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Effect of Photoperiod on Growth and Efficiency of Yolk-Sac Utilization in Alevins of Brook Trout (*Salvelinus fontinalis*)

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Authors' Contributions

NB and FDS conceived and planned the project. MYO performed the experimental work and collected the data. UK analyzed the data and wrote the manuscript.

Key words

Brook trout *Salvelinus fontinalis* alevin, growth rate, photoperiod, yolk-sac consumption.

A B S T R A C T

Photoperiod is known as a key factor influencing the growth, feed conversion efficiency and other physiological functions of a fish. In this study, the effects of photoperiod on growth and yolk conversion efficiency in brook trout (*Salvelinus fontinalis*) alevins were demonstrated under three different photoperiod regimes. The newly hatched brook trout alevins (491.4 degree-days) were reared under a natural photoperiod regime (control group) and two fixed photoperiod regimes: 24h L (continuous light) and 24h D (continuous darkness). Brook trout alevins held under 24h L photoperiod regime had greater weight gain and yolk conversion efficiency (YCE) with lower development index (K_D) value while alevins held under 24h D photoperiod regime had the lowest growth rate and *YCE* with greater K_D value. In all groups, a strong linear correlation (above r^2=0.9) was found between alevin weight and degree-days, and yolk-sac weight and degree-days.

INTRODUCTION

The effects of photoperiod regime changes have been demonstrated in several species of families Salmonidae, Cichlidae and Sparidae and have concluded that photoperiod regimes play a major role in the initiation of a series of changes in feeding behavior, growth performance, and reproductive function without any adverse effects (Whitehead *et al.*, 1978; Saunders *et al.*, 1985; Jafri, 1989; Shaikh and Hafeez, 1993; Al-Marzouk *et al.*, 1994, 1995; Boeuf and Bail, 1999; Biswas *et al.*, 2004; Brown *et al.*, 2014). It has, therefore, the tendency to influence the overall performance of a fish. Therefore, providing the correct photoperiod may improve performance, profitability and sustainability of aquaculture practices (Adewolu *et al*., 2008). The artificially extended photoperiod method is one technique which has been used to increase production rate above the natural reproduction rate and at the same time, spread the reproduction throughout the whole year. The extended artificial photoperiod has also been successfully used in many fishes at their larval and juvenile stages to increase growth rate and production (Turker, 2005).

In this study, brook trout (*Salvelinus fontinalis* Mitchill 1814) alevins were reared under different photoperiod regimes to evaluate the effect of photoperiod regime on their growth and yolk-sac utilization efficiency. Brook trout is a salmonid species endemic to North America and artificially introduced to other parts of the world such as Europe, Asia, Africa, and South America (Tzilkowski, 2005). The species was introduced from Europe to Turkey in the 1990s (Innal and Erk'akan, 2006) and for a couple of decades it has been farmed in rainbow trout *Oncorhynchus mykiss* farms at small scale (Başçınar and Serezli, 2003), however, this small-scale production is not included in the aquaculture production figures of Turkey (FAO, 2014). Farming of this species at commercial scale is still limited due to inadequate baseline studies on its biology, daily food intake, gastric evacuation rate, and captive breeding and rearing techniques. Several studies have already been conducted to increase the production rate of this species in aquaculture.

The results of this study will help in proper hatchery management practices of brook trout alevins during their yolk-sac utilization phase to acquire larger size swim-up fry.

MATERIALS AND METHODS

Brook trout alevins

Eggs and milt (male seminal secretion) were obtained from hatchery-reared brood-stock of brook trout with the hand-stripping method during their spawning season. The fertilized eggs were transferred to the hatching incubator. The hatching incubator had a slow inflow and outflow of water while oxygen supplied was ensured by means of continuous air bubbling. More than 50% eggs were hatched on 491 degree-days.

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Photoperiod regimes

A total of 1500 alevins (hatched on 491 degree-days) were equally distributed among the three groups. Each group was exposed to a different photoperiod regime *i.e.*, control group (natural photoperiod regime), 24h L (continuous light) and 24h D (continuous darkness). The water temperature was measured with a digital thermometer twice a day (08:30 and 16:30).

Growth measurements

Ten alevins from each group were sampled at 491, 573, 655, 737, 817, 896 and 972 degree-days, and were anesthetized with 15 ppm benzocaine solution. The maximum length of each alevin was measured. They were, then, preserved in 10% formalin for 21 days. Fixed (preserved) alevins were dissected to separate their yolk-sac from the body. The alevin body and its yolk-sac were dried in an oven (Ecocell Drying Oven, MMM Medcenter, Germany) at 60 °C to constant weight, then finally weighted individually (Hansen, 1985).

The growth and yolk-sac absorption efficiency were calculated using the following parameters (equations):

Yolk conversion efficiency: $$YCE = \frac{L_t - L_0}{Y_0 - Y_t}$$

Yolk-sac consumption rate: $$YCR = \frac{Y_0 - Y_t}{t}$$

Daily length growth rate: $$LGR = \frac{l_t - l_0}{t}$$

Daily weight growth rate: $$WGR = \frac{W_t - W_0}{t}$$

Development index: $$K_D = \frac{10\,(Wet\ Wtt^{1/3})}{length}$$

Where, L_0, initial alevin dry weight; L_t, dry alevin weight at time *t*; Y_0, initial yolk-sac dry weight*;* Y_t, yolk-sac dry weight at time *t*; l_0, initial alevin length; l_t, alevin length at time *t;* W_0, initial wet weight; W_t, wet weight at time *t*; *Wtt*, weight*;* *t* is number of days.

The YCE (Blaxter, 1969) and YCR (Peterson and Martin-Robichaud, 1995) were calculated using dry weight instead of wet weight since according to Hodson and Blunt (1986) the percentage moisture of alevin is higher than the percentage moisture of yolk-sac. The LGR, WGR, and K_D were calculated in accordance with Peterson and Martin-Robichaud (1995) (cited by Kocabas *et al*., 2011).

Statistical analysis

The ANOVA test was used to determine the significance difference between the obtained data. Data analysis was performed using SAS, 9.04 and Ms. Excel, 2013 software. A simple linear regression was used to describe the correlation between yolk-sac weight & the degree-days, and alevins weight & the degree-days.

RESULTS

Hatching

The eggs were eyed at 16 day (194 degree-days) and were hatched on 42-day (491 degree-days) after fertilization. The mean wet weight and maximum length of initially hatched brook trout alevins were 42.52 (± 1.28 S.D) mg and 14.74 (± 0.18 S.D.) mm. The water temperature was between 11.70 (± 0.64 S.D.) and 12.14 (± 0.43 S.D.) °C. The total mortality rate in each group was found as 28% in control, 24.8% in 24h L, and 21.4% in 24h D.

Table I.- Duration (day, degree-days) of egg-eyed and hatching phases after fertilization.

Stage	Day (Degree-days)	Temperature, °C (Mean ± S.D)
Egg-eyed	16 (194.2)	12.14 ± 0.43
Hatching	42 (491.4)	11.70 ± 0.64

Weight and length

It was observed in all groups that the alevins length increased and then started to decrease after attending a maximum value (only initial and final values are given in Table II). The greater values of maximum length and weight were displayed by 24h L while the lowest values were found in 24h D group on day 42 (972 degree-days).

Parameters

The best growth rate and better yolk-sac utilization in 24h L group were also confirmed from the mean (± S.E.) values of YCE, YCR, LGR, WGR and K_D (Table III). The values of these parameters (except K_D) were comparatively higher in 24h L group. The lowest value of K_D was also observed in 24h L group that shows the best growth rate and yolk-sac utilization in 24h L group. According to these parameters, a poor growth was found in 24h D group.

Linear correlation

A strong correlations were found between yolk-sac weight & the degree-days, and alevins weight & the degree-days that was described by linear regression. The yolk-sac weight was continuously decreasing by each day (degree-days after hatching) due to its absorption by alevins in all groups (Fig. 1). The rate of decrease in yolk-sac weight was significantly similar in control and 24h L groups and both showed a slope value of 0.0432. The slope value of 24h D group was smaller (0.0424) than that of control and 24h L groups. There was also a strong correlation between alevins weight and degree-days (Fig. 2). In all groups the alevins weight were increasing by each day (degree-days after hatching). The highest value of regression slope was found in 24h L group while the lowest value was shown by 24h D group.

24h L group: □
Control group: ■ (grey)
24h D group: ■

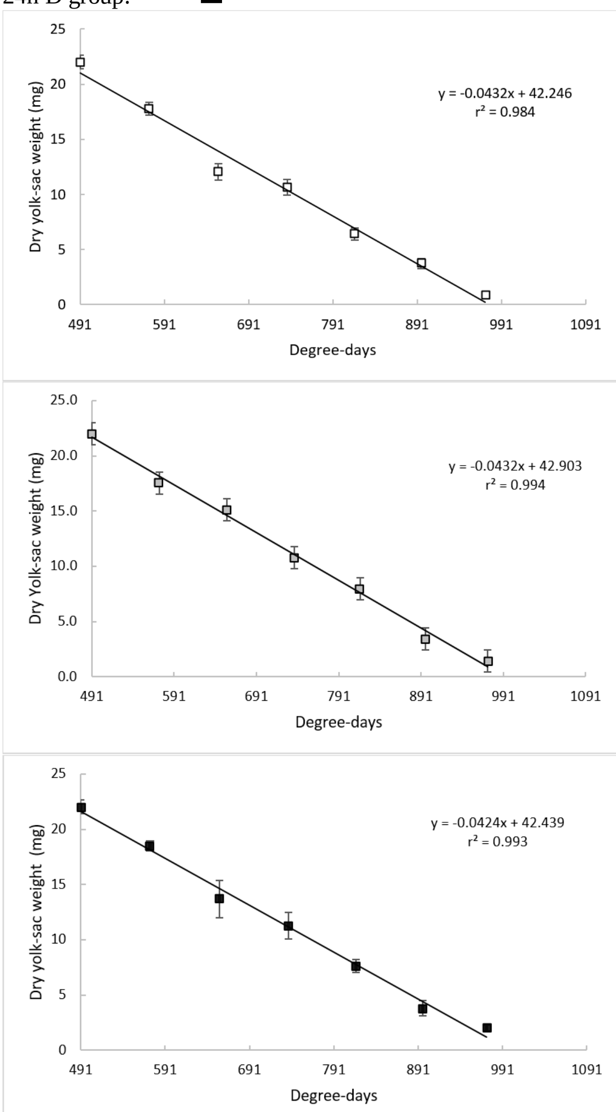

Fig. 1. Linear correlation between brook trout (*Salvelinus fontinalis*) yolk-sac weight and degree-days.

24h L group: □
Control group: ■ (grey)
24h D group: ■

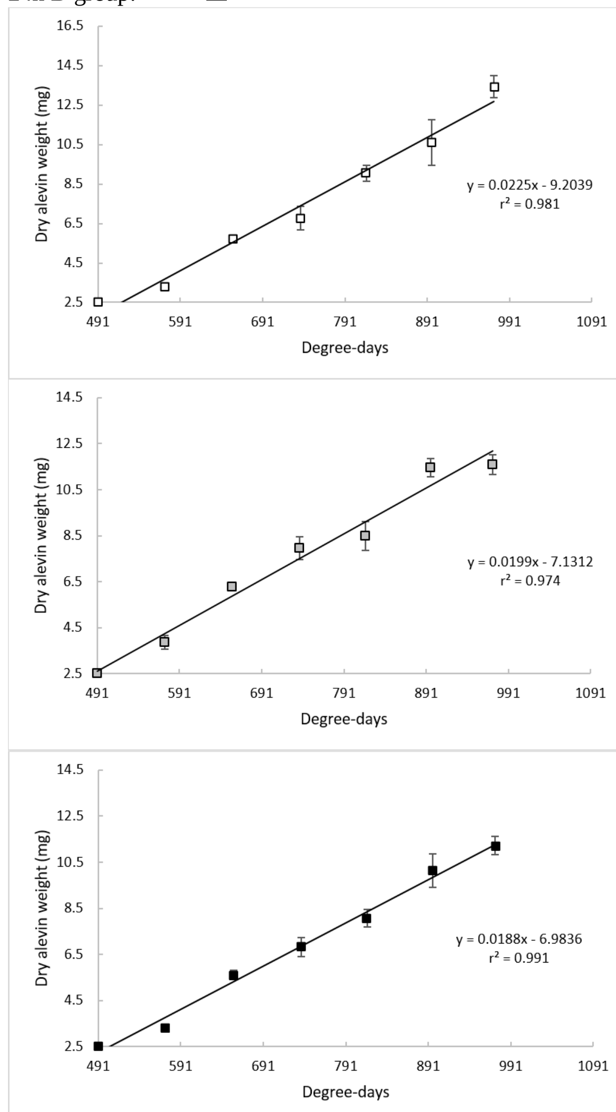

Fig. 2. Linear correlation between brook trout (*Salvelinus fontinalis*) alevin weight and degree-days.

DISCUSSION

Our study results showed that the extended photoperiod regime effectively influences the growth performance of brook trout alevins. The larger size alevins were produced by 24h L group. The best growth rate and yolk-sac utilization of brook trout alevins in 24h L group could also be confirmed from the parameter

Table II.- Effect of different photoperiod regimes on brook trout (*Salvelinus fontinalis*) alevins length (mm), wet and dry weights (mg) of yolk-sac and alevins. Values represent mean ± S.E.

	Day (DD)	Control	24h L	24h D	p
Dry alevin weight	0 (491)	2.5 ± 0.18	2.5 ± 0.18	2.5 ± 0.18	1.000
	42 (972)	11.6 ± 0.44[b]	13.4 ± 0.57[a]	11.2 ± 0.41[b]	0.006
Dry yolk-sac weight	0 (491)	22.0 ± 0.63	22.0 ± 0.63	22.0 ± 0.63	1.000
	42 (972)	1.42 ± 0.17[ab]	0.85 ± 0.26[b]	1.93 ± 0.31[a]	0.021
Wet yolk-sac weight	0 (491)	42.5 ± 1.28	42.5 ± 1.28	42.5 ± 1.28	1.000
	42 (972)	3.77 ± 0.42	2.21 ± 0.57	3.91 ± 0.59	0.062
Wet alevin weight	0 (491)	19.8 ± 0.44	19.8 ± 0.44	19.8 ± 0.44	1.000
	42 (972)	91.2 ± 3.11[ab]	94.4 ± 3.16[a]	81.8 ± 2.75[b]	0.016
Alevin length	0 (491)	14.7 ± 0.18	14.7 ± 0.18	14.7 ± 0.18	1.000
	42 (972)	24.0 ± 0.25[a]	24.3 ± 0.38[a]	22.73 ± 0.35[b]	0.005

*DD, degree-days

Table III.- Yolk-sac efficiency (YCE), yolk-sac consumption rate (YCR), daily length growth rate (LGR- mm/day), daily weight growth rate (WGR-mg/day) and development index (K_D) of brook trout (*Salvelinus fontinalis*) alevins held under different photoperiod regimes. Values represent mean ± S.E.

Parameters	Control 42-day (972 DD)	24h L 42-day (972 DD)	24h D 42-day (972 DD)	F	P
YCE*	0.44 ± 0.01[b]	0.51 ± 0.012[a]	0.43 ± 0.02[b]	6.47	0.005
YCR*	0.48 ± 0.011	0.50 ± 0.01	0.48 ± 0.01	1.44	0.255
LGR	0.22 ± 0.01[a]	0.23 ± 0.005[a]	0.19 ± 0.004[b]	22.44	<0.001
WGR**	0.77 ± 0.17[a]	0.80 ± 0.04[a]	0.54 ± 0.034[b]	10.99	<0.001
K_D**	1.89 ± 0.01[ab]	1.88 ± 0.01[b]	1.94 ± 0.013[b]	5.45	0.010

*Calculated from dried yolk-sac
**Calculated from total wet weights of alevin and yolk-sac (wet alevin + wet yolk-sac)

values of YCE, YCR, LGR, WGR, and K_D (Table III). Moreover, according to these parameters, alevins held under continuous darkness had the lowest growth rate than in the other two groups, and showed the smallest final length and weight.

In all groups, the increment in length of alevins during yolk-sac utilization phase increased until attending a maximum value and then directly started to decrease till the complete utilization of yolk-sac (only initial and final values are given in Table II). The increment in alevin length during yolk-sac utilization phase is a biologically important aspect and most of this length increment occurs in post-anal part of the alevin body which means the development of locomotory capability (Peterson *et al.*, 1996). Thus, those with a maximum final length will be more active and subsequently maximizing their initial feeding (exogenous feeding) success which could result a lower mortality because those fail to begin the initial feeding after the complete consumption of yolk-sac will be quickly died due to starvation (Morretti, 1999; Başçınar, 2010).

The dry weight of brook trout alevins increased linearly and significantly with time (degree-days after hatching). The highest slope value was found in 24h L group that means their growth was comparatively higher than control and 24h D groups. According to Hodson and Blunt (1986) the dry weight of rainbow trout *Salmo gairdneri* alevin is also increased linearly with degree-days. Generally, the best growth performance of fish alevins at extended photoperiod regimes have been reported by several studies. According to Puvanendran and Brown (2002) the Atlantic cod (*Gadus morhua*) alevins grew better at 18 L:06 D than 12 L:12 D photoperiod regime. The sole (*Solea solea*) alevins also showed better growth rate under continuous photoperiod regimes (Fuchs, 1978). Though teleost fishes grow better during yolk-sac utilization phase under extended photoperiod regimes, but some fish species *e.g.*, sea bass (European seabass) did not give better growth rate under extended photoperiod regimes (Barahona-Fernandes, 1979; Villamizar *et al.*, 2009).

In conclusion, the extended photoperiod regime (*e.g.,* 24h L) positively improved the growth rate of brook trout alevins while the alevins held under complete darkness (*e.g.,* 24h D) does not support the better growth rate of alevins. The result of this study could be used for the proper hatchery management of brook trout alevins during yolk-sac utilization phase to acquire larger size alevins which will ultimately increase the chances of initial feeding success which will result in decrease mortality rate of this species during the transition from endogenous (yolk-sac) to exogenous feeding.

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