to raise tilapia stocks in brackish or seawater environments to certify a source of low-priced and high-quality protein (animal origin) for future (Ng and Romano, 2013; Saikia and Das, 2015). Therefore, tilapias may be suitable to reduce pressure on wild fish stocks (Dey, 2000; Ponzoni *et al.*, 2011; Nguyen, 2015; Yue *et al.*, 2016; Fitzsimmons, 2016). Cultivated tilapias attained marketable size from 600 g to 1000 g in 180-270 days of culture period, respectively. Due to these characters tilapias have been cultivated in 120 countries (Lim and Webster, 2008).

Red tilapia is gaining more popularity among fish culturist as its growth is excellent in brackish water and even in seawater (Stickney 1986; Daudpota *et al.*, 2016). However, the data regarding salinity effect on its growth is scarce. The current research reports optimum salinity for desired growth, feed efficiency, adaptation and survival of red tilapia in captivity.

MATERIALS AND METHODS

Fingerlings of Red tilapia, *Oreochromis* sp. (mean body weight 5±0.07g and mean total length 16.2±0.4 cm) were collected from Sun-bright Red Tilapia and Ornamental Fish Hatchery. Subsequently, they were transported into Aquaculture Research Laboratory of Centre of Excellence

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in Marine Biology, University of Karachi. They were acclimated for one week and then stocked into seawater tanks (60 cm × 30 cm × 45 cm; 10 fish per tank.) at different salinity levels of 15‰, 20‰, 25‰, 30‰, 35‰ and 40‰ with 2 replications. All tanks were well aerated throughout the experimental period. Artificial floating pelleted feed (35% crude protein, 5.8% crude fat, 6.7% crude fiber, 9.8% moisture and 8.4% ash) was purchased from Oryza Organic Private Limited, Lahore. Fish were fed at 3% of total biomass two time daily (9:00 and 16:00). Body weight and total length of individual fish was noted weekly and the amount of ration to be supplied to fish was then adjusted. Siphoning of each tank was done after 1 h feeding to remove waste material from bottom and new water was added to maintain required water level. Finally, growth performance and food conversion of fish juveniles were calculated by using the following formulae (Abbas and Siddiqui, 2013; Daudpota *et al*., 2016):

$$\text{WG} = \text{Mean FW} - \text{Mean IW}$$

$$\text{MDWG} = \frac{\text{Fresh WG in fish (g)}}{\text{Culture period (days)}}$$

$$\text{WG \% of IW} = 100 \times \frac{\text{FW} - \text{IW}}{\text{IW}}$$

$$\text{FCR} = \frac{\text{Diet given}}{\text{WG}}$$

$$\text{CF} = \frac{\text{FW}}{\text{Final length}^3} \times 100$$

$$\text{SGR} = \frac{\text{Ln FW} - \text{Ln IW}}{\text{Culture period (days)}} \times 100$$

$$\text{SR\%} = 100 \times \frac{\text{Final No. of fish}}{\text{Initial No. of fish}}$$

Where, WG is weight gain, FW is final weight, IW is initial weight, MDWG is mean daily weight gain, FCR is feed conversion ratio, CF is condition factor, SGR is specific growth rate and SR is survival rate.

Water quality parameters such as temperature, pH, dissolved oxygen (DO) and ammonia were monitored throughout the study period. Temperature of the water was noted on daily basis by thermometer. DO of the water was noticed with the help of portable test kit (Merck KGaA, 64271, Germany). The pH of tank water was determined by using pH meter (EzDO 6011, Taiwan). Ammonia was determined with portable test kits (Merck KGaA, 64271, Germany) and salinity was observed by hand -held refractometer (ATAGO, S/Mill-E, 0.100%, made in Japan) on daily basis.

At the end of the trial, fish meat was stored at -20°C for biochemical analysis (AOAC, 2000). Blood samples (1.50 ml) were taken from caudal vein of each fish by using anticoagulant (EDTA, 1 mg/ml) and without it as well. The plasma constituents were determined by using the calorimetric methods of the Boehringer Corp as described by Papoutsoglou and Voutsinos (1988).

Data regarding weight and length increment, survival and biochemical constituents were statistically analyzed (Zar, 1996) by using statistical software Minitab 17.

RESULTS

The growth of red tilapia (*Oreochromis* sp.) fingerlings in term of WG and SGR was significantly ($P<0.05$) higher at 15‰ to 30‰ salinity levels than of those reared at 35‰ and 40‰ salinity (Table I). Similar trend was found for FCR and SR of the fish. FCR was more or less similar ($P<0.05$) at all salinity levels (Table I). Condition factor (CF) of the fish was found to be significantly ($P<0.05$) higher at 40‰ than those of 15‰ to 35‰. Relationship of mean fish weight was significantly ($P<0.05$) higher at 15‰ to 30‰ than 35‰ and 40‰ salinity levels (Fig. 1). Water quality parameters like pH, temperature, ammonia and dissolved oxygen were monitored daily throughout the experimental period. These parameters were within the acceptable range: water temperature was 28.32±0.09°C, DO was 7.35±0.11 mg/L, water pH was 7.8±0.11 and ammonia never exceeded 0.023±0.005 mg/L (Table II). Relationship between body weight and total length of the present study shows that red tilapia fingerlings reared at 15‰, 20‰, 25‰ and 30‰ was significantly ($P<0.05$) higher than 35% and 40% salinity levels (Fig. 2). Moisture, ash and protein contents of the cultured fish meat was not

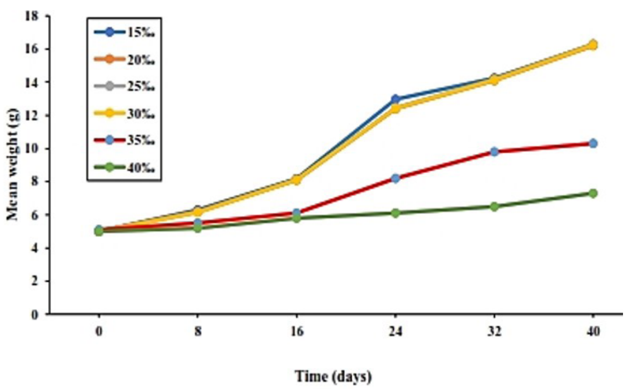

Fig. 1. Relationship between mean fish weight and time for fish reared at different salinity level.

Table I.- Growth parameters of red tilapia (*Oreochromis* sp.) reared at different salinity level for 40 days.

Parameters	Salinity level (‰)					
	15	20	25	30	35	40
IW(g)	5.0±0.07^{a}	5.0±0.05^{a}	5.0±0.04^{a}	5.0±0.07^{a}	5.1±0.6^{a}	5±0.05a
FW (g)	16.26±0.4^{a}	16.2±0.2^{a}	16.3±0.2^{a}	16.24±0.3^{a}	10.3±0.02^{b}	7.3±0.03^{b}
IL (cm)	6.44±0.05^{a}	6.48±0.08^{a}	6.48±0.08^{a}	6.48±0.07^{a}	6.4±0.02^{b}	6.4±0.01^{b}
FL (cm)	11.74±0.2^{a}	11.68±0.14^{a}	11.66±0.15^{a}	11.74±0.13^{a}	9.4±0.01^{b}	6.9±0.02^{b}
WG	11.26±0.01^{a}	11.3±0.07^{a}	11.3±0.01^{a}	11.24±0.03^{a}	5.2±0.03^{b}	2.3±0.02^{b}
WG % of IW	225.2±0.14^{a}	224±0.71^{a}	226±0.71^{a}	224.8±0.56^{a}	101.9±2.3^{b}	46±1.4^{b}
MDWG	0.28±0.001^{a}	0.28±0.002^{a}	0.28±0.001^{a}	0.28±0.002^{a}	0.13±0.001^{b}	0.06±0.002^{b}
SGR	2.95±0.02^{a}	2.94±0.01^{a}	2.95±0.01^{a}	2.94±0.06^{a}	[illegible]	0.95±0.02^{b}
FCR	0.7±0.06^{a}	0.7±0.04^{a}	0.7±0.06^{a}	0.8±0.06^{b}	[illegible]	0.7±0.04^{a}
FCE	2.5±0.02^{a}	2.5±0.02^{a}	2.5±0.02^{a}	[illegible]	[illegible]	0.83±0.01^{b}
SR (%)	100±0.0^{a}	100±0.0^{a}	100±0.0^{a}	[illegible]	95±0.1^{b}	90±0.3^{b}
CF	1±0.01^{a}	1.02±0.02^{a}	1.03±0.01^{a}	[illegible]	[illegible]	2.2±0.02^{a}

Values of the same row carrying the same superscripts are not statically significant (P> 0.05). IW, initial weight; FW, final weight; IL, initial length; FL, final length; WG, weight gain; MDWG, mean daily weight gain; SGR, specific growth rate; FCR, food conversion ratio; FCE, food conversion efficiency; SR, survival rate; CF, condition factor.

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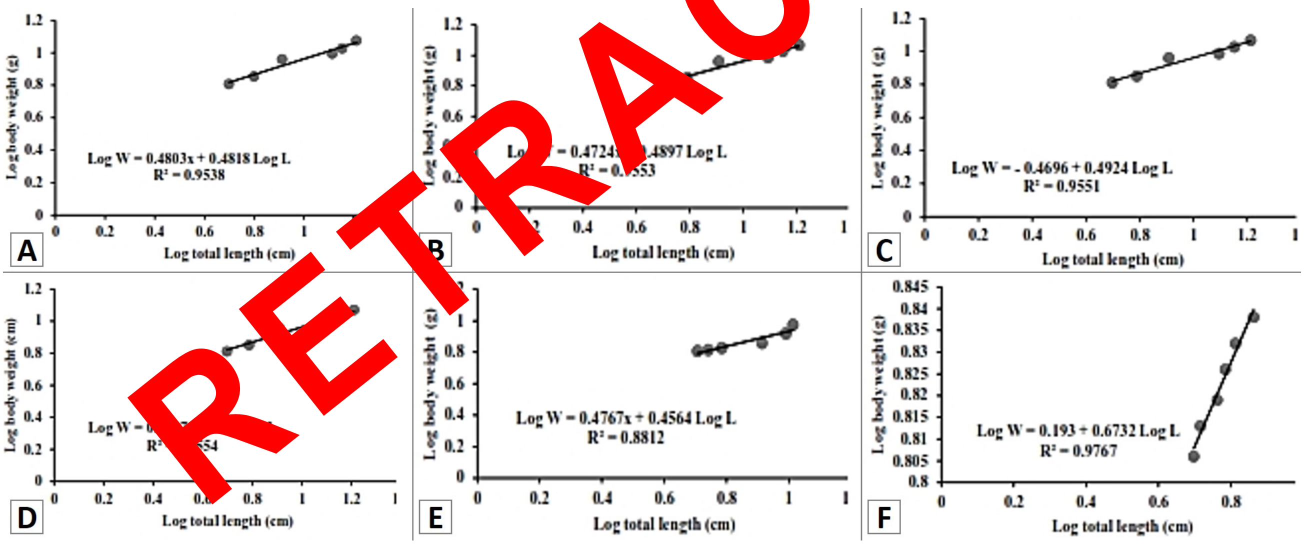

Fig. 2. Length-weight relationship of red tilapia fingerlings *Oreochromis* sp. reared on different salinity levels (A, 15‰; B, 20‰; C, 25‰; D, 30‰; E, 35‰; F, 40‰).

affected ($P > 0.05$) by the salinity levels (Table III). No statistically important differences were observed between groups regarding the cholesterol level, plasma triglycerides and hematocrit values ($P > 0.05$; Table IV, Fig. 3).

DISCUSSION

In the present study, the salinity level of 30‰ was adequate to optimize WG, SGR, CF and survival rate in fingerling red tilapia growing from 5 g to 16.3 g. SGR of the fish was higher at 15‰, 20‰, 25‰ and 30‰ than reported by other researchers. For instance, Rahim *et al.* (2017) found SGR=3.21% while using fish oil, soybean oil, olive oil and palm oil in the diet of black fin sea bream (*Acanthopagrus berda*). These observations are higher than those of the present study (SGR: 2.82%-2.83%). Furthermore, Kapute *et al.* (2016) achieved maximum results *i.e.,* 1.8 for *Tilapia rendalli* in pond (200 m^2). In addition, Abbas and Siddiqui (2009) reported SGR 0.9 % to 2.2 % at different feeding levels of mangrove red snapper (*Lutjanus argentimaculatus*). Solomon and Okomoda (2012) found that SGR of *Oreochromis niloticus* ranged from 0.65 % to 1.4 % as different duckweed percentages were used in artificial feed. Daudpota *et al.* (2016) documented SGR of 2.1%-2.2% in comparative study of tilapia *Oreochromis* species. In another study of Daudpota *et al.* (2014), red tilapia showed SGR values ranging from 1.46%-1.69% on different stocking densities.

Table II.- Water quality parameters recorded at different salinity levels with mean values and standard error throughout the study period of 40 days.

Salinity (%)	Temperature (°C)	DO (mg/L)	pH	Ammonia (mg/L)
15	28.3	7.4	7.8	0.02
20	28.2	7.5	7.9	0.02
25	28.4	7.4	7.6	0.02
30	28.4	7.3	7.8	0.02
35	28.2	7.2	7.9	0.03
40	28.4	7.3	7.8	0.03
Mean	28.32	7.35	7.8	0.023
SE±	0.09	0.11	0.11	0.005

In the present study, WG of the fish was higher than documented by various researchers. Solomon and Okomoda (2012) reported gain in weight from 1.56 g to 1.92 g of *Oreochromis niloticus* when duckweed was included in its diet with different concentration. Daudpota *et al.* (2016) found WG from 2.5 g to [illegible] g of Nile tilapia. FCR of the fish was 0.7-0.8 at all salinity levels. Similar results have been reported in other fish, such as black fin sea bream *Acanthopagrus berda* ([illegible]him *et al.* (2017a,b,c), red tilapia *Oreochromis* sp. (Daudpota *et al.*, 2014 and 2016), Nile tilapia *O. niloticus* (Solomon and Okomoda, 2012).

In artificial fish farming system, water quality parameters are directly affected by fish metabolism and feeding efficiency as well (Ertan *et al.*, 2015; Kapute *et al.*, 2016). In this study, water quality parameters were within the acceptable range for fish farming (Daudpota *et al.*, 2014; Malik *et al.*, 2014; Iqbal *et al.*, 2014; Emmanuel *et al.*, 2014; Shah *et al.*, 2014 and Chugtai *et al.*,2015).

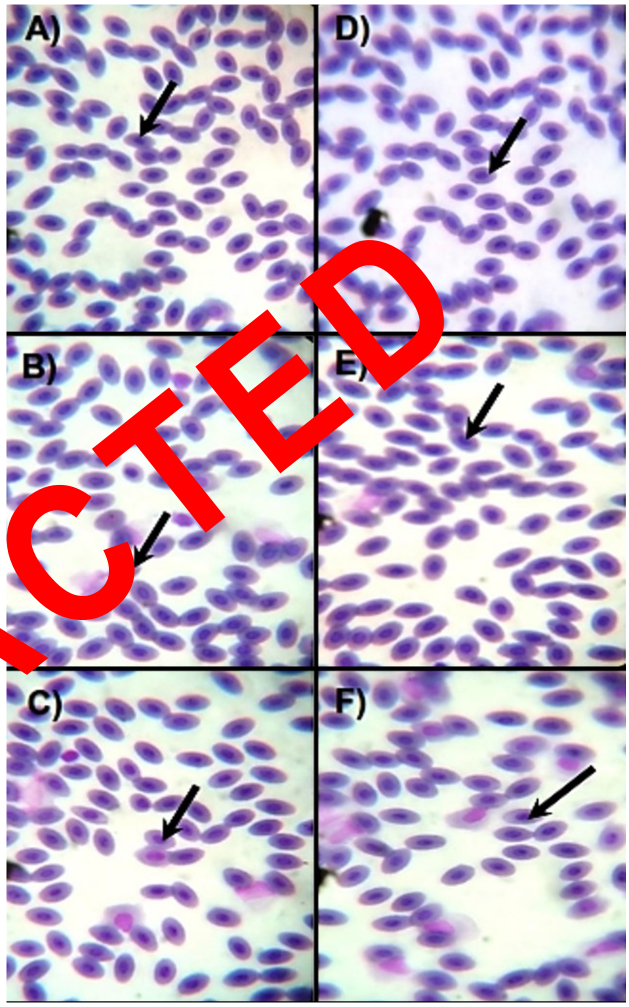

Fig. 3. Blood smear of red tilapia fingerlings *Oreochromis* sp. reared on different salinity levels (A, 15‰; B, 20‰; C, 25‰; D, 30‰; E, 35‰; F, 40‰). Arrow, micronucleus (Giemsa stained: 1000X).

Table III.- Biochemical composition of Red tilapia hybrid (*Oreochromis* sp.) reared in glass tanks for the period of 40 days.

	Salinity level (‰)						
	Initial	15	20	25	30	35	40
Crude protein (%)	16.21±0.1[a]	17.16±0.2[a]	17.23±0.3[a]	17.18±0.4[a]	17.26±0.3[a]	17.23±0.2[a]	17.21±0.2[a]
Moisture (%)	70.57±0.1[a]	71.16±0.2[a]	71.23±0.3[a]	71.18±0.4[a]	71.26±0.3[a]	71.23±0.2[a]	71.21±0.2[a]
Lipid (%)	2.49±0.3[a]	2.52±0.2[a]	2.50±0.1[a]	2.51±0.2[a]	2.49±0.2[a]	2.50±0.1[a]	2.48±0.1[a]
Ash (%)	4.13±0.4[a]	4.18±0.3[a]	4.18±0.4[a]	4.17±0.4[a]	4.17±0.4[a]	4.16±0.4[a]	4.16±0.1[a]
Crude fiber (%)	2.04±0.1[a]	2.04±0.1[a]	2.65±0.1[a]	2.63±0.1[a]	2.66±0.1[a]	2.58±0.3[a]	2.57±0.1[a]

Table IV.- Hematological parameters of juvenile red tilapia fed at different salinity levels for 40 days.

Parameters	Salinity level (‰)					
	15	20	25	30	35	40
Haematocrit[1]	42.2±3.1[a]	42.3±6.2[a]	43.3±4.3[a]	43.1±3.1[a]	43.2±6.2[a]	43.4±5.2[a]
Total lipids[2]	1385.3±67.1[a]	1369.8±58.2[a]	1322.4±56.6[a]	1353.6±60.6[ab]	1383.5±52.2[a]	1371.2±49.9[a]
Triglycerides[2]	163.4±55.0[a]	166.2±56.1[a]	169.4±55.6[a]	167.8±52.1[a]	165.5±58.2[a]	169.1±56.0[a]
Cholesterol[2]	151.0±40.3[a]	155.1±48.2[a]	156.9±46.2[a]	154.8±50.4[a]	153.7±51.5[a]	154.1±52.0[a]

[1]Measured as %; [2]Measured as mg 100 ml^{-1}; Values (mean ± SE, n = 3) in the same row with similar superscripts are not significantly different (P > 0.05); Initial fish blood analysis: hematocrit 42.6%, total plasma lipids 1485.2 mg 100 ml^{-1}, triglycerides 166.9 mg 100 ml^{-1} and cholesterol 149.9 mg 100 ml^{-1}.

Generally, blood is considered as a tool for the transportation of nutrients, metabolites and inorganic ions (Abbas and Siddiqui, 2009). In the present study, all fishes were found to be healthy over the duration of the experiment and the values of the haematocrit were in normal range. Evidence to support this is available in another study of Papotsoglou and Voutsinos (1988). Similar individual tendency has been reported in rainbow trout *Salmo gairdneri* (Papoutsoglou and Papaparaskeva-Papoutsoglou, 1979; Hile 1982; Papoutsoglou and Voutsinos, 1988), mangrove red snapper Lutjanus argentimaculatus (Abbas and Siddiqui, 2013) and red-spotted grouper *Epinephelus akaara* (Kayano *et al*., 1993; Kang'ombe and Brown, 2008). In most of the above studies, great differences in plasma lipids and cholesterol levels were observed among groups for chemically different foods. In this study, salinity level did not cause any significant differentiation in the amount of these hematological parameters.

In conclusion, the growth performance, adaptation and survival of red tilapia was higher up to salinity level of 30‰ than 35‰ and 40‰. On the basis of these results, this specie can be recommended for coastal aquaculture or inland saline water areas to promote the brackish/ saline water aquaculture of Pakistan.

CONCLUSION

It is concluded that red tilapia fingerlings can be reared up to 30% salinity level it would be more productive for saline areas as well as coastal fish culturist.

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Statement of conflict of interest

Authors have declared no conflict of interest.

REFERENCES

Abbas, G. and Siddiqui, P.J.A., 2009. Effects of different feeding level on the growth, feed efficiency and body composition of juvenile mangrove red snapper, *Lutjanus argentimaculatus* (Forsskal 1775). *Aquacul. Res.*, **40**: 781−789. https://doi.org/10.1111/j.1365-2109.2008.02161.x

Abbas, G. and Siddiqui, P.J.A., 2013. The effects of varying dietary protein level on growth, feed conversion, body composition and apparent digestibility coefficient of juvenile mangrove red snapper, *Lutjanus argentimaculatus* (Forsskal 1775). *Aquacul. Res.*, **44**: 807−818. https://doi.org/10.1111/j.1365-2109.2012.03096.x

AOAC., 2000. *Official methods of analysis of association of official analytical chemists*. 17th edn. Association of Official Analytical Chemists, Arlington, USA.

Cao, L., Naylor, R., Henriksson, P., Leadbitter, D. and Metian, M., 2015. China's aquaculture and the world's wild fisheries. *Science*, **347**: 133-135. https://doi.org/10.1126/science.1260149

Chughtai, M.I., Mahmood, K. and Awan, A.R., 2015. Growth performance of carp species fed on salt-tolerant roughages and formulated feed in brackish water under polyculture system, *Pakistan J. Zool*., **47**: 775-781.

Cressey, D., 2009. Aquaculture: future fish. *Nature,* **458**: 398-400. https://doi.org/10.1038/458398a

Cruz, E.M., Rhidha, M. and Abdullah, M.S., 1990. Production of African freshwater tilapia *O. spilurus* (Gunther) in seawater. *Aquaculture*, **84**: 41–48.

https://doi.org/10.1016/0044-8486(90)90298-2
Daudpota, A.M., Abbas, G., Kalhoro, I.B., Shah, S.S.A., Kalhoro, H., Rehman M.H. and Gaffar, A., 2016. Effect of feeding frequency on growth performance, feed utilization and body composition of Nile tilapia, *Oreochromis niloticus,* cultured in low salinity water. *Pakistan J. Zool.* **48**: 171-177.
Daudpota, A.M., Siddiqui, P.J.A., Abbas, G., Narejo, N.T., Shah, S.S.A., Khan, N. and Dastagir, G., 2014. Effect of dietary protein level on growth performance, protein utilization and body composition of Nile tilapia cultured in low salinity water. *Int. J. Int. Mult. Stud.,* **2**: 135-147.
Dey, M.M., 2000. The impact of genetically improved farmed Nile tilapia in Asia. *Aquacul. Econ. Manage.,* **4**: 107-124. https://doi.org/10.1080/13657300009380263
Emmanuel, T.D.M., Felix, K.Y.A. and Ken, A., 2014. Comparative growth study of *Oreochromis niloticus* and *Sarotherodon galilaeus* under two different culture regimes (Hapa-In-Pond and cage systems). *Int. J. Fish. aquat. Stud*., **1**: 53-59.
Ertan, E., Agrah, N. and Tarkan, A.S., 2015. The effects of salinity, temperature and feed ratio on growth performance of European sea bass (*Dicentrarchus labrax* L., 1758) in the water obtained through reverse osmosis system and a natural river. *Pakistan J. Zool*., **47**: 625-633.
FAO, 2014. *The state of world fisheries and aquaculture*. Rome, pp. 223.
Ferreira, J.G., Sequeira, A., Hawkins, A.J.S., Newton, A. and Nickell, T.D., 2009. Analysis of coastal and offshore aquaculture: Application of the FARM model to multiple systems and shellfish species. *Aquaculture,* **289**: 32-41. https://doi.org/10.1016/j.aquaculture.2008.12.017
Abbas, G. and Siddiqui, P.J.A., 2009. Effect of Different feeding levels on the growth, feed efficiency abd boday composition of juvenile mangrove red snapper, *Lutjanus argentimaculatus* (Forsskal 1775). *Aquacul. Res.,* **40**: 781-789. https://doi.org/10.1111/j.1365-2109.2008.02161.x
Hile, S., 1982. A literature review of the blood chemistry of rainbow trout, *Salmo gairdneri*, rich. *J. Fish Biol.,* **20**: 535–569. https://doi.org/10.1111/j.1095-8649.1982.tb03954.x
Iqbal, R., Ali, M., Narejo, N.T. and Umar, K., 2014. Effect of varying levels of protein from different animal sources on growth and survival of carp, *Cirrhinus mrigala*, reared in cemented cisterns. *Pakistan J. Zool*., **46**: 1599-1604.
Kang'ombe, J. and Brown, J.A., 2008. Effect of salinity on growth, feed utilization, and survival of *Tilapia rendalli*, under laboratory conditions. *J. appl. Aquacul.*, **20**: 256-271.
Kapute, F., Valeta, J., Likongwe, J., Kang'ombe, J., Nagoli, J. and Mbamba, D., 2016. Growth performance of three tilapia fish species raised at varied pond sizes and water depths. *Int. J. Fish. Aquacul.,* **8**: 81-86. https://doi.org/10.5897/IJFA2016.0566
Kayano, Y., Yao, S., Yamamoto, S. and Nakagawa, H., 1993. Effects of feeding frequency on the growth and body constituents of young red-spotted grouper, *Epinephelus akaara. Aquaculture,* **110**: 271-278. https://doi.org/10.1016/0044-8486(93)90375-9
Lim, C. and Webster, C.D., 2008. Tilapia: biology, culture and nutrition. *Afri. aquat. Sci.*, **33**: 103-103.
Malik, A., Waryani, B., Kalhor, I.B., Kalhoro, H., Shah, S.A. and Narejo, N.T., 2014. To observe the effect of growth performance and adaptation of exotic fish red tilapia (hybrid) in climate of Fish Hatchery Chilya, Thatta, Sindh-Pakistan. *Sindh Univ. Res. J. (Sci. Ser.),* **46**: 461- 464.
Martins, C.I.M., Eding, E.H., Verdegem, M.C.J., Heinsbroek, L.T.N. and Schneider, O., 2010. New developments in recirculating aquaculture systems in Europe: A perspective on environmental sustainability. *Aquacul. Engin.,* **43**: 83-93. https://doi.org/10.1016/j.aquaeng.2010.09.002
Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky, N. and Beveridge, M.C.M., 2000. Effect of aquaculture on world fish supplies. *Nature,* **405**: 1017-1024. https://doi.org/10.1038/35016500
Ng, W.K. and Romano, N., 2013. A review of the nutrition and feeding management of farmed tilapia throughout the culture cycle. *Rev. Aquacul.,* **5**: 220-254. https://doi.org/10.1111/raq.12014
Nguyen, N.H., 2015. Genetic improvement for important farmed aquaculture species with a reference to carp, tilapia and prawns in Asia: achievements, lessons and challenges. *Fish Fisher.,* **17**: 483-506. https://doi.org/10.1111/faf.12122
OECD/FAO, 2015. *Agricultural outlook 2015*. OECD Publishing, Paris, pp. 143.
Papoutsoglou, S.E. and Papaparaskeva-Papoutsoglou, E., 1979. Further observations on haematological and liver characteristics of farmed rainbow trout (*S. gairdneri* R.). *Thalassographica,* **3**: 21–34.
Papoutsoglou, S.E. and Voutsinos, G.A., 1988. Influence of feeding level on growth rate of *Tilapia aureus* (Steindachner) reared in a closed circulated system. *Aquacul. Fish. Manage.,* **19**: 291–298. https://doi.org/10.1111/j.1365-2109.1988.tb00432.x

Ponzoni, R.W., Nguyen, H.N., Khaw, H.L., Hamzah, A. and Abu-Bakar, K.R., 2011. Genetic improvement of Nile tilapia (*Oreochromis niloticus*) with special reference to the work conducted by the World Fish Center with the GIFT strain. *Rev. Aquacul.*, **3**: 27-41. https://doi.org/10.1111/j.1753-5131.2010.01041.x

Rahim, A., Abbas, G., Gallus, L., Ferrando, S., Hafeez-ur-Rehman, M., Ghaffar, A. and Mateen, A., 2017a. Effect of ration level and feeding frequency on growth, nutrient utilization and body composition of juvenile black fin sea bream, *Acanthopagrus berda* (Forsskal 1775). *Pakistan J. Zool*., **49**: 557-563.

Rahim, A., Abbas, G., Naeem, M., Ferrando, S., Gallus, L., Hafeez-ur-Rehman, M., Ghaffar, A. and Mateen, A., 2017b. Effect of different oils on growth, feed conversion and body composition of juvenile black fin sea bream, *Acanthopagrus berda* (Forsskal 1775). *Pakistan J. Zool*., **49**: 655-661. https://doi.org/10.17582/journal.pjz/2017.49.2.655.661

Saikia, S.K. and Das, D.N., 2015. Sustainable aquaculture: Agro-ecological role of and global overview. FAO, Rome, Italy. Periphyton in rice fish farming. *Rev. Aquacul.,* **7**: 172-186. https://doi.org/10.1111/raq.12062

Shah, S.A., Malik, A., Kalhoro, H., Kalhoro, I.B., Wadhar G.M. and Maher, G.M., 2014. Growth performance of exotic catfish Pangas, *Pangasius hypophthalmus* (Sauvage, 1878) at Fish Hatchery Chilya Thatta, Sindh, Pakistan. *Sindh Univ. Res. J. (Sci. Ser.),* **46**: 205-208.

Solomon S.G. and Okomoda, V.T., 2012. Growth performance of *Oreochromis niloticus* fed duckweed (*Lemna minor*) based diet in outdoor hapas. *Int. J. Res. Fish. Aquacul.,* **2**: 61-65.

Stickney, R.R., 1986. A review of tilapia salinity tolerance. *Progr. Fish-Cultur.*, **48**: 161-167. https://doi.org/10.1577/1548-8640(1986)48<161:TTOSW>2.0.CO;2

Watanabe, W.O., Clark, J.H., Dunham, J.B., Wicklund, R.I. and Olla. B.L., 1990. Culture of Florida red tilapia in marine cages: The effect of stocking density and dietary protein on growth. *Aquaculture,* **90**: 123–134. https://doi.org/10.1016/0044-8486(90)90336-L

Yue, G.H., Lin, H.R. and Li, J.L., 2016. Tilapia is the fish for next generation aquaculture. *Int. J. Mar. Sci. Ocean Technol*., **3**:11-13.

Zar, J.H., 1996. *Bio-statistical analysis*. Prentice-Hall Inc., New Jersey, pp. 662.