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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

ROUTINE OXYGEN CONSUMPTION RATE OF THE BLACK SEA TROUT (*Salmo trutta labrax* Pallas, 1811)

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Abstract: Aim of this study is to determinate oxygen consumption rate of Black Sea trout, (*Salmo trutta labrax* Pallas, 1811*)* in the sea water (18‰ salinity) in tanks at farm condition. Two different fish size were used as small size and big size which average weights 54.1 ±3.06 (n=300) and 507.0 ±17.71 (n=32) g, average total lengths 17.7 ±0.36 and 35.5 ±0.44 cm respectively. Water temperature averaged 10.0 ±0.01°C during the experiment. The amount of dissolved oxygen was measured during 3 days inlet and outlet of each tank. Oxygen consumption rate was found to be in the range of 95.2-140.0 mgO_2kg/h according to fish size. It was observed that O_2 consumption increased in the daylight period.

Keywords: Oxygen consumption, Black Sea trout, *Salmo trutta labrax*, Water quality

Özet: **Karadeniz Alabalığının (*Salmo trutta labrax* Pallas, 1811) Rutin Oksijen Tüketimi**

Bu çalışmanın amacı, Karadeniz Alabalığının (*Salmo trutta labrax* Pallas, 1811) deniz suyunda (‰18 tuzluluk) çiftlik şartlarında tanklarda oksijen tüketim oranını belirlemektir. Denemede ortalama ağırlıkları 54.1 ±3.06 g (n=300) ve 507.0 ±17.71 g (n=32) ve total boyları 17.7 ±0.36 ve 35.5 ±0.44 cm olan iki farklı balık grubu kullanılmıştır. Deneme süresince su sıcaklığı ortalama 10.0 ±0.01°C olmuştur. Her tankın giriş ve çıkış suyunda üç gün boyunca çözünmüş oksijen miktarı ölçülmüştür. Oksijen Tüketim Oranı balık büyüklüğüne bağlı olarak 95.2-140.0 $mgO_2kg/saat$ arasında değişmiştir. Oksijen tüketiminin aydınlık dönemde artığı tespit edilmiştir.

Anahtar Kelimeler: Oksijen Tüketimi, Karadeniz Alabalığı, *Salmo trutta labrax*, Su kalitesi

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Introduction

Black Sea trout *(Salmo trutta labrax* Pallas, 1811), the subspecies of the brown trout, *Salmo trutta,* (Linnaeus, 1758), live widely in the European Continent including the North-East Black Sea coasts, the Black Sea, the Avoz and Hazar Basins of Turkey (Elliott, 1994). It is called Black Sea trout (Cheritskiy, 1988; Okumuş *et al*., 2004) by some researchers in order to emphasize its geographical origin and some called it Black Sea salmon (Barach, 1962; Solomon, 2000).

The Black Sea trout is specified as anadromous form (Ryman, 1983; Hindar *et al*., 1991) by researchers, who analyzed the brown trout into three different ecotypes according to their life styles as brook, sea and lake. Çiftçi (2006), who studied the population genetics of the brook and sea forms of the Black Sea trout in the East Black Sea region, reported that there is no difference between the two forms and the Black Sea trout, sampled from the rivers disembogued into the East Black Sea belong to the Tuna family group when it comes to its population.

The first study regarding the artificial breeding of brown trout was probably carried out by Jacobi in Germany in 1739 and their artificial breeding have been spread in Europe from that date on (Coste, 1853). The adaptation of the Black Sea trout to culture conditions was made in 1998, using the brood stocks taken from the rivers in the Black Sea Region in the spawning season (Aksungur *et al*., 2005).

The spawning season of the Black Sea trout, which reach sexual maturity at the ages of 2-3, is the months September-December in the East Black Sea Region of Turkey (Tabak *et al*., 2002). That fish over 11.5 cm lengths can adapt to seawater is reported by Kurtoğlu (2002), who studied the smoltification features and the loss of parr tags in the adaptation of the Black Sea trout to seawater. Studies to increase the cultivation of this species and to develop natural stocks continue in Turkey. Recently this species is started to be cultivated in the fresh water and sea cages. In an attempt to increase this species' activity in the aquaculture, research attempts have been focused on the understanding of the factors that affect the growth, feed evaluation and survival rate (Çakmak *et al*., 2008).

Environmental factors such as the temperature of the water and salinity can not be controlled under the farm conditions. When the environmental factors change, the metabolic balance regarding the oxygen consumption changes and the environmental oxygen level can be a limiting factor.

The oxygen consumption of Salmonidae species is affected by a number of factors such as the temperature of the water and the fish size (Fivelstad and Smith, 1991; Forsberg, 1994); the feeding rate (Brett and Groves, 1979); the feeding diet Forsberg, 1997); salinity (Forsberg, 1994); the swimming speed (Wilson *et al*., 2007) and the stress level (Smart, 1981; Barton and Schreck, 1987; Barton, 2002). That the lethal dissolved oxygen level at temperatures of 7-21°C is 1.6-2.8 mg/L for the brown trout is reported by Doudoroff and Shumway 1970) in their technical report. The effects of the physiologic stress in the acidic water and the effects of low salinity to the oxygen consumption of the juvenile brown trout were studied by Carrick (1981), and Altınok and Grizzle (2003) respectively.

Although many authors have studied oxygen consumption using small respirometer chambers in which fish remain inactive, the application of these results to commercial aquaculture is not very realistic (Jobling, 1981). Therefore, it seems more appropriate to determine the oxygen consumption rate under fish farming conditions as it is done with the Atlantic salmon, *Salmo salar* L. (Fivelstad and Smith, 1991; Forsberg, 1994; Fivelstad *et al*., 1999), juvenile walleye, *Sander vitreus* (Yager and Summerfelt, 1993), White sturgeon, *Acipenser trunsmontanus* (Thomas and Piedrahita, 1997), Wolffish, *Anarhichas minor* (Foss *et al*., 2003) and Scaldfish, *Paralichthys dentatus* (Katersky *et al*., 2006).

Oxygen requirement of fish is a fundamental variable of aquaculture system design and management, as it is often the basis for determining water flow rates for sustaining stock (Timmons *et al*., 2001; Merino *et al*., 2009) and the artificial re-oxygenation requirements for certain reared fish biomass and the temperature regime (De la Gandara *et al*., 2002).

The Black Sea trout is a commercially important fish in the Black Sea region of Turkey for land based farm and also marine farming. There is a lack of knowledge regarding the oxygen consumption rates of Black Sea trout in farming conditions. Therefore, the present study of the oxygen consumption of Black Sea trout between small size fish (54.1 g) and big size fish (507.0 g) was conducted in tank under farm conditions. The determination of oxygen consumption by Black Sea trout in farm conditions will provide valuable information on the oxygen requirement of these fish in an aquacultural setting and should be valuable for designing and managing a rearing facility for the intensive culture of Black Sea trout.

Materials and Methods

Fish

The fish used in this study are composed of the 3rd generation individuals that were reproduced from the fish captured from the Fırtına, Kapistre and Çağlayan brooks of the East Black Sea Region of Turkey. All fish used in this experiment had kept in tanks of 6 m diameters until the trials, were anaesthetized benzocaine, (0.05 g/L) 5 days prior to the start of the trials, weighed individually and total length recorded to the nearest 0.1 g and 0.1 cm, and distributed to fiberglass tanks of 1.15x1.15x0.5 m at 20 kg/m^3 in stock density.

Experimental design

Initial biomass was around 8 kg per tank. Each tank had a side water inlet and a central outlet. In this experiment two different size fish were used. The first group defined as small size fish group (n=300), S1 and S2, and the second group defined as big size fish (n=32), B1 and B2, average weights and total lengths were 57.7 ±4.29 g and 18.0 ±0.53 cm, 50.6 ±4.33 g and 17.4 ±0.49 cm, and 507.3 ±27.06 g and 35.8 ±0.62 cm, 506.7 ±23.74 g and 35.3 ±0.64 cm respectively. Big size fish were consisting of mature male and female fish.

Prior to and during the trial, the fish were fed with commercial trout feed (Blacksea feed, Turkey) at 08:30 am and 03:30 pm two times in a day by hand until satiation The unfed food and the fish feces in the tanks were flushed 30 minutes after each feeding. Between the trial dates, the sun rose at 06:00 am and set at 05:20 pm at the trial place. All the tanks were flowed constant running seawater filtered by sand filter of 12.0 L/m in flow rate during the trial. The flow rate was checked twice a day.

Determination of oxygen consumption

Inflow and outflow water dissolved oxygen (DO) concentrations were measured to ± 0.01 mg0_2/L with oxygen probes (YSI 556, USA; oxguard, Denmark), calibrated with the Winkler method, on the basis of 24 hours for 3 days at 20 minutes intervals. One oxygen probe was located into pipeline of inflow water and another probe was moved from one outlet of tank to another by hand.

The Specific O_2 Consumption Rate VO_2, (mgO_2kg/h) is calculated according to the formula (Jobling, 1982).

$VO_2 = (V_F\ \delta pO_2) / (B)$

Where, V_F is the water flow (L/h) through the tank, δpO_2 the difference in O_2 concentration between the inlet and outlet water and B is the total biomass in the tank. To determine the effects of oxygen diffusion from the air into the water corrections for O_2 variations between inlet and outlet water were performed in the tanks without fish before start and after termination of the experiment.

Statistical analysis

All statistical analyses were performed with SPSS software for windows. Kolmogorov Smirnov, t-test, Mann-Whitney and Kruskal Wallis Test were applied to test for overall differences between oxygen consumption rates in groups and days. Significant differences were established 0.05 level.

Results and Discussion

The big size fish used in the first trial were 2+ years old and some of them have reached sexual maturity and females were striped around 1 month before trial. The small size fish were adapted to the seawater 3 months prior to the trial. The initial mean weight of the fish was not significantly different between B1 and B2 and also S1 and S2 (t-test, $P>0.05$) and no mortality occurred in any of the experimental groups throughout the study.

Mean daily oxygen consumption rate ranged from 95.2 ±2.13 to 140.0 ±2.90 mgO_2kg/h according to fish size (Table 1). Oxygen consumption was significantly influenced by fish size (Mann-Whitney, $P<0.05$). Interaction tested between daylight and night on Specific O_2 Consumption Rate in the big and small size groups were significantly different (Mann-Whitney, $P<0.05$) (Table 2). Mean daily oxygen consumption in the big and small size groups among days were not significant (Kruskal Wallis Test, P>0.05). Water temperature averaged 10.0 ±0.01°C during the experiment.

Regarding newly initiated reproduction of Black Sea trout in the region, the dissolved oxygen plays a key role in the building cultivation system and rearing plans. The oxygen consumption of salmonid species is affected by the temperature and the fish size (Fivelstad and Smith, 1991; Forsberg, 1994). Black Sea trout as a salmonid is cold water species and so water temperature was kept to closest its optimal temperature in present study. The feeding rate (Brett and Groves, 1979) and the feeding diet (Forsberg, 1997) also have an important effect on oxygen consumption and thus feeding two times in a day by hand until satiation closed to farm condition was assigned as feeding rate and method.

This study showed that the specific oxygen consumption rate of Black Sea trout is lower in big size fish than that small size fish. Fidhiany and Winckler (1998) reported that the specific oxygen consumption decreases with increasing age and the general consensus is that oxygen uptake is directly proportional to the water temperature and feeding ration, and inversely proportional to fish size (Brown *et al.*, 1984; Forsberg, 1994; Tudor, 1999). The oxygen consumption data obtained in present study are comparable with studies of Carrick (1981), and Altınok and Grizzle (2003) for Brown trout. Fivelstad and Smith (1991) and Forsberg (1994) for Atlantic salmon and Webb (1971) for rainbow trout (Table 3).

However, the specific oxygen consumption rates of the two groups are lower than the values obtained by Fivelstad *et al.* (1999) in their study for the juvenile Atlantic salmon in 60-80 kgm^{-3} harvest stock density. The specific oxygen consumption rates of the big fish group in present study are in harmony with the oxygen consumption rate reported by Forsberg (1994).

It has been observed in the two fish groups that the oxygen consumption increases at the daylight period when the feeding and flushing activities take place (Figure 1).

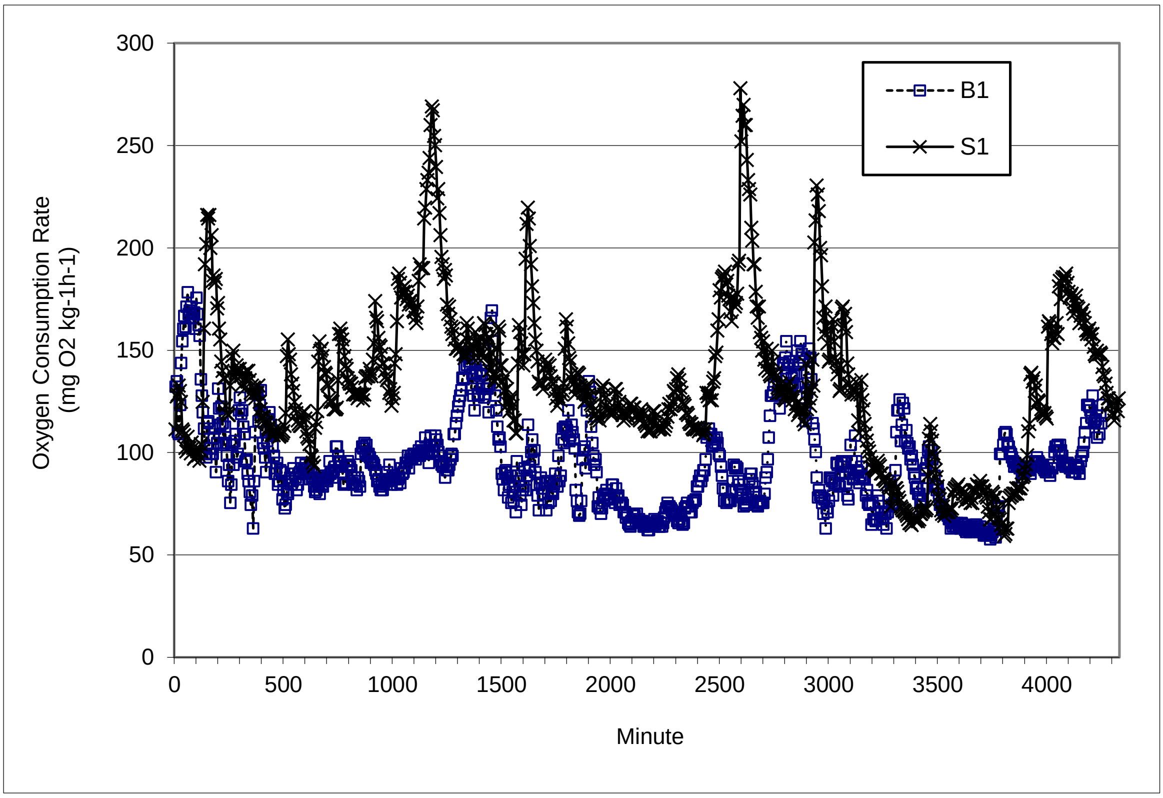

Figure 1. The specific oxygen consumption rates of the different size Black Sea trout (*Salmo trutta labrax, P.*) in farm condition.

The routine activities in the fish rearing such as tank cleaning, weighing, fish-grading, carriage, treatment applications, anaesthetization and taking samples are stress factors (Flos *et al*., 1988). It is reported by Smart (1981), Barton and Schreck (1987) and Barton (2002) that stress increases the oxygen consumption of the fish. In present study both fish groups consume more oxygen in the daylight period (06:00 am-05:20 pm) when the activities such as feeding and tank cleaning take place than the dark period (05:20 pm -06:00 am). The increase in the oxygen consumption of the fish during the daylight period when compared to the night period may stem from the stress factors.

No prior study regarding the oxygen consumption of the Black Sea trout at the temperature of this study and with 18‰ salinity rate is found during the literature search. In this study present data of the oxygen consumption of this fish will not only help in solving the problems faced in fish rearing and live fish transfers but also help in boosting the cultivation of the Black Sea trout and making it outstanding in the aquaculture.

Table 1. Mean Specific O_2 Consumption Rate (mgO_2kg/h) for Black Sea trout in two different weights in aquaculture tank environment (±SEM).

Fish Size (g)	O_2 Consumption Rate	Mean	P
B1 (507.3)	95.2±2.13	98.7±1.60[a]	P<0.05
B2 (506.7)	102.2±2.32		
S1 (50.6)	140.0±2.90	138.3±2.04[b]	P<0.05
S2 (57.7)	136.7±2.88		

Table 2. Mean Specific O_2 Consumption Rate (mgO_2kg/h) in daylight and night (±SEM).

Mean Fish Size (g)	Periods		
	Daylight	Night	P
Big (507.0)	110.5±2.99[a]	90.6±1.35[b]	0.05
Small (54.1)	149.3±4.03[a]	124.0±0.75[b]	0.05

Table 3. Oxygen consumption rate (mgO_2kg/h) of Black Sea trout and the others salmonid species

Species	Weight(g)	Water Temp.(°C)	Rate	Source
Black Sea trout	507.0	9.4-10.2	99.7	Present study
Black Sea trout	54.1	9.4-10.2	142.8	Present study
Brown trout (WS)	5.5	17.2	137	Altınok and Grizzle, 2003.
Brown trout	0.1-5.0	10.0	112-166	Carrick, 1981
Atlantic salmon	200-850	5-9	200-500	Fivelstad and Smith, 1991
Atlantic salmon	2000	8.5	71-118	Forsberg ,1994
Rainbow trout	258-291	15	74-76	Webb, 1971

Conclusion

Consequently, the determinations of oxygen consumption in this research for Black Sea trout in farm conditions provide valuable information of the oxygen requirement of these fish in an aquacultural setting. This information can be used for designing and sizing of a rearing facility for the intensive culture of Black Sea trout.

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