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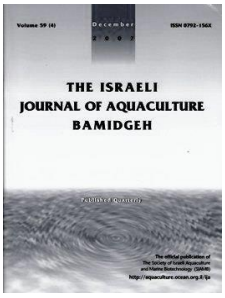

Growth and Feed Utilization by Golden Grey Mullet (*Liza aurata*) in a Coastal Lagoon Ecosystem, Fed Compound Feeds with Varying Protein Levels

Ioannis T. Karapanagiotidis[1*], Vasileios Karalazos[1,2], Nikolaos Kougioumtzis[1], Vasileios Tsiamis[1], Vasileios Tsiaras[1,3], Christos Neofitou[1], Ioannis Karacostas[2] and Ioannis Nengas[4]

[1] *Department of Ichthyology and Aquatic Environment, School of Agricultural Sciences, University of Thessaly, Fytoko Street, N. Ionia Magnesia's, 38446, Greece.*
[2] *BioMar Hellenic SA, Department of Research and Development, 2nd Industrial Zone of Volos, Block No 6, Velestino, 37500, Greece.*
[3] *Fisheries Association of Mandra, Prefecture of Xanthi, Domestichou 24 Komotini, 69100, Greece.*
[4] *Institute of Aquaculture, Hellenic Centre for Marine Research, Agios Kosmas Elliniko Athens, 16610, Greece.*

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Abstract

The effects of complimentary compound feeds with varying protein levels on growth performance, feed utilization, and whole body composition were studied in golden grey mullet, *Liza aurata*. Fish of initial weight 51.1±5.2 g were raised in hapas in a coastal lagoon and fed four iso-energetic diets containing 25%, 30%, 35% or 45% of crude protein for 20 weeks. *L. aurata* reared on the experimental diets showed relatively low growth rates (SGR ranged from 0.40 to 0.48%/day, and feed utilization parameters (FE ranged from 0.27 to 0.34) among dietary groups consistent with the known slow growth rate of the species. The growth performance and feed utilization of *L. aurata* was not significantly affected by dietary protein level, despite the fact that there was a trend indicating better fish growth and feed efficiency with increasing dietary protein level. This is indicative of the low protein requirements of *L. aurata,* although it could be that higher dietary protein concentrations could possibly improve growth performance. The farming of low-trophic species such as *L. aurata* allows under-utilized trophic resources to be better exploited for fish production. Thus any future advances in understanding the nutrition and feeding of *L. aurata* under culture conditions, could improve further the potential of this species, especially in regional and coastal aquaculture.

* Corresponding author, e-mail: ikarapan@uth.gr

Introduction

Golden grey mullet, *Liza aurata* (Risso, 1810) is widely distributed in the Mediterranean, Black, and southern Caspian seas, as well as along the Atlantic coast from Scotland and the southern coast of Norway and Sweden south towards Morocco (Thomson 1990). Together with other members of the Mugilidae family they inhabit coastal lagoons and estuaries where they constitute target species for artisanal fisheries (Katselis et al., 2007). They also play a crucial ecological role as biotic vectors of organic matter between littoral habitats and the open sea (Lefeuvre et al., 1999).

Mullet farming in extensive and semi-intensive ponds and reservoirs has been practiced worldwide for centuries, especially in the Far East and in the Mediterranean region (Crosetti and Cataudella, 1995) reaching a total global production of 134,329 metric tons in 2010 (FAO, 2012). Flathead grey mullet, *Mugil cephalus*, is the most important cultured mullet species. *Liza ramada*, *Liza aurata*, *Liza saliens*, *Valamugil seheli* and *Chelon labrosus* are cultured in the Mediterranean region and *Liza parsia*, *Liza tade* and *Liza macrolepis* are cultured in the Indo Pacific region (Pillay, 1990). Their potential for aquaculture stems from their euryhaline and eurytherm adaptability that allows them to grow well in a variety of ecosystems from coastal lagoons with saline and brackish waters to freshwater ponds (Crosetti and Cataudella, 1995). Moreover, fry production is high in certain seasons, and their capture almost entirely supports seed supply for mullet aquaculture (Crosetti and Cataudella, 1995). Mullets are also commercially important; *L. aurata* fetches 4-6 €/Kg on the Greek market (Hotos and Katselis, 2011). Mullets such as *M. cephalus* are not only cultured as food fish but also for their roe, highly prized as a nutritious delicacy and beneficial to human health (Kalogeropoulos et al., 2008). *Liza aurata* in particular is processed into a highly nutritional and prized smoked product, locally called "lykourinos". Most importantly mullets feed low in the food chain, either as direct primary consumers and detrivores, or at a secondary level feeding on small macrofauna (Lebreton et al., 2011). Their nutritional requirements therefore could be met by natural sources and low cost supplementary feeds (Crosetti and Cataudella, 1995).

Despite the economic importance of mullet as a major farmed fish species, no special feeds are commercially available for them in many countries. Apart from dependence on fry availability, further development of mullet farming depends on the development of reliable mass propagation techniques and on the availability of reliable low cost and efficient feeds that could enhance production. However, our knowledge of their nutritional requirements is limited. Most literature describes the trophic ecology and feeding habits of mullets in the wild. Mullets demonstrate omnivorous, opportunistic feeding behaviour (water filtering or benthophagous) with a large variety of food items, such as plants, detrital matter, microalgae, benthic meiofauna, and small macrofauna, being part of their diet (Lebreton et al., 2011) but very little information is available regarding growth performance and feed utilization of mullets fed formulated compound diets. Research has focused mainly on *Mugil cephalus* (Papaparaskeva-Papoutsoglou and Alexis, 1986; Argyropoulou et al., 1992; Luzzana et al., 2005) although other mullet species have also attracted researchers' interest (Ojaveer et al., 1996; El-Sayed and El-Ghobashy, 2011). Knowledge regarding the growth performance of farmed *L. aurata* is limited (Chervinski 1975; 1976). The influence of periphyton substrates and supplemental feeding on the species growth performance has been evaluated (Richard et al., 2010). Information on protein and other nutritional requirements can contribute to the development of mullet farming and improve the potential of these low trophic level species, especially in regional and coastal aquaculture. The importance of this has been recently highlighted (SEACASE, 2010) in terms of environmental protection and restoration in areas of particular ecological interest, as well as of employment opportunity, and development in rural coastal areas. The aim of the present study was to elucidate the effects of supplementary compound feed with varying protein levels on the growth and feed utilization of cultured golden grey mullet, *L. aurata* in a coastal lagoon ecosystem.

Materials and methods

Fish and facilities. Golden grey mullet, *L. aurata*, with a mean initial body weight of approximately 45 g were collected from the Lafra lagoon (Northeast Greece) using a long handled fishing net. Fish were taxonomically identified, selected individually, and stocked in a large hapa suspended near the banks of the lagoon and acclimated for 50 days in a hapa prior the onset of the trial. During this phase they were fed once daily at 2% of total biomass with an experimental practical diet (P30, Table 1) containing 30% protein. Fish were observed eating the compound feed on the water surface and at the bottom of the part of the hapa that was close to the bank. After this acclimation period, fish with a mean initial body weight of 51.1 ± 5.2 g (mean ± standard deviation) were randomly divided into 12 hapas (2.5L×2W×1D) m, 30 fish/cage. There were 4 treatment groups with three replications of each treatment. The hapas were constructed of 3 mm mesh net and positioned along the banks of the lagoon approximately 25 cm above the water surface to prevent fish escaping. The installation was covered with anti-predator net. The fish were allowed to feed on natural food at the bottom. Water quality parameters were monitored regularly throughout the experimental period (July-November). During the entire experimental period, mean water temperature ranged from 12-26 °C, dissolved oxygen at midday varied from 7.7-9.7 mg/l, salinity varied from 27.0-32.8 g/l, and pH was relatively constant at 7.8 ± 0.3. Mortality was calculated at the end of the experiment as most of the dead fish sank to the base of the hapa and were difficult to detect on a daily basis.

Experimental diets and feeding. Four extruded diets (2 mm pellet size), in the form of sinking pellets, were formulated (HCMR, Athens, Greece) using the same basal ingredients (fishmeal, wheat meal, corn meal, fish oil, vitamin and mineral premixes) and varying only in protein content. Specifically, the four experimental diets were iso-energetic (19 Mj/kg) and contained 25%, 30%, 35% or 45% crude protein (groups P25, P30, P35 and P45, respectively). The proximate composition of the experimental diets is shown in Table 1.

Table 1. Formulation and chemical composition (percentage as fed) of the four experimental diets fed to golden grey mullet for 20 weeks.

	P25	*P30*	*P35*	*P45*
Component (g/kg)				
Fishmeal[1]	265	352	438	607
Wheat meal	436	353	282	149
Corn meal	200	200	200	200
Fish oil[2]	74	64	51	15
Vitamin & mineral premix[3]	20	20	20	20
Methionine – lysine	2.5	2.5	2.5	2.5
Monocalcium phosphate	2.5	2.5	2.5	2.5
Chemical composition (%)				
Dry matter	90.6	91.4	91.8	91.2
Crude protein	25.5	29.9	35.8	45.2
Crude fat	9.2	8.1	8.2	6.6
Ash	4.7	6.6	7.3	8.7
Fiber[4]	1.4	1.3	1.3	1.2
Carbohydrates[5]	51.2	46.8	40.5	30.7
Gross Energy (Mj/kg)[6]	18.5	18.3	18.7	18.6
Protein:Energy (g protein/Mj)	13.8	16.3	19.2	24.3

[1] Dry matter: 91.0%, crude protein: 69.2%, crude lipid: 8.1%).
[2] Salmon & sardine oil (50:50) containing 21% of n-3 HUFA.
[3] Vitamin and mineral supplement (per kg of mixture): Vitamins: E, 58.3 g; K3, 3.3 g; B1, 3.3 g; B2, 6.6 g; B6, 3.3 mg; B12, 10 mg; folic acid, 3.3 g; biotin, 100 mg; C, 33.3 g; nicotinic acid, 16.6 g; pantothenic acid, 13.3 g. Minerals: Co, 170 mg; I, 248 mg ($Ca(IO_3)_2$); Mn, 10 g (MnO); Zn, 33 g (ZnO); Ca 235 g; Se 2,5 mg (Na_2SeO_3); Na 247,5 mg (Na_2SeO_3).
[4] Calculated by known fiber contents of ingredients.
[5] Calculated as 100 minus the sum of the percentages of crude protein, crude fat, moisture and ash.
[6] Calculated by known gross energy values for protein, fat and carbohydrates (5.64, 9.44 and 4.11 Kcal/g, respectively).

The fish were hand-fed every morning at a rate of 2% of initial biomass in triplicate groups of fish for a period of 20 weeks.

Sampling procedures. Prior to the commencement of the experiment, nine fish from the initial population were sampled for the proximate composition analysis of their whole body and another nine fish for the proximate composition analysis of muscle tissue. At the end of the experimental period, the fish were killed rapidly by immersion in ice water and their body weight and length were determined. Six fish from each hapa were sampled and stored at -20°C. Half of them (9 fish per dietary treatment) were used to

determine whole body and the other half for muscle proximate composition. Muscle samples were obtained by cutting a fillet from the dorsal to ventral fins. This section was then skinned, deboned and homogenized. For whole body analysis, fish were cut into pieces, minced in a meat grinder until homogenate subsamples of each fish were obtained. All samples, including samples taken from each of the experimental diets, were stored at -20°C until analysis.

Chemical analysis. Proximate analysis, based on methods described in AOAC (1995), was conducted to determine the nutrient composition of diets and muscle samples. Thermal drying to constant weight in an oven at 110°C for 24 h was conducted to determine moisture content of feeds and muscle samples. Crude protein content was determined by Kjeldahl analyses (nitrogen x 6.25; behr Labor-Technik, Germany). Crude fat was determined by exhaustive Soxhlet extraction using petroleum ether (40-60°C, BP) on a Soxtec System (Gerhard, Germany). Ash content was determined by dry ashing in porcelain crucibles in a muffle furnace at 600°C overnight.

Calculation of nutritional indices. The following formulae were applied to the data:

Condition factor (K) = $100 \times W\ (g)/TL^3\ (cm)$,

Weight gain (%) = $(W_F - W_I)/100/W_I$,

Mean daily weight gain (g/day) = $(W_F - W_I)$ /days,

Specific growth rate (SGR, %/day) = $100 \times [\ln W_F - \ln W_I]$/days,

Feed efficiency (FE) = wet weight gain (g)/feed given (g),

Protein efficiency ratio (PER) = weight gain (g)/protein given(g),

Nutrient retention (%) = 100 × nutrient gain (g)/nutrient given (g),

where, W_I and W_F are the initial and the final fish mean weights, TL the total length.

Statistical analysis. In order to determine any significant differences between dietary treatments, data were subjected to one-way ANOVA, followed by Tukey's post-hoc test to rank the groups. Differences were regarded as significant at $P < 0.05$. ANOVA was performed using SPSS 18.0 (2009; SPSS, Inc., Chicago, IL, USA).

Results

Survival percent in all dietary treatments at the end of the experimental period were recorded. Although survival was higher in P45 group, this difference was not significant (P<0.05). In all groups, weight increased by 78.2%-95.3%. Final body weight of 90.7-100.6 g and total length of 21.2-21.9 cm was reached in 20 weeks. The mean daily weight gain ranged from 0.28-0.35 g and the specific growth rate (SGR) ranged from 0.40-0.48%/day. Feed efficiency (FE) ranged from 0.27-0.34 and protein efficiency ratio (PER) ranged from 0.83-1.46. Growth performance and feed utilization of *L. aurata* was not significantly affected ($P > 0.05$) by the dietary protein level, despite the fact that there was a tendency towards higher weight gain, total biomass, FE, SGR, and PER with increasing dietary protein levels (Table 2).

Table 2. Growth performance and feed utilization of *L. aurata* fed the experimental diets.

	P25	*P30*	*P35*	*P45*
Initial weight (g/fish)	50.9±5.2	51.2±5.5	51.1±4.7	51.5±5.5
Final weight (g/fish)	90.7±19.9	91.3±16.0	94.6±11.7	100.6±8.2
Initial length (cm)	18.6±0.6	18.8±0.7	19.2±0.8	18.7±0.6
Final length (cm)	21.7±2.6	21.2±3.1	21.9±3.0	21.9±2.4
Initial condition factor	0.79±0.08	0.77±0.06	0.74±0.10	0.78±0.07
Final condition factor	0.88±0.06	0.88±0.07	0.90±0.08	0.90±0.04
Survival (%)	71.1±25.9	76.7±23.1	73.3±28.5	84.4±21.4
Total biomass (Kg)	2.01±1.03	2.05±0.51	2.13±1.05	2.52±0.51
Weight gain (%)	78.2±39.1	78.3±31.2	85.2±22.8	95.3±15.9
Mean daily weight gain (g/day)	0.28±0.14	0.29±0.11	0.31±0.08	0.35±0.06
Specific growth rate (%/day)	0.40±0.17	0.41±0.13	0.44±0.09	0.48±0.06
Feed efficiancy	0.27±0.13	0.29±0.12	0.31±0.07	0.34±0.07
Protein efficiency ratio	1.46±0.90	0.98±0.38	0.87±0.36	0.83±0.10
Protein retention (%)	19.1±3.1	12.1±6.4	7.3±4.5	11.6±1.7
Lipid retention (%)	30.4±14.2	34.1±7.8	43.3±12.9	49.7±3.9

Values represent means ± standard deviation of triplicates or of pooled data in case of weight and length. No statistical differences ($P > 0.05$) were found between treatments in any of the above parameters

Whole body and muscle proximate compositions of *L. aurata* fed the four experimental diets are shown in Table 3. Neither whole body nor muscle composition was significantly ($P > 0.05$) affected by increments in dietary protein level. On the other hand, all groups of fish had significantly different ($P < 0.05$) whole body and muscle compositions compared to the initial fish population. Whole-body protein ranged from 55.9-58.4% (dry weight basis) in fish fed the experimental diets as compared to 69.1% found in initial fish population. Conversely, whole-body lipid significantly increased in fish fed the experimental diets (17.3-24.8%) as compared to initial fish (7.8%). This was reflected in their energy contents (21.9-24.1 Kj/g vs. 19.78 Kj/g for fish at the end and at the start of the trial, respectively). Whole body protein and lipid contents tended to increase ($P > 0.05$) in fish fed diets P25 to P35 but decreased in fish fed diet P45. Protein retention ranged from 7.3 to 19.1% with the highest values coming from the P25 group, while lipid retention ranged from 30.4-49.7% and increased with increasing dietary protein level, although not significantly. A similar trend was observed in muscle composition with fish at the end of the experimental period having decreased muscle protein and increased lipid and energy contents compared to the initial fish population. Muscle lipid content of fish tended to increase with increasing dietary protein, but this again was not statistically significant.

Table 3. Whole body and muscle composition (dry weight) of *L. aurata* fed experimental diets.

	Initial	*P25*	*P30*	*P35*	*P45*
Whole body composition					
Dry matter (%)	24.86±3.91	25.76±3.34	24.49±2.76	26.92±4.82	26.10±4.46
Protein (%)	69.16±9.10^{a}	57.11±3.81^{b}	57.94±2.54^{b}	58.47±8.63^{b}	55.93±3.66^{b}
Lipid (%)	7.81±5.51^{a}	18.18±6.25^{b}	19.14±2.46^{b}	24.85±8.11^{b}	17.36±5.48^{ab}
Ash (%)	20.86±3.60^{a}	17.56±3.45^{ab}	14.41±1.86^{b}	14.24±1.73^{b}	15.20±1.19^{b}
Energy (Kj/g)	19.78±1.23^{a}	21.91±1.82^{ab}	22.70±0.94^{b}	24.14±1.55^{b}	22.03±1.39^{ab}
Muscle composition					
Dry matter (%)	21.92±1.92^{a}	24.12±1.36^{b}	24.13±0.55^{b}	24.04±1.26^{b}	24.20±1.13^{b}
Protein (%)	91.52±1.24^{a}	84.35±2.24^{b}	83.83±4.32^{b}	84.52±2.37^{b}	83.44±2.43^{b}
Lipid (%)	1.07±0.53^{a}	6.62±2.69^{b}	6.71±3.53^{b}	7.01±2.75^{b}	7.32±3.02^{b}
Ash (%)	5.64±0.70	5.21±0.43	5.22±0.22	4.78±0.42	5.23±0.14
Energy (Kj/g)[1]	22.36±0.15	23.45±0.62	23.15±0.79	23.76±0.62	23.42±0.48

Values represent means ± standard deviation (n=9). Values within each row not sharing a common superscript letter are significantly different ($P < 0.05$).

[1] Calculated from known gross energy values for protein, fat and carbohydrates (5.64, 9.44 and 4.11 Kcal g^{-1}, respectively).

Discussion

In all dietary treatments mortality occurred. P45 group had the highest survival rate, however the differences were not significant. This may indicate that these fish received a more nutritionally balanced diet. Mullet are known to be sensitive to handling which causes loss of scales and makes them prone to bacterial and fungal infections resulting in mortality even several days after stocking (Yashouv, 1972; Dankwa et al., 2004).

However in this study, the mortality rate observed could not be attributed to handling since handling occurred at the beginning when all fish were anaesthetised and special care was given during transportation and stocking. Moreover, transition from natural to artificial diets could not be considered a major factor affecting mortality since the fish were acclimated to the experimental diets for 50 days. Notably, the mean survival of *L. aurata* in all dietary treatments in the present study compares favourably with the findings of studies conducted with the species to date. High mortality averaging 47.0%-68.0% was reported in *L. aurata* reared in saltwater ponds on a 25% crude protein pelleted diet. This was attributed to low dissolved oxygen levels (Chervinski, 1975; 1976). In the present study the levels of dissolved oxygen recorded at midday were suitable for mullet rearing. Very low oxygen levels that are commonly observed in lagoon ecosystems during the night may be critical for survival, despite the fact that golden grey mullets are relatively well-adapted to hypoxic environments (Lefrancois *et al*. 2005). *L. aurata* raised with no artificial feed input in suspended cages in a marine pond had high mean survival rates (> 90%) and much lower ones (60%) when fish were raised in

fibreglass tanks and fed a pelleted diet (Richard et al., 2010). During the experiment, stress from fish entrapment in hapas could also explain the mortality data.

At the end of the 20-week feeding period growth rates of *L. aurata* were relatively low but comparable with that in previous studies noting the slow growth rate of the species (Vallet et al., 1970; Chervinski, 1975; 1976; Richard et al., 2010). Little is known about nutrition and feeding of *L. aurata* on compound feeds. In preliminary experiments with *Mugil auratus* (former name of *L. aurata*), a maximum growth rate as low as 0.05 g/day/fish for 10 g fish reared at 15 °C for 3 weeks, fed a diet with 25% protein content (dry weight) and at 10% of their body weight was reported (Vallet et al., 1970). Salinity also influences growth rates of *L. aurata* with maximum growth observed at 20% salinity (Vallet et al. (1970). In a series of feeding trials, golden grey mullet reared in saltwater ponds and fed a compound diet with 25% crude protein had higher growth rates than those observed in all dietary treatments in the present study. Individual daily growth increments were 0.6-0.95 g for fry (1 g) raised for 150-186 days and 0.85-1.0 g for fish during the second year of culture (Chervinski, 1975; 1976). The maximum daily individual growth for *L. aurata* fry reared in a periphyton-based marine pond for 63 days was as low as 0.04 g/day and even lower in fibreglass tanks where they received a pelleted (28% crude protein) diet (Richard et al., 2010).

L. aurata reared on the experimental diets showed relatively poor feed utilization. FE values were extremely low even for species known not utilise compound feeds efficiently, (Pruginin et al. 1975). Part of the experimental diets was probably not eaten by fish; however, due to the technical specifications of the rearing system (hapas) it was not possible to measure the uneaten feed. Low feed intake has also been observed in other experiments (Richard et al., 2010). In the present trial low feed intake could be due to the fact that the fish were of wild origin and therefore not properly adapted to dry feeds. The fact that the fish were not restricted from the natural food may also have been a factor. The access of fish to the natural food was part of the feeding strategy of the experiment. For such a low trophic level species, it is favourable to complement their natural feeding with dry diets, and therefore any future development in the nutrition and feeding of the species under culture conditions should also include natural feeds in parallel to the dry diet diets. In addition, the nutritional profile of the diets used in this experiment may not have supplied the specific requirements of the species due to our lack of knowledge in this area.

Growth performance and feed utilization of *L. aurata* was not significantly ($P > 0.05$) affected by dietary protein level, despite the fact that there was a non significant trend towards higher weight gain, total biomass, FE, SGR, and PER with increasing dietary protein level. This is possibly indicative of low protein requirements of *L. aurata*. Protein requirements for maximum growth are known to be low in various mullet species as seen here for *L. aurata*. Diets with protein levels ranging from 12%-60%, tested under laboratory conditions on *M. capito,* suggested a dietary protein level of 25% as optimal for this species, although higher protein diets resulted in higher feed efficiencies which were not significant (Papaparaskeva-Papoutsoglou and Alexis, 1986) This was also seen in the present study. *M. capito* fed on a 15% crude protein diet grew equal to fish fed diets with protein levels up to 50%, suggesting even lower protein requirements and better carbohydrate utilization of mullet species (Alexis and Papaparaskeva-Papoutsoglou 1986). Adult *M. capito* fed on a 25% crude protein diet grew the same as fish fed on diets with a protein level as high as 70% (Vallet et al., 1970).

Maximum growth rates were achieved on a 70% crude protein diet in *L. aurata* fry fed with diets of various protein and carbohydrate levels, compared to diets with lower protein levels such as 60%, 45% and 25% (Vallet et al., 1970). Feed efficiency values in these experiments were even lower than those found in the present study with authors stating that the source of protein, either plant or animal, in the diet does not seem to have any influence on FE; the latter has also been reported for *M. cephalus* (Luzzana et al. 2005). Larger fish require lower dietary protein levels (presumably 25%) due to shifts in their feeding preferences as they change their feeding habits from zooplanktonivorous during its younger stages to herbivorous and detritivorous in its older stages.

For thick-lipped grey mullet (*Chelon labrosus*), increasing the dietary protein level from 38% to 49% or 59%, at two protein-to-energy ratios (19.72 and 29.83 mg

protein/Kj gross energy, respectively), did not result in higher fish growth rates and led to lower voluntary feed consumption. Growth among fish fed a low-lipid diet was generally poorer than that of fish fed a high-lipid diet of the same protein level thus perhaps lipid was a more effective source of non-protein energy than carbohydrate for *C. labrosus* (Ojaveer et al., 1996). Very high carbohydrate levels in fat-free diets are not utilised effectively by *M. cephalus*, and performance does not appear to be affected by the different sources of dietary oil (Argyropoulou et al., 1992). It seems that fish use dietary lipid efficiently as an energy source, but their capacity to utilize carbohydrate varies considerably between species and depends on variables such as digestibility and starch complexity (Wilson, 1994). In the present study, decrease in the protein content of the fishmeal-based diets was achieved mainly by increasing the carbohydrate fraction. A diet (P25) with 51% carbohydrate level resulted in similar fish growth to P45 with 30% carbohydrate indicating that the species denotes its omnivorous feeding habits.

The proximate composition values are within the range reported for *L. aurata* (Chervinski, 1976; Boran and Karacam, 2006; Ghelichpour and Shabanpour, 2011; Ardalan et al., 2012). Under the specific culture conditions and diets in our study, no significant effect of dietary protein level on the body and muscle composition of *L. aurata* was observed. Previous studies on *M. capito*, showed that no significant changes occur in body protein when dietary protein level is above the optimum (Papaparaskeva-Papoutsoglou and Alexis, 1986; Alexis and Papaparaskeva-Papoutsoglou, 1986), while body fat content may be increased (Alexis and Papaparaskeva-Papoutsoglou, 1986) or decreased (Papaparaskeva-Papoutsoglou and Alexis, 1986) indicating lipid synthesis from protein or carbohydrate sources, respectively. Whole body protein of *M. cephalus* increased when fish were fed low lipid diets, but this was less apparent in fish fed high lipid diets (Ojaveer et al., 1996).

The slight increases in *L. aurata* body and muscle lipids, observed in the present study, may imply that excess dietary protein was not retained in the body, neither was it utilised for growth, but rather was catabolised to metabolic energy, which in turn was transformed to somatic lipid. This is supported by the fact that lipid retention was much higher in fish feeding with elevated dietary protein levels. On the contrary, increasing the lipid and carbohydrate levels in the diet resulted in maximum protein retention and minimum lipid retention in fish indicating that lipid is a preferable non-protein energy source for *L. aurata* as well as for *M. cephalus* (Ojaveer et al., 1996).

In conclusion, *L. aurata* reared on diets of varying protein levels exhibited relatively low growth parameters and poor feed utilization consistent with the slow growth rate of the species. The species is known to grow slower than other mullets, such as *M. cephalus* and *C. labrosus* (Gautier and Hussenot, 2005). The growth performance and feed utilization of *L. aurata* was not significantly affected by dietary protein level. These results are applicable to lagoon cage culture of golden grey mullet and thus may not be valid for other environments. The farming of low-trophic species such as *L. aurata* allows under-utilized trophic resources to be better exploited for fish production. Thus any future advances in our knowledge on nutrition and feeding under culture conditions could further improve the potential of these species, especially in regional and coastal aquaculture.

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