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PROTEIN AND ENERGY REQUIREMENTS OF STRIPED MULLET *Mugil cephalus* LARVAE

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ABSTRACT

Two experiments were carried out to determine protein and energy requirements of striped mullet (*Mugil cephalus*) larvae for maintenance and maximum growth. In experiment 1 a diet containing 38% dietary crude protein and 2.45 kcal metabolizable energy / g was fed at seven incremental rates [1-13% of body weight (BW) daily] to larvae (0.195g initial BW) for 5 wk. In experiment 2, seven isocaloric diets containing (14-38% crude protein levels) were fed at satiate rate of feeding to larvae (0.2g initial BW) for 6 wk. In experiment 1, Striped mullet BW increased linearly as feeding rate increased, up to 34.61mg protein and 345.6cal gross energy / g BW daily (r^2 = 0.99), and also as dietary crude protein increased up to 26% in experiment 2 (r^2 = 0.99). The relationships between BW gain (Y) and the increase of protein and energy intake (X), could be expressed by the equations Y = - 58.06 + 16.20 X for protein and Y= - 57.98 +1.62 X for gross energy. Also, the increase in body protein and energy (Y) with the increase of protein and energy intake (X) could be expressed by the equations Y = - 11.33 + 2.68 X; r^2 = 0.98 for protein and Y = -85.67 + 3.48 X; r^2 = 0.99 for energy. From the mathematical models, maintenance requirements of striped mullet (0.195g initial BW) could be estimated as Y= 0 to be 3.6 - 4.2 mg protein /(g BW .d) and 24.6 - 35.8 cal gross energy /(g BW .d). Thus the data could recommend 3.9mg protein and 30.2cal gross energy /g BW daily as maintenance requirements for striped mullet larvae of 0.195g initial BW. Also, from the same data 34.6mg protein and 345.6 cal gross energy /g BW daily could be recommended as the maximum growth requirements for the same striped mullet larvae. The data of experiment 2, indicate that 26 % dietary crude protein is the dietary crude protein needed for maximum growth and feed efficiency of 0.2g striped mullet fed at incremental dietary crude protein levels from 14-38%.
Keywords: Protein & Energy requirements, Striped mullet Larvae.

INTRODUCTION

Mullet (*Mugilidae*) represent some of the most promising fish species for commercial aquaculture (Benetti, 1985). They are good candidates for both mono- and polyculture and have strong market demand and high price in many countries (e.g. Brazil, Cuba, Colombia, Venezuela, Spain, Egypt and elsewhere) (Benetti and Fagundes Netto 1991, Guinea and Fermandez, 1991 and El-Dahhar *et al*., 2000a). But, the lake of nutritional requirements of mullet fish, especially in the period of acclimatization, limiting the increase of their production (El-Dahhar, 1999).

After establishing some constituents of mullet larval acclimatization needs, e.g. the use of exogenous zymogen in mullet feed (El-Dahhar, 1999), descending salinity acclimatization (El-Dahhar *et al*., 2000a) determination of some vitamin requirements for mullet larvae (El-Dahhar, 2000), survival rate improved from zero to over 90% under the laboratory conditions. Thus, it is possible now to determine the nutritional requirements and establish diets for mullet larvae during the period of acclimatization.

Mullet growth like most fish species depends to large extent on supplementary food, and the cost of feed constitutes the principal part of the total production costs. Furthermore, feeding rate for mullet is still based on the feeding rate of other species rather than on mullet data. Determination of feeding rate with respect to the nutritional requirements, dietary composition and the effect of environmental conditions may help in saving feed or promoting fish growth, and thus increase the income of the fish farmers. For establishing feeding level of a fish species, some major factors should taken into consideration e.g. maintenance requirements, growth requirements and feed utilization for all purpose (Hepher, *et al*., 1983). Mullet maintenance requirement is still unknown. Thus, it is important to determine maintenance requirements of striped mullet, as well as the feed utilization under the laboratory conditions. Presently in this study protein and energy requirements for maintenance and maximum growth of striped mullet were determined in experiment 1 using different feeding rates. In experiment 2, the optimum dietary protein requirement of striped mullet was determined using different dietary crude protein levels.

MATERIALS AND METHODS

Facilities and Fish:

Two experiments were carried out in the Faculty of Agriculture Saba Basha Alexandria University to determine protein and energy requirements of striped mullet (*Mugil cephalus*) larvae for maintenance and maximum growth using different feeding rates and different dietary protein levels in glass aquaria. Aquaria were (100×30×40 cm) supplemented with continuos aeration using salt water. Desired salinities were made in aquaria by dissolving crude salts obtained from El-Nassr Salinas Co. Borg El-Arab Salinas Sector, Alexandria Egypt. Water was changed daily by stocked water using flow rate of 600 ml / minute to flush out wastes. Fish were fed twice daily at 9:00 and 15:00h with amount adjusted weekly intervals in response to weight gain. Larvae, caught from the wild (El-Max larval collection center), ranged in weight (0.17-0.215g) with an average of 0.195 ± 0.02g. The newly transferred larvae were stoked in glass aquaria for 24 h, then salinity acclimatization takes place at the next day starting from the wild salinity in which the larvae caught from (about 7 ppt). Salinity acclimatization was made by reducing salinity 1 ppt daily using the appropriate amount of freshly stoked tap water according to El-Dahhar *et al*., 2000a.

Diets Formation and Preparation:

Seven diets (Table 1), were formulated from commercial ingredients of fishmeal, shrimp meal, wheat flour, wheat bran, soybean meal, yellow corn, bone meal, vitamin and mineral mixture. Soybean meal to fish meal to shrimp meal in a fixed ratio (2:1:1) were added at graded levels to achieve seven dietary crude protein levels (14%, 18%, 22%, 26%, 30%, 34% and 38%).

Table 1: Composition and analysis of the test diets (air-dry basis).

Protein level (%)	14	18	22	26	30	34	38
Ingredients:							
Wheat flour	20.2	16.0	11.7	7.4	5.1	2.0	0.0
Wheat bran	34.6	29.8	25.1	20.4	15.2	10.2	5.0
Shrimp meal	2.0	5.0	8.0	11.0	14.0	17.0	20.0
Soybean meal	4.0	10.0	16.0	22.0	28.0	34.0	40.0
Yellow corn	27.0	24.0	21.0	18.0	13.5	9.6	4.8
Fish meal	2.0	5.0	8.0	11.0	14.0	17.0	20.0
Corn oil	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Bone meal	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Carboxymethyl cellulose	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Vit. & Men. Mix[1]	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Ascorbic acid	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Proximate Analysis:							
Dry mater	90.36	90.13	90.49	90.50	89.90	90.51	90.30
Crude protein (N × 6.25)	13.95	18.07	22.20	26.33	30.48	34.61	38.46
Crude fat	7.91	7.32	6.81	6.31	6.01	6.22	6.08
Crude fiber	7.14	6.53	6.13	6.21	5.95	6.54	6.43
Carbohydrate (NFE)[2]	54.15	50.47	46.14	41.78	36.57	30.95	26.14
Ash	7.21	7.74	9.21	9.87	10.89	12.19	13.19
Gross energy kcal/100g	376.5	379.8	381.3	382.7	382.6	385.5	386.8

1. Vitamin and mineral mixture / Kg Premix: Vitamin A, 4.8 million IU; D3, 0.8 million IU; E, 4 g; K, 0.8 g; B_1, 0.4 g; riboflavin, 1.6 g; B_6, 0.6g; B_{12}, 4 mg; Pantothinic acid, 4 g; Nicotinic acid, 8 g; Folic acid, 0.4g; Biotin, 20 mg; choline chloride, 200 g; Cu, 4 g; I, 0.4 g; Iron, 12 g; Mn, 22 g; Zn, 22 g; Selenium, 0.4 g.

[2] NFE is nitrogen free extract.

All diets were formulated to contain 2,450 kcal of metabolizable energy/kg (air-dry basis) based on the feedstuff values reported by NRC (1993). Dry ingredients were milled through screen (0.6mm diameter hole) before mixing into the diets. Corn oil, emulsified with equal amount of water using 0.7 % phosphatedyl choline (lecithin) according to El-Dahhar and El-Shazly (1993), was added to the diets. Mixtures were homogenized in a feed mixer Model SNFGA (Kitchen Aid St. Joseph, MI 49085 USA). Boiling water were then blended to the mixtures at the rate of 50 % for pelleting. The diets were pelleted using meat grinder of Kitchen Aid with a 1.5mm diameter and kept frozen in a deep freezer until they were used. An autoclave was used to heat treat the diets for 15 min after adding boiling water using a maximum pressure of 1.2 kg /cm^2 G.

Experimental design:

First experiment:

A 7×3 complete randomized blocks design was utilized with seven feeding rates (1, 3, 5, 7, 9, 11 and 13%) of the fish body weight daily using diet 7 (38% crude protein) with amount adjusted weekly intervals in response to weight gain for five wk. Treatments were replicated in three glass aquaria each was stocked with 20 larvae of 0.195 ± 0.02g mean initial BW. This experiment was administered to determine daily protein and energy requirements and evaluate effect of feeding rate on survival and growth of striped mullet larvae. Vitamins and minerals mixture and 4% exogenous zymogen were added to diets after heat treatment. Diets were pelleted using meat grinder of the kitchen Aid with a 1.5mm diameter and kept frozen in deep-freezer until used. Gross energy of the diet was calculated from Macdonald's Tables as crude protein, crude fat and carbohydrate to be 5.8, 9.3 and 4.1 Kcal/g respectively (Macdonald *et al*., 1973).

Second experiment:

The optimum dietary crude protein level for growth and feed utilization of striped mullet fry was determined using different dietary crude protein levels. A 7×3 complete randomized blocks design was used with seven protein levels 14%, 18%, 22%, 26%, 30%, 34% and 38% replicated in three glass aquaria. Each glass aquarium was stocked with 20 fry of 0.2 ± 0.01g mean initial BW. Fish were given feed twice daily for 42 days. Feeding was done throughout the experiment and the fish were considered satiated when they did not show an interest in the feed. Daily feed consumption was determined.

Management:

Prepared salt water stored in one cubic meter fiber glass tanks located in the laboratory. Salinities were adjusted in each aquarium separately. Water temperature were maintained constant at 24 C by means of electric aquarium heaters with thermostats, one in each glass aquarium. The front side of each aquarium was covered with dusky plastic sheet to prevent fish disturbance. Fish were fed twice daily (9:00 AM and 3:00 PM). Water of each aquarium was siphoned to eliminate dead fish and wastes. Freshly stocked salt water was replaced the removed water. Before the experiment, aquaria were rinsed with chlorinated water for 24h then salt water was applied to each aquarium.

Water preparation, salinity adjustments, water temperature, fish feeding, aquaria management, heat treating of the diet and exogenous zymogen additions were made according to El-Dahhar 1999.

Analytical methods:

Samples of thirty fish at start and five from each aquarium at the end of both experiments were taken randomly and were frozen for body composition analysis. Frozen samples were dried and passed trough a meat grinder into one composite homogenate per aquarium. Chemical analysis of homogenized fish and experimental diets were carried out and salinities were confirmed using burette titration for chloride against standard 0.014N silver nitrate according to the AOAC (1984). A Cole Palmer (Chicago, IL, USA) Oxygen meter (Model 5946-55) was used to determine dissolved oxygen and water temperature; they were 5.9 ± 0.8 ppm and 24 ± 0.5 ^{o}C, respectively.

Statistical analysis:

The analyses of variance (ANOVA) were made according to Snedecor and Cochran (1967). The relationship between feeding rate and each of gain, daily protein intake, daily energy intake, increase in body protein and energy were determined by linear regression analysis (Gomez and Gomez, 1976). The data can be used to determine the maintenance requirements of striped mullet larvae by regressing growth rate back to zero (Gatlin III *et al*. 1986).

RESULTS

Feeding striped mullet on a diet containing 38% crude protein at seven incremental feeding rates from 1 to 13 % of body weight (BW) daily in experiment 1 (Table 2), resulted in a linear increase in BW gain, $r^2 = 0.99$ (Figures 1 and 2). The linear portion of the growth was observed with increasing feed intake up to 34.61mg protein and 345.6cal gross energy / g BW daily. The relationships between BW gain (Y) and the increase of protein and energy intake (X), could be expressed by the equations Y=- 58.06 + 16.20 X for protein (Fig. 1) and Y= - 57.98+ 1.62 X for gross energy (Fig. 2). Maintenance requirements calculated from these equations (as BW gain = zero) of striped mullet (0.195 g initial BW)/ g of their body weight daily were found to be 3.6 mg protein and 35.8 cal gross energy/g BW daily. Gain, specific growth rate (SGR) and survival were increased significantly (P < 0.01) by increasing feeding rate up to 9% of the total biomass daily. However, the increase of these criteria as feeding rate increased beyond 9% was not significant (P > 0.05). Also, weight gain of striped mullet was significantly (P < 0.01) affected by increasing dietary protein levels in experiment 2 (Table 2).

Table 2

It increased significantly ($P < 0.01$) as dietary protein level increased up to 26 %. Increasing the level of protein from 26 to 38% did not exert any additional advantage to growth of fish after 6 weeks experimental period. SGR [100 ln (final BW) –ln (initial BW)/ number of days] was also increased with increasing dietary crude protein level at the same trend of growth and feed intake (Table 2).

Striped mullet body compositions (Table 3) was also affected by increasing feeding rate and dietary crude protein level. The body protein contents increased significantly ($P<0.01$) as feeding rate increased from 1 to 9 % of BW and also as dietary crude protein increased from 14 to 30%. The increase in body protein concentration of the fry at a feeding rate fed more than 9 % of BW and 30% dietary crude protein level were not significant ($P > 0.05$). Fat contents of striped mullet body also increased significantly ($P<0.01$) as feeding rate increased from 1 to 5% of BW and as dietary crude protein increased from 14 to 18%. Fish fed at feeding rates more than 5 % of BW daily exhibited increased levels of fat contents in the body. On the other hand, moisture contents of the fish body decreased significantly ($P<0.01$) as feeding rate increased and also as dietary crude protein level increased up to 30%. Net gain in the body protein and energy of striped mullet increased linearly with the increase in feeding rate up to 34.61 mg protein and 345.6 cal gross energy /g BW daily. The increase in body protein and energy (Y) with the increase in protein and energy intake (X) could be expressed by the equations $Y = - 11.33 + 2.68 X$; $r^2 = 0.98$ for protein (Fig. 1) and $Y = - 85.67 + 3.48 X$; $r^2 = 0.99$ for energy (Fig. 2). From the regression analysis, maintenance requirements could be calculated at Y= zero. It could be calculated as 4.2 mg protein and 24.6 cal gross energy were the maintenance requirements of striped mullet (0.195g BW) /g of the fish BW daily.

From the mathematical models, maintenance requirements of striped mullet (0.195-g initial BW) could be estimated. They were found to be 3.6 - 4.2 mg protein /(g BW .d) and 24.6 - 35.8 cal gross energy /(g BW .d). Thus, it could be recommended that the striped mullet larvae of 0.195g initial BW require 3.9mg protein /g BW and 30.2 cal gross energy /g BW daily as maintenance requirements. Also, from the same data 34.6mg protein and 345.6 cal gross energy /g BW daily could be recommended as the maximum growth requirements for the same striped mullet fry. The data of experiment 2, (Tables 2 and 4) indicate that 26 % dietary crude protein is the dietary crude protein needed for maximum growth and feed efficiency of 0.2-g striped mullet fed at incremental dietary crude protein levels from 14 to 38%.

Feed consumption increased significantly ($P < 0.01$) with the increase of feeding rate and dietary protein level (Table 2). Also, feed conversion ratio (FCR, feed/gain) ranged from 1.72 ± 0.02 to 3.57 ± 0.51 with increasing feeding rates from 1 to 13% of BW. The fry maintained at 1, 11 and 13% of

BW exhibited significantly (P < 0.01) higher FCR values than fry maintained at the other feeding rates. No significant differences were obtained between treatments from 3 to 9% of BW. Also, feed consumption increased significantly (P < 0.01) with increasing dietary protein level. Fish maintained at 26 - 38% dietary protein levels achieved higher feed consumption significantly (P < 0.01) than those maintained at 14 - 22% dietary protein levels. However, FCR improved with increasing dietary protein level. The maximum significant improvement (P < 0.01) in FCR were achieved when dietary protein level increased from 14 to 18%. Further improvements of FCR 2.06 and 2.09 were obtained with fish maintained at 26 and 30% crude protein diets, respectively. This improvement was not significant (P > 0.05). In general, improvement in FCR approached corresponding to the increases in body weight gain.

Protein efficiency ratio (PER), protein productive value (PPV) and energy retention (ER) of striped mullet of 0.2g initial BW increased significantly (P < 0.01) as feeding rate increased up to 5% of the fish BW daily. Thereafter, they decreased not significantly (P > 0.05) up to 9% of BW and significantly (P < 0.01) up to 13% of BW. However, PER and PPV increased insignificantly (P > 0.05) as dietary crude protein increased up to 18% in experiment 2, then decreased insignificantly (P > 0.05) as dietary crude protein increased up to 30% and significantly (P < 0.01) up to 38% dietary protein level. But, ER increased significantly (P < 0.01) up to 18% and insignificantly (P > 0.05) up to 30% dietary protein level and then decrease. From these data it could also be seen that 34.6mg protein and 345.6 cal gross energy/ g BW daily are the maximum growth requirements of striped mullet larvae of 0.195g initial BW. Also, 26% dietary crude protein could be recommended as the maximum growth requirement for striped mullet of 0.2g initial BW.

Table 3: Initial and final body proximate composition of striped mullet fry (0.2g initial BW) fed at various feeding rates and various dietary protein level in experiments 1 and 2.

Feeding rate (% of BW)	Protein intake Mg /g BW	Energy intake cal /g BW	Moisture (%)	Crude protein (%)	Crude fat (%)
			Experiment 1:		
Initial	---	---	78.15	12.20	5.78
1	3.85	38.4	69.56 ± 0.29 ^{A}	14.72 ± 0.01 ^{B}	10.36 ± 0.10 ^{C}
3	11.54	115.2	69.51 ± 0.54 ^{A}	15.09 ± 0.21 ^{B}	11.09 ± 0.41 ^{B}
5	19.23	192.0	68.53 ± 0.04 ^{AB}	15.05 ± 0.04 ^{B}	12.19 ± 0.11 ^{A}
7	26.92	268.8	69.58 ± 0.48 ^{A}	15.14 ± 0.09 ^{B}	11.77 ± 0.23 ^{AB}
9	34.61	345.6	68.19 ± 0.49 ^{AB}	16.24 ± 0.07 ^{AB}	11.96 ± 0.31 ^{AB}
11	42.31	422.4	65.21 ± 0.81 ^{B}	16.68 ± 0.11 ^{A}	12.09 ± 0.05 ^{AB}
13	45.00	499.2	65.21 ± 0.81 ^{B}	16.77 ± 0.12 ^{A}	12.28 ± 0.06 ^{A}
			Experiment 2:		
Dietary protein level (%)					
Initial			80.64	9.95	6.00
14			68.60 ± 0.32 ^{A}	14.37 ± 0.29 ^{C}	10.71 ± 0.21 ^{B}
18			70.27 ± 0.51 ^{A}	15.08 ± 0.28 ^{C}	11.47 ± 0.25 ^{AB}
22			67.74 ± 0.13 ^{AB}	15.27 ± 0.04 ^{C}	12.23 ± 0.14 ^{AB}
26			68.68 ± 0.47 ^{A}	15.50 ± 0.13 ^{BC}	12.19 ± 0.30 ^{AB}
30			67.88 ± 0.32 ^{AB}	16.13 ± 0.09 ^{ABC}	12.47 ± 0.05 ^{AB}
34			64.85 ± 0.59 ^{B}	17.18 ± 0.42 ^{AB}	13.21 ± 0.61 ^{A}
38			64.60 ± 0.53 ^{B}	17.32 ± 0.14 ^{A}	13.71 ± 0.08 ^{A}

Values represent means of N = 3 replicates / treatment. Means (±SE) in the same row having the same superscript are significantly different (P < 0.01)

Table 4: Mean protein efficiency ratio, protein productive value and energy retention of striped mullet fry (0.2g initial BW) fed at various feeding rates and various dietary protein levels in experiments 1 and 2.

Feeding rate (% of BW)	Protein intake mg /g BW	Gross Energy intake cal /g BW	Protein Efficiency Ratio PER [1]	Protein Productive Value PPV [2](%)	Energy Retention ER [3] (%)
Experiment 1:					
1	3.58	35.4	1.18 ± 0.16 ^{D}	15.95 ± 2.49 ^{C}	30.36 ± 1.66 ^{AB}
3	11.54	115.2	2.14 ± 0.02 ^{AB}	33.13 ± 1.35 ^{AB}	32.31 ± 1.00 ^{AB}
5	19.23	192.0	2.43 ± 0.03 ^{A}	36.89 ± 0.22 ^{A}	35.75 ± 0.10 ^{A}
7	26.92	268.8	2.19 ± 0.04 ^{AB}	33.44 ± 0.42 ^{AB}	29.88 ± 0.74 ^{AB}
9	34.61	345.6	1.99 ± 0.03 ^{ABC}	33.43 ± 0.51 ^{AB}	27.82 ± 0.16 ^{ABC}
11	42.31	422.4	1.62 ± 0.03 ^{BCD}	27.98 ± 0.61 ^{BC}	22.91 ± 0.41 ^{BC}
13	45.00	499.2	1.29 ± 0.03 ^{CD}	22.46 ± 0.24 ^{BC}	18.50 ± 0.35 ^{C}
Experiment 2:					
Dietary protein level (%)					
14			1.77 ± 0.05 ^{AB}	24.65 ± 1.22 ^{ABC}	13.45 ± 0.64 ^{B}
18			2.01 ± 0.09 ^{A}	30.65 ± 1.97 ^{A}	20.49 ± 1.27 ^{AB}
22			1.98 ± 0.04 ^{A}	30.58 ± 0.75 ^{A}	25.46 ± 0.74 ^{A}
26			1.85 ± 0.04 ^{A}	28.98 ± 0.89 ^{AB}	27.65 ± 0.36 ^{A}
30			1.57 ± 0.03 ^{ABC}	25.93 ± 0.49 ^{ABC}	28.17 ± 0.56 ^{A}
34			1.28 ± 0.03 ^{BC}	22.78 ± 1.19 ^{BC}	27.71 ± 1.38 ^{A}
38			1.11 ± 0.02 ^{C}	20.02 ± 0.54 ^{C}	27.48 ± 0.47 ^{A}

Values represent means of N = 3 replicates / treatment. Means (±SE) in the same row having the same superscript are significantly different (P < 0.01)

1. PER = gain / protein fed.

2. PPV = 100 (gained protein / protein intake).

3. ER = 100 (gained energy / energy intake).

DISCUSSION

The data of fish weight gain in plot against protein or energy intake in experiment 1 (Figs. 1 and 2) indicate that 34.6 mg protein intake and 345.6 cal gross energy intake/g BW daily and more get the maximum growth of striped mullet (*Mugil cephalus*) of 0.195g initial BW. Also, from the data of experiment 2, 26% dietary crude protein level and more produce maximum growth of striped mullet of 0.2g initial BW. However, SGR, PER, PPV and ER (Tables 2and 4) in both experiments were significantly (P < 0.01) higher at these protein and energy daily intakes (experiment 1) and at this dietary crude protein level (experiment 2) than the higher levels, they show a considerable decrease at higher levels. This protein optimum is similar to that reported for grey mullet (*Mugil capito*) of 0.8 and 3g BW by Vallet *et al*. (1970) and for grey mullet of 2.5g BW by Papaparaskeva-Papoutsoglou and Alexis (1986).

These relatively low protein requirements are accompanied by low values of PER, PPV and ER. These values are known to affect by energy content of the diet in the form of fat. The maximum values of PER and PPV observed in experiment 2 are lower than those observed for rainbow trout fed diets with low or high energy content (Takeuchi *et al*., 1978). Also, they are lower than PER and PPV observed for Nile tilapia fed graded protein level from 12 to 32% dietary crude protein levels (El-Dahhar *et al.*, 1999) and for *Clarias* catfish fed 20 – 40% dietary crude protein levels (Jantrarotai *et al*. 1998). Therefore, mullet seems likely to utilize protein for body growth less efficiently than do rainbow trout, Nile tilapia and *Clarias* catfish. However, the values of PER and PPV obtained in the present work for striped mullet are higher than those found by Cowey *et al*., (1970) for plaice. While, they are about the same as those found by Sabaut and Luquet (1973) for gilthead bream and those reported by Papaparaskeva-Papoutsoglou and Alexis (1986) for *M. capito*.

Most fish studied are either carnivorous or omnivorous. Mullet have been variously described as vegetarian, planktophagous, detritivorous, omnivorous and even carnivorous (Brusle, 1981; Benetti and Fagundes Netto 1991). They change their food performances from carnivorous to herbivorous as they grow bigger (Albertini-Berhaut, 1974). Thus their ability to use protein as an energy source could be affected by dietary crude protein levels (Alexis and Papaparaskeva-Papoutsoglou, 1986). The same authors also stated that the metabolic behavior of the fish studied so far to digest protein could be attributed to various factors. Genetically utilizing protein, as an energy source is an important factor, so the metabolism of carnivorous fish might gear towards the use of protein as an energy source that affected by dietary protein level. Dietary energy level is another factor. Doubling the lipid content of diet for rainbow trout with constant protein level, decreases protein metabolism in the form of glutamic pyrovic transaminase activity in the liver by almost four times (De la Higuera *et al*., 1977). Lipids are known to be efficiently utilized as an energy source and their protein sparing action has been reported (Lee and Putnam, 1973 and Watanabe *et al*., 1983).

The results of the present study have shown that with increasing feeding rates, weight gain of striped mullet (0.195 g) increased (Table 2). Final body weight increased with increasing feeding rates up to 9% of the total BW daily. Increasing feeding rate beyond 9% had no significant effects on growth. El-Dahhar (1993) in two experiments arrived to similar results with Nile tilapia fry of initial body weight of 0.21 and 0.6g. He found that weight gain increased with increasing feeding rate up to 13 and 12% of the total body weight daily respectively. Also, El-Dahhar *et al.*, (1999) with Nile tilapia of 0.63g initial BW found that the optimum feeding rate is around 10% of the total BW daily. Gatline III *et al*., (1986) fed catfish diets containing 25 and 35 % crude protein at incremental feeding rate (0-5 % of BW daily). They found that weight gain increased linearly ($r^2 = 0.95$) as feeding rate increased up to 3.5 % BW daily of the 25 % crude protein diet and 2.5% of BW daily of the 35 % crude protein diet. Feed efficiency of these catfish declined with the higher feeding rates. Likewise, catfish grow better when they were fed 4 % of BW daily than 6 % of BW daily at 26ºC (Andrews and Stickney, 1972).

FCR as a function of feeding rates is important in the fish culture. Too much rates of feeding, waste feed, approach the rate required for maintenance, decrease fish growth, and increase the rate of conversion. Generally, it was found that when fish were fed at rate lower than satiation, fish fed the higher protein diets grow faster and hence protein requirements increase. Clark *et al*. (1990) reported a maximum growth rate for Florida red tilapia (*O. urolepis hornorum* X *O. mossambicus* monosex) fed *ad libitum* rate

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Fig (1): Effect of increasing levels calculated protein intake (mg/gm BW.d) on striped mullet gain and change in body protein (mg). Each symbol represents the mean of three observations.

Fig (2): Effect of increasing levels calculated energy intake (Kcal/g BW.d) on striped mullet gain and change in body energy (Kcal/g). Each symbol represents the mean of three observations.

in floating marine cages when the diet containing 32% crude protein. Li and Lovell (1992) found that weight gain of channel catfish (*Ictalurus puncitatus*), fed graded dietary protein level from 26 to 38 % crude protein, increased linearly when the fish were fed at restricted rate of feeding and decreased linearly when they were fed at satiation rate. In the present study weight gain of *M. cephalus* larvae of 0.195g initial weight increased with increasing dietary crude protein up to 26% and no significant improvement was happened when the diet was containing more than 26% dietary crude protein level (Table 2). This optimum protein is similar to 25.5% dietary protein level that reported for *M. capito* of 2.5g when reared at the laboratory in 150-l glass aquaria with 12 ppt salinity (Papaparaskeva-Papoutsoglou and Alexis, 1986). El-Dahhar (1993 and 1994) stated that, weight gain and FCR of Nile tilapia improved as dietary protein level increased up to 30% for juvenile of 1 g body weight and 26% for fingerlings of 9.6 g BW.

Body weight gain, body protein and energy of larval striped mullet (0.195g initial BW) increased linearly as protein and energy intake increased ($r^2 = 0.99$). From the mathematical models, maintenance requirements could be calculated as 3.9 mg protein and 30.2 cal gross energy /g BW daily. A comparison between results of protein and energy maintenance and maximum growth requirements of some fish species is shown in Table 5. Some differences among the results were found to be due to different fish species and different experimental conditions e.g. fish size, feeding rate, rearing temperature and others. The smaller fish required more than larger fish due to their higher metabolic rate (Halver, 1988). Alexis and Papaparaskeva-Papoutsoglou, (1986) reported a decrease in the daily protein and energy requirements of *M. capito* from 13.5 to 5.3 mg protein /g BW daily and 215.3 to 190.3 cal gross energy /g BW daily as *M. capito* increase in BW from 2.5 to 12.7g (Table 5). Also, they recommend a decrease in the optimum dietary protein requirement from 25.5 to 15% as BW increased from 2.5 to 12.7g. El-Dahhar (1993 and 1994) and El-Dahhar *et al.*, (1999 and 2000b) stated that at the same temperature, increasing fish size decreased maintenance and maximum growth requirements for both protein and energy (Table 5). He also recommend 52,48, 36, 17.3 and 13.3 mg protein /g BW for 0.2, 0.66, 1.0, 6.3and 9.6 g BW *O. niloticus*. Also, Schaberclus, (1933) found a 24.48 kcal /(kg BW .d) as energy requirement for carp weighted 12g and 797 kcal / (kg BW .d) for 600g carp. At the same time temperature affected requirements. Hepher *et al*., (1983) found that specific routine metabolism of red tilapia was 25.4 cal / day at 20.9ºC and 36.7 cal / day at 24.3ºC. The same authors also found that energy maintenance requirement of red tilapia (phenotypically *Oreochromis niloticus)* fingerlings of 1.0g BW increased from 51 to 73 cal/g BW as water temperature increased from 20.9 to 24.3ºC.

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احتياجات صغار أسماك البوري من البروتين والطاقة

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في تجربتين معمليتين أجريتا في الأحواض الزجاجية تم تقدير احتياجات صغار أسماك البوري من البروتين والطاقة ،استخدم في التجربة الأولي عليقه تحتوي علي 38% بروتين و 245 ك كالورى طاقة ميتابولزمية / 100 جم عليقة لتغذية صغار أسماك البوري ذات متوسط وزن 0.195 جم علي أن تغذي الأسماك باستخدام سبعة معدلات للتغذية (1-13% من وزن الأسماك يوميا) ذلك لمدة خمسة أسابيع. وفي التجربة الثانية استخدمت سبعة علائق متماثلة في الطاقة ومختلفة في نسبة البروتين الخام (14- 38%) لتغذية أسماك البوري ذات متوسط وزن 0.2 جم لدرجة الإشباع مرتين يوميا لمدة ستة أسابيع. وقد تكوينت العلائق من مكونات تجارية وتم تزويدها بنسبة 4% من الإنزيمات الخارجية مع الطبخ في الأتوكلاف لمدة 15 دقيقة بحيث يتم إضافة الفيتامينات والإنزيمات بعد الطبخ . وقد تم استخدام اليرقات البرية في هذه التجارب بعد الحصول عليها من مركز تجميع الزريعة في المكس . وكان متوسط وزن اليرقات في حدود 0.2جم. وتم استخدام اليرقات في التجارب بعد الأقلمة علي الظروف المعملية لمدة أسبوعين .

من النتائج يتضح أن وزن الجسم لأسماك البوري يزيد زيادة مطردة بزيادة معدلات التغذية في التجربة الأولي من 3.58 إلي 34.61مجم بروتين ومن 35.4 إلي 345.6 كالورى طاقة كلية / 1 جم من وزن الأسماك يوميا (ر^2 = 0.99) وما زاد عن ذلك من البروتين أو الطاقة في العليقه لم يكن له نفس التأثير المطرد. وقد اتضح أيضا أن البروتين والطاقة الكلية في جسم الأسماك تزيد بمعدلات مطردة أيضا بنفس الزيادة في معدل التغذية (ر^2 = 0.98، 0.99 علي التوالي). وقد أمكن حساب الاحتياجات الحافظة من المعادلات الرياضية وذلك باعتبار الزيادة في الوزن أو في بروتين أو طاقة الجسم = صفر. ومن ذلك اتضح أن الاحتياجات الحافظة لأسماك البوري ذات متوسط وزن ابتدائي 0.195جم هي 3.9مجم بروتين 30.2 كالورى طاقة كلية / 1 جم من وزن الأسماك يوميا.ومن هذه المعادلات اتضح أيضا أن 34.6مجم بروتين 345.6 كالورى طاقة كلية / 1 جم من وزن الأسماك يوميا يمكن أن يوصي بها لأسماك البوري ذات وزن 0.2جم لأعلي معدل نمو. ومن التجربة الثانية اتضح أنه بزيادة تركيز البروتين في العليقه يزيد معدل النمو بزيادة معنوية حتى 26% من البروتين الخام، الأسماك التي غذيت علي علائق تحتوى علي 14 - 18% بروتين خام حققت نموا أقل معنويا من نمو الأسماك التي قد غذيت علي علائق تحتوي علي من 26 – 38 % بروتين خام. كما اتضح أن الكفاءة التحويلية للبروتين وكذلك القيمة الإنتاجية للبروتين تنخفض معنويا بزيادة تركيز بروتين الغذاء وكان انخفاضها معنويا بزيادة بروتين الغذاء عن 30%. وبالتالي يمكن التوصية بأن تكون نسبة بروتين الغذاء لأسماك البوري ذات وزن 0.2جم هي 26% وذلك لإعطاء أعلي معدل نمو وأعلي كفاءة غذائية.

Table 5: Comparison between results of maintenance and maximum growth requirements of some fish species.

Fish species	Body weight (g)	Water Tempe-rature (°C)	Maintenance Requirements Protein mg/g BW	Maintenance Requirements Energy Cal/g BW	Maximum Growth Requirements Protein mg/g BW	Maximum Growth Requirements Energy cal/g BW	Dietary Protein Level (%)	Author(s)
Striped mullet	0.19	24.5	3.9	30.2	34.6	345.6	38.0	Present work
Striped mullet	0.2	24.5			26.3	382.7	26.0	Present work
Grey mullet	2.5	23.3			13.5	215.3	25.5	Alexis and Papaparaskeva-Papoutsoglou, 1986.
Grey mullet	12.7	24.0			5.8	190.3	15.0	Papaparaskeva-Papoutsoglou and Alexis, 1986.
Nile Tilapia	0.2	27.5	10.0	106.9	48.0	513.1	39.6	El-Dahhar, 1993.
Nile Tilapia	0.63	27.0	7.0	76.5	32.0	395	32.0	El-Dahhar *et al.*, 1999
Nile Tilapia	0.76	27.0			30.6		24.0	El-Dahhar *et al.*, 1999
Red Tilapia	1.0	24.3		73.0				Hepher *et al*., 1983.
Red Tilapia	1.0	20.9		51.0				Hepher *et al*., 1983.
Nile Tilapia	1.0	27.5	8.6		36.0		30.2	El-Dahhar, 1994.
Hybrid T.	2.9	26.0	4.2		11.9		24.0	Shiau & Huang, 1989.
Nile Tilapia	3.6	27.0			25.8		20.0	El-Dahhar *et al.*, 2000
Nile Tilapia	6.3	27.5	4.3		17.5		34.9	El-Dahhar, 1993.
Nile Tilapia	9.6	27.5	3.6		13.3		26.6	El-Dahhar, 1994.
Red Tilapia	11.4	20.0	3.7		42.0		28.2	Zonneveld & Fadholi, 1991.
Catfish	8.5	27.3	1.3	15.1	8.8	99.8	25.0	Gatlin III *et al*., 1986.
Catfish	9.6	27.3	1.3	15.1	8.8	99.8	35.0	Gatlin III *et al*., 1986.

Data are based on recalculation of original data.