



## Growth performance and biochemical blood parameters of Nile tilapia, *Oreochromis niloticus*, and thinlip mullet, *Liza ramada*, fed a diet supplemented with lemon (*Citrus aurantifolia*) peel in a polyculture system

Mohamed M. Toutou<sup>1</sup>, Ali A. Soliman<sup>1</sup>, Mohamed A. Elokaby<sup>2</sup>, Ragaa A. Ahmed<sup>3</sup> and Baghdadly. E. S<sup>3</sup>

1- Fish Nutrition Laboratory, Aquaculture Division, National Institute of Oceanography and Fisheries (NIOF), Egypt.

2- Fish Rearing Laboratory, Aquaculture Division, (NIOF), Egypt.

3- Department of Aquaculture, Faculty of Fish & Fisheries Technology, Aswan University.

\*Correspondence Author :mtoutou50@yahoo.com

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### ABSTRACT

The objective of the current study was to evaluate the growth performance, survival, feed utilization, whole body composition and biochemical blood parameters of Nile tilapia, *Oreochromis niloticus* and thinlip mullet, *Liza ramada*, fed diets supplemented with four levels of lemon peel (0, 0.5, 1 and 2%) in a polyculture system. The fish were stocked in 2×5×1 m concrete tanks at a density of 40 Nile tilapia (0.6 g) and 10 thinlip mullet (3.3 g) fingerlings per tank and were fed a pelleted diet (~25% Crude protein), twice daily for 77 days. Treatment with 2% lemon peel had significant positive effects on growth, feed utilization and total biomass of Nile tilapia, whereas 0.5% lemon peel was optimal for thinlip mullet. The blood parameter results showed that Nile tilapia fed 2% dietary lemon peel had the lowest triglyceride, amylase and glucose levels. In contrast, thinlip mullet fed 0.5% dietary lemon peel had the highest levels of amylase and glucose compared with the other groups.

### INTRODUCTION

Aquaculture requires optimization of nutrition to efficiently raise fish for the purpose of food production. Fish nutrition is the study of nutrients and energy sources essential for fish health, growth and reproduction (Hixson, 2014). In recent years, aquaculture has been growing at an annual rate of 3.2%. This is mostly attributed to developments in fish feed manufacture, which is the biggest cost factor, and the use of more productive aquaculture systems (FAO, 2016). However, this production is obstructed by unexpected mortalities that may be owing to negative interactions between pathogenic bacteria and fish. To face this problem, farmers often use antibiotic compounds to cure bacterial diseases (Cabello, 2006). However, the use of antibiotics leads to antibiotic resistance in bacteria as well as residues in fish fillets (Esiobuet *et al.*, 2002). Due to the side effects as well as the resistance that pathogens build against antibiotics, many attention has recently been spend to extracts and biologically active compounds secluded from plant species. Using of plant extracts, and other alternative forms of medicinal treatments, is widely popular (Cowan, 1999).

In recent years, immune-stimulant plants or their by-products have been used in aquaculture feed as an antibiotics alternative. The most important advantages of natural products are that they neither cause any residue problems nor have any negative effects on fish health or humans and the environment (Baba *et al.*, 2016). A number of agro-industrial by-products or wastes such as citrus pulp, citrus meal, citrus seed meal, citrus molasses and citrus peels are generated from fresh citrus after the main products of interest have been removed or extracted during processing or after peeling for direct human consumption, especially in developing countries (Oluremiet *al.*, 2007). The residue left after extraction of the juice is called citrus pulp (50–70% of the fruit by weight). Citrus pulp contains 60–65% peel, 30–35% internal tissues and up to 10% seeds (Crawshaw, 2004). Many studies illustrated lemon as an important health-promoting fruit rich in phenolic compounds as well as vitamins, minerals, dietary fibre, essential oils and carotenoids. Lemons contain vitamin C, also known as ascorbic acid (Njoku *et al.*, 2011). Vitamin C has antioxidant and therapeutic properties in many organisms. Among the vitamins essential for fish growth, vitamin C has been found to be an important element for the growth, reproduction and physiology of fish. This is because, unlike other animals, fish lack the enzyme gulonolactone oxidase necessary in the last step in the biosynthesis of ascorbic acid (Merchie, *et al.*, 1997). Growth performance, survival, haematological, biochemical and immunological variables are among the most significant physiological indicators of fish health (Campbell, 2004). Thus, the objectives of the present study were to evaluate the effects of dietary lemon peel on the growth and biochemical blood parameters of polycultured Nile tilapia and thinlip mullet.

## MATERIALS AND METHODS

### Fish and experimental design:

This experiment was conducted at the Fish Nutrition Laboratory, Baltim Research Station, National Institute of Oceanography and Fisheries (NIOF), Egypt, during summer 2018. Nile tilapia and thinlip mullet fingerlings were purchased from a private fish farm in Kafr El-Sheikh Governorate, Egypt. After acclimation in a concrete tank (5×10×1 m) for two weeks, forty Nile tilapia and ten thinlip mullet fish with an average weight of (0.6±0.1 and 3.3±0.4 g, respectively) were randomly stocked in 12 concrete tanks (2×5×1 m), representing four treatments with three replicates each. The experimental tanks were cleaned and supplied with fresh underground water and aeration. Water quality parameters, including temperature, pH (Jenway Ltd., Model 350 pH meter) and dissolved oxygen (Jenway Ltd., Model 970-dissolved oxygen meter), were measured weekly. Throughout the experimental period, the ambient water temperature, dissolved oxygen and pH were 24.0 ± 2.0°C, 6.0 ± 2.0 mg/l, and 7.9 ± 0.2, respectively. Fish were fed the experimental diets (5% to 3%) twice per day at 09.00 and 14.00 h, 6 days per week for 11 weeks. A flow-through system was used in this study with 10% daily water exchange.

### Experimental diets and feeding regime

Isonitrogenous (~25% crude protein), isocaloric (~442 Kcal/100 g gross energy, GE) experimental diets were prepared as shown in Table (1). The ingredients were blended with additional water to make a paste of each diet. The pastes were pelleted into an appropriate size suitable for the experimental fish size. The feed was dried in an oven that was thermostatically regulated at 60°C for 24 hours and was then stored in plastic bags at –20°C until use. Four experimental diets were formulated (C, L1, L2 and L3); C was considered the control diet. Lemon peel (L1, L2 and L3) was

added (0.5, 1, 2%), and the formulated feed was prepared in the fish nutrition laboratory (NIOF). The proximate chemical analyses of the formulated feed (on a dry matter (DM) basis) are presented in Table (1). During the experiment, the total quantity of feed consumed by fish in each tank was determined, and the feed intake of each individual fish was calculated accordingly.

Table 1: The composition and chemical analysis (% on dry matter basis) of the experimental diets.

Ingredients	Composition of experimental diets/kg.			
	Control	L1	L2	L3
Fish meal (65% CP)	100	100	100	100
Soybean meal (44% CP)	220	220	220	220
Wheat bran	300	300	300	300
Sesame meal	100	100	100	100
Yellow corn	120	120	120	120
Wheat flour	60	55	50	40
Premix <sup>1</sup>	20	20	20	20
Fish oil	30	30	30	30
Sunflower oil	30	30	30	30
Dicalcium phosphate	20	20	20	20
Lemon peel	0	5	10	20
Total	1000	1000	1000	1000
Chemical composition %				
Dry matter (DM)	93.8	92.9	91.4	90.1
Crude protein (CP)	25.3	25.1	25.2	24.9
Ether extract	11.3	11.4	11.5	11.6
Ash	12.0	12.1	12.2	12.2
Crude fibre	4.3	4.3	4.5	4.6
Nitrogen-free extract (NFE) <sup>2</sup>	47.1	47.1	46.6	46.7
Gross energy (kcal/100 g DM) <sup>3</sup>	442.9	442.8	442.2	492.0

<sup>1</sup>Premix Composition: - Each 1 kg contains Vit. A (400000 i.u.), Vit.D3 (100000 i.u.), Vit. E (230 mg), Vit. K3 (165 mg), Vit.B1 (300 mg), Vit.B2 (80 mg), Vit.B6 (200 mg), Vit.B12 (1 mg), Vit. C (650 mg), niacin (1000 mg), methionine (3000 mg), choline chloride (10000 mg), folic acid (100 mg), biotin (2 mg), pantothenic acid (220 mg), magnesium sulphate (1000 mg), copper sulphate (1000 mg), iron sulphate (330 mg), zinc sulphate (600 mg), cobalt sulphate (100 mg), and calcium carbonate, up to 1000 mg.

<sup>2</sup>NFE = 100 - [% Ash + % lipid + % protein + % Fibre]

<sup>3</sup>Gross energy (GE) was calculated as 5.64, 9.44 and 4.11 kcal/100 g for protein, lipids and NFE, respectively (NRC, 1993).

### Growth performance and feed utilization efficiency:

At the end of the experiment, fish were harvested, counted, and weighed. The growth performance and feed utilization parameters were determined as follows:

Weight gain (WG; g) = FW – IW

Specific growth rate (SGR; %/fish/day) =  $100 * [(\ln FW) - (\ln IW)] / \text{experimental days}$ ,

where FW: final fish weight (g); IW: initial fish weight (g)

Condition factor (K value) =  $100 * [\text{Fish weight, g} / \text{fish length}^3, \text{cm}]$

Fish survival (%) =  $100 * [\text{Final number of fish} / \text{initial number of fish}]$

Daily Feeding Rate (%/fish weight/day) =  $100 * [FI / FW]$ ,

where FI = total actual feed intake (g) based on fresh matter (FM) or dry matter (DM); FW = average weight of fish (g)

Feed conversion ratio (FCR) based on DM = feed intake (g) as dry weight/weight gain (g);

Feed conversion ratio (FCR) based on FM = feed intake (g) as fresh matter/weight gain (g); Protein efficiency ratio (PER) = weight gain (g)/protein intake (g);

Protein productive value (PPV; %) =  $100 * [\text{protein gain (g)} / \text{protein intake (g)}]$ .

### Proximate chemical analyses of feed and fish

At the beginning of the experiment, a sample of the tested fish (approximately 30 fish) was randomly collected and preserved for initial body chemical composition. At the end of the experiment, 15 fish from each treatment were sampled for determination of proximate chemical composition. Specimens of the tested feeds and fish samples were subjected to proximate chemical analyses to measure the moisture, crude protein (CP), crude lipid, crude fibre, and ash contents according to AOAC (2000).

### Serum biochemistry:

Blood samples were collected, placed in centrifuge tubes and allowed to clot at room temperature. Serum was then separated by centrifugation at 3000 rpm for 10 minutes. The serum was kept at -20°C until analysis of cholesterol, triglycerides creatinine, urea, lipase and amylase. Creatinine and urea (mg/dl) were quantitatively estimated according to the method of Henry (1964). Serum glucose (mg/dl) was quantitatively estimated by enzymatic colorimetric methods described by Trinder (1969), and serum cholesterol (mg/dl) was estimated by enzymatic colorimetric methods described by Thomas (1992). Serum triglycerides (mg/dl) were estimated according to the method of Friedewald *et al.* (1972). Lipase and amylase (U/l) were measured calorimetrically using commercial kits purchased from Bio-diagnostic Co. (Alexandria, Egypt).

### Statistical analysis:

Data collected on the investigated traits (growth performance, feed utilization, biochemical and blood serum analyses) were analysed with one-way analysis of variance (ANOVA) using the SPSS version 16 statistical package to evaluate the differences between treatment were assessed using Duncan's multiple range test at the  $P \leq 0.05$  level. SPSS (1997).

## RESULTS

The growth performance parameters of Nile tilapia and thinlip mullet are presented in Table 2. A significant increase ( $P \leq 0.05$ ) in the final body weight (FW), weight gain (WG) and specific growth rate (SGR) was observed in response to the diets supplemented with 0.5, 1.0, and 2% lemon peel (Nile tilapia) and 0.5% lemon peel (thinlip mullet) compared to the control.

Table 2: Growth variables and indices of Nile tilapia and thinlip mullet at the end of the 77-day feeding trial.

	Nile tilapia			
	C	L1	L2	L3
Initial wt.	0.73±0.01	0.73±0.01	0.72±0.01	0.73±0.01
Final wt.	14.54±0.99 <sup>c</sup>	19.98±0.39 <sup>b</sup>	19.75±0.59 <sup>b</sup>	22.96±0.09 <sup>a</sup>
Weight gain	13.81±0.99 <sup>c</sup>	19.25±0.39 <sup>b</sup>	19.04±0.58 <sup>b</sup>	22.24±0.08 <sup>a</sup>
SGR	3.88±0.09 <sup>c</sup>	4.31±0.02 <sup>b</sup>	4.31±0.04 <sup>b</sup>	4.49±0.01 <sup>a</sup>
Survival	77.50±1.44	76.67±0.83	72.50±5.20	74.17±1.67
	Thinlip mullet			
	C	L1	L2	L3
Initial wt.	3.53±0.08	3.45±0.16	3.45±0.06	3.50±0.08
Final wt.	15.16±0.47 <sup>b</sup>	19.16±0.93 <sup>a</sup>	15.77±0.23 <sup>b</sup>	14.56±0.15 <sup>b</sup>
Weight gain	11.63±0.44 <sup>b</sup>	15.71±0.78 <sup>a</sup>	12.32±0.26 <sup>b</sup>	11.06±0.23 <sup>b</sup>
SGR	1.89±0.04 <sup>b</sup>	2.22±0.01 <sup>a</sup>	1.97±0.04 <sup>b</sup>	1.85±0.04 <sup>c</sup>
Survival	76.67±6.67 <sup>b</sup>	93.33±3.33 <sup>a</sup>	90.00±5.77 <sup>a</sup>	83.33±6.67 <sup>ab</sup>

The highest final body weight, weight gain, and SGR were recorded in tilapia fed the 2% dietary lemon peel. The Nile tilapia survival results showed that there were no significant differences between the lemon peel treatments and the control treatment. In contrast, the thinlip mullet survival results differed significantly between treatments, with the highest value observed in the L1 treatment followed by L2, L3 and the control, which had the lowest value. Also, the highest final body weight, weight gain and SGR were recorded in the fish fed on 0.5% lemon peel.

Table 3: Total growth and total biomass indices of the polyculture (Nile tilapia and thinlip mullet) at the end of the 77-day feeding trial.

	C	L1	L2	L3
Initial wt.	1.29±0.02	1.27±0.03	1.26±0.02	1.28±0.02
Final wt.	14.69±0.76 <sup>c</sup>	19.76±0.25 <sup>ab</sup>	18.79±0.34 <sup>b</sup>	20.91±0.15 <sup>a</sup>
weight gain	13.40±0.78 <sup>c</sup>	18.49±0.24 <sup>ab</sup>	17.52±0.33 <sup>b</sup>	19.63±0.13 <sup>a</sup>
SGR	3.16±0.08 <sup>b</sup>	3.57±0.02 <sup>a</sup>	3.51±0.02 <sup>a</sup>	3.63±0.01 <sup>a</sup>
Feed intake	32.37±0.96 <sup>b</sup>	34.87±0.47 <sup>a</sup>	33.15±2.09 <sup>a</sup>	36.85±1.25 <sup>a</sup>
FCR	2.42±0.07 <sup>b</sup>	1.88±0.02 <sup>a</sup>	1.89±0.08 <sup>a</sup>	1.88±0.05 <sup>a</sup>
PER	1.65±0.04 <sup>b</sup>	2.12±0.03 <sup>a</sup>	2.14±0.10 <sup>a</sup>	2.18±0.06 <sup>a</sup>

The SGR and PER values of whole polyculture species fed diets supplemented with 0.5, 1, and 2% lemon peel were significantly ( $P \leq 0.5$ ) higher than those of polyculture species fed the control diet. However, the feed conversion ratio (FCR) measured in fish fed diets supplemented with 0.5, 1, and 2% lemon peel was significantly ( $P \leq 0.5$ ) lower than that in fish fed the control diet.

The effects of dietary lemon peel on the biochemical composition of Nile tilapia are presented in Table (4), which shows that no significant differences were observed for moisture content. An increase in the lemon peel level to 0.5% and 1% induced a significant reduction in the crude protein (CP) content of the fish whole body compared to the control. At the same time, non-significant different was recorded in the value of CP of the fish fed on 2% lumen peel compared to the control.

Table 4: Biochemical composition of Nile tilapia and thinlip mullet at the end of the feeding trial (dry matter weight basis).

	Nile tilapia				
	Initial	C	L1	L2	L3
Moisture	78.83±0.26	75.30±0.55 <sup>a</sup>	74.43±0.42 <sup>a</sup>	74.20±1.17 <sup>a</sup>	75.87±0.50 <sup>a</sup>
CP	58.80±0.36	68.07±0.30 <sup>a</sup>	63.17±0.09 <sup>b</sup>	63.67±0.52 <sup>b</sup>	68.30±0.15 <sup>a</sup>
EE	11.27±0.18	16.87±0.35 <sup>b</sup>	23.20±0.10 <sup>a</sup>	22.23±0.59 <sup>a</sup>	12.50±0.10 <sup>c</sup>
Ash	29.50±0.23	14.40±0.06 <sup>b</sup>	12.87±0.09 <sup>c</sup>	13.23±0.15 <sup>c</sup>	18.20±0.06 <sup>a</sup>
	Thinlip mullet				
	Initial	C	L1	L2	L3
Moisture	77.83±0.32	72.37±0.26 <sup>a</sup>	66.43±0.27 <sup>b</sup>	65.20±1.00 <sup>c</sup>	67.47±0.93 <sup>b</sup>
CP	54.50±0.52	62.40±0.49 <sup>a</sup>	52.40±0.06 <sup>b</sup>	53.47±0.49 <sup>b</sup>	52.23±0.23 <sup>b</sup>
EE	12.17±0.09	20.60±0.26 <sup>d</sup>	36.83±0.42 <sup>a</sup>	35.50±0.21 <sup>b</sup>	33.97±0.15 <sup>c</sup>
Ash	32.40±0.52	16.60±0.26 <sup>a</sup>	9.57±0.15 <sup>c</sup>	10.03±0.03 <sup>c</sup>	12.80±0.21 <sup>b</sup>

The ether extract (EE) content of fish fed the 2% lemon peel diet was significantly lower than that measured in fish fed the 1%, 0.5% and control diets. Fish in the L3 treatment had the significantly ( $p \leq 0.05$ ) highest ash content compared to that in fish in the L1, L2 and control treatments.

With respect to variations in the biochemical composition of thinlip mullet, there were significant differences ( $p \leq 0.05$ ) in the ash, protein, ether extract and moisture contents at the beginning and end of the feeding trial (Table 4). The final protein and ash contents of the fish fed the control diet were significantly higher than

those of fish fed the 0.5%, 1% and 2% dietary lemon peel. Fish fed 0.5% lemon peel had a significantly higher ether extract content compared with fish fed the 1% and 2% lemon peel and the control diet.

The final mean biochemical blood parameters (creatinine, cholesterol, triglyceride, amylase, lipase and glucose) of Nile tilapia are presented in Table (5). Nile tilapia fed diet containing 2% lemon peel had the highest creatinine level compared to other groups. Non significant treatment differences were observed for lipase. The highest triglyceride, amylase and glucose contents were recorded in fish fed on 0.5% dietary lemon peel (L1) compared to other treatments and the control. The groups fed 2% dietary lemon peel had the lowest cholesterol, triglyceride, amylase and glucose contents. An increase in the lemon peel level from 0.5% to 1% induced a significant increase in cholesterol and a significant decrease in glucose.

Table 5: Biochemical blood parameters of Tilapia and thinlip mullet at the end of the feeding trial.

	Nile tilapia			
	C	L1	L2	L3
Creatinine	0.40±0.01 <sup>d</sup>	0.50±0.02 <sup>c</sup>	0.60±0.01 <sup>b</sup>	0.70±0.01 <sup>a</sup>
Cholesterol	101±2.08 <sup>c</sup>	117±2.52 <sup>b</sup>	157±3.79 <sup>a</sup>	81±1.15 <sup>d</sup>
Triglyceride	115±2.08 <sup>b</sup>	134±3.06 <sup>a</sup>	94±2.08 <sup>c</sup>	75±1.53 <sup>d</sup>
Amylase	231±3.46 <sup>b</sup>	473±5.13 <sup>a</sup>	208±3.21 <sup>c</sup>	201±2.89 <sup>c</sup>
Lipase	3±0.12 <sup>a</sup>	3±0.15 <sup>a</sup>	3±0.06 <sup>a</sup>	3±0.10 <sup>a</sup>
Glucose	102±3.21 <sup>b</sup>	130±2.08 <sup>a</sup>	94±1.73 <sup>c</sup>	42±0.58 <sup>d</sup>
	Thinlip mullet			
	C	L1	L2	L3
Creatinine	0.70±0.01 <sup>b</sup>	0.70±0.01 <sup>b</sup>	0.70±0.01 <sup>b</sup>	1.40±0.06 <sup>a</sup>
Cholesterol	117±1.73 <sup>c</sup>	117±2.31 <sup>c</sup>	142±2.65 <sup>b</sup>	157±2.89 <sup>a</sup>
Triglyceride	135±2.89 <sup>b</sup>	135±3.46 <sup>b</sup>	272±4.04 <sup>a</sup>	273±4.93 <sup>a</sup>
Amylase	25±1.53 <sup>a</sup>	25±0.51 <sup>a</sup>	15±0.21 <sup>c</sup>	19±0.32 <sup>b</sup>
Lipase	2±0.06 <sup>b</sup>	2±0.06 <sup>b</sup>	2±0.12 <sup>b</sup>	4±0.12 <sup>a</sup>
Glucose	60±1.53 <sup>b</sup>	89±1.73 <sup>a</sup>	55±1.15 <sup>c</sup>	49±1.15 <sup>d</sup>

The results presented in Table (5) indicate significant changes in blood biochemical parameter levels in thinlip mullet. The significantly highest creatinine, cholesterol, triglyceride and lipase levels were observed in response to diets containing 2% dietary lemon peel. The group fed 0.5% dietary lemon peel had significantly higher amylase and glucose values than the other groups.

## DISCUSSION

The present study revealed that all tested levels of lemon peel (0.5, 1 and 2%) had a significant effect on the growth performance and total biomass of Nile tilapia and thinlip mullet. Feed acceptance by the fish was similar for all treatments, with no observed rejection. Limonene, the main component of the essential oils of lemon and grapefruit (Kirbaslar *et al.*, 2006) has been reported to be effective against termites (Raina *et al.*, 2007), beetles (Tripathi *et al.*, 2003) and fungi (Sharma and Tripathi 2006). Some studies have shown that a dietary supplement containing limonene and thymol had growth-promoting effects in poultry and some fish species (Ahmadifar *et al.*, 2011, 2014; Dalkilic *et al.*, 2015; Acaret *et al.*, 2015; Pérez-Sánchez *et al.*, 2015; Shad *et al.*, 2016; Zidan *et al.*, 2016 and Ngugiet *et al.*, 2017). In our study, Nile tilapia fed 2% dietary lemon peel had the best FBW, WG and SGR values. We observed a significant increase in FBW, SGR and % WG in thinlip mullet fed 0.5% lemon peel compared to 1 and 2% lemon peel and the control group. Based on the results

obtained in this study, it is concluded that the growth rate of biomass (Nile tilapia and thinlip mullet) was affected by the dietary lemon peel levels, and FW, WG and SGR increased significantly ( $P \leq 0.05$ ) with increasing levels. In addition, the SGR, PER and total biomass of Nile tilapia and thinlip mullet fish fed 0.5, 1, and 2% dietary lemon peel increased significantly ( $P \leq 0.05$ ) compared to the control group. The feed conversion ratio (FCR) of fish fed 0.5, 1, and 2% dietary lemon peel was significantly lower than that of fish fed the control diet. The current findings are consistent with results obtained for Mozambique tilapia, *Oreochromis mossambicus*, when the essential oil extracted from *Citrus sinensis* peels was used in the diet (Acaret *et al.*, 2015). The improved growth performance and food conversion efficiency of fish fed different levels of dietary lemon peel may be attributed to the antimicrobial and antioxidant properties (Milos *et al.*, 2000). Additionally, lemon peel may provide a cheap source of vitamin C that can be fortified into fish feed.

Creatinine is the end product of creatine metabolism and aids in muscle contraction. Most of the creatinine in the body is removed by the kidneys. Because of this, the levels of creatinine in the blood can indicate whether the kidneys are functioning properly (Walker *et al.*, 1990). In the current study, Nile tilapia and thinlip mullet fed diets containing 2% lemon peel had significantly higher creatinine levels than fish in the other treatments, i.e., 0.7 and 1.4 mg/dL for Nile tilapia and thinlip mullet, respectively, followed by 1% dietary lemon peel (0.6 and 0.7 mg/dL for Nile tilapia and thinlip mullet, respectively) and 0.5% dietary lemon peel (0.5 and 0.7 mg/dL for Nile tilapia and thinlip mullet, respectively). Normal creatinine values range from 0.8 to 1.4 mg/dL (Solomon 2014). This means that all the recorded creatinine values for both fish species were within the normal range, confirming the non-negative impacts of lemon peel on Nile tilapia and thinlip mullet.

Glucose is one of the most important energy substrates used by fish to cope with physiological stress; therefore, plasma glucose levels have been used as an indicator of the stress response. Cortisol and glucose have been reported to increase in teleosts exposed to stress (Mommensen *et al.*, 1999). In our study, one of the reasons that fish fed 2% lemon peel had the lowest glucose values may be because stress was avoided under high levels of (vitamin C) lemon peel.

In the present study, Nile tilapia fish fed 2% lemon peel had the lowest cholesterol and triglyceride levels; these values were significantly different from those measured in the other treatments. The highest cholesterol, triglyceride and lipase levels in thinlip mullet were observed in response to diets containing 0.5% lemon peel. The concentration of cholesterol in the blood can be influenced by nutrition, activity level, and hepatic activity and can be changed by the sexual cycle of fish. Triglycerides are the major lipids of adipose tissue and are the most important form of fat storage in the body. The concentration of triglycerides in the blood is influenced by the fat content in the diet and is therefore an important blood component to be evaluated in the use of new diets (Van der Boon *et al.*, 1991).

Lipase secretion is characteristic of a highly organized intestine. Lipase is often analysed in combination with two other vital enzymes: protease and amylase. While lipase breaks down fats, protease digests proteins and amylase processes carbohydrates.

Levels of enzymatic activity measured by different authors are difficult to compare due to the use of different methods. Compared to other fish, lipase activity in juvenile sterlets and other sturgeon species is low (German *et al.*, 2004; Furneet *et al.*, 2005). In this study, lipase and amylase activity differed significantly between the groups of thinlip mullet fed the different levels of dietary lemon peel. However, we

did not observe significant effects of various levels of dietary lemon peel on lipase activity in Nile tilapia.

## CONCLUSION

Based on the results obtained in this study, it can be concluded that the biomass growth rate of Nile tilapia and thinlip mullet is affected by different levels of dietary lemon peel. The addition of 2% dietary lemon peel had positive effects on the growth, feed utilization and total biomass of Nile tilapia, whereas the highest values for thinlip mullet were observed in the group treated with 0.5% lemon peel. The blood parameter results showed that Nile tilapia had the lowest triglyceride, amylase and glucose levels in response to 2% dietary lemon peel. By contrast, thinlip mullet fed 0.5% dietary lemon peel had the highest values of amylase and glucose.

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