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Effects of feeding rate and frequency on growth and feed utilization efficiency in the camouflage grouper (*Epinephelus polyphekadion*) fingerlings fed a commercial diet

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ABSTRACT

A feeding trial was conducted to determine the effects of feeding rate and feeding frequency on growth and feed utilization efficiency of the camouflage grouper E. polyphekadion fingerlings fed commercial feed. Survival between treatments were not significantly different from each other. Final average body weight (ABW) and weight gain of grouper fed the commercial diet at either 2, 3 or 4 % body weight (bw) were superior to that of fish fed at 1% bw. Average feed intake (AFI) for individual grouper were highest in those fed at 3% and 4% bw and were significantly higher than in grouper fed at 1% and 2% bw. Specific growth rate (SGR) in grouper fed commercial diet at 2, 3 and 4% bw were significantly higher than in those fed at 1% bw. Efficiency of feed conversion (FCE) were higher in fish fed at 1 and 2% bw than in those fed at 3% and 4% bw. In contrast to feeding rate, feeding frequency did not significantly affect all the growth and efficiency indices. The feeding ration, using the quadratic model, which provided the maximum FCE was estimated to be 1.2 % bw.

Key words: *E. polyphekadion* fingerlings, feeding frequency, feeding rate, growth, survival,

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INTRODUCTION

In aquaculture, the importance of efficiency of utilization of formulated feeds could not be overemphasized. It affects the economic returns of a culture facility and reduces environmental pollution [15, 16, 21]. Good feed management is the result of good feed conversion which is the result of adequate knowledge about energetic needs of the fish, adequate distribution of feed and good feeding techniques. In order to optimize production, a fish farmer has to feed the fish at a level that ensures good growth and minimal waste. Estimates of daily feed requirements based on theoretical considerations can serve as a control of aquaculture systems but they should be combined with visual observations of feeding activity to 'fine-tune' feed ration [1].

If feeding frequency is decreased, the rate at which feed is supplied must be increased. This may influence feed waste, because the fish may not be able to capture all the pellets before they pass out of the culture system. Thus, attempts should be made to adjust rates of feed supply to the feeding rate of the species, and the duration of meals (i.e. feeding frequency) should be adjusted according to the time required for all feeding individuals to become satiated. However, there is, a lack of knowledge about feeding rates at given feeding frequencies of fish in culture.

Groupers are cultured in Asia where the grow-out culture are in cages. Feeding ration given on alternate days was found to be optimum at 5% resulting in the best weight, and relatively good survival rate and best feed efficiency with time [8]. Feeding rate and frequency are known to affect fish growth and FCR. Optimal growth, good feed conversion and high survival rate were observed in satiation feeding of young grouper with one feeding every 2 days [7]. Serrano and Apines [18] observe that the daily consumption rate of *Epinephelus coioides* range from 2.57% to 4.20%. As the culture of groupers becomes more intensive, strategies for supplementary feeding should be assessed for maximum economic returns. Feeding rate and feeding frequency are important considerations as they can affect growth, survival and fillet composition as well as water quality. Feeding at the optimum rate and frequency can result in tremendous savings in feed costs.

Since the grouper culture industry continues to expand, there is a need to know what feeding rate and frequency are optimal for better production and economic returns for the camouflage grouper. The study aims to determine the effects of feeding rate and feeding frequency on growth and feed utilization efficiency of *E. polyphekadion* fingerlings fed commercial feed under control running water conditions.

MATERIALS AND METHODS

Experimental Fish: Healthy swim-up fingerlings of the Camouflage grouper, *Epinephelus polyphekadion* (2.1±0.14 g) were obtained from the Fish Farming Center of the Ministry of Agriculture, Saudi Arabia. Camouflage grouper fingerlings were reared in 55 L circular bucket in a completely flow-through culture system with sufficient aeration. Average body weight (ABW) was measured at the beginning of the experiment and every 7 days. Survival rate, average feed intake, Specific Growth Rate (SGR) and food conversion efficiency (FCE) were estimated. For SGR and FCE, the following formulae were used:

$SGR = [(lnw2 – lnw1)/(t2 – t1)] X 100$

Feed conversion efficiency (FCE) = [(dry weight diet, g) x (wet wt. gain, g)-1]

Experimental Design and Feeding Treatments: Grouper fingerlings were divided randomly into a 4 x 3 factorial experiment with two independent variables: feeding rate (i.e. % bw) and feeding frequency (i.e. number of times of feeding in a day) at 4 levels (i.e. 1%, 2%, 3% and 4%) and 3 levels (i.e. once daily, 1x; twice daily, 2x; and four times daily, 4x) respectively. Each treatment were divided into 3 replicates and arranged randomly following the procedure described by APHA (1971) with 25 fish replicate^{-1}. Camouflage grouper fingerlings were fed a commercial obtained from a locally feed manufacturer ARASCO. The label of the diets revealed that it contained 48% crude protein, 10% crude fat, 1.5% crude fiber, 11% moisture, 15% ash and 14.5% digestible carbohydrate (i.e. nitrogen-free extract). Fingerlings were fed daily at 1100 for 1x treatment; at 0900 and1330 for 2x treatment; and at 0900, 1100, 1330, and 1700 for 4x treatment. The feeding trial lasted for 8 weeks.

Water parameters: Salinity, temperature, pH and dissolved oxygen (DO) were monitored daily at 0600 (YSI model 57, YSI Co., Ohio, USA). Total ammonia-nitrogen (TAN) was monitored weekly.

Statistical Analysis: Comparison between treatment means of parameters were analyzed using two-way analysis of variance (TWO-WAY ANOVA) followed by Tukey test if there are significant differences, for the means in weight gain (WG), average feed intake fish^{-1} (AFI), specific growth rate (SGR), food conversion efficiency (FCE) [29]. Statistical analyses for survival rates were performed on data after square root transformation. Data were tested for homogeneity of variance and normality of data prior to ANOVA. Results were considered significant at 5% level of significance ($P < 0.05$).

In estimating maximum FCE, data were analyzed by fitting quadratic regression equation used in fish to estimate protein and amino acids [2, 6, 22]. In this method, a polynomial equation to the third power was fitted into the data and the first derivative of the equation (i.e. a quadratic equation) was used to fit the response data obtained from feeding a dietary series:

$$R = a + bI + cI^2$$

where R is the measured response; I is the independent variable (i.e. feeding rate); and a, b, and c are constants that are calculated to provide the best fit of the data.

The value of I that produces the maximum response I_{max} in the first derivative of the equation was calculated as follows:

$$I_{max} = -0.5\ (b/c)$$

All statistical analyses were done with the Statistical Package for the Social Sciences (SPSS) Version 17 software (Chicago, Illinois, USA).

RESULTS

Survival between treatments were not significantly different from each other (Table 1). Final ABW of grouper fed the commercial diet were not significantly different at either 2, 3 or 4 % body weight (bw) and were all superior to those grouper fed at 1% bw. Subsequently, this was also the trend in weight gain since the initial ABW were all similar. AFI for individual grouper were significantly higher in those fed at 3% and 4% bw than in grouper fed at 1 and 2% bw. SGR were significantly similar in grouper fed commercial diet at 2, 3 and 4% bw and significantly higher than in those fed at 1% bw. However, FCE values were higher in fish fed at 1 and 2% bw than in those fed at 3 and 4% bw.

Table.1. Growth performance indices of grouper *E. polyphekadion* fingerlings fed with different feeding rates and frequencies. Mean values with different superscript letters in the same column were significantly different (*P*<0.05).

Feeding Rate (% bw)	Feeding Frequency	No. of fish	Survival (%)	Initial ABW (g)	Final ABW (g)	Ave. Feed Intake/fish (AFI) (g)	Specific Growth Rate	Food Conversion Efficiency
1	1x	25	94.7±2.47	2.11	3.92±0.66	1.54±0.00	0.44±0.12	1.09±0.43
	2x	25	90.8±1.15	2.11	3.84±0.33	1.71±0.07	0.43±0.06	1.00±0.15
	4x	25	95.5±2.75	2.11	3.72±0.16	1.60±0.16	0.41±0.09	0.95±0.27
Mean			93.7±2.49		3.92±0.19[b]	1.62±0.07[bc]	0.43±0.02[b]	1.01±0.07[a]
2	1x	25	93.7±4.62	2.11	4.30±0.30	3.56±0.30	0.51±0.09	0.60±0.12
	2x	25	94.2±9.10	2.11	5.47±0.13	3.99±0.13	0.69±0.05	0.84±0.11
	4x	25	92.7±0.87	2.11	5.07±0.19	3.90±0.19	0.63±0.04	0.76±0.05
Mean			93.5±0.76		4.95±0.16[a]	3.82±0.23[b]	0.61±0.09[a]	0.73±0.12[ab]
3	1x	25	95.8±4.62	2.11	3.80±0.39	6.56±0.39	0.43±0.02	0.26±0.02
	2x	25	93.0±4.21	2.11	5.03±0.68	8.03±0.68	0.63±0.04	0.36±0.04
	4x	25	98.0±8.11	2.11	4.85±0.40	7.81±0.40	0.60±0.05	0.35±0.03
Mean			95.6±2.51		4.56±0.11[a]	7.47±0.80[a]	0.55±0.11[ab]	0.32±0.06[bc]
4	1x	25	94.3±0.76	2.11	5.34±0.02	7.47±0.66	0.67±0.02	0.43±0.05
	2x	25	98.0±0.87	2.11	5.51±0.40	7.81±0.40	0.69±0.02	0.43±0.04
	4x	25	92.7±2.75	2.11	5.05±0.07	3.90±0.19	0.63±0.07	0.74±0.11
Mean			95.0±2.73[(NS)]		5.30±0.20[a]	6.39±2.17[ab]	0.67±0.03[a]	0.54±0.18[b]

Two-way ANOVA showed that feeding frequency did not affect any of the dependent variables measured and thus, no interactive effect was detected in the two independent variables (i.e. with feeding rate). When the data were rerun using one-way ANOVA (Table 2), it revealed significant differences (P<0.05) in the means of weight gain, average feed intake, feed conversion efficiency and specific growth rate when the feeding rate was varied.

From the polynomial model in Figure 1, the estimated feeding ration that provided the maximum FCE was 1.2 % bw and this corresponded to an SGR of 0.50.

Table 2. One-way analyses of variance (ANOVA) of feeding rate vs. growth and efficiency parameters.

Index	Source of variation	Degrees of freedom	Sum of square	Mean square	F	Significance
WG	Between groups	3	3.600	1.200	5.569	0.023*
	Residual	8	1.724	0.215		
	Total	11	5.323			
AFI	Between groups	3	62.205	20.735	15.393	0.001*
	Residual	8	10.776	1.347		
	Total	11	72.981			
FCE	Between groups	3	0.773	0.258	18.842	<0.001*
	Residual	8	0.109	0.0137		
	Total	11	0.883			
SGR	Between groups	3	0.0948	0.0316	5.789	0.021*
	Residual	8	0.0437	0.0055		
	Total	11	0.139			

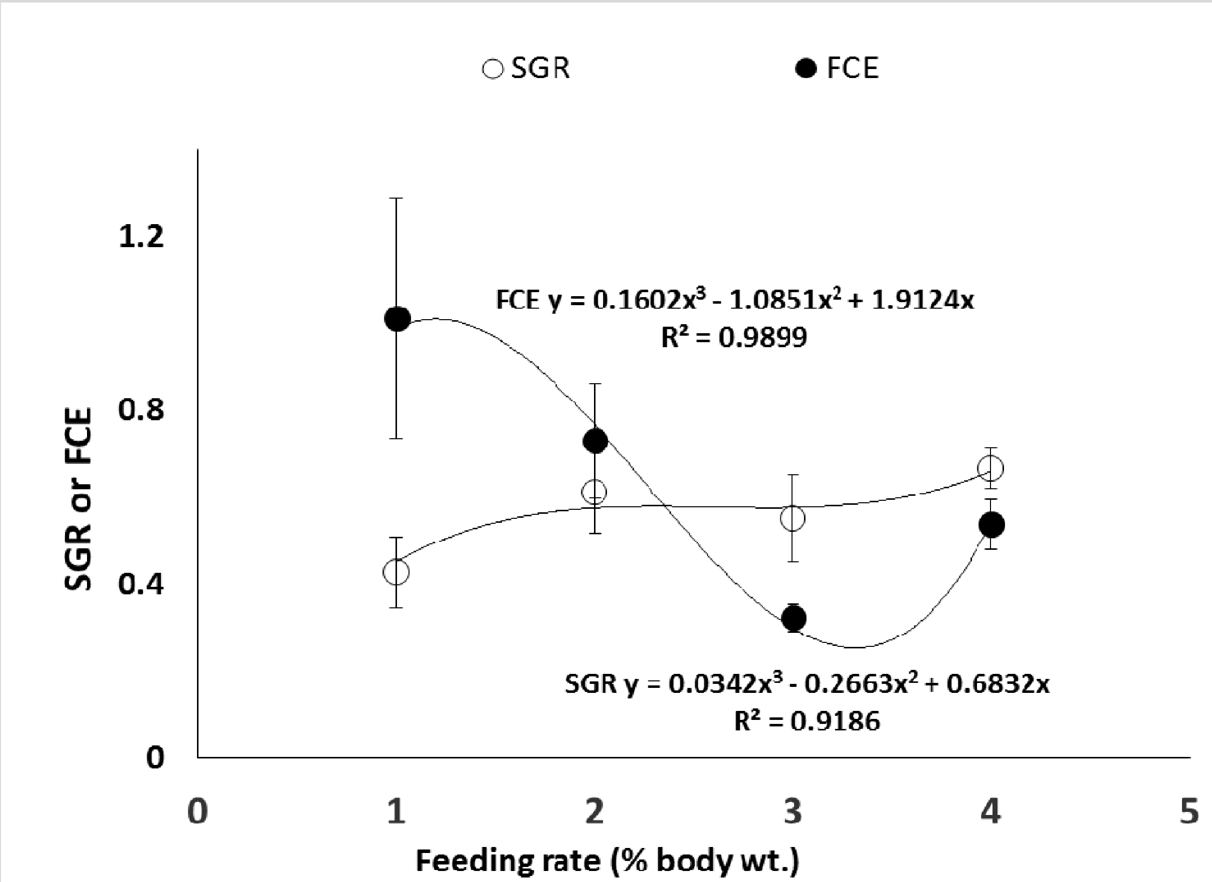

Figure 1. Specific growth rate and feed conversion efficiency of *E. polyphekadion* fingerlings fed at different feeding rates over an eight-week experimental period.

DISCUSSION

The range of dietary energy ingested between maintenance ration, when no growth occurs, and maximum ration, when maximum growth occurs, is the 'scope for growth' [11]. Within the scope for growth, the higher the ration the higher the growth rate. The relationship between the two has been described by Ivlev [13] and termed by him 'the growth coefficient of the first order (K_1)'. The same relationship between food ration and growth rate in terms of SGR was demonstrated in the present study starting from 1% up to 4% bw. When the SGR curve in Figure 1 was fitted to a linear curve, R had a value of 0.83 (not shown). The same linear relationship between growth efficiency and ration have been observed by Paloheimo and Dickie [17]. Many studies have confirmed this form of relationship between growth and ration (e.g. Huisam [12]). Brett [4] attributes this conclusion to the scatter of the points of growth:ration and to a not well defined growth rate at maximum feeding level.

Brett [4] described the relation between growth rate of sockeye salmon fingerlings and food ration (per cent of bw day^{-1}); the increase in food ration above the 'optimal level' does increase growth rate, although at a lower efficiency. He further stated that as long as the cost of the marginal gain in fish weight, i.e. that weight added over the gain on lower feeding rate, is higher than that of marginal feeding ration, added to achieve the extra gain, fish farmers will consider it economically worthwhile. Maximum economical ration will be attained when the two balance. Thus, in the present study, the estimated feeding ration that provided the maximum efficiency was 1.2 % bw and this corresponded to an SGR of 0.50; the highest mean SGR obtained was 0.67 which was the result of feeding the camouflage grouper at 4% bw. This was considerably lower than that observed in the European sea bass *Dicentrarchus labrax* L. where the optimum feeding rate for sea bass fingerlings (3 g) reared in sea water and fresh water is found to be 3.0% and 3.5% bw day^{-1}, respectively [10].

Feeding rate is also a strategy in minimizing variation in size within a group of fish. If a lower amount is fed, aggressive fish will consume most of the feed, thereby increasing size variation within a group of fish. The idea is to feed enough at a feeding to satiate aggressive fish, allowing less aggressive fish the opportunity to eat. Given that groupers are opportunistic feeder, it was reasonable to expect that feeding frequency might influence growth and efficiency in the present study; this was not observed in the present study.

Many studies have shown that multiple feeding results in a more efficient utilization of the feed than a single feeding [11] but many studies also show that feeding frequency does not influence efficiency of feed conversion nor growth. This was the findings of Biswas *et al.* [3] in mrigal, *Cirrhinus mrigala*, and rohu, *Labeo rohita;* Webster *et al.* [20] and Jarboe and Grant [14] in channel catfish, *Ictalurus punctatus*; Wang *et al*. [19] in hybrid sunfish; Carlos [5] in bighead carp (*Aristicthys nobilis*); Dada *et al.* [9] in *Heterobranchus bidorsalis*. In the present study, we also did not find any significant effect of varying feeding frequency on all the parameters measured when we performed a two-way ANOVA (not shown).

In conclusion, feeding frequency did not significantly affect any of the growth and feed efficiency parameters measured under the conditions of the experiment. Thus, no interaction between these two factors were monitored. ABW, WG and SGR of grouper fed at 2, 3 or 4 % bw were superior to those fed at 1% bw. FCE was higher in grouper fed at 1 and 2% bw than in those fed at 3% and 4% bw. The feeding rate which resulted in the maximum efficiency was estimated to be 1.2 % bw. It is thus recommended that growth and FCE of European sea bass could be improved by feeding them at about 1.2% bw day^{-1} regardless of feeding frequency.

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