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Effects of yeast (*Saccharomyces cerevisiae*) on growth performances, body composition and blood chemistry of Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758) under different salinity conditions

Sutthi N.[1*]; Thaimuangphol W. [1]

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Abstract

The growth performance, body composition and blood chemistry of Nile tilapia (*Oreochromis niloticus*) reared under different salinities (0 ppt, 5 ppt, 10 ppt and 20 ppt) and different diets (0.5% yeast [*Saccharomyces cerevisiae*] supplement diet and basal diet) were investigated during 90 days. Fish fed with yeast supplement diet and reared at 5 ppt water salinity showed significantly improved (p<0.05) growth performances as weight gain (WG), specific growth rate (SGR) and average daily growth gain (ADG) compared to fish fed with basal diet. Feed conversion ratio (FCR) of fish fed with yeast supplement diet reared at all salinity levels (0, 5 and 10 ppt) was significantly lower than fish fed with basal diet (p<0.05). Cortisol levels of fish fed with yeast supplement diet were significantly lower than those of the basal diet group at 10 ppt (p<0.05). Both fish groups showed significant increases in cortisol and malondialdehyde (MDA) levels at salinity of 10 ppt compared to fish reared at 0 and 5 ppt (p<0.05). Crude protein content of fish fed with yeast supplement diet and reared at salinity levels of 0 and 10 ppt was higher than those fed with basal diet (p<0.05). Fish fed with yeast supplement diet showed a decrease in crude lipid content under salinity regime up to 10 ppt (p<0.05). Thus, Nile tilapia fed with yeast supplement diet at 0.5% showed improved growth performance, body composition and blood chemistry under salinity treatments (0 ppt and 5 ppt).

Keywords: Yeast, Nile tilapia, Growth performances, Blood chemistry, Salinity

1-Department of Agricultural Technology, Faculty of Technology, Maha Sarakham University, Maha Sarakham 44150, Thailand

*Corresponding author's Email: nantaporn.s@msu.ac.th

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Introduction

Rising mean global temperatures are causing glaciers to retreat (Tandong *et al*., 2011). Global warming also directly reduces the area of inland water, especially during the summer season in Thailand. Maha Sarakham Province is located in the northeast of Thailand (16.0132° N, 103.1615° E) and a long period of warm dry weather resulted in a drought, with reservoir levels and irrigation systems severely affected (Office of Agricultural Economics, 2015). The area was declared a drought disaster zone. Drought conditions increase freshwater salinity because Maha Sarakham Province has approximately 2,848,000 ha of underground rock salt (Department of Mineral Resources, 2009). Soil salinity is a global threat to agricultural because it reduces plant growth (Yan *et al*., 2015). Soil salinity also has an adverse effect on freshwater fish growth. Tilapia are among the most important warm water fish species used for aquaculture production in Thailand, and Nile tilapia (*Oreochromis niloticus*) is the most popular with a yield of 205,896 tons in 2016 (Department of Fisheries, 2018). Tilapia can adapt to a wide range of environments (Charo-Karisa *et al*., 2006) and can be cultivated in brackish water after acclimatization (Dominguez *et al*., 2004). However, Nile tilapia (*O. niloticus*) acclimated and adapted to high water salinity with lower survival rates compared to blue tilapia (*Oreochromis aureus*) and *Oreochromis mossambicus* (Kamal and Mair, 2005). Salinity is an environmental factor that affects fish survival rates (Iqbal *et al*., 2012; Küçük *et al*., 2013), and brackish water results in low survival rates of Nile tilapia (*O. niloticus*) larvae sized 1-2 cm (Basuki and Rejeki, 2015). Some published evidence have been reported that Nile tilapia (*O. niloticus*) cannot tolerate salinities above 20 ppt (Baroiller *et al*., 2000) and showed skin lesions and body injuries (Ali *et al*., 2006). However, 100% survival rate of Nile tilapia fingerlings was recorded at 0 to 7 ppt salinity levels (Lawson and Anetekhai, 2011), with 81.67% at 15 ppt (Basuki and Rejeki, 2015). Thus, salinity is one environmental factors that influences survival rate and growth rate of different stages of Nile tilapia (*O. niloticus*) (Pongthana *et al*., 2010; El-Dahhar *et al*., 2011; Iqbal *et al*., 2012; Küçük *et al*., 2013; Moorman *et al*., 2014; Basuki and Rejeki, 2015). Salinity tolerance affected growth performance dependent on fish species and was strain-specific (Suresh and Lin, 1992; Garcia-Ulloa *et al*., 2001). Probiotics have now become commonplace in health-promoting 'functional foods' for improved growth in animal production (Irianto and Austin, 2002; Newaj-Fyzul *et al*., 2014) and yeast (*Saccharomyces cerevisiae*) is commonly used in animal feeds (Nalage *et al*., 2016). Yeast has high potential content of β-glucans, mannan oligosaccharides (MOS) and nucleic acid (Li and Gatlin, 2006; Refstie *et al*., 2010; Kühlwein *et al*., 2014) which improve growth, energy and high nutrient digestibility (Lara-Flores *et al*., 2003). Several previous reports have

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been stated that dietary supplements with MOS improved local velocity absorption surface in fish species such as *Oncorhynchus mykiss* (Staykov *et al*., 2007), *Sciaenops ocellatus* (Zhou *et al*., 2010), *Dicentrarchus labrax* (Torrecillas *et al*., 2007, 2011), *Sparus aurata* (Gültepe *et al*., 2011), *Carassius auratus gibelio* (Akrami *et al*., 2012) and *Channa striata* (Talpur *et al*., 2014). Suitable levels of yeast supplement concentrations ranged 0.1-1% of diet kg^{-1} but 0.5% of diet kg^{-1} optimized growth rate and immune response in fish (Ortuño *et al*., 2002; Mazurkiewicz *et al*., 2005; Abdel-Tawwab *et al*., 2008). Under stress conditions, probiotics can prevent and reduce harmful effects of various stressors and enhance the immune system (Taoka *et al*., 2006). Probiotics increased antioxidant status by ameliorating oxidative stress factors (Mohapatra *et al*., 2012) such as waterborne cadmium exposure (Zhai *et al*., 2017) and crowding stress (Reyes-Cerpa *et al*., 2018). Scant published evidence exists concerning fish cultured under salinity stress and fed with probiotics. Researches on Nile tilapia fed with the probiotic *Lactobacillus plantarum* at 10^{11} CFU ml^{-1} supplemented diet and cultured under 9-12 ppt salinity in a polyculture system with marine shrimp (*Litopenaeus vannamei*) have indicated that tilapia groups fed with a probiotic-supplemented diet had high potential for growth performance and survival rate under salinity stress. Here, effects of yeast supplement diet on growth performances, body composition and blood chemical analysis of Nile tilapia were evaluated under diverse salinity treatments.

Materials and methods

Supplemental diet preparation

Baker's yeast (*S. cerevisiae*) was obtained as a commercial preparation (Perfect®, Thailand). Procedures of feed preparation were modified from our previous reports (Sutthi *et al*., 2018b). Briefly, 0.5% yeast supplement diet was prepared from 5 g of baker's yeast mixed with 20 g of guar gum (pellet binder) and 1 kg of 32% protein commercial feed, then sprayed with water (10 ml kg^{-1} diet) and air dried. The pellets then have been coated with 4% agar solution at 10 ml kg^{-1} diet and air dried again (Panase *et al*., 2018). For the basal diet, the method also added guar gum with coating by 4% agar solution but without yeast supplement.

Fish and experimental design

Sex reversed (male) juveniles of Nile tilapia (*O. niloticus*) were obtained from Maha Sarakham Inland Fisheries Research and Development Center, Thailand. After acclimatization in 1,000 L of freshwater in fiberglass tanks for two weeks, healthy specimens with initial average weight of 7.51±0.26 g were randomly assigned into eighteen glass tanks (50×30×38 cm) with 10 fish in each tank. Rock salt from Maha Sarakham Province was used to prepare stock water salinity at 0, 5 and 10 ppt, measured using a salinity meter. Treatments were performed for three different salinities (0, 5 and 10 ppt) and two diet groups as (1) 0.5% yeast

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supplement diet, and (2) basal diet, with three replications. Fish were fed twice per day at 3% of body weight throughout the 90-days' experimental period (Panase *et al*., 2018). Water was changed every week for all treatments and the three different salinity levels were maintained. Water quality parameters as temperature, dissolved oxygen and pH were measured using a CyberScan PC 650 (Eutech Instruments, Singapore) and total ammonia nitrogen (TAN) content was assessed using a test kit (Tetra®, Germany).

Sampling and analyses of biochemical parameters

After 90 days, the fish were anesthetized by clove oil (5 ml L^{-1}) and blood samples were collected from the caudal vein following Van Doan *et al*. (2018) method. Collected blood was immediately transferred into two tubes as (1) sterile Eppendorf tubes without anticoagulant for keeping serum, and (2) anticoagulant (EDTA) tubes for collected plasma. Blood samples in Eppendorf tubes were allowed to clot (1 h at room temperature and 4 h at 4 °C) and then centrifuged at 5000×g, 10 min, at 4 °C. All serums were stored at -20 °C until required for use, while plasma was separated from blood using anticoagulant (EDTA) tubes by centrifugation at 1.500×g, 10 min, at 4 °C and stored in a cryotube at -20 °C (Beheshtipour, 2019).

Blood biochemical analysis

Serum aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were detected using commercial reagent kits (AST/GOT Liqui-UV® and ALT/GOT Liqui-UV®, Stanbio, USA, respectively). AST and ALT concentration levels (units L^{-1}) determined with kinetic assay using a TC6060L fully automated Chemistry Analyzer (Tecom Science Co., Ltd., China). Glucose level has been detected using commercial reagent kits (Glucose LiquiColor®, Stanbio, USA), glucose concentration level (mg dl^{-1}) has been determined with end-point assay using a TC6060L fully automated Chemistry Analyzer (Tecom Science Co., Ltd., China). Serum cortisol level (µg dl^{-1}) has been determined using radioimmunoassay (RIA) with a cortisol test kit (Biogenetech, USA), and measured with an automatic gamma counter wizard 1470/2470 (Perkin Elmer, USA). Lipid peroxidation analysis to measure thiobarbituric acid reactive substances (TBARS) has been conducted to determine malondialdehyde (MDA) following our previous method (Sutthi *et al*., 2018a). Plasma MDA concentration level (µM L^{-1}) has been determined from the absorbance reading at 532 nm using a GENESYS™ 20 Visible Spectrophotometer (Thermo Fisher Scientific, Germany), and compared with the 1,1,3,3-tetraethoxypropane (TEP) standard curve (Sigma-Aldrich, USA).

Proximate analysis and organosomatic indices

Fillets of three fish were randomly sampled from each tank for proximate analysis using standard methods

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(AOAC, 1995). Samples were dried in an oven at 60 °C for 24-36 h. Nitrogen was determined by the Kjeldahl method and crude protein was calculated as N×6.25. Crude lipid content was analyzed following the soxhlet method, while ash content was determined by incineration in a muffle furnace at 600 °C for 4 h. Organosomatic indices such as %fillet, gonadosomatic index (%GSI), hepatosomatic index (%HSI) and viscerosomatic index (%VSI) were computed as follows (Biswas and Takeuchi, 2003; Da *et al*., 2012; Panase *et al*., 2018):

Fillet (%) = [100× (fillet weight (g)/body weight)].

Gonadosomatic index (% GSI) = [100× (gonad weight (g)/body weight)].

Hepatosomatic index (% HSI) = [100× (liver weight (g)/body weight)].

Viscerosomatic index (%VSI) = [100×(visceral weight (g)/body weight)].

Data analysis

All fish were determined for growth rate using the mathematical growth model described by Bagenal (1978) and Panase and Mengumphan (2015) as follows:

Weight gain (WG; g) = final weight (g) – initial weight (g).

Length gain (LG; cm) = final length (cm) – initial length (cm)

Average daily gain (ADG; g day^{-1}) = [final weight (g) – initial weight (g)]/days

Specific growth rate (SGR; %/day)= 100×[{Ln final weight (g)–Ln initial weight (g)}/days]

Feed conversion ratio (FCR)=total feed (g)/weight gain (g)

Survival Rate (SR, %)=[number of survived fish/initial number of fish]×100

Statistical analysis

Data were tested for normality using Shapiro-Wilk test, and test for homogeneity of variance using the Levene's Test before analysis. All data were examined for two-way analysis of variance (ANOVA), with means determined by Tukey's multiple comparison tests for pat a significance level of $p<0.05$. Results were presented as mean±standard deviation (SD).

Results

Growth performance and survival rate

Effects of yeast (*S. cerevisiae*) supplement in diet on growth performance and survival rate under different salinity levels for 90 days are displayed in Fig. 1. Weight gain (52.67±2.10 g), SGR (2.45±1.98 % day^{-1}) and ADG (0.58±0.45 g day) of fish fed with 0.5% yeast supplement diet reared at 5 ppt water salinity were significantly higher than fish fed with basal diet ($p<0.05$). Under diverse salinity levels, fish in the group fed with 0.5% yeast supplement and reared at 10 ppt showed significantly lower weight gain than fish reared at 5 ppt by Tukey's test ($p<0.05$). Fish fed with basal diet and reared at 10 ppt showed weight gain (38.23±3.33 g), SGR (1.90±0.13 % day^{-1}) and ADG (0.42±0.03 g day^{-1}), lower than fish reared at 0 and 5 ppt salinity. No significant improvements were

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observed in length gain and survival rate. FCR of fish fed with 0.5% yeast supplement diet reared at 0, 5 and 10 ppt salinities were 1.33±0.09, 1.14±0.09 and 1.42±0.15, respectively, and significantly lower than those fed with basal diet (1.82±0.12, 1.75±0.39 and 1.96±0.12, respectively) by Tukey's test (p<0.05). Throughout the 90-days' experimental period, water temperature ranged between 24.52 and 26.20 °C, dissolved oxygen 4.21-5.83 mg L^{-1}, pH 6.54-7.37 and TAN 0.25-2.00 mg L^{-1}. These parameters presented no significant difference (p>0.05) between all treatments.

Biochemical parameters

Effects of yeast (*S. cerevisiae*) supplement in diet on biochemical parameters and lipid peroxidation under different salinity levels for 90 days are displayed in Fig. 2. Significant difference was observed in cortisol (5.04±0.30 µg dl^{-1}) levels of fish fed with 0.5% yeast supplement diet, lower than those of the basal diet group at 10 ppt salinity level (7.06±1.60 µg dl^{-1}) (p<0.05). Under different salinity concentrations, cortisol and MDA levels significantly increased in both fish groups fed with 0.5% yeast supplement (86.33±8.38 unit L^{-1} and 88.50±8.80 µM L^{-1}, respectively) and fish fed with basal diets (7.06±1.60 µg dl^{-1} and 103.30±12.97, respectively) at 10 ppt than those reared at 0 and 5 ppt salinities (p<0.05). No significant difference was observed in AST, ALT and glucose levels by Tukey's test (p>0.05).

Proximate analysis and organo-somatic indices

Proximate analyses of fish fillets exposed to 0.5% yeast under diverse salinities are presented in Table 1. Under the three different salinity concentrations (0, 5 and 10 ppt), fish fed with 0.5% yeast supplement showed crude protein content higher than fish fed with basal diet (p<0.05). However, crude lipid contents of fish fed 0.5% yeast supplement diet reared at 0 and 5 ppt (2.57% and 2.60 %, respectively) were significantly higher compared 10 ppt (1.59%) by Tukey's test (p<0.05). No significant differences were observed in % ash, %fillet, gonadosomatic index (%GSI), hepatosomatic index (%HSI) and viscerosomatic index (%VSI) in all treatments by Tukey's test (p>0.05).

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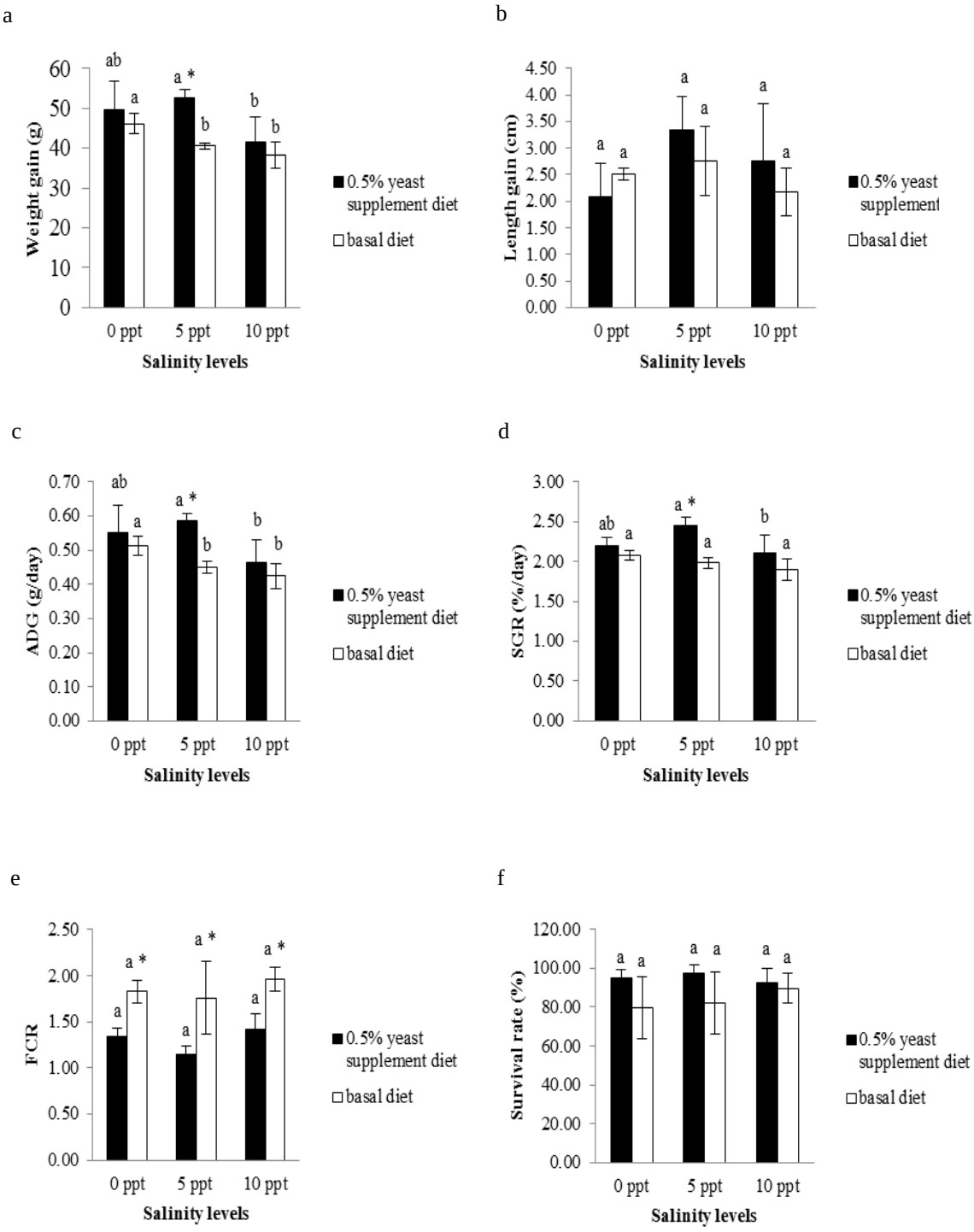


Figure 1: Effects of yeast supplement diet on growth performances of Nile tilapia for 90 days. Data are presented as mean ± SD. Different superscripts (^{a,b}) indicate significant differences between levels of salinity in the same diet group ($p<0.05$). An asterisk (*) indicates significant differences in diet groups at the same salinity level ($p<0.05$).

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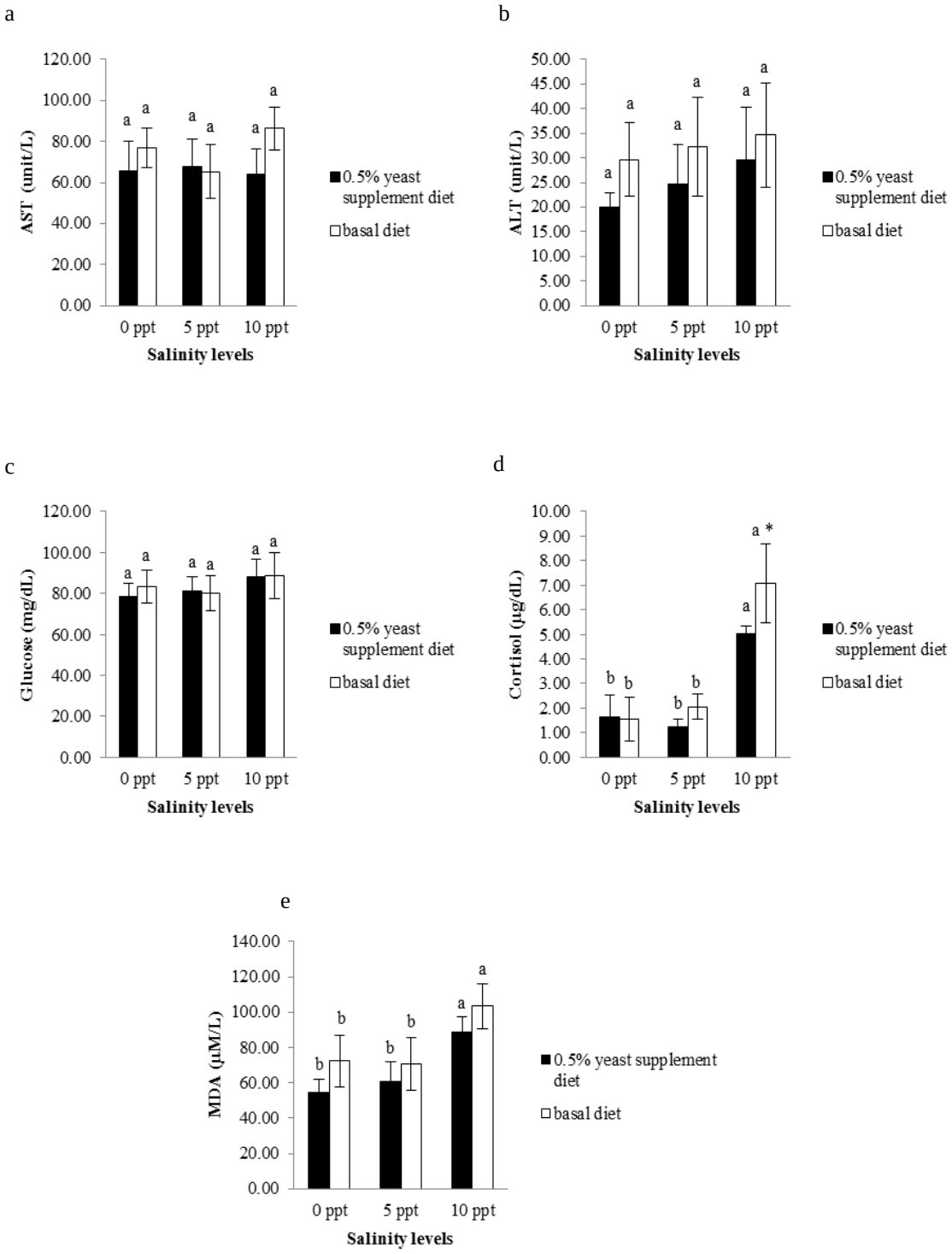


Figure 2: Effects of yeast supplement diet on blood chemistry of Nile tilapia for 90 days. Different superscripts (^{a,b,c}) indicate significant differences between levels of salinity in the same diet group ($p<0.05$). An asterisk (*) indicates significant differences in diet groups at the same salinity level ($p<0.05$).

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Table 1: Proximate chemical analysis (%dry matter basis) of fish fillets and organosomatic indices (%fillet, gonadosomatic index (%GSI), hepatosomatic index (%HSI) and viscerosomatic index (%VSI)) of Nile tilapia fed on 0.5% yeast supplement and basal diet at different salinities for 90 days.

Diet group	Parameter	Salinity level		
		0 ppt	5 ppt	10 ppt
0.5% Yeast supplement diet	%Crude protein	82.35±3.96^{a*}	83.94±0.24^{a*}	81.79±3.29^{a*}
	%Crude lipid	2.57±0.15^{a}	2.60±0.25^{a}	1.59±0.50^{b}
	%Ash	5.25±2.04^{a}	4.45±0.08^{a}	5.41±1.14^{a}
	%Fillet	27.21±5.92^{a}	31.10±3.98^{a}	26.71±4.83^{a}
	%GSI	2.15±1.04^{a}	2.09±1.19^{a}	0.92±0.50^{a}
	%HSI	2.16±0.35^{a}	2.41±0.65^{a}	2.26±0.25^{a}
	%VSI	5.01±0.55^{a}	5.23±0.45^{a}	4.93±0.23^{a}
Basal diet	%Crude protein	76.63±1.08^{a}	75.82±2.11^{a}	72.63±5.99^{a}
	%Crude lipid	2.45±0.72^{a}	2.39±0.57^{a}	1.89±0.49^{a}
	%Ash	4.67±0.09^{a}	4.90±0.08^{a}	4.71±0.13^{a}
	%Fillet	27.81±4.41^{a}	27.54±3.27^{a}	23.12±3.85^{a}
	%GSI	1.31±0.23^{a}	1.92±1.19^{a}	0.80±0.53^{a}
	%HSI	2.06±0.85^{a}	2.36±0.95^{a}	2.19±0.75^{a}
	%VSI	5.11±0.63^{a}	5.03±0.35^{a}	4.98±0.31^{a}

Data are given as mean±SD. Mean values in the same row with different superscripts (^{a,b}) indicate significant differences between levels of salinity in the same diet group (p<0.05). An asterisk (*) indicates significant differences in diet groups at the same salinity level (p<0.05).

Discussion

In this study, growth performance results of diet supplemented with yeast (*S. cerevisiae*) under diverse salinities during the 90-day experiment show, fish fed with 0.5% yeast supplement diet under 5 ppt salinity had better growth in terms of weight gain, SGR and ADG than those fed with basal diet (p<0.05). The lowest FCR has been found in fish fed with 0.5% yeast supplement diet, significantly lower than fish fed with basal diet under diverse salinities (p<0.05). Furthermore, fish reared at 0-5 ppt salinity showed higher potential growth performance than fish reared at 10 ppt (Fig. 1). Scant data exist concerning the effects of probiotics on salinity tolerance in Nile tilapia. Jatobá *et al*. (2011) investigated Nile tilapia fed with the probiotic (*Lactobacillus plantarum*) as 10^{11} CFU ml^{-1} supplemented diet in a polyculture system with marine shrimp (*Litopenaeus vannamei*) at 9-12 ppt salinity concentrations. They have found that tilapia groups fed with a probiotic-supplemented diet showed higher potential for final weight, feed efficiency and yield than fish fed with basal diet. This result has indicated that Nile tilapia fed with probiotics were able to enhance their growth performance at higher salinities. SGR, weight gain, and food intake of blue tilapia (*Oreochromis aureus*) were high in 12 ppt salinity, with lowest results recorded in 24 ppt (Küçük *et al*., 2013), while FCR of hybrid tilapia (*O. niloticus*×*O. urolepis urolepis*) was better in 15, 25 and 35 ppt salinities than 2 ppt (Mapenzi and Mmochi, 2016). El-Zaeem *et al*. (2011) reported that genetically modified Nile tilapia gave poorest FCR at 32 ppt salinity, which did not differ significantly with the result at 16 ppt salinity. Normally, salinity tolerance was found to be more

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closely related to body size than age (Villegas, 1990). Chowdhury *et al*. (2006) have reported that biomass growth of adult Nile tilapia was significantly affected by salinity at 8 ppt, more than net production at 15 ppt and 22 ppt. However, we found that survival rate (79.49-97.44%) of Nile tilapia fingerlings was not significantly different for fish fed with 0.5% yeast supplement and basal diet under different salinities (0-10 ppt) for 90 days. Our results were similar to Jatobá *et al*. (2011) who also had found that probiotics did not affect survival rate under 9-12 ppt water salinity polyculture with marine shrimp. Lawson and Anetekhai (2011) reported 100% survival rate of Nile tilapia fingerlings reared between 0 and 7 ppt salinity. Other tilapia, as juveniles of blue tilapia *(Oreochromis aureus)*, Nile tilapia (*O. niloticus*) and Florida red tilapia showed optimal survival (>81%) in salinity levels up to 20 ppt (Nugon, 2003), while poor survival rates were recorded at 35 ppt salinity regimes for *O. aureus* (54%) and Florida red tilapia (33%) (Nugon, 2003). Mississippi commercial tilapia survived salinity up to 10 ppt but recorded poor survival at 20 ppt (5%) (Nugon, 2003). The hybrid tilapia (*O. niloticus*×*O. urolepis urolepis*) gave better survival and growth rates in saline water than *O. niloticus* (Mapenzi and Mmochi, 2016). Scientists believe that since Nile tilapia is a euryhaline species, it had been developed from marine teleost ancestry (Suresh and Lin, 1992). Fish can control their homeostasis via chloride cells in gill filaments, which proliferate and increase Na^+/K^+ ATPase activity to regulate blood salt concentration when subjected to high salinity levels (Avella *et al*., 1993). Normally, tilapia species can be reared from freshwater into brackish and seawater after acclimatization (Dominguez *et al*., 2004). However, fish require pre-acclimation for an optimal period before transfer to a new environment (Kamal and Mair, 2005). Nile tilapia showed slower acclimation and low survival rate in full strength seawater compared with blue tilapia (*Oreochromis aureus*) and Mozambique tilapia (*Oreochromis mossambicus*) (Kamal and Mair, 2005).

Blood chemical analysis for AST and ALT activities involves aminotransferases produced in hepatocyte cells in the liver. Plasma levels are low when animals are healthy but increase when they become sick and enzymes leak into the blood causing liver damage or death (Park *et al*., 2012; Pakhira *et al*., 2015). Stress conditions also induce higher levels of AST and ALT (Park *et al*., 2012; Nandi *et al*., 2018). For example, under stress through long-term starvation, AST and ALT levels of the olive flounder (*Paralichthys olivaceus*) significantly increased compared to the fed group (Park *et al*., 2012). Rohu (*Labeo rohita*) under stress condition with pathogens showed significantly higher AST and ALT levels than the control group fed with probiotic (Nandi *et al*., 2018). We previously reported that Nile tilapia reared in water treated with probiotics *Bacillus* spp. (*B. subtilis*, *B. megaterium* and *B. licheniformis*) and

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yeast (*S. cerevisiae*) showed decreased AST and ALT levels compared with the control group (Sutthi *et al*., 2018a). Present study showed no significant differences of AST and ALT levels between Nile tilapia fed with 0.5% yeast (*S. cerevisiae*) and basal diet under 0-10 ppt salinity. This result indicated that fish fed with yeast at salinity of 0-10 ppt show no effects on liver cells. Moreover, we also found no significant difference on glucose level between Nile tilapia fed with 0.5% yeast (*S. cerevisiae*) and basal diet under 0-10 ppt salinity (p<0.05). Similarly, Küçük *et al*. (2013) found that plasma glucose in blue tilapia (*Oreochromis aureus*) was not significantly affected by salinity difference (8-24 ppt). Other studies also have been found that glucose level in fish did not change during salinity exposure (Morgan *et al*., 1997; Arjona *et al*., 2009; Mylonas *et al*., 2009). Generally, glucose is an indicator of secondary phase stress response in fish (Barton and Iwama, 1991; Morgan and Iwama, 1997; Wendelaar-Bonga, 1997). Under stress conditions, catecholamine hormones, adrenaline and noradrenaline are released into blood circulation, and in conjunction with cortisol, they elevate glucose production through glucogenesis and glycogenolysis pathways (Iwama *et al*., 1999) to cope with the energy demand produced by the stressor. Thus, 0-10 ppt of salinity stress had no effect on AST, ALT and glucose levels because the fish may have become acclimatized to high salinity concentrations before the experiment began (Küçük *et al*., 2013). However, our results presented that fish fed with 0.5% yeast supplement in diet and reared at 10 ppt salinity had cortisol levels lower than those fed with basal diet (p<0.05). Cortisol levels of both fish groups fed with 0.5% yeast supplement and basal diet showed an increased trend for salinity regimes from 0 to 10 ppt (Fig. 2d). Our results concurred with Kammerer *et al*. (2010) who reported that plasma cortisol and osmolality in tilapia changed rapidly in response to salinity stress. High salinity concentration is associated with changes in blood chemistry (Küçük *et al*., 2013) and increased metabolic rates (Othman *et al*., 2015) which may inhibit growth. Normally, salinity chronic stress can promote physiological changes in cortisol level after an exposure period of hours, days, or weeks (McEwen, 2008). Cortisol level is a primary feature and good target indicator for stress studies in fish (Barton and Iwama, 1991) and is frequently used as a stress indicator (Morgan and Iwama, 1997). Furthermore, MDA is a biomarker, which is used to assay cell oxidative stress damage (Livingstone, 2001; Valavanidis *et al*., 2006) and a pollution stress detector in aquatic animals (Favari *et al*., 2002). MDA levels found here showed significant increase in both fish fed with 0.5% yeast supplement and basal diet at 10 ppt than at 0 and 5 ppt (p<0.05). Nile tilapia fed with *Lactobacillus plantarum* CCFM8610 supplement in diet and reared under waterborne cadmium exposure showed improved lower levels of MDA than the control group (Zhai *et al*., 2017).

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Atlantic salmon (*Salmo salar*) fed with yeast (*Xanthophyllomyces dendrorhous*) and subjected to crowding stress showed decreased MDA levels compared to the control group (Reyes-Cerpa *et al*., 2018). B-glucan is a major structural component of yeast cell walls (Vallejos-Vidal *et al*., 2016) which inhibits MDA levels against cell oxidative stress (Sener *et al*., 2005). Thus, our results indicated that Nile tilapia survived at salinity regimes up to 10 ppt and exhibited good growth and blood chemistry at 0-5 ppt.

Proximate analysis results demonstrated that Nile tilapia fed 0.5% yeast under all salinity stress concentrations (0-10 ppt) showed crude protein content higher than fish fed with basal diet (p<0.05). Our results agreed with Asadi Rad *et al*. (2012) who reported that body protein of Nile tilapia fed with yeast (*S. cerevisiae*) supplementation in diet significantly have been affected. Yeast has high potential contents of β-glucans, mannan oligosaccharides (MOS) and nucleic acid (Li and Gatlin, 2006; Refstie *et al*., 2010; Kühlwein *et al*., 2014) which improve growth, energy and high nutrient digestibility (Lara-Flores *et al*., 2003). Moreover, yeast supplementation enhanced food intake and improved fish body composition with increase in deposited nutrients (Abdel-Tawwab *et al*., 2008). Our results showed increasing levels of crude lipid content in fish fed 0.5% yeast supplement diet reared at 0 and 5 ppt compared with 10 ppt (p<0.05), while fish fed with basal diet recorded no significant differences in crude lipid percentage under diverse salinity. These findings concurred with El-Zaeem *et al*. (2011) who reported that protein content of Nile tilapia at salinity levels of 0-16 ppt was higher than fish reared at 32 ppt, while lipid content showed no significant differences. High salinity concentrations of 20-24 ppt significantly decreased the hepatosomatic index of blue tilapia (*Oreochromis aureus*) (Küçük *et al*., 2013). Our results showed that Nile tilapia reared under salinity concentrations of 0-10 ppt had similar hepatosomatic indices. Normally, Nile tilapia do not tolerate salinities above 20 ppt and are not suitable for culture in full-strength salinities (Baroiller *et al*., 2000). Our results suggested that Nile tilapia fed with 0.5% yeast diet showed enhanced body compositions of crude protein and crude lipid content, even when reared under salinity stress up to 10 ppt.

Our results demonstrated that fish fed with 0.5% yeast (*S. cerevisiae*) supplement diet showed high growth performance, with enhanced crude protein and crude lipid content in fillets. Cortisol levels and MDA content also improved under salinity stress. Salinity regimes of 0-10 ppt were well tolerated by fish fed with 0.5% yeast supplement; however, we suggest that culture of Nile tilapia (*O. niloticus*) in aquatic environments should be better in salinities up to 5 ppt than 10 ppt.

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