

# Influence of Ulva meal on growth, feed utilization, and body composition of juvenile Nile tilapia (*Oreochromis niloticus*) at two levels of dietary lipid

Sebahattin Ergün · Murat Soyutürk · Betül Güroy · Derya Güroy · Daniel Merrifield

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**Abstract** A nutrition trial was conducted to investigate the effects of dietary lipid levels and supplemental Ulva meal on growth performance, feed efficiency, nutrient utilization, and body composition of juvenile Nile tilapia, *Oreochromis niloticus*. Four isonitrogenous (CP 40%) diets containing 0% and 5% Ulva meal were formulated to contain 10% (low-lipid; LL) and 20% (high-lipid; HL) crude lipid. Triplicate groups of fish (~10 g) were fed to apparent satiation three times daily for 16 weeks. Fish fed 5% Ulva meal showed an increased growth performance ( $P < 0.05$ ) compared with fish fed non-Ulva supplemented diets, irrespective of dietary lipid level. In particular, the incorporation of Ulva meal improved specific growth rate (SGR), feed conversion ratio (FCR), and protein efficiency ratio (PER). Feeding fish 5% Ulva meal diets resulted in significantly lower carcass lipid content. The results indicate that 5% inclusion of Ulva meal at both dietary lipid levels improves growth performance, feed efficiency, nutrient utilization, and body composition of Nile tilapia.

**Keywords** Dietary lipid · Ulva meal · Nile tilapia · Growth · Feed utilization

## Introduction

Tilapiines can tolerate a wide range of environmental factors and stress conditions; therefore, they are the one of the most important and successfully farmed fish species (Rinchard et al. 2002; Suresh 2003). The production volume of farmed tilapia has increased threefold over the past decade, from 703,086 mt in 1995 to 2,025,560 mt in 2005 (FAO 2007). As a result, tilapia has been described as the most important aquaculture species of the twenty-first century (Fitzsimmons 2000).

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S. Ergün (✉) · M. Soyutürk · B. Güroy · D. Güroy  
Department of Aquaculture, Çanakkale Onsekiz Mart University, Canakkale, Turkey  
e-mail: sergun@comu.edu.tr

D. Merrifield  
Aquaculture and Fish Nutrition Research Group, School of Biological Sciences,  
University of Plymouth, Plymouth, Devon, UK

In recent years, *Ulva* species have become important macroalgae, which have been investigated as a dietary ingredient for a wide range of fish species. Low-level dietary incorporation of *Ulva* meal has resulted in improved growth, feed utilization, physiological activity, disease resistance, carcass quality, and reduced stress response (Mustafa and Nakagawa 1995; Wassef et al. 2005; Valente et al. 2006). *Ulva* species have a good vitamin and mineral profile and are especially rich in ascorbic acid (Ortiz et al. 2006; García-Casal et al. 2007). Vitamin C promotes lipid metabolism, which may result in the alteration of body composition and nutrient deposition in fish, and thus may reduce carcass lipid and increase protein levels (Miyasaki et al. 1995; Ji et al. 2003).

*Ulva* meal has been successfully used as a feed ingredient for tilapia. Recent studies have shown incorporation of *Ulva* meal may enhance carcass composition (Güroy et al. 2007; Azaza et al. 2008). Recommended dietary lipid levels for tilapia are 6–10% (Jauncey and Ross 1982), yet it has been suggested that elevating levels to 18% may result in a protein-sparing action (De Silva et al. 1991). However, the inclusion of lipid that exceeds optimum levels can result in reduced growth performance and increased lipid deposition, thus reducing product quality and shelf life (Ellis and Reigh 1991; Chou and Shiau 1996). The aim of this study was to observe the effects of *Ulva* meal on growth performance, feed utilization, and body composition of *Oreochromis niloticus* fed excessive dietary lipid.

## Materials and methods

### Experimental diets and feeding regime

Green macroalgae (identified as *U. rigida*) was obtained fresh, among other seaweeds and various algal species, from the near-shore waters of the Dardanelles coast, Canakkale, Turkey. *Ulva* samples were thoroughly washed with seawater, dried in an oven at 40°C for 48 h, and ground to powder for proximate analysis (Table 1). Four diets were formulated to contain 40% crude protein, which fulfills the requirement for tilapia. The diets were designed to provide 10% (low-lipid; LL) and 20% (high-lipid; HL) crude lipid with or without 5% incorporation of *Ulva* meal (HL-U, LL-U). Diet formulation and proximate composition is shown in Table 2. All dietary ingredients were blended thoroughly, moistened, cold-pelleted with a laboratory feed extruder, and dried at 40°C for 24 h. Diets were stored at –20°C. The test diets were fed to apparent satiation three times daily, at 09.00; 12.00, and 17.00 h, for 6 days a week.

### Fish and aquarium facilities

Juvenile *O. niloticus* were obtained from the Faculty of Fisheries, Cukurova University, Adana, Turkey, and transported to the Aquarium Unit of the Faculty of Fisheries,

**Table 1** Chemical composition of dietary ingredients

	Crude protein	Crude lipid	Crude ash
Fish meal	73.93	8.37	7.20
<i>Ulva</i>	9.91	0.11	26.67
Soybean meal	53.26	1.62	6.04
Corn starch	1.91	0.08	0.33
Wheat	17.05	0.40	0.86

**Table 2** Percentage and proximate composition of the experimental diets containing different energy and Ulva levels

Ingredients (%)	LL	LL-U	HL	HL-U
Fish meal	30.0	30.0	30.0	30.0
Ulva	0.0	5.0	0.0	5.0
Soybean meal	31.5	31.5	31.5	31.5
Wheat	12.0	12.0	12.0	12.0
Corn starch	15.0	10.0	5.0	0.0
Vitamin	2.0	2.0	2.0	2.0
Mineral	2.0	2.0	2.0	2.0
Fish oil	6.5	6.5	16.5	16.5
Binder	1.0	1.0	1.0	1.0
Nutrient contents (DM%)				
Crude protein	40.68	40.72	40.73	40.67
Crude lipid	9.97	10.01	19.96	20.03
Crude ash	8.19	8.20	8.21	8.30
NFE <sup>a</sup>	41.16	41.07	31.10	31.00
Gross energy (kJ g <sup>-1</sup> ) <sup>b</sup>	20.54	20.55	22.78	22.78
P:E (mg kJ <sup>-1</sup> )	19.81	19.82	17.88	17.85

LL low lipid, LL-U low lipid with Ulva, HL high lipid, HL-U high lipid with Ulva, DM dry matter

<sup>a</sup> Nitrogen-free extracts (NFE) = matter – (crude lipid + crude ash + crude protein)

<sup>b</sup> Gross energy calculated according to 23.6 kJ g<sup>-1</sup> protein, 39.5 kJ g<sup>-1</sup> lipid, and 17.0 kJ g<sup>-1</sup> NFE

Çanakkale Onsekiz Mart University, Çanakkale, Turkey. Fish were acclimated to laboratory conditions for 2 weeks and fed a commercial diet (crude protein: 40%, crude lipid: 10%). A total of 120 fish (~10 g) were randomly distributed among the 12 experimental tanks and allocated one of the four dietary treatments for 16 weeks. Fish were weighed and recorded every 2 weeks after a 24-h starvation period. Water was changed daily at a rate of approximately 20% to maintain water parameters. Throughout the feeding trial, water was slightly brackish (salinity = 0.2 mg l<sup>-1</sup>) and weakly alkaline (pH 7.45). Water temperature was maintained between 25°C and 27°C. A 9-h light/15-h dark photoperiod was maintained throughout the entire experimental period.

### Analytical procedures

Carcass samples were homogenized and analyzed for proximate composition at the beginning and end of the feeding trial. Proximate analysis was conducted on all ingredients, test diets, and fish samples. Moisture, total lipid, crude protein, and ash content were all determined by standard Association of Official Analytical Chemist (AOAC) (2003) methodology. Gross energy of the diets was calculated using the conversion factors of 23.6, 39.5, and 17.0 kJ g<sup>-1</sup> for protein, lipid, and nitrogen-free extract (NFE), respectively (Brett and Groves 1979).

### Evaluation of growth performance

Growth performance and feed utilization were analyzed in terms of final individual fish weight (g), weight gain (WG, %), specific growth rate (SGR, % day<sup>-1</sup>), feed conversion ratio (FCR), protein efficiency ratio (PER), net protein utilization (NPU), and net energy utilization (NEU). The following formulae were used:

$$WG = 100 \times [(\text{final fish weight (g)} - \text{initial fish weight (g)})/\text{initial fish weight}]$$

$$SGR = 100 \times [(\ln \text{ final fish weight}) - (\ln \text{ initial fish weight})]/\text{experimental days}$$

FCR = feed intake (g)/weight gain (g)

PER = weight gain (g)/protein fed (g)

NPU = [(final body protein (g) – initial body protein (g))/dietary protein consumption (g)] × 100

NEU = [(final body energy (g) – initial body energy (g))/dietary energy consumption (g)] × 100

### Statistical analysis

Data were subjected to a one-way analysis of variance (ANOVA). When a significant difference was found among treatments, Duncan's multiple range test was performed (Zar 2001). Statistical analysis was performed using the Statgraphics 7.0 version for Windows (Manugistics, Rockville, MD, USA) and results accepted at the 5% level.

### Results

Results obtained for growth performance and diet utilization during the tilapia feeding trial are summarized in Table 3. All diets were readily accepted by fish, indicating no issues relating to palatability of algal supplemented diets. However, all fish displayed a generally poor appetite, possibly due to water quality fluctuations resulting from daily water changes. No mortalities were observed during the experimental period. Data indicate that dietary Ulva meal, at the two lipid levels tested, significantly improved fish growth and diet utilization when compared with the non-Ulva-supplemented groups. The incorporation of Ulva in the diets of LL groups significantly increased weight gain (from 120% to 148%), SGR (from 0.71 to 0.81), and PER (from 1.29 to 1.35) and improved FCR (from 1.90 to 1.82). Ulva supplementation did not affect NPU or NEU in LL groups. The inclusion of Ulva significantly improved weight gain (from 122% to 179%), SGR (from 0.71 to 0.92), FCR (from 2.21 to 1.44), PER (from 1.11 to 1.71), NPU (from 12.94 to 23.05), and NEU (from 9.75 to 12.95) in fish fed the diet of HL. Overall, best improvements in all parameters measured were found in HL dietary groups.

**Table 3** Growth performance and nutrient utilization of *Oreochromis niloticus* fed with experimental diets

	LL	LL-U	HL	HL-U
Mean initial weight g	10.66	10.67	10.66	10.69
Mean final weight g	23.53 ± 0.17 <sup>a</sup>	26.50 ± 0.51 <sup>b</sup>	23.71 ± 0.12 <sup>a</sup>	29.91 ± 0.05 <sup>c</sup>
Weight gain (%)	120.73 ± 1.67 <sup>a</sup>	148.36 ± 4.60 <sup>b</sup>	122.42 ± 1.06 <sup>a</sup>	179.79 ± 0.15 <sup>c</sup>
SGR	0.71 ± 0.01 <sup>a</sup>	0.81 ± 0.02 <sup>b</sup>	0.71 ± 0.01 <sup>a</sup>	0.92 ± 0.01 <sup>c</sup>
FCR	1.90 ± 0.01 <sup>c</sup>	1.82 ± 0.03 <sup>b</sup>	2.21 ± 0.02 <sup>d</sup>	1.44 ± 0.01 <sup>a</sup>
PER	1.29 ± 0.01 <sup>b</sup>	1.35 ± 0.02 <sup>c</sup>	1.11 ± 0.01 <sup>a</sup>	1.71 ± 0.01 <sup>d</sup>
NPU	14.78 ± 0.51 <sup>a,b</sup>	16.96 ± 0.91 <sup>b</sup>	12.94 ± 1.14 <sup>a</sup>	23.05 ± 0.42 <sup>c</sup>
NEU	11.72 ± 0.33 <sup>a,b</sup>	11.48 ± 0.83 <sup>a,b</sup>	9.75 ± 0.46 <sup>a</sup>	12.95 ± 0.95 <sup>b</sup>

Values are mean ± standard error of mean (SEM) of three replicates ( $n =$  three tanks per diet)

LL low lipid, LL-U low lipid with Ulva, HL high lipid, HL-U high lipid with Ulva, DM dry matter, SGR specific growth rate, FCR feed conversion ratio, PER protein efficiency ratio, NPU net protein utilization, NEU net energy utilization

Figures in the same row having the same superscript are not significantly different ( $P > 0.05$ )

**Table 4** Whole-body composition (% fresh weight basis) of *Oreochromis niloticus* at the beginning and end of the experiment

	Initial	LL	LL-U	HL	HL-U
Moisture	71.6 <sup>a</sup>	75.6 <sup>b</sup>	76.0 <sup>b</sup>	75.7 <sup>b</sup>	76.9 <sup>b</sup>
Crude protein	19.1 <sup>b</sup>	14.9 <sup>a</sup>	15.2 <sup>a</sup>	15.0 <sup>a</sup>	15.5 <sup>a</sup>
Crude lipid	1.4 <sup>a</sup>	3.5 <sup>c</sup>	2.4 <sup>b</sup>	3.8 <sup>c</sup>	2.7 <sup>b</sup>
Crude ash	4.7 <sup>a,b</sup>	4.5 <sup>a,b</sup>	4.8 <sup>a,b</sup>	4.1 <sup>a</sup>	5.1 <sup>b</sup>

LL low lipid, LL-U low lipid with Ulva, HL high lipid, HL-U high lipid with Ulva

Figures in the same row having the same superscript are not significantly different ( $P > 0.05$ )

Variations in tilapia composition among dietary treatments at the end of the feeding trial are shown in Table 4. Fish fed Ulva meal, at both lipid levels, displayed a marginal improvement in carcass protein. However, this was not significant. A significant reduction of approximately 30% body lipid was found in Ulva groups at both dietary lipid levels. Moisture levels remained the same in all treatments. An increase of ash content was found in group HL-U.

## Discussion

The importance of *U. rigida* as a possible alternative feed ingredient for cultured fish has been demonstrated in recent years (Wassef et al. 2005; Valente et al. 2006; Diler et al. 2007). However, information on the use of algal products and aquatic plants in practical feeds for cultured tilapia are relatively few (El-Sayed 1992; Naegel 1997; Fasakin et al. 1999; Fiogbé et al. 2004). Dietary inclusion of Ulva meal can be considered a very interesting dietary ingredient for Nile tilapia if supplemented at the correct level. Supplementation of 5% Ulva meal was used in our study, as no negative effects on growth performance, feed utilization, and body composition were found at this level in a previous trial (Güroy et al. 2007); however, negative consequences can result from using levels between 10% and 20% (Güroy et al. 2007; Azaza et al. 2008).

Results of our investigation suggest that low-level inclusion of Ulva meal can significantly improve growth performance and nutrient utilization of tilapia fed high-lipid diets. The SGR of fish in this trial was comparable with results reported previously when juvenile tilapia were fed high-lipid diets and subjected to large daily water changes (Mbahinzireki et al. 2001; Willie et al. 2002; Kang'ombe et al. 2007). Despite relatively low-growth performance, significant improvements were found in Ulva-fed groups (Table 3). Compared with LL diet, fish fed LL-U displayed improved weight gain, SGR, PER, and FCR. However, NPU and NEU were not affected. The supplementation of dietary Ulva meal resulted in greater benefits when fed with high-lipid diets; HL-U-fed fish displayed significantly improved weight gain, SGR, FCR, PER, NPU, and NEU compared with the HL group. In fact, HL-U-fed fish showed the best performance in all parameters measured.

Dietary lipids in aquafeeds are an important source of energy and essential fatty acids (Sargent et al. 2002). Optimum lipid levels results in improved growth rates, feed conversion ratios, nutrient utilization, and reduced nitrogen excretion (Yigit et al. 2002; Martins et al. 2007). However, excessive lipid can lead to decreased feed intake and may reduce the utilization of other nutrients, resulting in poor growth performance (Hemre and Sandnes 1999). Furthermore, extreme dietary lipid concentrations can increase lipid levels

in the liver, visceral organs, and whole body of the fish due to an increased lipid deposition, which has a detrimental effect on fish product quality. Compared with non-Ulva supplemented groups, fish fed Ulva meal, at both lipid levels, resulted in a significant reduction of body lipid by approximately 30%. Ulva-fed fish also displayed a marginal improvement in carcass protein; however, this was not significant. The effective substance provided by algae is not known, but protein, fiber, minerals, and trace elements need to be considered. The observed benefits may be explained by the high vitamin C content of Ulva meal (Ortiz et al. 2006; García-Casal et al. 2007), which effects lipid metabolism and may result in alteration of body composition and nutrient deposition in fish (Miyasaki et al. 1995; Nakagawa 1997; Nakagawa et al. 2000; Ji et al. 2003).

The effects of dietary algal meals on carcass lipids can be contradictory; whereas some reports suggest an elevation of total lipids (Mustafa et al. 1995; Diler et al. 2007), others suggest a decrease (Güroy et al. 2007; Azaza et al. 2008). Farmed fish are often of low quality due to the comparatively high lipid content; the mobilization of these lipid reserves is an important parameter for improved body composition. Our study further indicates the potential role of algae as a feed additive for aquafeed, particularly tilapia. However, a more comprehensive investigation is required in long-term feeding trials to evaluate the full potential of algal products and optimum dietary inclusion levels.

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## References

- AOAC (2003) Official methods of analysis of the association of official analytical chemists, 17th edn. Association of Official Analytical Chemist, Arlington, Virginia
- Azaza MS, Mensi F, Ksouri J, Dhraief MN, Brini B, Abdelmouleh A, Kraiem MM (2008) Growth of Nile tilapia (*Oreochromis niloticus* L.) fed with diets containing graded levels of green algae Ulva meal (*Ulva rigida*) reared in geothermal waters of southern Tunisia. *J Appl Ichthyol* 24:202–207
- Brett JR, Groves TDD (1979) Physiological energetics. In: Hoar WS, Randall DJ, Brett JR (eds) *Fish Physiology*, vol VIII. Academic Press, New York, pp 279–352
- Chou B-S, Shiau S-Y (1996) Optimal dietary lipid level for growth of juvenile hybrid tilapia *Oreochromis niloticus* × *Oreochromis aureus*. *Aquaculture* 143:185–195
- De Silva S, Gunaskera RM, Shim KF (1991) Interactions of varying dietary protein and lipid levels in young red tilapia: evidence of protein sparing. *Aquaculture* 95:305–318
- Diler İ, Tekinay AA, Güroy D, Güroy B, Soyuturk M (2007) Effects of *Ulva rigida* on the growth, feed intake and body composition of common carp, *Cyprinus carpio*. *J Biol Sci* 7:305–308
- Ellis SC, Reigh RC (1991) Effects of dietary lipid and carbohydrate levels on growth and body composition of juvenile red drum, *Sciaenops ocellatus*. *Aquaculture* 97:383–394
- El-Sayed A-FM (1992) Effect of substituting fish meal with *Azolla pinnata* in practical diets for fingerlings and adult Nile tilapia *Oreochromis niloticus* (L). *Aquacult Fish Manag* 23:167–173
- Food and Agriculture Organization of the World Health Organization (2007) *FAO yearbook of fishery statistics*, Vol. 100/2. FAO, Rome, p 202
- Fasakin EA, Balogun AM, Fasuru BE (1999) Use of duckweed, *Spirodela polyrrhiza* L. Schleiden, as a protein feedstuff in practical diets for tilapia, *Oreochromis niloticus* L. *Aquac Res* 30:313–318
- Fiogbé ED, Micha JC, Van Hove C (2004) Use of a natural aquatic fern, *Azolla microphylla*, as a main component in food for the omnivorous-phytoplanktonophageous tilapia, *Oreochromis niloticus* L. *J Appl Ichthyol* 20:517–520
- Fitzsimmons K (2000) Tilapia: the most important aquaculture species of the 21st century. In: Fitzsimmons K, Filho JC (eds) *Tilapia aquaculture in the 21st century*. Proceedings from the Fifth International Symposium on Tilapia Aquaculture. American Tilapia Association and DPA/MA, Rio de Janeiro, Brazil, pp 3–8
- García-Casal MN, Pereira AC, Leets I, Ramírez J, Quiroga MF (2007) High iron content and bioavailability in humans from four species of marine algae. *J Nutr* 137:2691–2695

- Güroy BK, Cirik Ş, Güroy D, Sanver F, Tekinay AA (2007) Effects of *Ulva rigida* or *Cystoseira barbata* meals as a feed additive on growth performance, feed utilization, and body composition in Nile tilapia, *Oreochromis niloticus*. Turk J Vet Anim Sci 31:91–97
- Hemre G-I, Sandnes K (1999) Effect of dietary lipid level on muscle composition in Atlantic salmon *Salmo salar*. Aquacult Nutr 5:9–16
- Jauncey K, Ross B (1982) A guide to Tilapia feeds and feeding. Institute of Aquaculture, Stirling, p 111
- Ji H, Om A, Yoshimatsu T, Hayashi M, Umino T, Nakagawa H, Asano M, Nakagawa A (2003) Effect of dietary vitamins C and E fortification on lipid metabolism in red sea bream *Pagrus major* and black sea bream *Acanthopagrus schlegeli*. Fish Sci 69:1001–1009
- Kang'ombe J, Likongwe JS, Eda H, Mtimuni JP (2007) Effect of varying dietary energy level on feed intake, feed conversion, whole-body composition and growth of Malawian tilapia, *Oreochromis shiranus*-Boulenger. Aquac Res 38:373–380
- Martins DA, Valente LMP, Lall SP (2007) Effects of dietary lipid level on growth and lipid utilization by juvenile Atlantic halibut (*Hippoglossus hippoglossus*, L). Aquaculture 263:150–158
- Mbahinzireki GB, Dabrowski K, Lee K-J, El-Saidy D, Wisner ER (2001) Growth, feed utilization and body composition of tilapia *Oreochromis* sp. fed with cottonseed meal-based diets in a recirculating system. Aquacult Nutr 7:189–200
- Miyasaki T, Sato M, Yoshinaka R, Sakaguchi M (1995) Effect of vitamin C on lipid and carnitine metabolism in rainbow trout. Fish Sci 61:501–506
- Mustafa MG, Nakagawa H (1995) A review: dietary benefits of algae as an additive in fish feed. Isr J Aquacult-Bamid 47:155–162
- Mustafa MG, Wakamatsu S, Takeda T, Umino T, Nakagawa H (1995) Effects of algae meal as a feed additive on growth performance, feed efficiency, and body composition in red sea bream. Fish Sci 61:25–28
- Naegel LCA (1997) *Azolla* meal as a supplemental feed ingredient for tilapias. In: Fitzimmons K (ed) Proceedings of the 4th International Symposium on Tilapia in Aquaculture, Orlando, FL, USA, pp 20–30
- Nakagawa H (1997) Effect of dietary algae on improvement of lipid metabolism in fish. Biomed Pharmacother 51:345–348
- Nakagawa H, Mustafa MG, Takii K, Umino T, Kumai H (2000) Effect of dietary catechin and Spirulina on vitamin C metabolism in red sea bream. Fish Sci 66:321–326
- Ortiz J, Romero N, Robert P, Araya J, Lopez-Hernández J, Bozzo C, Navarrete E, Osorio A, Rios A (2006) Dietary fiber, amino acid, fatty acid and tocopherol contents of the edible seaweeds *Ulva lactuca* and *Durvillaea antarctica*. Food Chem 99:98–104
- Rinchard J, Mbahinzireki G, Dabrowski K, Lee KJ, Garcia-Abiado MA, Ottobre J (2002) Effects of dietary cottonseed meal protein level on growth, gonad development and plasma sex steroid hormones of tropical fish tilapia *Oreochromis* sp. Aquacult Int 10:11–28
- Sargent JR, Tocher DR, Bell GJ (2002) The lipids. In: Halver JE, Hardy R (eds) Fish nutrition. Academic Press, San Diego, CA, pp 181–257
- Suresh V (2003) Tilapias. In: Lucas JS, Southgate PC (eds) Aquaculture: farming aquatic animals and plants. Blackwell Publishing, Oxford, UK, pp 321–345
- Valente LMP, Gouveia A, Rema P, Matos J, Gomes EF, Pinto IS (2006) Evaluation of three seaweeds *Gracilaria bursa-pastoris*, *Ulva rigida* and *Gracilaria cornea* as dietary ingredients in European sea bass *Dicentrarchus labrax* juveniles. Aquaculture 252:85–91
- Wassef EA, El-Sayed AFM, Kandeel KM, Sakr EM (2005) Evaluation of *Pterocla dia* and *Ulva* meals as additives to gilthead seabream *Sparus aurata* diets. Egypt J Aquat Res 31:321–332
- Willie L, McLean E, Goddard JS, Byatt JC (2002) Dietary lipid level and growth hormone alter growth and body conformation of blue tilapia, *Oreochromis aureus*. Aquaculture 209:219–232
- Yigit M, Yardim Ö, Koshio S (2002) The protein sparing effects of high lipid levels in diets for rainbow trout (*Oncorhynchus mykiss*, W. 1792) with special reference to reduction of total nitrogen excretion. Isr J Aquacult-Bamid 54:79–88
- Zar JH (2001) Biostatistical analysis, 4th edn. Prentice-Hall, Inc, Upper Saddle River, NJ, p 931