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Research Article

Growth Performance and Food Conversion Ratio of Siberian Sturgeon (*Acipenser baeri* Brandt) at Different Daily Feeding Rates

Ferit RAD
University of Mersin, Faculty of Fisheries, Department of Aquaculture, Mersin - TURKEY
Gülten KÖKSAL, Mevlüt KINDIR
University of Ankara, Faculty of Agriculture, Department of Fisheries, Ankara - TURKEY

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Abstract: The effects of different daily feeding rates on the specific growth rate and food conversion ratio of Siberian sturgeon (*Acipenser baeri*) were investigated in order to determine the optimum daily feeding rate for fish with an initial mean weight of 1736 ± 37 g. To this end, a Latin Square experimental set-up was designed consisting of four groups of 25 fish fed a rainbow trout diet at four different daily feeding rates (0.75, 1.00, 1.25 and 1.50% body weight/day) for four 2-week periods. Water temperature varied between 19 and 22 °C throughout the experiment.

Mean specific growth rate and food conversion ratio values were found to be significantly different ($P < 0.05$) between the four treatments. The means of specific growth rate and food conversion ratio for fish fed at 0.75%, 1.00%, 1.25% and 1.50% body weight/day were computed as 0.47, 0.88, 0.89 and 0.64% day^{-1} and 1.71, 1.25, 1.40 and 2.43, respectively.

At 19-22 °C the optimum daily feeding rate for Siberian sturgeon of 1736 g was determined to be 1.00% body weight/day.

Key Words: Siberian sturgeon (*Acipenser baeri*), optimum feeding rate, specific growth rate, food conversion ratio.

Farklı Günlük Yemleme Oranlarında Sibirya Mersin Balığının (*Acipenser baeri* Brandt) Büyüme Performansı ve Yem Dönüşüm Oranı

Özet: Bu araştırmada farklı günlük yemleme oranlarının Sibirya mersin balığının (*Acipenser baeri*) büyüme ve yemden yararlanma performansı üzerine etkileri araştırılarak optimum günlük yemleme oranının saptanması amaçlanmıştır. Bu amaçla balıkların vücut ağırlıklarının % 0,75, % 1,00, % 1,25 ve % 1,50'si olmak üzere 4 farklı günlük yemleme oranının, ortalama başlangıç canlı ağırlıkları 1736 ± 37 g olan Sibirya mersin balıklarının spesifik büyüme oranı ile yem dönüşüm oranı üzerindeki etkileri araştırılmıştır. Deneme 19-22 °C su sıcaklığında ve her biri 2'şer haftadan oluşan 4 periyot halinde "tekrarlanan ölçümlü Latin kare düzeni" içerisinde yürütülmüştür. Denemede yem olarak gökkuşağı alabalığı (*Oncorhynchus mykiss*) yemi kullanılmıştır.

Ortalama spesifik büyüme oranı ve yem dönüşüm oranı bakımından yemleme grupları arasındaki fark, istatistiki olarak önemli ($P < 0,05$) bulunmuştur. Ortalama spesifik büyüme oranı, vücut ağırlıklarının % 0,75, % 1,00, % 1,25 ve % 1,50'si oranında yemlenen balıklarda sırasıyla % 0,47, 0,88, 0,89 ve 0,64 $gün^{-1}$ olarak saptanırken ortalama yem dönüşüm oranı sırasıyla 1,71, 1,25, 1,40 ve 2,43 olarak bulunmuştur.

Bu değerler ışığında 19-22 °C su sıcaklığında ortalama ağırlıkları 1736 olan Sibirya mersin balıkları için optimum günlük yemleme oranının vücut ağırlığının % 1,00'i olduğu saptanmıştır.

Anahtar Sözcükler: Sibirya mersin balığı (*Acipenser baeri*), optimum günlük yemleme oranı, spesifik büyüme oranı, yem dönüşüm oranı.

Introduction

In intensive aquaculture feed constitutes 30-60% of variable operating costs, meaning that effective feed management is crucial to the viability and success of fish farming operations of any species (1,2). Specific growth rate and food conversion ratio are the two most important factors indicating the effectiveness of feed management and economic performance in aquaculture (3). From an economic standpoint, these points mark the boundaries of the efficient zone for profit maximization

or cost minimization (4). Along with water temperature and fish size, these two parameters are closely associated with daily feeding rate or ration size (3). The determination of optimum ration size (daily feeding rate) giving the best growth and food conversion ratio is, therefore, an important element for the effective feed management (1,2,4) and successful commercialization of any fish species.

Sturgeon species (*Acipenseridae*) are considered to be potential candidates for commercialization and species diversification in aquaculture (5-8). Along with a well-established North American species, i.e. white sturgeon (*Acipenser transmontanus*), Siberian sturgeon (*Acipenser baeri*) has also proven to be a potential candidate for aquaculture (6,9-11). A good deal of work has been carried out to determine the optimum daily feeding rates for white sturgeon of different sizes (3,12-16). However, most work on the Siberian sturgeon is concerned with the nutritional physiology of the species and the feeding of juvenile fish (10,17-24). For example; the works of Sadowski et al. (25,26) look at determining the optimal ration for Siberian sturgeon rather than ration size. As a result, we have not been able to come across literature on optimum daily feeding rates for 1-2 kg Siberian sturgeons. To fill this gap a feeding trial was conducted to evaluate the growth and food conversion performance of Siberian sturgeon at different daily feeding rates and to determine the optimum daily feeding rate giving the highest specific growth rate and lowest food conversion ratio for sturgeons of 1.5-2.0 kg.

Materials and Methods

This experiment was performed with 1733 ± 37 g Siberian sturgeons (*Acipenser baeri*) originally imported as juveniles from France. To enhance the power with limited replication and to overcome the potential size effects of the fish, a Latin Square experimental set-up was designed consisting of four groups of 25 fish fed at four different daily feeding rates for four 2-week periods (3). Four shaded outdoor fiberglass tanks (2 x 2 x 1 m) were employed, each supplied with spring water at a constant flow rate of 2 L/sec. Water temperature ranged between 19.0 and 22.0 °C throughout the experiment with the mean being 21.7 °C. The values of dissolved oxygen and pH were 6.2 ± 0.2 mg/L and 7.4, respectively.

Four different feeding rates, namely 0.75%, 1.00%, 1.25% and 1.50% of body weight (BW) /day, were tried using commercial rainbow trout feed containing 45% protein and 10% fat (values declared by the manufacturer). Feeding rates were determined based on the findings of Hung et al. (13,14) for white sturgeon and recommended feeding rates for salmon and rainbow trout of similar weights (27). Feed was dispensed over 24 h using a belt feeder (FIAP belt feeder, 5 kg, 24 h) since continuous feeding was found to be more suitable for the sturgeon species (24).

Rations were corrected daily for growth based on a similar growth-ration model described by Storebakken and Austreng (28) and Hung et al. (14). The following relations were used:

A) FCR = R/SGR (27)

where

FCR = Food conversion ratio

R = Daily feeding rate (% BW/day)

SGR = Specific growth rate (% day^{-1})

B) $B_t = (B_{t-1} \times SGR) + B_{t-1}$

where

B = Total biomass (kg)

T = Day (1-14)

SGR = Specific growth rate (% day^{-1})

Based on the findings of our first experiment (11), the FCR for the first period was assumed to be 1.96 and rations were corrected daily according to computed specific growth rate and body weight increase. In subsequent periods the ration was corrected using the FCR calculated for the same feeding rate treatment in the previous period. The feeding rate treatments were changed within each tank at the beginning of each subsequent period and, therefore, all four treatments were applied to each group (3).

The growth and food conversion performances of fish were computed as SGR, % day^{-1} and FCR, respectively, as formulated by Laird and Needham (27). To this end, weight measurements were conducted on all fish at the

end of each 2-week period using an electronic balance (Olivetti, ± 5.0 g). The fish were fasted for a day prior to weighing.

Within the Latin Square experimental set-up the following general linear model was used for statistical analysis, performed in Windows Statistica medium:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \delta_k + \varepsilon_{ijk}$$

where

Y_{ijk} = Measured specific growth rate or feed conversion ratio

μ = mean of population

α_i = Effect of period, i

β_j = Effect of tank, j

δ_k = Effect of feeding rate, k

ε_{ijk} = Random error

Significant differences between treatments in terms of mean values of investigated parameters were ranked using Duncan's test to determine the optimum ration size (29).

Results

The mean values of SGR and FCR obtained at each feeding rate are given in Table 1. Best specific growth rates (0.88 and 0.89% day^{-1}) and food conversion ratio (1.25 and 1.40) were measured at groups fed 1.00% and 1.25% of body weight per day. The effects of tanks and periods were insignificant ($P > 0.05$), while differences between mean values of specific growth rate and food conversion ratio obtained at different daily feeding rates were statistically significant ($P < 0.05$) (Table 2).

Table 1 . Mean values of specific growth rate and food conversion ratio of Siberian sturgeon at different daily feeding rates.

Feeding rate (%BW/day)	Specific growth rate (%/day)[1]	Food conversion ratio[2]
0.75	0.47 ± 0.06	1.71 ± 0.33
1.00	0.88 ± 0.16	1.25 ± 0.25
1.25	0.89 ± 0.06	1.40 ± 0.11
1.50	0.64 ± 0.07	2.43 ± 0.30

1: SGR = (ln W_t – ln W_0/t) x 100 (Laird and Needham, 1988), W_t: final weight; W_0: initial weight; t: duration

2: FCR = Feed offered (kg)/weight gained (kg) (Laird and Needham, 1988)

Table 2. Results of statistical analysis*.

Factor	DF		SS		MS		F		P	
	SGR	FCR	SGR	FCR	SGR	FCR	SGR	FCR	SGR	FCR
Feeding rate	3	3	0.49730	3.3375	0.16577	1.1125	4.90	5.68	0.047	0.035
Period	3	3	0.15290	1.1005	0.05097	0.3668	1.51	1.87	0.306	0.235
Tank	3	3	0.13445	1.1387	0.04482	0.3796	1.32	1.94	0.351	0.225
Error	6	6	0.20295	1.1746	0.03383	0.1958				
Total	15	15	0.98760	6.7514						

*: $Y_{ijk} = \mu + \alpha_i + \beta_j + \delta_k + \varepsilon_{ijk}$

Y_{ijk} = Measured specific growth rate or food conversion ratio

μ = mean of population

α_i = Effect of period, i

β_j = Effect of tank, j

δ_k = Effect of feeding rate, k

ε_{ijk}= Random error

Discussion

Silva and Anderson (1) define optimum ration size as the one giving the best growth and food conversion ratio. Moreover, according to Cacho et al. (4) maximum growth occurs at the limit of voluntary food intake (satiation), while maximum feed efficiency occurs at some level below satiation. Based on the above mentioned definitions and a statistical analysis of the results obtained, the optimum feeding rate for Siberian sturgeon of 1.5-2.0 kg under our experimental conditions (water temperature, 19-22 °C, rainbow trout diet containing 45% protein and 10% fat) seems to be between 1.00 and 1.25% BW/day. The mean values of SGR obtained at these two feeding rates, i.e. 0.88 and 0.89% day^{-1}, are very close to each other, while the FCR of sturgeons fed at 1.00% BW/day was better (1.25) (Table 1). Since a similar growth performance is achieved under both feeding rates, feeding sturgeons at 1.00% BW/day is more likely to be the optimum point and better practice as far as economic considerations are concerned. Consequently, feeding large sturgeons (1.5-2.0 kg) above or below 1.00% BW/day does not favor either the growth or food conversion ratio. Sturgeons fed 0.75 and 1.5% BW/day showed lower growth rates and poorer food conversion ratios (Table 1). Significant increases in SGR with higher feeding rates of 1.00 and 1.25% BW/day suggest that a large portion of dietary nutrients have gone into growth rather than maintenance. Reduced growth at 1.50% BW/day can be explained by a reduction in the retention of dietary nutrients when feed intake was high. The suppressed growth in sturgeons fed 0.75% BW/day suggests that the bulk of the dietary nutrients were consumed for maintenance (3).

We have not found relevant literature on the optimum feeding rate of large Siberian sturgeons. It is therefore difficult to compare our findings with other sources or trials. However, Kaushik et al. (18) have reported the optimum feeding rate for Siberian sturgeons of 90-400 g as being 1.3-1.55% BW/day at 17.5 °C depending on dietary content. In another experiment, Medale and Kaushik (6) have determined the daily food intake of 1700 g Siberian sturgeons at 18.0 °C as being 0.5% BW/day and an SGR of 0.31% day^{-1}.

The optimum feeding rates for white sturgeon of different size groups are, however, well established (3,12-14,30) and there is room for comparison. At 26 °C optimum daily feeding rate for 30 g white sturgeon, has been determined to require 2.5-3.0% BW/day (13). Hung and Lutes (12) have determined the optimum daily feeding rate for 30-100 g white sturgeon juveniles to be 2.0% BW/day at 20.2 °C. The optimum feeding rate for white sturgeons of 0.25-0.5 kg has been found to be 1.5-2.0% BW/day at 18 °C (3) and 1.3% BW/day for white sturgeons weighing 767 g at 22 °C. (14). Daily feeding rates for white sturgeon at 16.5 °C (12-20 °C) have been reported to be from 4.2% BW/day for 1-month-old fish to 0.41% BW/day for 3-year-old fish (7.21 kg) (30).

As poikilothermic animals, the body temperature, metabolic rate and growth of sturgeon are affected by water temperature. Therefore, the optimum feeding rates of sturgeon reared at different water temperatures are different. Moreover, the size and shape of rearing tanks, age and size of fish, stocking densities, water flow rate, feed placement and feeding strategy are also factors that have some effect on the optimum feeding rate of sturgeons (12). Taking into consideration all the above factors and the fact that the feeding rate of fish (expressed as % BW/day) decreases with increasing body weight and increases with increasing water temperature (27), our findings are consistent and explainable when compared with the optimum feeding rates recommended for white sturgeon by Hung and Lutes (12), Hung et al. (3,13,14) and Doroshov (30) and those of Medale and Kaushik (6) and Kaushik et al. (18) for Siberian sturgeon.

The daily feed intake of 1700 g Siberian sturgeon has been reported to be 0.5% BW/day at 18 °C by Medale and Kaushik (6). The increased food intake of fish with increasing water temperature within a certain range explains the higher feeding rate applied in our experiment and recommended optimum feeding rate of 1.0% BW/day, since our experiment was performed at 21.7 °C. Moreover, the higher SGR (0.88% day^{-1}) obtained for fish fed 1.0% BW/day in our experiment proves that Siberian sturgeon of 1700 g can be fed over 0.5% BW/day at higher water temperatures.

Our experiment was conducted with Siberian sturgeons weighing 1736 g, while the optimum feeding rates (1.3-1.55% BW/day) recommended by Kaushik et al. (18) are for smaller fish (90-400 g) that naturally require a higher daily feeding rate due to the fact that ration size (% BW/day) decreases with increasing body weight (27).

The results of present study and a previous experiment (11) demonstrate that Siberian sturgeon is a potential candidate for commercialization and species diversification in Turkey as far as growth performance and food conversion ratio are concerned. The growth performance and food conversion ratio of Siberian sturgeon are comparable with those of commonly cultured species, i.e. rainbow trout, sea bass and sea bream. Nevertheless, further efforts are needed to establish hatchery techniques, i.e. the artificial propagation and juvenile production of Siberian sturgeon in Turkey, if this species is to be seriously considered as a candidate for commercialization and species diversification.

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