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Original Research Article

NIGHT FEEDING REGIME IMPROVES WATER QUALITY, GROWTH PERFORMANCE AND FEEDING BEHAVIOUR OF EUROPEAN EELS, *Anguilla anguilla*

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Abstract: This study was aimed to explore differences between day and night feeding of farmed European eels (*Anguilla anguilla*) on: (1) the growth and feeding behaviour of eels; and (2) the subsequent impact on the quality of the culture water. A 30 day field experiment was conducted in which 40 European eels (186.4 ± 9.26 g) were arbitrarily allocated into two replicate concrete ponds (200 x 100 x 125cm) that were divided into two treatment groups, one receiving feed by day (DF) and the other receiving feed at night (NF). Results revealed a significant improvement in eel's growth performance (larger final weight and faster growth) of the fish that were fed by night (NF). Moreover, feeding behaviour was also improved in the NF group with a significantly shorter latency to start feeding and shorter feeding duration. As a consequence of improved feeding behaviour, more favourable water quality conditions (higher dissolved oxygen concentrations and lower ammonia concentrations) were observed in the NF group. In conclusion, feeding eels by night could considerably enhance the culturing of eels by promoting enhanced growth and feeding behavior, and simultaneously improving water quality.

Key words: feeding regime; European eel; behaviour; nocturnal feeding; growth; performance

Introduction

The European eel (*Anguilla anguilla*) is a commercially important fish species that is distributed worldwide. It is a catadromous fish which spawns in the Sargasso Sea. For reproduction and spawning, the eel's larvae migrate to the Atlantic coast at which larvae molt several times till reach silver eels stage then return to lake or liver habitat to feed and grow up until it reach partial maturation. At this stage of growth, eels migrate to the marine water for another cycle of proliferation and spawning (1).

Due to a large demand in eels for consumption and a dwindling stock in the wild, the

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farming of eels has become increasingly popular in recent years. Given that the activity is still relatively new, there are many aspects of eel culture that are to date unknown. For example, preferences in feeding time and variations in diurnal and nocturnal feeding patterns.

Most fish species show daily rhythms in locomotion and feeding behaviour. These activities are carried out diurnally or nocturnally according to the species of fish in question (2). Previous studies have described the locomotion and feeding activities of the European eel as mainly nocturnal with increased activity around the time of light shifts; from dark to light and light to dark (1). Feeding at an optimal time of day can yield biological advantages to the species in question such as reducing energy loss (3). The European eel is thought to feed both diurnally and nocturnally and its feeding patterns are thought to be independent of locomotor activity (4).

In eel culture, to avoid feed waste and its bad effects on water quality, animals are provided with feed in a single meal per day and uneaten feed was removed as soon as possible. The feed should be provided daily in the same time to improve the feeding utilization and digestion because fish prepare its digestive secretions just before the upcoming meal that giving the opportunity for better feed digestibility (5).

From this perspective, little is known about the effect of feeding time on European eel (*Anguilla anguilla*) reared for commercial production. Consequently, this study was aimed to investigate the effect of feeding time on the growth performance and feeding behavior of the European eel (*Anguilla anguilla*) reared in concrete ponds in Egypt, as well as the subsequent impact on water quality.

Materials and methods

Animal, management and experimental design

A total of 80 farmed animals were obtained from the General Authority for Fish Resources Development (GAFRD), Cairo, Egypt. The experiment was conducted in 4 equal-sized concrete tanks (200 x 100 x 125 cm). The study was conducted in two treatments; one receiving feed by day (DF) and the other receiving feed at night (NF), two replicates each with continuous air pumping as a source of oxygen. Each tank was supplied with a separate water inlet and outlet covered with mesh to prevent the entrance of undesirable fish and predators and to prevent the escape of the study animals. The bottom of each pond contains crockery and PVC pipes (Figure 1). The eels were placed in a quarantine tank for 30 days to allow them to recover from the stress of transport. The experimental tanks were first disinfected and filled with water before being stocked with 10 randomly selected eels of a similar body weight. The eels in the first two tanks were fed during daylight at 7 am (DF) and the eels in the second two tanks were fed during nighttime at 7 pm (NF). The eels were fed raw fish flesh for 30 day, with a feeding ratio of 10% of body weight. The eels received feed once every 24 hours on a mesh in the corner of each pond to prevent leakage of the feed to the pond bottom. Committee of Aquatic Animal Care and Use in Research, Faculty of Aquatic Sciences and Fisheries, Kafrelsheikh University, Egypt, approved the protocol and conduct of the study.

Water quality analysis

Water quality was analysed once per week at 10 am and 10 pm on the same day to evaluate the quality of pond water. The physicochemical properties of water was assessed in three samples (250 ml each) in each treatment to determine total ammonia, unionized ammonia (UIA) using Martini MI 405 portable photometer. For estimation of temperature, pH, electrical conductivity (EC), total dissolved solids (TDS) and salinity a multiparameter meter was used (HI9829-03042-HANA). Dissolved oxygen (DO) was determined in each treatment at different water depth (20, 80 and 120 cm) using a specific DO meter (AQ 600 Milwaukee, Romania).

Fish performance and growth indicators

Eel feed intake (FI) was calculated everyday along the experiment (30 day). All 40 eels

were weighed at the beginning of the experiment (initial body weight, IBW). At the end of the experiment, the eels were collected from the treatment ponds using a suitable narrow net and retained in different clean plates. The eels were dried using a clean sterile filter paper to remove the excess water from the body before measuring and weighing of final body weight (FBW). Weight gain (WG) was calculated as (FBW-IBW), specific growth rate (SGR): 100[(FBW-IBW)/t]; where (t) is the culture period in days. Feed conversion ratio (FCR) equal to feed intake/ weight gain.

Eel behaviour

The behaviour of eels during feeding was recorded by the observer during the feeding process. Latency to start feeding (the time elapsed between provision of the feed on the mesh and the first eel starting to eat in seconds) and feeding duration (the time elapsed between starting of feed till the ending of feed in minutes) were calculated.

Statistical analysis

The data was subjected to distribution normality test before analysis. Data were analyzed using Graph Pad™ Prism 6. Data were compared by the Student's *t*-test with the significance level $P<0.05$. Results are presented as means ± SEM.

Results

The outcomes of water parameters analysis are presented in Table 1. Dissolved oxygen concentrations were significantly higher in the NF group both during daylight and night except at 10 am at 20 cm depth. Total ammonia, unionized ammonia and pH were significantly lower in the NF group than in the DF group. There were no significant differences in temperature, salinity, TDS and EC between the NF and DF group.

The growth performance parameters are presented in Table 2. The growth performance parameters (FBW, WG, FI, FCR and SGR) were significantly improved by feeding eels at night in comparison to DF.

Feeding behaviour of European eels (*Anguilla anguilla*) is shown in Figures 2 and 3. There was a significant difference in latency to start feeding and the feeding duration between the DF and NF group. The latency to start feeding was shorter in NF than DF group. While the feeding duration was prolonged in DF compared to NF group.

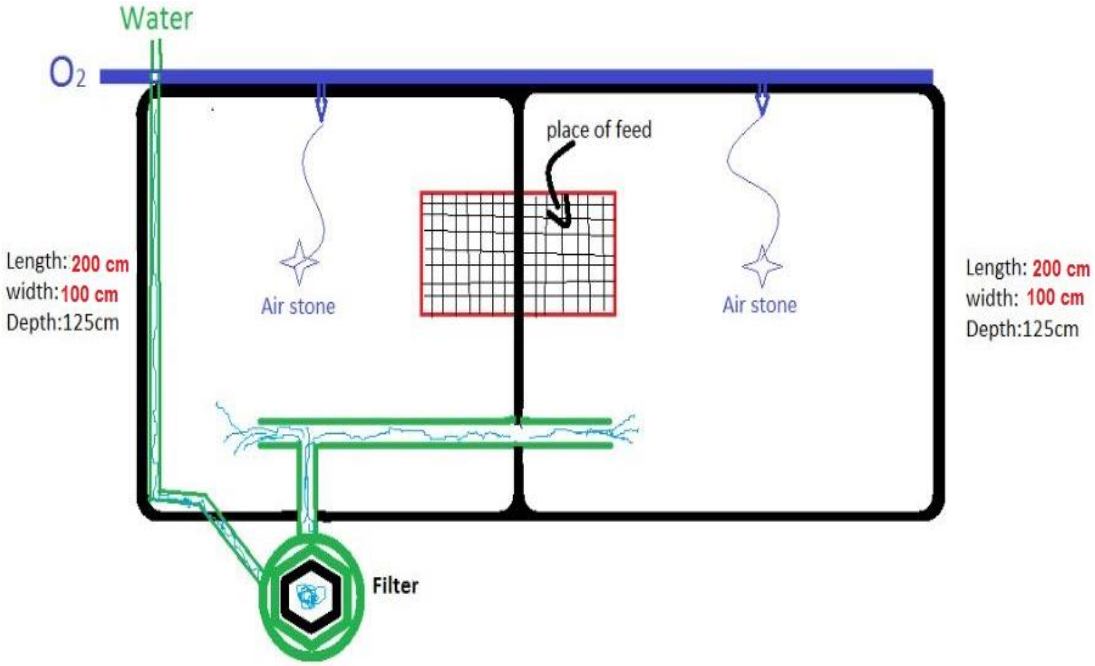

Figure 1: Design of concrete pond used for rearing of European eels (*Anguilla anguilla*)

Table 1: Effect of feeding regime on water quality of European eels (*Anguilla anguilla*)

Water parameter	Monitoring time	Day feeding	Night feeding	*P*-value
DO	10 am			
	20 cm depth	14.370± 0.186	15.030±0.606	0.388
	80 cm depth	7.367±0.273	10.730±0.722	0.031*
	120 cm depth	2.933±0.177	4.933±0.166	0.001*
	10 pm			
	20 cm depth	8.533±0.291	9.900±0.208	0.023*
	80 cm depth	5.233±0.203	6.900±0.300	0.014*
	120 cm depth	1.633±0.203	3.967±0.491	0.028*
Temperature	10 am	24.00±0.058	23.97±0.088	0.770
	10 pm	20.17±0.219	20.20±0.265	0.928
PH	10 am	8.233±0.088	7.577±0.137	0.022*
	10 pm	9.133±0.145	7.900±0.058	0.002*
Total ammonia	10 am	0.027±0.003	0.013±0.004	0.047*
	10 pm	0.034±0.003	0.022±0.001	0.047*
UIA	10 am	0.00237	0.00077	0.001*
	10 pm	0.0119	0.0001	0.001*
Salinity (ppt)	10 am	1.900±0.057	1.900±0.058	0.999
	10 pm	1.900±0.057	1.900±0.058	0.999
TDS	10 am	302.000±9.539	301.700±8.988	0.981
	10 pm	300.000±9.210	300.700±7.951	0.981
EC	10 am	591.300±13.040	592.000±13.230	0.973
	10 pm	590.300±13.100	590.000±13.410	0.974

Dissolved oxygen (DO), unionized ammonia (UIA), total dissolved salts (TDS), Electric conductivity (EC). Asterisks indicate significant differences between experimental groups (Student t-test *p<0.05)

Table 2: Effect of feeding regime on performance of European eels (*Anguilla anguilla*).

	Day feeding	Night feeding	*P*-value
Initial body weight (g)	186.000±3.559	186.800±14.600	0.958
Final body weight (g)	189.100±3.609	203.100±5.258	0.042*
Weight gain (g)	3.050±0.450	16.250±2.822	0.002*
Feed intake (g)	16.600±1.024	66.200±5.017	0.001*
Feed conversion ratio	6.473±0.483	4.632±0.259	0.004*
Specific growth rate	0.09±0.004	0.542±0.003	0.001*

Asterisks indicate significant differences between experimental groups (Student t-test *p<0.05)

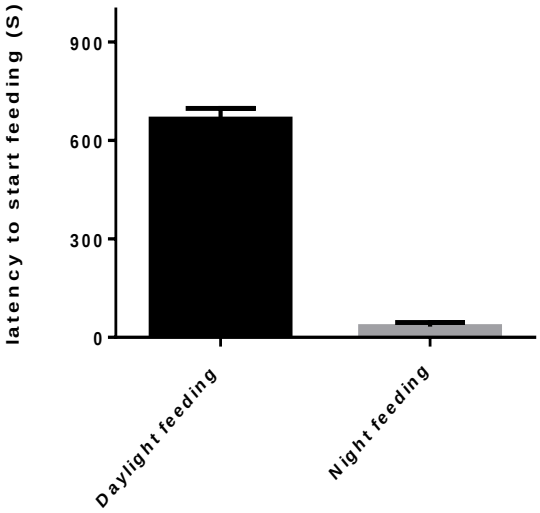

Figure 2: Effect of feeding regime on feeding behaviour (latency to start feeding) of European eels (*Anguilla anguilla*). (Student t-test *p*-value =0.001)

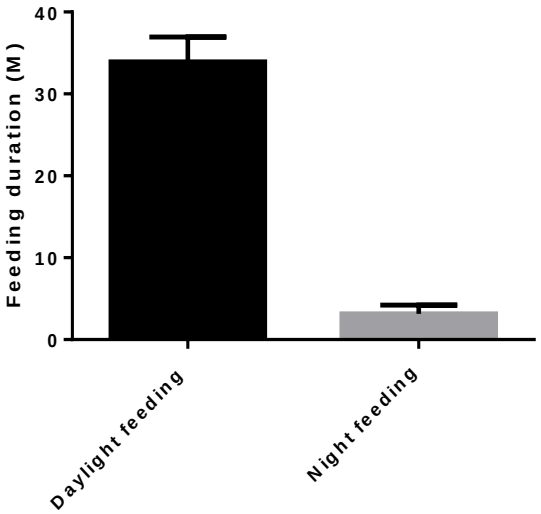

Figure 3: Effect of feeding regime on feeding behaviour (feeding duration) of European eels (*Anguilla anguilla*). (Student t-test *p*-value =0.001)

Discussion

The present study showed that NF regime influenced water quality parameters, growth performance and feeding behaviour of European eels (*Anguilla anguilla*). Water quality is a key factor in the success of any aquaculture system. When stocking eels in high densities, a higher level of DO is needed to attain better growth and to maintain normal activity. Furthermore, pond water exchange by pumping of new water and drain the old one in a regular way is also required (6). Water samples should be analysed regularly for DO, TDS, UIA and temperature. The DO in eel's water should be not less than 3 ppm, UIA level not more than 0.2 mg/L and PH around 7 (7). Additionally many trials were done to improve the quality of pond water and decrease the load of pollutants (8) which if discharged will cause environmental hazard.

The process of NF improved the water quality measurements in form of increased level of DO; which considered the most important determinant for the soundness of aquaculture, (9) both during daylight and night in the three points of monitoring (20, 80 and 120 cm from water surface). Moreover, it reduced the level of PH, total ammonia and UIA both during both monitoring. Generally, low pH will decreased the level of toxic form of ammonia (UIA), which is the most dangerous form. On the other hand, the feeding time has no significant effect on water temperature, salinity, TDS and EC even during daylight and night monitoring. This improvement in the water quality in the NF group has a direct effect on enriching the rearing environmental resource (3). Water quality improvement due to NF will decrease the rate of water exchange, which is more economic and decrease the water pollution load (6). In this study, eels were reared in a temperature ranged from 20.2 to 24°Cwhich considered within the optimum range of rearing temperature in captivity (10). Not only this lower temperature was found to reduce bacterial growth in rearing tanks, but also improved water quality and enhanced survival rates of cultured eels (10). It also reduced the basal metabolic rate of cultured eels and saved the metabolic energy that may have a direct effect in form of improved growth and indirect effect in form of reduced eel's waste products and therefore improving water quality (11). These findings have coincided with Degani et al. (12) who found that the level of DO and UIA concentrations depend on stocking rate, fish metabolic products and pond water quality.

Herein the two groups of European eels displayed different patterns of growth performance. The NF eels showed higher growth performance in form of higher FBW, WG, FI and SGR than DF. While it showed a lower feed conversion ratio than DF. This may be attributed to the increased activity of eels during the night (1) that improved feed intake and consequently improved performance (3). For individual eel weight in the DF group, there was an extensive difference between individuals which may be due to differences in genetic makeup of the individuals within the same treatment or due to their different feeding habits. The same finding was observed by López-Olmeda et al. (4). In addition, the improvement in water quality in the NF group especially high DO and low ammonia, UIA and pH found to have a direct impact on growth performance of eels. Degani et al. (12) reported that DO, total ammonia, temperature and pH are considered an important factors affecting eels performance. Interactions among these parameters greatly affect the rate of growth in eels. Lo´pez-Olmeda et al, (13) found that the feeding time may affect the cortisol level in eels. The lower level of cortisol was observed during the night. Feeding time may be affected by cortisol level and gastric secretion (e.g. gastric PH). Feeding eels once per day may improve digestive secretion that may be increased just before the next meal. This may be the explanation for improved digestion and performance (14). All of these factors may be interrelated with higher WG and FI, lower FCR and improved growth performance in NF group compared to DF group.

Feeding behaviour of European eels was influenced by feeding time. Day feeding group showed prolonged latency to start feeding and feeding duration. This may be due to the reduction of European eel's activity during daylight (1). In addition, the high level of cortisol during daylight period may influence on eels behaviour and the eels become very nervous and stressed that might make differences in the feeding duration or FI which depend on the stress level (4). Furthermore, the prolonged latency to start feeding and feeding duration in the DF group may have a direct impact on the water quality of this group. It may lead to waste of unconsumed feed and then decomposed in pond water (10). This process may be the reason for higher pH, total ammonia and UIA in DF than NF group. Similar findings were observed by Degani et al. (12) and Taufiq et al. (6).

Conclusion

The obtained results suggested that manipulating both environmental and managemental factors can regulate healthy growth performance and feeding behaviour of European eel (*Anguilla anguilla*). Night feeding regime improved water quality, growth performance and feeding behaviour of European eels. Water quality improvement due to NF will reduce the rate of water exchange.

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Conflict of interest

The authors declare that they have no conflict of interest.

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