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Research Article

Growth and Feed Utilization in Juvenile Black Sea Turbot (*Psetta maeotica*) under Different Photoperiod Regimes

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Abstract: The effects of 4 different experimental photoperiod regimes, LDN (natural photoperiod), LD24:0 (24 h light:0 h dark), LD12:12 (12 h light:12 h dark) and LD0:24 (0 h light:24 h dark), on feed intake and growth parameters of juvenile turbot (21 ± 2.3 g) in the Black Sea were determined. Growth was highest in the group exposed to the continuous photoperiod (LD24:0), followed by the LD12:12, LDN and LD0:24 groups in descending order. The lowest growth rate was recorded in the LD0:24 group. According to the results obtained, LD24:0 and LD12:12 photoperiod exposures are best for better growth and food conversion in juvenile turbot.

Key Words: Turbot, *Psetta maeotica*, photoperiod, growth, feed utilization

Farklı Fotoperyot Uygulamalarının Kalkan Balığı (*Psetta maeotica*) Yavrularında Büyüme ve Yem Değerlendirme Üzerine Etkileri

Özet: Bu çalışmada 4 farklı deneysel fotoperyotun (LDN; Doğal Fotoperyot, LD24:0; 24 saat ışık:0 saat karanlık, LD12:12; 12 saat ışık:12 saat karanlık ve LD0:24; 0 saat ışık:24 saat karanlık) Karadeniz'deki yavru kalkanlarda (21 ± 2,3 g) yem alımı ve büyüme parametreleri üzerine etkileri belirlenmiştir. En yüksek büyüme LD24:0 grubunda elde edilirken, bunu sırasıyla LD12:12, LDN ve LD0:24 grupları izlemiştir. En düşük büyüme oranı LD0:24 grubunda bulunmuştur. Bu araştırmadan elde edilen sonuçlara göre, LD24:0 ve LD12:12 fotoperiyot rejimlerinin kalkan balığı yavrularında daha iyi büyüme ve yem dönüşümü sağlanması açısından en iyileri oldukları söylenebilir.

Anahtar Sözcükler: Kalkan, *Psetta maeotica*, fotoperyot, büyüme, yem tüketimi

Introduction

Photoperiod and light intensity manipulation have been successfully used to improve the growth of larval and juvenile stages of a number of fish species. Exposure to extended photoperiods has been shown to lead to increased growth rates in salmonids, *Salmo salar* (1), halibut, *Hippoglossus hippoglossus* (2), Atlantic cod, *Gadus morhua* (3), and Atlantic turbot, *Scophthalmus maximus* (4-6), which is of great aquacultural interest in Europe (7), and production has gradually increased throughout recent years. However, there is a lack of information about the effects of photoperiods on the growth and feed utilization of the Black Sea representative of turbot (*Scophthalmus maeoticus*, also called *Psetta maeotica*), which is a new candidate with increasing potential for the Turkish aquaculture industry.

The turbot has often been divided into 2 subspecies, *Psetta maxima maxima* and *Psetta maxima maeotica*, the latter being referred to as the Black Sea representative and an endemic subspecies (8). Both *Psetta maxima* (Rafinesque, 1810) and *Scophthalmus maximus* (Linnaeus, 1758) refer to the same turbot (9,10). The Black Sea turbot is known as *Psetta maeotica* or *Scophthalmus maeoticus* (Pallas, 1811) (11).

Light intensity is important for fish and larvae, which must be reared within a light range that depends on developmental stage and species (12). The effect of light intensity on the growth of turbot as other demersal marine fishes may be important, and different cultivation strategies may be required for different life history phases. Improved fish growth in relation to light regime has been attributed to a number of factors including higher food conversion efficiency, lower activity and lower oxygen consumption (4,13).

The aim of the present study was to evaluate the effects of photoperiod regimes on the growth of juvenile Black Sea turbot during their first winter.

Materials and Methods

Juvenile turbot (n = 360, 21 g, SD = 2.3) used in the experiment were obtained from the Japan International Cooperation Agency (JICA) and the Central Fisheries Research Institute in Trabzon, Turkey, and transported to the marine research unit of the Faculty of Fisheries, University of Ondokuz Mayıs in Sinop, Turkey. The fish were acclimated to the experimental conditions for 2 weeks prior to the start of the study, which was carried out from 26 March 2004 to 12 May 2004, a total of 45 days. All fish were individually weighed to the nearest gram fortnightly during the experiment. After each feeding period of 15 days, the next day (day 16, 31 and 46) the fish were weighed and deprived of feed for 1 day; hence these days were not counted as feeding days. During the acclimation period they were fed a commercial fishmeal-based extruded rainbow trout diet (diameter 3 mm; 40.2% crude protein; 28.1% crude lipid; 24.2% nitrogen free extract; 20.7 kJ/g diet gross energy; 19.4 P:E (mg/kJ)).

In total 360 juvenile turbot were randomly distributed into 50-l rectangular polypropylene indoor rearing tanks (30 juveniles per tank with 3 replicates for each photoperiod treatment). A seawater flow-through system was arranged and the water flow rate was adjusted to exchange 100% of the total volume every hour. The same diet that was used during the acclimation period was also offered during the experiment. All groups were hand-fed to satiation twice daily during natural daylight hours. Fish were considered satiated when they began to ignore the feed. Uneaten feed was removed and stored seperately to calculate feed conversion. Samples of juvenile turbot were sacrified and used to determine the initial carcass composition. The fish were macerated with a mortar and pestle for proximate analysis. All analyses were performed in triplicate. Water quality parameters during the experiment were as follows: temperature 6.5 -14 ºC, pH 7.5, dissolved oxygen (DO_2) 8 mg l^{-1} and salinity 17.8-18.1 ‰.

Four light regimes and experimental groups totalling 12 tanks were established. One group remained on a natural photoperiod (LDN) for Sinop, Turkey (42 °N). The 3 other photoperiods were constant light 24 h light:0 h dark (LD24:0), 12 h light:12 h dark (LD12:12) and 0 h light:24 h dark (LD0:24). Light was provided by one 26-W fluorescent daylight tube installed in the tank cover. Each tank with light regimes was enclosed within a box made from black plastic sheeting to prevent the escape of light to the surrounding tanks and to enable isolation from natural light.

Relative growth rate (RGR), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were calculated using standard formulae outlined by Yigit et al. (14). At the end of the experiment, fish from all treatments were weighed, and some were sacrificed and treated as previously described for subsequent proximate analysis. Experimental diet and fish samples were analyzed for proximate composition (15) as follows: moisture content by oven drying at 105 °C for 24 h, protein (N x 6.25) by the micro-Kjeldahl technique using the Kjeltec system, and lipid by extracting the residue with 40-60 °C petroleum ether for 8 h in a Soxhlet apparatus.

Analysis of variance (ANOVA) was performed using MINITAB 13.0. Duncan's multiple range test was employed to test differences among the means. The compared parameters were final weight, RGR, SGR and FCR. Significance was reported at $P < 0.05$.

Results

The growth performance and survival rates of juvenile turbots are presented in Table 1. Mean final weights of fish exposed to the 4 light regimes (± SD; n = 3 tanks per treatment) were 31.2 ± 3.0, 30.2 ± 1.9, 25.8 ± 2.0 and 28.5 ± 2.2 g for the fish reared under LD24:0, LD12:12, LD0:24 and LDN photoperiods, respectively. By the end of the experiment, the fish exposed to LD24:0 were significantly ($P < 0.05$) larger than those exposed to LD12:12, LDN and LD0:24. Final weights of individuals in the LD24:0, LD12:12, and LDN treatments were 11-21% higher than those in the LD0:24 group. The LD24:0 and LD12:12 groups had significiantly higher ($P < 0.05$) SGR and RGR than the LDN and LD0:24 groups.

Daily feed intake (DFI) was significantly ($P < 0.05$) affected by photoperiod treatments. Fish with the lowest

Table 1. Growth performance and survival of juvenile turbot (Psetta maeotica) after 45 days reared under different photoperiod regimes. Values (mean ± SD) with different superscripts in the same row are significantly different at the 5% level.

	LD24:0	LD12:12	LD0:24	LDN
Initial wet weight (g)	21.3 ± 2.54[a]	21.2 ± 1.81[a]	21.4 ± 2.34[a]	21.4 ± 2.27[a]
Final wet weight (g)	31.2 ± 3.00[d]	30.2 ± 1.91[c]	25.8 ± 2.01[a]	28.5 ± 2.22[b]
Weight gain (g)	9.87	8.98	4.34	7.13
Relative growth rate (%)	46.24 ± 2.25[c]	42.27 ± 1.24[c]	20.3 ± 1.5[a]	33.41 ± 1.34[b]
Specific growth rate (%/day)	0.84 ± 0.03[c]	0.78 ± 0.02[c]	0.41 ± 0.03[a]	0.64 ± 0.02[b]
Survival (%)	100	100	100	100

Relative growth rate = % increase in weight = (final wet weight - initial wet weight/initial wet weight) x 100
Specific growth rate =% increase in weight = [(Ln final wet weight – Ln initial wet weight) / days] x 100

Table 2. Feed utilization in juvenile turbot (Psetta maeotica) exposed to different photoperiod regimes for 45 days.

	LD24:0	LD12:12	LD0:24	LDN
Daily dry feed intake (g/fish)	0.24 ± 0.01[d]	0.21 ± 0.00[c]	0.13 ± 0.00[a]	0.16 ± 0.00[b]
Daily dry protein intake (g/fish)	0.09 ± 0.00[d]	0.08 ± 0.00[c]	0.05 ± 0.00[a]	0.07 ± 0.00[b]
Daily dry energy intake (kJ/fish)	4.97 ± 0.24[d]	4.33 ± 0.12[c]	2.77 ± 0.13[a]	3.51 ± 0.08[b]
Feed conversion ratio	1.18 ± 0.10[a]	1.13 ± 0.03[a]	1.49 ± 0.05[b]	1.15 ± 0.03[a]
Protein efficiency ratio	2.29 ± 0.21[b]	2.38 ± 0.06[b]	1.81 ± 0.06[a]	2.34 ± 0.07[b]
Protein retention (g)	1.96 ± 0.08[c]	1.55 ± 0.03[c]	0.62 ± 0.05[a]	1.26 ± 0.04[b]
ANPR (%)	41.9 ± 3.59[b]	37.78 ± 1.01[b]	23.77 ± 0.98[a]	38.1 ± 1.16[b]

Values (mean ± SD) with different superscripts in the same row are significantly different at the 5% level.
Feed conversion ratio = g wet feed intake / g wet weight gain
Protein efficiency ratio = wet weight gain in g – dry protein intake
Protein retention = dry final body protein in g – dry initial body protein in g
Apparent net protein retention =[(final wet weight in g x final wet body protein in %) – (initial wet weight in g x initial wet body protein in %) / dry protein in g] x 100

growth rate (LD0:24 photoperiod) had the lowest feed intake. FCR and apparent net protein retention (ANPR) were significantly ($P < 0.05$) affected by photoperiod treatments (Table 2).

Whole body composition data are presented in Table 3. A significant increase was recorded for whole body protein in fish exposed to LD24:0 when compared to the other 3 groups. The lowest whole body protein content was found in the experimental fish exposed to the LD0:24 photoperiod; however, these fish were not significantly different ($P > 0.05$) in body protein than those in the LDN and LD12:12 groups.

The highest body lipid, and the lowest body ash content were found in fish exposed to LD24:0, followed by those in the LD12:12 and LDN photoperiod groups.

Discussion

The results of the present study show that the growth performance and feed utilization of juvenile turbot were significantly affected by photoperiod regimes over the 45 days of the experiment.

Growth of turbot was significantly better in longer light phases of LD24:0 and LD12:12 than in the shorter phases of LD0:24 and LDN. This very likely reflects the benefits of increased period of the visual feeding period (12,16). These findings suggest that long-term extended photoperiod has a growth promoting effect on turbot. Improved appetite, greater ration and higher food conversion efficiency are factors commonly reported to be responsible for teleost growth under continuous light (3). This appears to comply with studies on salmonids

Table 3. Final whole body composition of Psetta maeotica exposed to different light regimes. Initial values are given in the first line.

Light Regimes	Moisture (%)	Crude Protein (%)	Lipid (%)	Ash (%)
Initial values	79.62	16.32	2.78	1.16
LD24:0	78.26 ± 0.76[a]	17.44 ± 0.08[b]	2.69 ± 0.01[c]	1.11 ± 0.02[a]
LD12:12	79.15 ± 1.35[a]	16.59 ± 0.11[a]	2.55 ± 0.03[b]	1.32 ± 0.03[b]
LD0:24	80.12 ± 0.32[a]	15.99 ± 0.47[a]	2.39 ± 0.06[a]	1.36 ± 0.08[b]
LDN	79.48 ± 0.81[a]	16.66 ± 0.24[a]	2.46 ± 0.03[ab]	1.29 ± 0.03[b]

Values (mean ± SD) with different superscripts in the same row are significantly different at the 5% level.

that have shown that extended photoperiod has growth promoting effects (17,18).

The feed intake of fish exposed to the continuous light (LD24:0) regime was significantly higher ($P < 0.05$) than that of fish in the other 3 groups. The LD0:24 group consistently had the lowest feed intake ($P < 0.05$), as also mentioned by Boeuf and Le Bail (12) and Stefansson et al. (6). A decreased growth rate has been observed when the photoperiod regime was kept shorter than the natural (19,20). A minimal intensity light threshold is required to leave the fish to develop hunting activity (21). Below this threshold, the young fish are unable to detect and catch food (12).

In contrast to our findings, Pichavant et al. (22) could not detect any growth promoting effects of extended photoperiod in juvenile turbot over a 60-day period, nor could Hallaraker et al. (23) for halibut over a 56-day period. Additionally, Hole and Pittman (24) observed the best growth at 1 to 10 lx compared to 500 lx (12 h light at 11 and 14 °C) in Atlantic halibut. Furthermore, Pichavant et al. (22) did not find any difference in food utilization over a 60-day photoperiod manipulation. In contrast, Imsland et al. (4) reported that in juvenile turbot exposed to continuous light, growth rate was slightly enhanced above those of fish maintained at natural photoperiod, 16 h light:8 h dark, and 24 h light:0 h dark regimes, after 3 months of exposure at 10 and 16 °C, but not throughout the 6-month experiment. However, Imsland et al. (5) reported a better long-term growth (18 months) of turbot when exposed to extended daylength during the first winter. These results agree with our findings regarding better growth in turbot reared under extended photoperiod regimes.

An increase in growth rate with increasing feed intake has been observed in turbot (25,26). The same trend was observed here as growth rate increased with elevating feed intake and feed conversion ratio. Fish growth and food conversion efficiency were closely correlated and were generally highest in the increasing photoperiod groups. As noted by Boeuf and Le Bail (12), growth might be influenced by light through a better food conversion efficiency and not just stimulated food intake. SGR and FCR were significantly lower in fish exposed to the LD0:24 photoperiod regime. This was also observed in the studies by Imsland et al. (4) and Stefansson et al. (6).

One of the most important factors influencing fish growth is the water temperature (27,28). Data of the optimum temperature ranges are available for many fish species. For turbot, optimal temperature ranges for growth were previously reported between 16 and 19 °C for Norwegian turbot between 25 and 75 g (29) and between 16 and 20 °C for French turbot between 35 and 40 g (26). Although a temperature of 22 °C has been considered superoptimal for growth of turbot by Imsland et al. (29), growth rates obtained in the present study are lower than those of other studies (4,30), probably due to the low ambient water temperature (6.5–14 °C) during the course of this experiment conducted in winter.

Fish exposed to LD24:0 group in the present study demonstrated the highest whole body protein and lipid content but the lowest crude ash content when compared to the other photoperiod groups. The best protein retention was also recorded in the group exposed to continuous light.

In conclusion, our results show that the feed intake and growth of juvenile turbot are influenced by photoperiod. The results also suggest that LD12:12 is adequate for a good growth of juvenile turbot, as the fish growth in this group was similar to that held under the 24L:0D regime. The photoperiod is an environmental factor that can be easily modified in intensive aquculture systems. A simple photoperiod manipulation could be an easy way to increase the juvenile turbot growth parameters and to reduce feed conversion rates.

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