

Original Article

Survival, Growth, Feed Efficiency and Carcass Composition of Rabbitfish, *Siganus Rivulatus*, Fed Different Dietary Energy and Feeding Levels

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Abstract

A feeding trial was conducted to study the effects of dietary energy level and feeding level or daily energy density (DED) on growth, feed conversion, nutrient retention efficiencies, carcass composition, apparent nutrient digestibility and cost benefit analysis for fingerling of rabbitfish, *Siganus rivulatus*. Twelve net cages, each with dimensions of 1x1x0.4m were stocked with 10 fingerlings (10g/fish initial weight). The fish were fed three isonutrogenous diets (25% CP), with varying three oil supplement (0.5 and 10%), and digestible energy levels (3882, 4056 and 4360 kcal/kg diet), at of 2 and 4% body weight/day (BW/d), corresponding six daily energy densities based on calorie per 1g BW of fish per day. Fish were fed the experimental diets three times daily, six days a week for 98 days. Fish were weighed every two week intervals and feed amounts were adjusted on the basis of the new fish weight. Final body weight, gain and specific growth level (SGR) were increased with an increase in dietary energy level at 2% feeding level but no trends were evident at 4% feeding level. Feed conversion (FCR), protein efficiency ratio (PER), productive protein value (PPV%) and energy retention (ER%) were higher when fish were fed at 2% than 4% feeding level. Furthermore, increasing daily energy density resulted in an increase in SGR until level of 162.4cal/g BW of fish. However the differences in SGR above 155.2cal/g BW were not significant ($P > 0.05$). There are a positive effect between energy density and SGR ($y = 0.099x + 0.5$, $r^2 = 0.88$). Fat content of carcass increased by increasing both energy and feeding levels while protein content did not affected.

Key Words: Rabbitfish, *Siganus rivulatus*, Dietary energy, Growth, Digestibility.

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Introduction

The studies on fish nutrition only began about forty years ago (Robaina and Izquierdo, 2000). Since then, significant advances have been made in all aspects of this subject. The number of farmed aquatic species has also been also dramatically increased. Nutrient requirements for most of the first cultured species have not yet been defined and current recommendations are mostly based on data obtained with few selected species such as rainbow trout and channel catfish (Kaushik, 1995). For this reason, research studies on basic nutrition are needed for any candidate species of interest to aquaculture (Robaina and Izquierdo, 2000).

Rabbitfish hold particular promise for marine aquaculture development by virtue of their herbivorous/omnivorous feeding habits and consequent ability to feed low on the aquatic food chain (Tacon, et al. 1990), their high tolerance to environmental factors, tolerance to rough handling and crowding (Carumbana and Luchavez, 1979), fast growth and possibility to obtain their seeds from the wild or by artificial propagation. The requirements of protein and energy for rabbitfish have been investigated by a number of authors (Soletchnik, 1983; Parazo, 1991; Shalaby, 1998 and Shalabi, et al. 2001) and daily feed amounts (El-Sayed, et al. 1993; El-Dakar, 1999 and El-Meligi, 2003). It has been demonstrated that dietary energy contents affect feed intake. Fish might be able to adjust their digestible energy intake (El-Meligi, 2003). They reported that daily DE intakes per unit body weight by rainbow trout were similar between fish fed low and high-energy diets differing in digestible starch and fat levels.

In rabbitfish, it was found that increasing energy intake through increasing feeding level resulted in an increase of final body weight and growth but not for feed conversion and nutrient efficiency (El-Dakar, 1999). At the same time, dietary protein and energy levels may affect the feeding intake in fish. Daily feed intake may decrease as fish generally have been eaten to meet an energy requirement (McGoogan and

Gatlin, 1999). Researcher (Boujard and Médale, 1994) found that juvenile rainbow trout had lower intake when fed higher energy diets. Knowledge about optimum feeding levels is important not only for promoting good growth and feed efficiency, but also for preventing water quality deterioration as the result of excess feeding and enhancing economic viability of aquaculture processing (Ng, et al. 2000). Studies published on the interaction between daily feed intake and dietary energy levels were scarce. Therefore, the present study sought to determine the effect of different dietary energy and feeding levels to obtain the optimum DED and studied their effects on growth, feed conversion, nutrient retention efficiencies, carcass composition, apparent nutrient digestibility and cost benefit analysis for fingerlings of rabbitfish, *Siganus rivulatus*.

Materials and Methods

This work was carried out at the Mariculture Research Center, Faculty of Environmental Agricultural Sciences, Suez Canal University, El-Arish, North-Sinai, Egypt.

Fish and Culture Facility

Rabbitfish were collected from Mediterranean Sea coast at El-Arish. The fish caught were transported in small plastic bucket (50L-capacity) immediately to a rectangular fiberglass tank filled with fresh seawater. Fish were kept in the tank for one week conditioning period. During this period, dead fish was replaced by a healthy one. After the conditioning period they were sorted according to the weight. The feeding trial was in twelve net cages (100x100x40cm; LxWxH) placed in a large fiberglass tank using two replicate cages per treatment. Each cage was provided with pieces of lead surrounding the bottom to prevent floating and a wooden frame on the top for support. Ten fingerlings of fish having the same weight (10g/fish) were allotted and randomly distributed into experimental cages. Experimental fish were reared in fresh seawater. Water salinity, temperature, pH,

dissolved oxygen and photoperiod values were 34 ± 2 ppt, 28 ± 2 , 8.5 ± 0.3 , 7ppm and 12 hour, respectively. Static water system provided with continuous aeration was used and approximately 35% of the water was changed every day at 800h.

Experimental Diets and Feeding

Fish were fed three experimental diets containing 0, 5 and 10% oil represented to three digestible energy levels of 3882, 4056 and 4360 kcal/kg diet, respectively at restricted two feeding levels of 2 and 4% BW/d, namely L2, M2, H2 and L4, M4, H4, respectively. The nutritional treatments were corresponding to six DED levels, based on calorie per unit body weight per day. Fishmeal and soybean meal were used as protein sources, a mixture of cod liver oil and sunflower oil (1:1 v/v ratio) was used as a lipid source. Wheat milling by-product and corn starch were used as sources of carbohydrate level. The experimental diets were prepared by mixing dry ingredients with water. Then pelleted diet was produced through a meat mincer with a 1.5-mm diameter. The pellets were dried by air and stored at -20°C until use. Ingredient composition of the diets is presented in (Table 1). The feed was divided into three equal parts and fed to the fish at 9.00, 12.00 and 15.00 hrs, six days a week. Fish were weighed at two-week intervals and feed amounts were readjusted accordingly. Feeding period of the experiment was 98 days.

The gross energy (GE) contents of the experimental diets and fish samples were calculated by using factors of 5.65, 9.45 and 4.22 kcal/g of protein, lipid and carbohydrate level, respectively (NRC, 1993). Digestible energy (DE) content was calculated from standard physiological fuel values as 4, 4 and 9 kcal/g of protein, carbohydrate and lipid, respectively (Garling and Wilson, 1976).

Digestibility Trail

After 12 weeks of the experiment, fish in each cage were transferred to glass aquarium with dimensions of 70x30x40cm, under the same culture conditions of the feeding experiment, to determine apparent digestibility coefficient

(ADC) by direct method according to (Lovell, 1989). Fish were fed test diets for two weeks, during this period feces in each tank were collected in petery dishes. Uneaten feed and water were removed and collected feces were homogenized and stored in a plastic bag at -20°C for further analysis.

Samples Collection and Analysis

Fish samples were taken at the beginning experiment to keep frozen at -20°C for subsequent analysis of body composition. At the end of the experiment, five fish were taken randomly sampled from each cage, killed and dissected. Samples of carcass of each cage were pooled and stored frozen at -20°C for subsequent proximate composition analysis. Fish carcass, feed and collected faces were chemically analyzed according to AOAC (1990).

Statistical Analysis

The results of the experiment were statistically analyzed using the two-way analysis of variance, fixed-effect model to determine the significant differences among treatment means. All statistical analyses were performed according to (Snedecor and Cochran, 1967) using the m-state C software (MStat-C, 1988), Differences were subjected to Duncan's Multiple Range-Test (Duncan, 1955).

Results

Surviving, Growth, Feed Utilization and Digestibility

Survival rate among all fish groups was insignificant (Table 1). At the feeding level of 2% BW/d, final body weight, gain and SGR increased with increasing energy level (Table 2). However, no significant differences ($P >0.05$) were observed in growth parameters among fish groups of M2 and H2, while poor growth rate was obtained with group L2. At the higher feeding level, growth performance of rabbitfish was higher than those found at low feeding level. The maximum weight gain and growth were found with M4 group. However, no significant differences ($P >0.05$) were observed between H4 and L4. There was a significant interaction

between dietary energy level and feeding level. There is also a positive effect ($y = 0.099X + 0.5$, $r^2 = 0.88$) between DED and SGR of fish (Figure 1). The optimum DED was found at 162 cal/day/fish, it could be covered with a diet containing 4056 kcal DE/kg at 4% BW/d.

Table 1: Ingredient composition and chemical analysis proximate of the experimental diets:

Item	Diet No.		
	1	2	3
Gram per 100g			
Fish meal, herring meal (72% CP)	17.5	17.5	17.5
Soybean meal (48% CP)	22	22	22
Wheat brain	15	15	15
Wheat milling by-product	15	15	15
Corn starch	26.5	21.5	16.5
Cod liver oil	0	2.5	5
Sunflower oil	0	2.5	5
Vitamin premix ¹	2	2	2
Mineral premix ¹	2	2	2
Total	100	100	100
Proximate analysis (% on DM basis)			
Dry matter	92.73	92.87	94.16
Crude protein	25.04	26.35	25.39
Ether extract	6.27	10.38	15.01
Crude fiber	1.56	1.65	1.41
Ash	9.22	9.92	8.35
Nitrogen free extract	57.91	51.70	49.84
Calculated energy value			
Gross energy kcal/kg	4451	4651	4956
Digestible energy kcal/kg	3882	4056	4360
P/E ratio mg CP/kcal DE	64.54	64.90	58.23

1. Eco Vit, Egyptian Veterinary produces and feed additives Co., Demyatta, Egypt. Each kilogram contains 15000 IU, 15000 IU, 2mg, 2.5mg, 2mg, 10mg, 3mg, 5mg, 2mg, 2mg, 5.5mg, 200g, 90g, 40g, 2.5g, 48g, 3.6g, 23.5g, 8g, 450mg, 200mg and 20mg of vitamin A, vitamin D3, vitamin E, vitamin B2, vitamin K3, nicotinamide, vitamin B6, vitamin B12, vitamin B1, folic acid, Ca-d-pantothenate, calcium, phosphate, sodium, copper, magnesium, manganese, zinc, iron, cobalt, iodine, and selenium, respectively.

Feed intake was strongly affected by increasing feeding level from 2% to 4% (Table 3). Lower feed intake was found with low energy density (L2). However, no significant difference ($P > 0.05$) were found between fish fed medium and high energy levels at 2% BW/d. At 4% BW/d, feed intake was reduced at higher energy diet (H4). It was clear that, feed, protein and energy intakes were elevated by increasing feeding level (i.e. energy intake was increased with increasing dietary energy levels). But, protein intake affected by feeding level, not by energy level. Feed conversion ratio was improved as dietary energy level increased when fish received 2% BW/d feed. However, the best FCR was found with M4 group, represented 162.4 cal/g BW DED (Figure 2). Increasing dietary energy beyond this level resulted in a decline in FCR. Protein efficiency ratio and productive protein values were improved by increasing dietary energy levels but they were reduced by increasing feeding level. Rabbitfish was more efficiently utilize protein when received 2% BW/d than 4% BW/d. Both PER and PPV% increased by increasing dietary energy level at low feeding level (Table 3). However, they increased up to medium energy level then leveled off at higher feeding level. The same trend was found for energy retention efficiency. Energy retention increased by increasing DE level and decreased with increasing of feeding level. Data in (Table 4) show that increasing of feeding level resulted in an increase in digestibility of DM, CP, EE and NFE. However, apparent nutrient digestibilities were higher at high energy-level than at other dietary energy levels.

Carcass Composition

No significant differences ($P > 0.05$) in protein content of all fish groups were observed. However, fat content increased with increasing dietary energy and feeding levels (Table 5). There was an interaction in EE and DM contents by combination of dietary energy and feeding levels. On the other hand, ash content decreased by increasing energy and feeding levels.

Cost–benefit Analysis

Cost benefit analysis (Table 6) showed that incidence cost for fish fed 2% feeding level was lower than those fed 4% BW/d. At lower feeding level, IC decreased dramatically with increasing of dietary energy levels. However at higher

feeding level (4%) IC improved at medium DE level but it elevated at higher DE level. On contrast profitability level was occurred at high energy diet and lower feeding level considerable high feeding level resulted in lower PI at all DE levels.

Table 2: Effect of dietary energy and feeding levels on growth performance and survival of rabbitfish1:

Feeding level	Energy level ²	Initial wt. g/fish	Final wt. g/fish	Gain ¹ g/fish	SGR ² %/day	Survival %
2% Feeding level						
Low	L2	10.20	17.69 ^c	7.49 ^c	0.56 ^d	95
Medium	M2	10.25	21.18 ^c	10.66 ^c	0.71 ^{cd}	100
High	H2	10.25	21.62 ^c	11.37 ^c	0.76 ^c	95
4% Feeding level						
Low	L4	10.21	27.23 ^b	17.02 ^b	1.00 ^b	100
Medium	M4	10.49	34.40 ^a	23.91 ^a	1.21 ^a	100
High	H4	10.32	32.09 ^a	21.77 ^a	1.16 ^b	90
Analysis of variance, P>F						
Feeding level	F		0.001	0.001	0.02	0.061
Energy level	E		0.021	0.01	0.048	0.048
Interaction	FxE		0.36	0.35	0.02	0.41
Pooled standard error		0.03	0.49	0.50	0.02	2.81

Values within the same column with different superscripts were significantly different at level of $P < 0.05$.

1. Gain= (final weight - initial weight)

2. Specific growth level= $100(\ln \text{final weight} - \ln \text{initial weight}/\text{days})$

Survival, Growth, Feed Efficiency and Carcass Composition of Rabbitfish

Table 3: Effect of dietary energy and feeding levels on feed and nutrient intake, feed conversion and nutrient efficiencies of rabbitfish:

Energy/feeding levels	Feed g/fish	Intakes		FCR ¹		Nutrient utilization		
		Protein g/fish	Energy kcal/fish	g/g	PER ² g/g	PPV ³ %	ER ⁴ %	
2% Feeding level								
Low	L2	21.17 ^e	4.92 ^e	87 ^d	2.62 ^{bc}	1.52 ^{bc}	34.19 ^{bc}	14.59 ^d
Medium	M2	24.60 ^d	6.02 ^d	106 ^c	2.14 ^b	1.77 ^{ab}	42.74 ^b	24.00 ^b
High	H2	24.52 ^d	5.86 ^d	115 ^c	2.03 ^a	1.94 ^{ab}	53.14 ^a	29.27 ^a
4% Feeding level								
Low	L4	56.80 ^c	13.90 ^c	259 ^b	3.10 ^d	1.22 ^c	28.80 ^d	14.67 ^d
Medium	M4	64.92 ^a	15.89 ^a	280 ^a	2.52 ^{bc}	1.50 ^{bc}	32.12 ^{cd}	18.97 ^c
High	H4	61.47 ^b	14.70 ^b	287 ^a	2.66 ^{cd}	1.48 ^{bc}	27.55 ^d	17.31 ^{cd}
Analysis of variance, P>F								
Feeding level F		0.001	0.001	0.001	0.014	0.012	0.0006	0.001
Energy level E	--	0.003	0.001	0.036	0.06	0.04	0.008	
Interaction FxE		0.06	0.016	0.001	0.000	0.001	0.018	0.011
Pooled standard error		0.30	0.07	1.90	0.065	0.04	1.06	0.45

Values within the same column with different superscripts were significantly different at level of P <0.05

1. Feed conversion ratio= DM intake/weight gain
2. Protein efficiency ratio= weight gain/protein intake
3. Productive protein value= 100(protein gain/protein intake)
4. Energy retention %= 100(gross energy gain/gross energy intake)

Table 4: Effect of dietary energy and feeding levels on apparent nutrient digestibilities¹ of rabbitfish:

Energy/feeding levels	Apparent digestibility coefficient ¹ (%)					NFE ²
	Dry matter	Crude protein	Ether extract	Crude fiber		
2% Feeding level						
Low	L2	74.38	92.54	85.94	40.30	57.79
Medium	M2	69.51	91.45	81.56	36.84	64.89
High	H2	87.95	95.61	90.65	48.84	82.93
4% Feeding level						
Low	L4	89.52	96.86	88.17	42.11	75.09
Medium	M4	86.00	94.46	90.71	46.81	79.88
High	H4	86.74	89.29	87.15	42.59	85.19

Values within the same column with different superscripts were significantly different at level of P >0.05

1. ADC= 100 (nutrient intake – nutrient in feces)/nutrient intake
2. Nitrogen free extract

Table 5: Effect of dietary energy¹ and feeding levels on carcass composition of rabbitfish²:

Energy/feeding levels	Dry matter %	Crude protein	Crude lipid	Ash
Initial fish	27.75	49.22	28.40	21.8
2% Feeding level				
Low	L2	30.44 ^e	57.18 ^a	21.41 ^e
Medium	M2	35.44 ^{bc}	53.46 ^a	26.61 ^c
High	H2	39.30 ^a	53.10 ^a	29.32 ^b
4% Feeding level				
Low	L4	33.29 ^d	57.36 ^a	23.95 ^d
Medium	M4	34.60 ^c	54.90 ^a	28.67 ^b
High	H4	34.47 ^c	49.33 ^a	32.91 ^a
Analysis of variance, P>F				
Feeding level F		0.001	0.19	0.001
Energy level E		0.001	0.24	0.001
Interaction FxE		0.001	0.31	0.025
Pooled standard error		0.035	0.80	0.078

1. L, M and H diets containing digestible energy of 3882, 4056 and 4360 kcal/kg, respectively and the number below refer to feeding level.

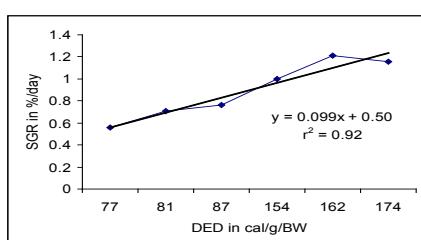
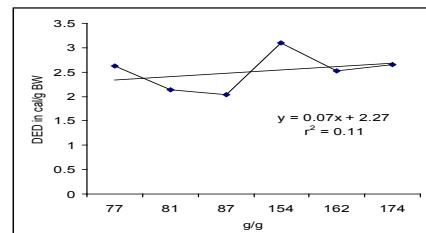
2. Values within the same column with different superscripts were significantly different at level of P >0.05.

Table 6: Effect of dietary energy and feeding levels on cost-benefit analysis of rabbitfish:

Feeding level	Energy level	Incidence cost ¹	Profit index ²
2% feeding level			
Low		3.43	2.06
Medium		2.91	2.42
High		2.81	2.50
2% feeding level			
Low		4.02	1.75
Medium		3.42	2.06
High		4.61	1.52

1. Incidence cost= feed cost to produce 1 kg weight gain fish.

2. Profit index= value of fish/cost of feed consumed, 1 kg fresh fish equals 6 Egyptian pound (1LE= 0.18 US\$)

**Fig. 1:** Relationship between DED and SGR.**Fig. 2:** Relationship between DED and FCR.

Discussion:

Results indicated that increasing feeding level from 2 to 4% BW/d resulted in a significant increase (P<0.05) in final body weight, gain and SGR. However, PER, PPV and ER% decreased as feeding level increased. These results are in agreement with those obtained by researchers EL-Sayed et al. (1993); El-Dakar (1999); El-Meligi (2003); Yufera et al. (1995); El-Sayed (2002) and Abdelghany and Ahmad (2002). Body weight and SGR were proportional to the level of digestible energy offered. However, growth of fish received 4% improved significantly with increasing DE levels up to

4056 kcal/kg (medium level) and leveled off with further increase in energy levels. From previous studies, growth and feed efficiency of rabbitfish were affected by dietary energy (Parazo, 1991; Shalaby, 1998; Shalabi, et al. 2001 and Parazoa, 1990). The scientist Soletchnik (1983) recommended that feeds for optimum growth of rabbitfish fry should contain total energy about 3700 kcal/kg DE in diet of 33% protein. Findings of Parazoa (1990) showed that growth rate increased with increasing energy levels up to 3832 kcal/kg DE in 35% CP diet of *S. guttatus* fry. In case of *S. rivulatus*, (Shalaby, 1998) reported that growth performance was not affected by increasing dietary lipids or energy levels. The present study showed the differences among fish fed different energy levels were insignificant ($P > 0.05$) due to lower activity of lipolytic enzymes (Von Westernhagen and Rosenthal, 1976). Histochemical studies on the intestinal bulb of rabbitfish showed that the variation observed in the activities of digestive enzymes may reflect the feeding habit of *S. rivulatus*. This may have lead to weak lipolytic and moderate level proteolytic energy activities and strong activity of β -glucuronidase, which is responsible for carbohydrate level digestion (Von Westernhagen and Rosenthal, 1976). Therefore, there was an improvement in ADC of carbohydrate levels with increasing both dietary energy and feeding levels in diets of *S. rivulatus* in the present study. Lower activities of lipid enzymes of *S. rivulatus*, resulted in less utilization of dietary lipids in diets (Lundberg and Lipkin, 1979).

Appetite of fish, as in higher vertebrate levels, appears to controlled by numerous factors. Involvement of brain regulation system via neuropeptides and neurotransmitters or feed intake of fish, as in mammals, has been suggested recently (Boujard and Médale, 1994). Feed and protein utilization improved by increasing energy level in diets at lower feeding level however, it declined at higher feeding level. The best FCR, PER and PPV was found at high-energy-diet at 2% BW/d. Increasing feed level resulted in an increase of energy lost in the feces as a proportion of the energy intake.

It may be decrease the efficiency of digestion and absorption. Therefore, not all feed intake converted to growth by fish. Study of El-Dakar (1999) showed that FCR, PER and PPV improved by decreasing feeding level. In other words, increasing energy density does not seem to be ensuring that requirements for maximal growth are met (McGoogan and Gatlin, 2000). The present study confirmed the above findings. Additionally, the lowest dietary energy levels were not high enough to support high growth levels and should be avoided (Shalaby, 1998). Improve growth and feed efficiency of red drum fed diets with increasing protein and energy density was occurred (Jirsa, et al. 1997). Increasing feeding level improved growth of *O. niloticus* but reduced FCR, PER, PPV and relative amount of metabolic energy due to increase of feed passage level through the digestive tract leading to depressed digestibility of gross energy (Meyer-Burgdorff, et al. 1989).

Carcass composition of rabbitfish was affected by energy and feeding levels showing in an increase in dry matter, protein, fat and energy contents and a decrease in ash content for carcass composition with increasing energy level. Except protein content of fish fed higher feeding level that was insignificant. In this connection, increasing dietary energy as lipids has shown to increase fat deposition in different species (Shearer, et al. 1997 and Koskela, et al. 1998). There has been evidence to demonstrate level a reduction of fat deposition when dietary energy levels reach a certain point which results in reduced consumption given that fish tend to eat to meet their energy need (McGoogan and Gatlin, 1999 and NRC, 1993). The cost-benefit analysis reveled that fish fed high-energy diet at 2% BW/d was superior to other test diets. However, increasing energy level cased a reduction of incidence cost and an increase of profit index for fish fed lower feeding level.

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