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EFFECT OF DIETARY ENERGY AND PROTEIN LEVELS ON SURVIVAL, GROWTH AND FEED UTILIZATION OF STRIPED MULLET *Mugil cephalus* LARVAE

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ABSTRACT

Two experiments were carried out to determine the effect of dietary energy and protein levels on survival, growth and feed utilization of striped mullet (*Mugil cephalus*) larvae in glass aquaria. In experiment 1, seven metabolizable energy (ME) (175, 190, 205, 220, 235, 250 and 265kcal/100g diet) in isonitrogenous (26% crude protein) feeding mixtures replicated three times were used to feed striped mullet larvae (0.173 $\pm$ 0.02g mean initial body weight, BW) for eight wk. In experiment 2, a 3 $\times$3 factorial design was employed in which nine test diets containing three levels of ME (200, 225 and 250kcal/ 100g) each with three dietary crude protein levels (18, 22, and 26%) were used to feed striped mullet larvae (0.33g initial BW) for eight weeks. Increasing dietary ME in experiment 1, resulted in significant (P< 0.01) increase in each of final body weight (FBW), BW gain, feed consumption, survival, specific growth rate (SGR), protein efficiency ratio (PER), protein productive value (PPV) and energy retention (ER) of striped mullet larvae of 0.173g initial BW. These increase were up to 235 kcal ME /100g diet. However, increasing ME in the diet beyond 235 kcal /100g did not exert any additional significant increase in any of these criteria (P > 0.05). In experiment 2, increasing dietary protein and ME also resulted in significant (P< 0.01) increase in all these measurements that taken on striped mullet (0.33g initial BW). Larvae that get increasing dietary ME from 200 to 225 kcal /100g diet, did not exhibit any significant increase in all measurements (P > 0.05). However, increasing dietary ME from 225 to 250 kcal /100g diet, resulted in significant increase in all these measurements and improved feed conversion ratio (FCR) (P < 0.01). Likewise, striped mullet larvae that get increasing dietary crude protein from 18 to 22 and to 26% exhibited significant (P < 0.01) increase in all estimated measurements and improved FCR. Body protein and fat contents also increased significantly (P<0.01) as ME increased from 175 to 235 kcal /100g diet in experiment 1 and from 200 to 250 kcal /100g diet in experiment 2. They also increased significantly (P < 0.01) as dietary crude protein increased from 18 to 22 and to 26% in experiment 2. On the other hand, moisture contents of the fish body decreased significantly (P<0.01) as ME increased up to 235 kcal /100g diet in experiment 1 and from 200 to 225 kcal /100g diet in experiment 2. It also decreased significantly (P < 0.01) as dietary crude protein level increased from 18 to 26%. In the conclusion of experiment 2, interaction between dietary crude protein and ME was also found to be significant (P < 0.01) for all the variables determined in experiment 2. They get the best values for striped mullet larvae maintained at 26% dietary crude protein with the medium level of energy 225kcal ME/100g diet and 22% dietary crude protein with the high level of energy 250kcal ME/100g diet. From this data it could be seen that the best level of ME was 235 kcal /100g diet when the diet containing 26 % crude protein. But, when the ME increased to 250 kcal /100g diet in experiment 2, dietary crude protein could be lowered from 26 to 22%.

Keywords: Energy, protein, survival, growth of striped mullet larvae.

INTRODUCTION

Mullet exhibit numerous traits considered beneficial for aquaculture (Nash and Shehadeh 1980; Benetti, 1985; Papaparaskeva-Papoutsoglou and Alexis, 1986 and El-Dahhar *et al.*, 2000), including the ability to adapt to rear in the polyculture system. The cost of the controlled production of fish depends mainly on the cost of feed, which constitute most of the economical expenses, and crude protein is typically the most expensive component in artificial diets for fish. Determination of the optimum dietary protein needed for maximum growth and feed utilization is essential in the formation of well-balanced and low cost artificial diets.

Much of the nutritional research with fish species has focused on minimizing crude protein in the diet for mullet (Albertini-Berhaut, 1974; Papaparaskeva-Papoutsoglou and Alexis, 1986; El-Dahhar, 2000) and tilapia (Jackson *et al*., 1982; Wu *et al*., 1994 & 1995 and El-Dahhar *et al*., 1999 & 2000). Both of these researches will tend to reduce the cost of feed. The initial results for striped mullet (*Mugil cephalus*) larvae of 0.2g initial BW fed at incremental dietary crude protein levels from 14 to 38% to determine protein requirements, El- Dahhar (2000) found that 26% dietary crude protein level is the level needed for maximum growth and feed utilization. Also, Papaparaskeva-Papoutsoglou and Alexis (1986) fed young grey mullet (*M. capito*), of average initial weight 2.5g, five semi-purified diets containing 12 – 60% protein. They found that 24% protein was required for maximum growth at 23 ^{o}C. While, Alexis and Papaparaskeva-Papoutsoglou (1986) found that the dietary protein content of 15% resulted in sufficient growth equal to 26, 37 and 50% dietary crude protein levels for grey mullet of 12.5g initial BW. The optimum protein level of the diet can be lowered if the energy level is increased, due to protein sparing action of energy nutrients (Lee and Putnam, 1973; Machiels and Henken, 1985; Serrano *et al*., 1992; Shiau and Peng, 1993; Jantrarotai *et al*., 1998 and El-Dahhar *et al*., 2000). However, increasing energy in catfish diet may decrease feed efficiency and leads to increase fat deposition (Reis *et al*., 1989). But, increasing energy in a diet for *Mugil capito,* indicates a better utilization of protein (Alexis and Papaparaskeva-Papoutsoglou, 1986). The purposes of the present study are to determine the effect of different dietary protein and energy levels on survival, growth and feed utilization. Protein sparing action of energy in form of lipid also could be determined for striped mullet (*Mugil cephalus*).

MATERIALS AND METHODS

Facilities and Fish:

Two experiments were carried out to determine the effect of dietary metabolizable energy (ME) and protein levels on survival, growth and feed utilization of striped mullet (*Mugil cephalus*) larvae in glass aquaria. Aquaria were (100 $\times$ 30 $\times$ 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 in response to weight gain. Larvae, caught from the wild (El-Max larval collection center), ranged in weight 0.168-0.179g with an average of 0.173 $\pm$ 0.02g in experiment 1 and 0.31-0.35g with an average of 0.329 $\pm$ 0.019g in experiment 2. 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 by 1 ppt daily using the appropriate amount of freshly stoked tap water according to El-Dahhar *et al*. (2000). Larvae were introduced to the experiments after two weeks acclimatization to salinity, artificial diets and the experimental conditions.

Diets Formation and Preparation:

Seven and nine test diets (Table 1) were used to feed striped mullet larvae in experiments 1 and 2, respectively. Diets were formulated from commercial ingredients of fishmeal, shrimp meal, wheat flour, wheat bran, soybean meal, yellow corn, bone meal, vitamins and minerals mixture. 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. Vitamins and minerals mixture and 4% exogenous zymogen were added to diets after heat treatment. 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. With a maximum pressure of 1.2 kg /cm^2 G, an autoclave was used to heat treat the diets for 15 min after adding boiling water. Gross energy of the diets 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).

Experimental Design:

Experiment 1: A 7$\times$3 complete randomized blocks design was utilized with seven ME (175, 190, 205, 220, 235, 250 and 265 kcal ME/ 100g diet) in isonitrogenous feeding mixtures (26% crude protein) fed to striped mullet larvae for eight wk. ME kcal/ kg (air-dry basis) of the ingredients was used to formulate diets based on the feedstuff values reported by NRC (1993). Treatments were replicated in three glass aquaria each was stocked with 25 larvae. This experiment was administered to evaluate the effect of ME level in isonitrogenous diets on survival, growth and feed utilization of striped mullet larvae.

Table 1: Composition and analysis of the 7 test diets used in experiment 1 and the nine diets used in experiment 2 (air-dry basis).

Metabolizable Energy level	175	190	205	220	235	250	265
Experiment 1							
Ingredients:							
Wheat flour	6.0	4.0	5.0	4.5	4.0	4.0	6.0
Wheat bran	50.3	47.0	43.3	39.3	35.4	31.8	27.4
Shrimp meal	12.0	12.3	12.5	13.0	13.3	13.5	13.8
Soybean meal	12.0	12.3	12.5	13.0	13.3	13.5	13.8
Yellow corn	0.5	3.4	4.0	5.5	7.5	9.0	9.0
Fish meal	12	12.3	12.5	13.0	13.3	13.5	13.8
Corn oil	1.0	2.5	4.0	5.5	7.0	8.5	10.0
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	90.25	90.02	90.29	90.35	89.97	90.39	90.21
Crude protein (N × 6.25)	26.08	6.06	25.97	26.19	26.17	26.06	26.07
Crude fat	5.98	7.76	9.21	10.54	11.87	13.34	15.64
Crude fiber	7.41	7.42	7.63	7.11	5.62	5.23	4.98
Carbohydrate (NFE)[2]	44.16	42.54	41.43	40.03	39.47	38.67	36.17
Ash	6.62	6.24	6.05	6.48	6.84	7.09	7.35
Gross energy kcal/100g	3.89	3.99	4.07	4.15	4.25	4.35	4.47

Experiment 2

Energy levels kcal/100g	200			225			250		
Protein levels (%)	**18**	**22**	**26**	**18**	**22**	**26**	**18**	**22**	**26**
Ingredients:									
Wheat flour	14.0	8.0	5.5	14.0	8.0	5.5	14.0	8.0	5.5
Wheat bran	51.2	47.3	42.8	45.8	42.9	38.3	40.7	37.2	32.8
Shrimp meal	5.2	9.0	12.5	6.0	9.3	13.0	6.2	9.7	13.5
Soybean meal	5.2	9.0	12.5	6.0	9.3	13.0	6.2	9.7	13.5
Yellow corn	10.0	8.5	5.0	10.0	9.0	5.0	11.5	10.5	6.0
Fish meal	5.2	9.0	12.5	6.0	9.3	13	6.2	9.7	13.5
Corn oil	3.0	3.0	3.0	6.0	6.0	6.0	9.0	9.0	9.0
Bone meal	2.0	2.0	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	3.0	3.0
Vit. & Men. Mix[1]	0.9	0.9	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	0.3	0.3
Proximate Analysis:									
Dry mater	90.25	90.98	90.35	90.58	90.89	90.68	90.28	90.39	90.57
Crude protein (N×6.25)	18.03	22.20	26.05	18.39	22.02	26.10	18.05	21.89	26.10
Crude fat	8.99	7.79	6.88	12.78	11.82	11.02	15.76	15.24	14.51
Crude fiber	8.21	7.96	7.24	7.21	6.91	6.64	5.31	4.89	5.18
Carbohydrate (NFE)[2]	49.53	46.52	43.23	46.43	43.50	39.63	46.11	42.02	37.63
Ash	5.49	6.51	6.95	5.77	6.64	7.29	5.05	6.35	7.15
Gross energy kcal/100g	3.92	3.93	3.93	4.17	4.17	4.17	4.42	4.43	4.42

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.

Experiment 2: Nine test diets at three levels of ME each with three levels of dietary crude protein levels were used in this experiment. Corn oil was added in graded levels to achieve three levels of ME (200, 225 and 250 kcal / 100g). Also, soybean meal to fish meal to shrimp meal in a fixed ratio (1:1:1) were added at graded levels to achieve the three levels of dietary crude protein levels (18, 22, and 26%) for each of the three levels of the dietary ME. The three levels of ME and the three levels of crude protein were evaluated in a 3 × 3 factorial arrangement for their effects on survival, growth and feed utilization of striped mullet larvae.

Management:

The previously prepared salt water was stored in one cubic meter fiberglass tanks located in the laboratory. Salinities were adjusted in each aquarium separately. Water temperature was maintained constant at 24 °C by means of electric aquarium heaters, one in each glass aquarium. The front side of each aquarium was covered with dusky plastic sheet to prevent fish disturbance. Fish were fed to satiation twice daily (9:00 am and 3:00 pm). After feeding, fish were considered satiated when they did not show an interest in the feed. Daily feed consumption was determined. Water of each aquarium was siphoned to eliminate dead fish and wastes. Freshly stocked salt water were 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 Association of Official Analytical Chemists (1984). A Cole Palmer (Chicago, IL, USA) Oxygen meter (Model 5946-55) was used to determine dissolved oxygen and water temperature; they were 6.1 ± 0.7 ppm and 24 ± 0.5 °C respectively. The analyses of variance (ANOVA) were made according to Snedecor and Cochran (1967).

RESULTS

The growth characteristics of all dietary groups over the whole experimental period in experiment 1 and 2 are presented in Table 2. Increasing dietary metabolizable energy (ME) for striped mullet larvae (0.173g initial BW) in experiment 1, resulted in significant ($P < 0.01$) increase in each of final body weight (FBW), body weight (BW) gain, feed consumption, survival and specific growth rate (SGR) up to 235 kcal ME /100g diet. However, increasing ME in the diet beyond 235 kcal /100g did not exert any additional significant increase in all these criteria ($P > 0.05$). In experiment 2, increasing dietary protein and ME also resulted in significant

(P< 0.01) increase in all these measurements that taken on striped mullet (0.33g initial BW). Larvae that get increasing dietary ME from 200 to 225 kcal /100g diet, did not exhibit any significant increase in FBW, BW gain, feed consumption, survival or SGR (P > 0.05). However, increasing dietary ME from 225 to 250 kcal /100g diet, resulted in significant increase in all these measurements and improve FCR (P < 0.01). Likewise, striped mullet larvae that get increasing dietary crude protein from 18 to 22 and to 26 exhibit significant (P < 0.01) increase in all measurement (gain, feed, survival and SGR) and improve FCR.

Increasing dietary ME levels in experiment 1 and dietary crude protein and ME in experiment 2 also affected body compositions of striped mullet (Table 3). The body protein contents increased significantly (P<0.01) as ME increased from 175 to 235 kcal /100g diet in experiment 1 and from 200 to 250 kcal /100g diet in experiment 2. Body protein and fat contents also

Table 3: Initial and final body proximate composition of striped mullet fry fed at seven dietary energy levels (experiment 1) and at three dietary energy levels X three dietary protein levels (experiment 2).

Energy level Kcal ME/100g	Protein level %	Moisture %	Crude Protein %	Crude Fat %
		Experiment 1		
175		70.29 ± 0.17 ^{AB}	14.82 ± 0.06 ^{D}	10.59 ± 0.39 ^{C}
190		69.48 ± 0.53 ^{AB}	15.13 ± 0.16 ^{CD}	10.99 ± 0.07 ^{BC}
205		68.28 ± 0.15 ^{BC}	15.51 ± 0.13 ^{BCD}	12.30 ± 0.34 ^{AB}
220	26	69.56 ± 0.55 ^{AB}	15.46 ± 0.29 ^{BCD}	12.39 ± 0.11 ^{AB}
235		67.66 ± 0.25 ^{BC}	16.92 ± 0.04 ^{AB}	12.76 ± 0.23 ^{A}
250		64.64 ± 0.90 ^{C}	16.79 ± 0.27 ^{ABC}	12.64 ± 0.33 ^{A}
265		64.92 ± 0.52 ^{C}	17.45 ± 0.24 ^{A}	13.13 ± 0.09 ^{A}
		Experiment 2		
200	18	70.29 ± 0.17 ^{A}	14.61 ± 0.17 ^{E}	10.59 ± 0.39 ^{D}
	22	69.81 ± 0.21 ^{AB}	15.27 ± 0.21 ^{D}	10.99 ± 0.07 ^{D}
	26	68.28 ±0.15 ^{B}	15.94 ± 0.18 ^{C}	12.30 ± 0.34 ^{C}
225	18	69.90 ± 0.38 ^{AB}	14.79 ± 0.27 ^{E}	12.39 ± 0.11 ^{C}
	22	69.66 ± 0.25 ^{AB}	15.17 ± 0.26 ^{D}	12.43 ± 0.29 ^{C}
	26	64.64 ± 0.90 ^{C}	16.79 ± 0.27 ^{B}	13.38 ± 0.31 ^{B}
250	18	69.40 ± 0.23 ^{AB}	15.77 ± 0.12 ^{C}	13.13 ± 0.09 ^{B}
	22	64.92 ± 0.52 ^{C}	16.81 ± 0.11 ^{B}	14.13 ± 0.09 ^{A}
	26	64.69 ± 0.51 ^{C}	17.45 ± 0.24 ^{A}	14.17 ± 0.13 ^{A}
Pooled Means				
200		69.46 ± 0.04 ^{G}	15.27 ± 0.03 ^{H}	11.29 ± 0.04 ^{I}
225		68.07 ± 0.11 ^{GH}	15.58 ± 0.04 ^{H}	12.73 ± 0.02 ^{H}
250		66.33 ± 0.09 ^{H}	16.68 ± 0.03 ^{G}	13.81 ± 0.02 ^{G}
	18	69.86 ± 0.02 ^{X}	15.06 ± 0.02 ^{Z}	12.04 ± 0.05 ^{Z}
	22	68.13 ± 0.10 ^{X}	15.75 ± 0.03 ^{Y}	12.52 ± 0.05 ^{Y}
	26	65.87 ± 0.08 ^{Y}	16.73 ± 0.03 ^{X}	13.28 ± 0.04 ^{X}

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

increased significantly ($P < 0.01$) as dietary crude protein increased from 18 to 22 and to 26% in experiment 2. The increase in body protein concentration of the larvae maintained at a ME more than 235 kcal /100g diet in experiment 1, was not significant ($P > 0.05$). Fat contents of striped mullet body also increased significantly ($P<0.01$) as ME increased from 175 to 205 kcal /100g diet in experiment 1 and from 200 to 225 and to 250 kcal /100g diet in experiment 2. Fish maintained at ME more than 205 kcal /100g in experiment 1 did not exhibited significant increased levels of fat contents in the body ($P > 0.05$). On the other hand, moisture contents of the fish body decreased significantly ($P<0.01$) as ME increased up to 235 kcal /100g diet in experiment 1 and 225 kcal /100g diet in experiment 2. It also decreased significantly ($P < 0.01$) as dietary crude protein level increased from 18 to 26%.

Protein efficiency ratio (PER), protein productive value (PPV) and energy retention (ER) of striped mullet (Table 4) increased significantly ($P < 0.01$) as ME increased up to 235 kcal /100g diet in experiment 1 and up to 250 kcal /100g diet in experiment 2. Thereafter, increase of dietary ME beyond 235 kcal /100g diet in experiment 1,did not affected them significantly ($P > 0.05$). However, PER decreased significantly ($P < 0.01$) as dietary crude protein increased from 18 to 26% in experiment 2. But, ER increased significantly ($P < 0.01$) as dietary crude protein increased from 18 to 26%. PPV was not affected significantly ($P > 0.05$) as dietary crude protein increased from 18 to 26%.

Similarly, interaction between dietary crude protein and ME was also found to be significant ($P < 0.01$) for all the variables determined in experiment 2. FBW, BW gain, feed consumption and SGR increased as dietary crude protein increased for all ME levels. They get significantly ($P < 0.01$) the best values for striped mullet larvae maintained at 22% dietary crude protein with the high level of energy 250kcal ME/100g diet. They were found to be 1.45g, 1.13g, 3.12g and 2.67%/d, respectively. They also get significantly ($P < 0.01$) high values at 26% dietary crude protein with the medium level of energy 225kcal ME/100g diet and found to be 1.36g, 1.03g, 2.97g and 2.56%/d, respectively. ER also follows the same trend. It exhibited the best value at 22% dietary crude protein with the high level of energy 250kcal ME/100g diet (20.88%) and at 26% dietary crude protein with the medium level of energy 225kcal ME/100g diet (20.66%). However, PER and PPV decreased as dietary crude protein increased, but they exhibited the best values for the larvae maintained at 22% dietary crude protein with the higher ME level 250 kcal /100g diet (1.65 and 29.51%, respectively). From these data it could be seen that the best level of energy was 235 kcal /100g diet when the diet containing 26 % crude protein in experiment 1. But, when the ME increased to 250 kcal /100g diet in experiment 2, dietary crude protein could be lowered from 26 to 22%.

Table 4: Mean protein efficiency ratio, protein productive value and energy retention of striped mullet fry fed at seven dietary energy levels (experiment 1) and at three dietary energy levels X three dietary protein levels (experiment 2).

Energy level Kcal ME/100g	Protein level %	Protein Efficiency Ratio(PER)	Protein productive value(PPV)%	Energy Retention (ER)%
		Experiment 1		
175		0.58 ± 0.04 ^{D}	9.41 ± 0.59 ^{C}	8.66 ± 0.36 ^{C}
190		0.67 ± 0.01 ^{CD}	11.17 ± 0.14 ^{BC}	9.99 ± 0.06 ^{C}
205		0.73 ± 0.02 ^{BCD}	12.41 ± 0.41 ^{BC}	11.45 ± 0.50 ^{BC}
220	26	0.98 ± 0.01 ^{B}	16.01 ± 0.40 ^{B}	14.28 ± 0.04 ^{AB}
235		1.02 ± 0.01 ^{ABC}	18.49 ± 0.17 ^{AB}	15.18 ± 0.26 ^{AB}
250		1.40 ± 0.01 ^{A}	24.31 ± 0.59 ^{A}	19.06 ± 0.58 ^{A}
265		1.41 ± 0.02 ^{A}	25.54 ± 0.15 ^{A}	19.47 ± 0.17 ^{A}
		Experiment 2		
200	18	1.37 ± 0.02 ^{B}	21.05 ± 0.23 ^{D}	12.97 ± 0.28 ^{D}
	22	1.14 ± 0.03 ^{C}	18.55 ± 0.32 ^{D}	13.90 ± 0.28 ^{D}
	26	1.16 ± 0.02 ^{C}	19.66 ± 0.31 ^{D}	17.78 ± 0.57 ^{B}
225	18	1.32 ± 0.05 ^{B}	20.67 ± 1.34 ^{D}	13.67 ± 0.54 ^{D}
	22	1.28 ± 0.09 ^{B}	20.57 ± 1.08 ^{D}	15.83 ± 0.79 ^{C}
	26	1.33 ± 0.02 ^{B}	23.87 ± 0.41 ^{CD}	20.66 ± 0.27 ^{A}
250	18	1.59 ± 0.05 ^{A}	26.93 ± 0.99 ^{AB}	16.02 ± 0.55 ^{BC}
	22	1.65 ± 0.01 ^{A}	29.51 ± 0.20 ^{A}	20.88 ± 0.12 ^{A}
	26	1.30 ± 0.02 ^{B}	24.52 ± 0.45 ^{BC}	20.25 ± 0.39 ^{A}
Pooled Means				
200		1.22 ± 0.01 ^{H}	19.75 ± 0.05 ^{H}	14.88 ± 0.09 ^{I}
225		1.31 ± 0.01 ^{H}	21.70 ± 0.09 ^{H}	16.72 ± 0.13 ^{H}
250		1.52 ± 0.01 ^{G}	26.99 ± 0.09 ^{G}	19.05 ± 0.09 ^{G}
	18	1.43 ± 0.01 ^{Y}	22.88 ± 0.13 ^{X}	14.22 ± 0.06 ^{Z}
	22	1.36 ± 0.01 ^{XY}	22.88 ± 0.20 ^{X}	16.87 ± 0.13 ^{Y}
	26	1.27 ± 0.01 ^{X}	22.69 ± 0.09 ^{X}	19.56 ± 0.06 ^{X}

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

DISCUSSION

Data presented herein clearly demonstrate that performance of striped mullet (*Mugil cephalus*) maintained at a diet containing 250 kcal ME /100g was superior to other treatments in both experiments. Differences in performance among protein levels in experiment 2 were most pronounced in fish fed 26% protein diets, which resulted in the fastest growth. In relation to the interaction between dietary ME and protein levels, striped mullet larvae exhibited the greatest survival, weight gain and feed utilization when they maintained at 22% dietary protein with 250 kcal ME /100g diet than the other protein levels at all ME levels used in experiment 2. These differences in survival and weight gain can be attributed to the increased feed intake and feed efficiency exhibited at 250 kcal ME /100g diets. Data from previous study in which various dietary protein levels from 14 to 38% at 245kcal ME/100g diets (El-Dahhar, 2000), support that striped mullet maintained at 26% dietary crude protein level exhibited superior growth characteristics when lipid contents was about 4%. In the present study, increasing the amount of energy in form of lipid (about 9%) in experiment 2, decreased dietary crude protein needed for maximum survival and growth from 26% to 22%. The energy available to fish by the diet under test is an important factor for the different behavior of fish to use protein as an energy source (Alexis and Papaparaskeva-Papoutsoglou, 1986). Also, De la Higuera *et al*., (1977) indicated that doubling the amount of lipid supplied in rainbow trout diets with a constant protein level, decreased protein metabolism in form of glutamic pyrovic transaminase activity in the liver almost by four times. Lipid is a good source efficiently utilized for energy and have a sparing action (Lee and Putnam, 1973; Watanabe, 1977 and Watanabe *et al*., 1979). This protein sparing action of lipids has also been repeatedly proven (Jürss, 1981). He observed a decrease in transaminase activity with the decrease of protein content and increase in the lipid content of the diet for rainbow trout.

Machiels and Henken, (1985) related *Clarias gariepinus* catfish growth and feed efficiency to be functions of dietary protein intake. They found that increasing protein intake of fish fed diets with different protein levels improved growth and feed efficiency. In the present study the data clearly indicated that fish fed the 26 % diets consumed more protein than those fed lower protein diets (Table 2) and therefore grew and utilized feed better. Energy retention (ER), which was low in fish fed the low protein diets (Table 4), is in agreement with that reported for *M. capito* (Alexis and Papaparaskeva-Papoutsoglou, 1986). However, for *M. cephalus*, the PPV was also low for the fish fed the lower (14%) protein diet leading El-Dahhar (2000) to conclude that some protein was used for energy. This is in contrast to the present study where PPV of fish fed the low protein diets was similar to that for fish fed higher protein diets in experiment 2. This is probably because fish fed the low protein diets consumed enough non-protein energy so that the energy intake of fish in this group was the highest, known from it’s least ER value (Tables 2and 4).

Increasing energy levels over 235 kcal ME/100g had no beneficial effects on fish performance in experiment 1. This agrees with results for *Clarias gariepinus* catfish (Degani *et al*., 1989) and hybrid striped bass (*Morone chrysops* × *M. saxatilis*) (Nematipour *et al*., 1992). However, studies with *C. gariepinus* (Machiels and Henken, 1985), channel catfish *Ictalurus punctatus* (Garling and Wilson, 1976), Nile tilapia *Oreochromis niloticus* (El-Sayed and Teshima, 1992) and rainbow trout *Oncoryhnchus mykiss* (Lee and Putnam, 1973), had shown that increasing both protein and energy to the optimum levels resulted in better growth of fish and improved feed efficiency. The difference may relate to energy source. Since in studies of Jantrarotai *et al*., (1998) with *Clarias* catfish and El-Dahhar (2000) with striped mullet *M. cephalus*, carbohydrate was the major energy source whereas in the others and in the present study more lipid were used for energy. This assumption was tested in experiment 2, in which corn oil was added in graded levels to achieve three levels of ME. In this experiment, optimum growth, survival and dietary utilization of striped mullet *M. cephalus* were attained at 22% protein and 250 kcal ME/100g. The protein level was lower and the energy level was the same as the previous result with striped mullet (El-Dahhar, 2000). Furthermore, the improved growth rates as well as protein sparing effect were observed in fish fed higher energy diets in experiment 2. These findings did not present in the previous study with striped mullet (El-Dahhar, 2000), who found that 26% protein was needed for maximum growth and feed utilization when carbohydrate as a source of energy was higher than lipid. The difference in protein requirement for striped mullet *M. cephalus* in the present study (22%) and the previous study (El-Dahhar, 2000) may due to the different ratios of carbohydrate and lipid. From this results it could be concluded that striped mullet *M. cephalus* utilize energy with a low ratio of carbohydrate to lipid more efficiently and this resulted in a protein sparing effect. Also, *Clarias* catfish use lipid as a source of energy more efficiently than carbohydrate (Jantrarotai *et al*., 1998 and Degani *et al*., 1989)

The results of fish performance and body composition obtained in this study are in general agreement with those obtained for striped mullet *M. cephalus* of nearly similar size 0.2g initial weight (El-Dahhar, 2000). However, a diet containing 22% crude protein with 250 kcal ME /100g resulted in greater survival, growth and feed utilization. While, a protein content of 26%, when the energy level was 245 kcal ME /100g, was found to be optimal for striped mullet *M. cephalus* in the previous study. Higher availability of protein mixture of the present study to the fish, which had a slightly different composition than the previous one (shrimp meal: soybean meal: fish meal, ratio of 1: 1: 1 compared to 1: 2: 1 ratio of the previous study) could be a reason of the difference.

It appears therefore that striped mullet *M. cephalus* is less required protein and energy than other fish species studied so far. Further experiments would clarify the relative importance of various energy sources for survival, growth and feed utilization.

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تـأثير مسـتويات الطاقـة والبـروتين علـي الحيويـة والنمـو والاسـتفادة مـن الغـذاء ليرقات أسماك البوري

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تم إجراء تجربتين لتقدير تأثير الطاقة والبروتين علي معدل الحيوية والنمو و الاستفادة من الغذاء ومكونات الجسم ليرقات أسماك البوري في الأحواض الزجاجية . ففي التجربة الأولي تم تكوين سبعة مستويات من الطاقة الممثلة (175، 190، 205، 220، 235، 250، 265ك كالورى /100جم علف) في علائق متساوية في نسبة البروتين (26% بروتين خام) ، وقد استخدمت هذه العلائق لتغذية يرقات البوري ذات متوسط وزن 0.173جم وقد تم تكرار كل معاملة في ثلاثة أحواض زجاجية لمدة ثمان أسابيع بعد فترة الأقلمة التي استمرت أسبوعين. وفي التجربة الثانية تم استخدام التصميم الإحصائي العاملي 3 × 3 لدراسة تأثير ثلاث مستويات من الطاقة الممثلة (200، 225، 250 ك كالورى /100جم علف) بكل منها ثلاث مستويات من البروتين (18، 22، 26%) علي حيوية ونمو يرقات البوري ذات متوسط وزن 0.33جم قد تم تكرار كل معاملة في ثلاثة أحواض زجاجية لمدة ثمان أسابيع بعد فترة الأقلمة التي استمرت أسبوعين.

وقد أوضحت النتائج في التجربة الأولى أنه بزيادة الطاقة الممثلة تسببت في زيادة كل من معدلات النمو والحيوية والإستفادة من الغذاء لليرقات ذات متوسط وزن ابتدائي 0.173جم وكانت الزيادة معنوية (بمستوي معنوية 0.01) حتى مستوي الطاقة 235 ك كالورى /100جم ولم تحدث زيادة معنوية بزيادة الطاقة عن ذلك. وقد أوضحت النتائج في التجربة الثانية أنه بزيادة نسبة بروتين وطاقة الغذاء يزيد كل من معدلات النمو والحيوية والإستفادة من الغذاء لليرقات ذات متوسط وزن ابتدائي 0.33جم معنويا (بمستوي معنوية 0.01)، ومن التحليل الكيماوي لجسم الأسماك في نهاية التجربة اتضح أنه بزيادة مستوي طاقة وبروتين الغذاء زاد محتوي جسم الأسماك من البروتين والدهن في كل من التجربتين الأولي والثانية ، وفي المقابل فقد نقص محتوي الجسم المائي بزيادة كل من الطاقة والبروتين في التجربتين أيضا ، وقد أوضح التفاعل بين عاملي التجربة (مستويات الطاقة والبروتين في الغذاء) أن كل مقاييس النمو والحيوية والإستفادة من الغذاء وصلت إلي أعلاها عندما كان بروتين الغذاء 26% مع المستوى المتوسط من الطاقة (225 ك كالورى /100جم علف) وأيضا عندما كان بروتين الغذاء 22% مع المستوى العالي من الطاقة (250 ك كالورى /100جم علف). ومن ذلك يتضح أن مستوي البروتين الأمثل ليرقات البوري ذات وزن ابتدائي 0.33جم يمكن أن يقل من 26 إلي 22% وذلك بزيادة مستوي الطاقة من 225 إلي 250 ك كالورى /100جم علف.

Table 2: Mean final weight, weight gain, feed intake, feed conversion ratio, percent survival, and specific growth rate (SGR) of striped mullet fry fed at seven dietary energy levels (experiment 1) and at three dietary energy levels X three dietary protein levels (experiment 2).

Energy level Kcal ME/100g	Protein level %	Final Weight (g/fish)	Weight Gain (g/fish)	Feed consumption (g/fish)	Feed conversion ratio FCR[1]	Survival (%)	SGR (% / d)
				Experiment 1			
175		0.36 ± 0.01 ^{C}	0.19 ± 0.01 ^{C}	1.25 ± 0.02 ^{C}	6.71 ±0.46 ^{A}	34.67 ± 1.3 ^{B}	1.30 ± 0.07 ^{C}
190		0.41 ± 0.01 ^{BC}	0.23 ± 0.01 ^{BC}	1.31 ± 0.04 ^{C}	5.70 ± 0.08 ^{AB}	52.00 ± 2.3 ^{AB}	1.50 ± 0.05 ^{C}
205		0.43 ± 0.01 ^{BC}	0.26 ± 0.01 ^{BC}	1.39 ± 0.01 ^{BC}	5.29 ± 0.12 ^{AB}	61.33 ± 4.8 ^{AB}	1.66 ± 0.02 ^{BC}
220	26	0.61 ± 0.03 ^{BC}	0.43 ± 0.03 ^{BC}	1.69 ± 0.10 ^{BC}	3.90 ± 0.03 ^{BC}	69.33 ± 9.3 ^{A}	2.24 ± 0.08 ^{BC}
235		0.74 ± 0.05 ^{ABC}	0.56 ± 0.05 ^{ABC}	2.11 ± 0.07 ^{BC}	3.74 ± 0.03 ^{BC}	78.67 ± 7.1 ^{A}	2.57 ± 0.04 ^{BC}
250		1.36 ± 0.01 ^{A}	1.18 ± 0.01 ^{A}	3.24 ± 0.06 ^{A}	2.73 ± 0.02 ^{C}	62.67 ± 8.7 ^{AB}	3.66 ± 0.01 ^{A}
265		1.33 ± 0.02 ^{A}	1.16 ± 0.02 ^{A}	3.14 ± 0.02 ^{A}	2.71 ± 0.03 ^{C}	81.33 ± 7.1 ^{A}	3.66 ± 0.03 ^{A}
				Experiment 2			
200	18	0.94 ± 0.02 ^{D}	0.61 ± 0.01 ^{D}	2.46 ± 0.06 ^{DE}	4.05 ± 0.06 ^{A}	72.0 ± 4.6 ^{D}	1.87 ± 0.04 ^{C}
	22	0.99 ± 0.02 ^{CD}	0.66 ± 0.02 ^{C}	2.60 ± 0.05 ^{CD}	3.96 ± 0.10 ^{A}	72.0 ± 2.3 ^{D}	1.95 ± 0.06 ^{BC}
	26	1.25 ± 0.02 ^{B}	0.93 ± 0.02 ^{B}	3.06± 0.02 ^{AB}	3.30 ± 0.05 ^{BC}	85.3 ± 3.5 ^{B}	2.41 ± 0.02 ^{A}
225	18	0.90 ± 0.03 ^{D}	0.57 ± 0.03 ^{D}	2.36 ± 0.02 ^{E}	4.15 ± 0.18 ^{A}	65.3 ± 9.6 ^{D}	1.81 ± 0.05 ^{C}
	22	0.99 ± 0.04 ^{CD}	0.66 ± 0.04 ^{CD}	2.36 ± 0.07 ^{E}	3.59 ± 0.23 ^{AB}	69.3 ± 8.7 ^{D}	1.96 ± 0.09 ^{BC}
	26	1.36 ± 0.03 ^{AB}	1.03 ± 0.03 ^{AB}	2.97 ± 0.07 ^{B}	2.87 ± 0.04 ^{DC}	85.3 ± 3.5 ^{B}	2.56 ± 0.05 ^{A}
250	18	1.10 ± 0.01 ^{C}	0.77 ± 0.01 ^{C}	3.67 ± 0.07 ^{C}	3.48 ± 0.10 ^{B}	80.0± 6.9 ^{C}	2.13 ± 0.05 ^{B}
	22	1.45 ± 0.02 ^{A}	1.13 ± 0.02 ^{A}	3.12 ± 0.05 ^{AB}	2.76 ± 0.01 ^{D}	88.0 ± 4.6 ^{AB}	2.67 ± 0.01 ^{A}
	26	1.42 ± 0.03 ^{A}	1.08 ± 0.04 ^{A}	3.18 ± 0.05 ^{A}	2.94 ± 0.05 ^{D}	92.0 ± 2.3 ^{A}	2.55 ± 0.05 ^{A}
Pooled Means							
200		1.06 ± 0.01 ^{H}	0.73 ± 0.01 ^{H}	2.71 ± 0.01 ^{H}	3.77 ± 0.01 ^{G}	76.44 ± 0.34 ^{H}	2.08 ± 0.01 ^{H}
225		1.08 ± 0.01 ^{H}	0.76 ± 0.01 ^{H}	2.56 ± 0.01 ^{H}	3.54 ± 0.02 ^{G}	73.33 ± 0.58 ^{H}	2.11 ± 0.01 ^{H}
250		1.33 ± 0.01 ^{G}	0.99 ± 0.01 ^{G}	2.99 ± 0.01 ^{G}	3.06 ± 0.01 ^{H}	86.67 ± 0.36 ^{G}	2.45 ± 0.01 ^{G}
	18	0.98 ± 0.01 ^{Z}	0.65 ± 0.01 ^{Z}	2.50 ± 0.01 ^{Z}	3.89 ± 0.01 ^{X}	72.44 ± 0.50 ^{Y}	1.94 ± 0.01 ^{Z}
	22	1.14 ± 0.01 ^{Y}	0.82 ± 0.01 ^{Y}	2.69 ± 0.01 ^{Y}	3.44 ± 0.02 ^{Y}	76.44 ± 0.49 ^{Y}	2.19 ± 0.01 ^{Y}
	26	1.35 ± 0.01 ^{X}	1.02 ± 0.01 ^{X}	3.07 ± 0.01 ^{X}	3.04 ± 0.01 ^{Z}	87.56 ± 0.23 ^{X}	2.51 ± 0.01 ^{X}

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

1. FCR = feed / gain.