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Growth Performance and Feed Conversion Efficiency of Siberian Sturgeon Juveniles *(Acipenser baeri)* Reared in Concrete Raceways

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Abstract: Culture of sturgeon species is of great economical and ecological importance for those countries whose natural stocks of *Acipenseridae spp.* have declined or been exterminated. Siberian sturgeon (*Acipenser baeri)* is considered one of the most suitable sturgeon species for aquaculture. This study was carried out in order to introduce the Siberian sturgeon to Turkey as a potential candidate for aquaculture and to investigate the growth and feed conversion performance of this species in concrete raceways (flow-through system) used in rainbow trout farming. A growth trial was conducted using 1300, 75 days old Siberian sturgeon juveniles imported from France. The initial mean body weight of juveniles was 9.20 ± 0.34 g and water temperature was 16-22 °C. Juveniles were fed with commercial trout feed throughout the 135-day experiment. The final mean body weight and survival rate were found to be 225.00±8.00 g and 91% respectively. Specific growth rate ranged from 2.90 to 1.30%day^{-1}. The mean condition factor at the end of the experiment was measured as 0.350±0.003 and feed conversion ratio was found to be 1.70. The mean population density at the end of the experiment was 16.60 kg/m^2. The final yield per liter of water flow was found to be 0.90 kg/l/min. The results obtained indicate that the growth performance of the Siberian sturgeon seems to be similar and even better than that of commercially cultured species in Turkey e.g. rainbow trout, sea bass and sea bream and that the Siberian sturgeon could be easily reared in concrete raceways used in rainbow trout farming.

Key Words: *Acipenser baeri,* Growth performance, Feed conversion ratio.

Kanal Tipi Betonarme Havuzlarda Yetiştirilen Sibirya Mersin Balıklarının *(Acipenser baeri)* Büyüme Performansı ve Yem Değerlendirme Etkinliği

Özet: Doğal stokları tükenmiş veya tükenme tehlikesi ile karşı karşıya kalan ülkeler için Mersin balıkları (*Acipenseridae spp.*) yetiştiriciliği hem ekolojik hemde ekonomik yönden önem taşımaktadır. Bu çalışmada, Türkiye sularında bulunmayan ancak yetiştiricilik için en uygun türlerden biri olan Sibirya mersin balığının (*Acipenser baeri*) su ürünleri sektörüne tanıtılması ile kanal tipi havuzlardaki (Açık sistem) büyüme ve yem değerlendirme performansının belirlenmesi amaçlanmıştır. Büyüme denemesinde Fransa'dan getirilen ve deneme başlangıcında ortalama ağırlıkları 9.20 ± 0.34 g olan 1300 adet (75 günlük) mersin yavrusu 135 gün boyunca 16-22 °C su sıcaklığında ticari alabalık yem ile beslenmeye alınmışlardır. Deneme sonunda ortalama canlı ağırlık ve yaşama oranı sırasıyla 225.00±8.00 ve %91 olarak saptanırken, spesifik büyüme oranı 2.90 ile 1.30 %$gün^{-1}$ arasında değişiklik göstermiştir. Ortalama kondisyon faktörü ile yem değerlendirme katsayısı ise sırasıyla 0.35±0.003 ve 1.70 olarak hesaplanmıştır. Deneme sonunda stok yoğunluğu 16.60 kg/m^2 ve bir litre debi başına düşen ürün miktarı 0.90 kg/l/dak olarak saptanmıştır. Deneme sonuçları, Sibirya mersininin büyüme performansının ülkemizde yetiştirilen türlerden (Gökkuşağı alabalığı, çipura ve levrek) daha iyi olduğunu ve alabalık yetiştiriciliğinde kullanılan kanal tipi betonarme havuzlarda yetiştirilebileceğini göstermektedir.

Anahtar Sözcükler: Acipenser baeri, Büyüme performensı, Yem değerlendirme katsayısı.

Introduction

Sturgeon farming is of great importance for those countries where wild stocks are declining or have been exterminated (1). Several species of sturgeon are now considered attractive candidates for whole-cycle production. Along with the North American species, i.e. white sturgeon (*Acipenser transmontanus*), which has attracted a good deal of interest and has proven to be a feasible candidate for aquaculture (2, 3), Siberian sturgeon (*Acipenser baeri,* Brandt) is also offering good prospects for aquaculture in Europe (1).

This nonmigrating freshwater species has shown a good growth performance in many types of production system and in tanks of different size and shape (4, 5) and is capable of reaching sexual maturity in captivity (6, 7). The results of primary research on feeding and nutritional physiology of Siberian sturgeon have also been promising (8, 11). Siberian sturgeon is also less demanding than many other cultured species e.g. rainbow trout in terms of water quality parameters (4, 12).

Turkey's landings of sturgeon species have collapsed since the 1970's due to over-fishing, dam construction and mining activities on the migration route of these species. Fishing of *Acipenseridae spp.* has therefore, been prohibited since 1979. Nevertheless, both sturgeon meat and caviar (imported) are well appreciated in Turkey and a potential market already exists meaning that there is room for initiating sturgeon farming in Turkey. The existing situation motivated the authors to initiate a project to introduce Siberian sturgeon to the Turkish aquaculture sector as a potential candidate for species diversification and to conduct a trial to assess the growth performance, yield per liter of water flow and feed conversion efficiency of this species in a flow-through system using concrete raceways employed in rainbow trout farming rather than using polyester tanks which are commonly used in growth performance experiments and sturgeon farming.

Materials and Methods

The on-growing trial was conducted in the Fish Production and Research Station of Ankara University (March-July 1997), using 1300 Siberian sturgeon (*Acipenser baeri,* Brandt) juveniles imported from France (L'ecloserie de Guyenne). Juveniles were conditioned at the diet and the facilities for 2 weeks upon their arrival at the station and prior to the trial. Two sand bottomed and shaded (13) concrete raceways, with dimensions of 8x1x0.8m, supplied with spring water at a constant flow rate of 2.0 l/sec/raceway, were used in the experiment. The hydraulic retention time was 33.34 min at the beginning of the experiment and 53.3 min towards the end of the trial due to increased water depth, corresponding respectively to 1.8 and 1.125 water exchange per hour. The juveniles (1300) were randomly distributed in the 2 raceways and the initial stocking density was arranged as 81.25 ind/m^2 (0.75 kg/m^2) according to Smith et al. (14). Thus, the initial loading rate was 0.025 kg/l/min. Water temperature varied between 16 and 22 °C throughout the experiment. Dissolved oxygen, ammonia-nitrogen content and pH of the water used in the station varies in the following ranges: 5.97-8.18 mgl^{-1}, 0.0425-0.640 mgl^{-1} and 7.07-8.06 respectively throughout the year (15).

Fish were fed on commercial trout feed of different pellet size. Pellet no. 2 and 3 were used. Protein content of the feed used varied between 45 and 47% depending on the pellet size, while the fat content was 10% (minimum).

At the beginning of the on-growing experiment the average (mean±se) body weight of the 75-day-old juveniles was 9.20 ± 0.34 g. The daily feeding rates were adjusted according to values recommended by Ronayi et al. (7) for Siberian sturgeon namely, 8% (5-10 g), 6% (10-50 g), 5% (50-100 g), 4% (100-200 g) and 3% (200-400 g) of body weight per day. Daily ration size was readjusted according to new body weight measurements and thus, the growth in total biomass, at the end of each successive period. Fish were fed twice a day using feeding plates (4 plates in each raceway).

Individual live body weight and total length measurements were conducted on 120 randomly taken individuals (60 fish from each raceway, ≈ 10% of the total population) at the end of every 4 successive periods namely, on day 41, 70, 106 and 135 respectively. Fish were fasted for one day before measurements. Weighing of the fish up to 100 g was conducted using a sensitive electronic balance (Shimadzu, EB-3200H-A, ±0.01 g sensitivity). Larger fish were weighed with an Olivetti electronic balance (± 5 g sensitivity). Total length measurements were corrected according to Brennan and Cailliet (16).

Growth performance of Siberian sturgeon was computed in terms of specific growth rate (%day^{-1}) and relative live body weight increase (%). Other parameters influencing the feasibility of aquaculture e.g. mortality rate, feed conversion ratio, harvesting density and yield per liter of water flow (kg/l/min) were also investigated. Yield per liter of water flow is a very common criteria in raceway terminology defined as loading rate (17). Condition factor and exponential weight-length relationship were also computed.

Statistical analysis were conducted using the "*Statistica*" program for Windows Ver. 5.0. One-way ANOVA test was computed to evaluate the differences in terms of mean body weight and total lengths between replicates. The differences were found to be statistically insignificant (P<0.05) in every successive period and therefore, body weight and total length measurements of two replicates were combined and evaluated as a single group for each period.

Results

Descriptive statistical data

Descriptive statistical data namely, minimum, maximum and mean body weight and total lengths as well as coefficient of variance in each successive experimental period are given in Table 1. Sturgeons reached the mean final weight of 225.00±8.00 g in 135 days (Figure 1). Based on coefficient of variances, Siberian sturgeons showed a greater variance in terms of live body weight than total length.

Growth Performance and mortality rate

Growth performance of sturgeon juveniles were computed in terms of specific growth rate ($\%day^{-1}$) and relative body weight increase (%). Specific growth rates in the 1st, 2nd, 3rd and 4th periods were found to be 2.90, 2.80, 2.20 and 1.30 $\%day^{-1}$ respectively. The highest BWI was observed (234%) in the first 41 days (Period 1) of the experiment (Table 2). The cumulative mortality rate throughout the 135-day experiment was found to be 9.00% (Table 2). The highest mortality was observed during the first 41 days (Period 1).

Weight-length relationships

Weight-length relationships were expressed as condition factor (Table 1), regression equation (Equation 1) and curve (Figure 2).

The mean initial and final values of CF were found to be 0.358±0.006 and 0.350±0.003 respectively (Table 1).

Based on the mean body weight and total length measurements and the weight-length model of Ricker (18), the following regression equation and curve were computed for Siberian sturgeons up to the mean weight of 225 g.

$W = 0.0043l^{2.9253}$ (Equation 1)

$R^2 = 0.99$

Feed conversion ratio

423.00 kg of feed was consumed during the 135-day experiment, corresponding to 254.00 kg (ΔW) biomass increase. The feed conversion ratio and feed efficiency were therefore, calculated as 1.70 and 0.60 respectively (Table 3).

Population density

The initial stocking density was 81.25 ind/m^2 corresponding to 0.75 kg/m^2. At the end of the 135-day experiment 16.60 kg (mean) of fish was harvested from unit area (m^2). The final yield per liter of water flow was calculated as 0.90 kg/l/min. (Table 4).

Table 1. Descriptive statistical data.

Day	Body weight (g)					Total length (cm)					Condition factor
	Mean±se	Max.	Min.	F[1]	CV[2]	Mean±se	Max.	Min.	F[1]	CV[2]	Mean±se
0	9.20±0.34	14.75	2.65	0.27	29.40	13.60±0.21	16.50	8.00	0.28	12.50	0.358±0.00
41	30.70±1.12	82.70	5.70	0.04	40.00	20.70±0.27	29.00	11.00	0.13	14.50	0.331±0.00
70	68.85±2.52	149.00	9.20	0.02	40.60	26.70±0.38	35.50	13.70	0.33	15.90	0.336±0.00
106	153.00±5.00	289.00	32.00	0.72	36.35	35.40±0.43	44.00	20.50	0.72	13.40	0.330±0.00
135	225.00±8.00	530.00	30.00	0.64	40.00	40.00±0.61	54.00	17.00	0.8	16.90	0.335±0.00

[1]F-test.

[2]Coefficient of variance.

Table 2. Mortality rate, mean specific growth rate and relative body weight increase of Siberian sturgeon juveniles in each successive experimental period.

Period	Cumulative mortality rate(%)	BWI(%)[*, 1]	SGR(%day-1)[*, 2]
1st (day 0-41)	4.75	234.00	2.90
2nd (day 42-70)	6.30	124.00	2.80
3rd (day71-106)	7.20	122.00	2.20
4td (day 107-135)	9.00	47.00	1.30

[*]Based on mean values of body weight.

[1]Relative body weight increase (%) = $\bar{w}_t - \bar{w}_0 / \bar{w}_0 \times 100$ (18).

[2]Specific growth rate ($\%day^{-1}$) = $\ln \bar{w}_t - \ln w_0 / t$ (19).

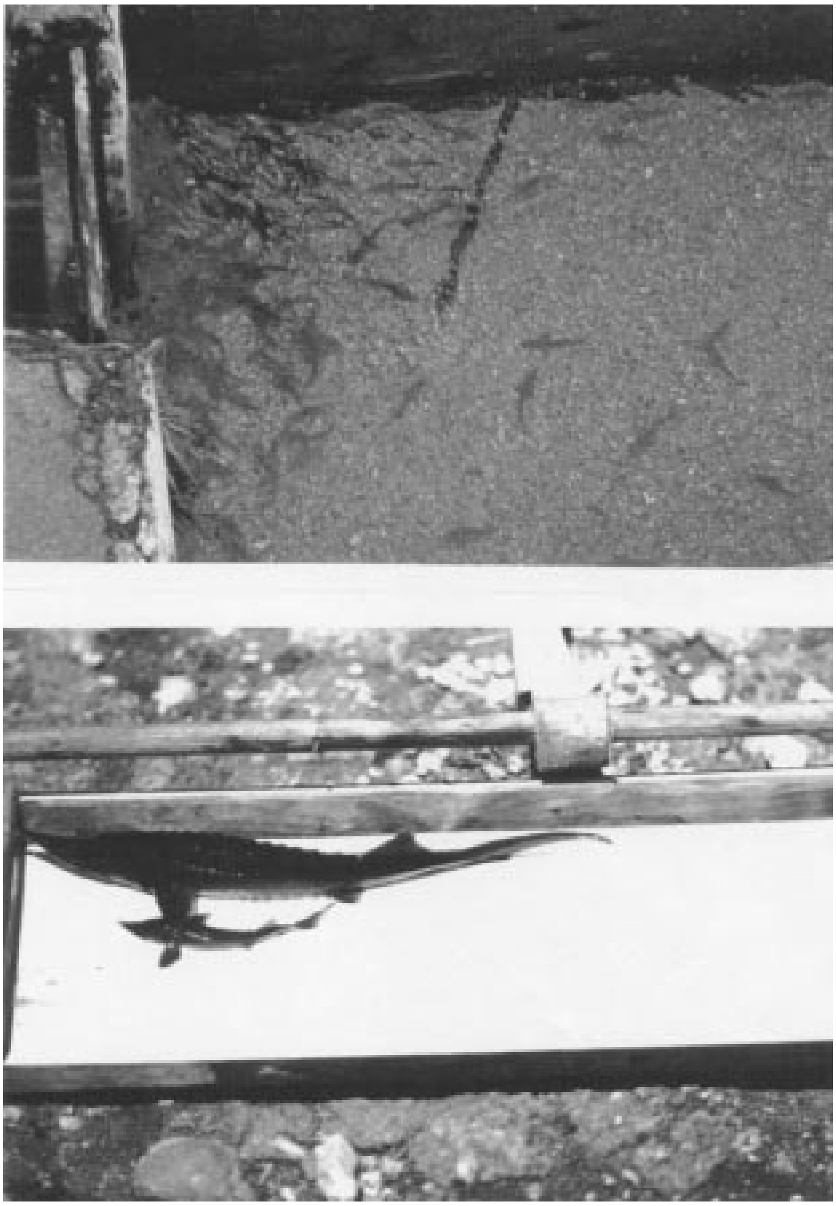

Figure 1. Siberian sturgeon *(Acipenser baeri).*

Discussion

Growth performance and mortality rate

The results we obtained on growth performance of Siberian sturgeon are in agreement with the results reported by Hung et al. (20); Ronayi et al. (7); Medale and Kaushik (12) and Kaushik et al.(13) using tanks of different sizes and shapes.

In our experiment 75-day-old Siberian sturgeon juveniles with a mean initial weight of 9.20±0.34 g reached the mean final weight of 225.00±8.00 g in 135 days (Table 1). The results reported by Ronayi et al. (7) in 22±1 °C indicate that 26-day-old Siberian sturgeon juveniles with a mean initial weight of 0.46 g reached the final weight of 258.25g in 196 days. Furthermore, in a second trial carried out by Ronayi et al. (7) on Siberian sturgeons, the 165-days old juveniles reached the final weight of 221.00 g in a recycling system using 2 m^3 tanks.

According to Hung et al. (20) sturgeons with good growth, double their body weight once every 4 weeks. The results of our body weight measurements (Table 1)

Table 3. Values of amount of feed consumed, biomass increase, feed conversion ratio and feed efficiency.

Feed (Kg)	$\overline{W}_t$[1] (Kg)	$\overline{W}_0$[2] (Kg)	ΔW^* (Kg)	FCR 3	Fe[4]
423.00	266.0	12.00	254.00	1.70	0.60

[1]Final mean total biomass ($\overline{w}_t \times N_t$).
[2]Initial mean total biomass ($\overline{w}_0 \times N_0$).
[3]Feed conversion ratio (FCR) = feed consumed/biomass gain ($\overline{W}_t - \overline{W}_0$) (19).
[4]Feed efficiency (FE)= biomass gain ($\overline{W}_t - \overline{W}_0$)/feed consumed (19).

Table 4. Population densities in each successive experimental period and yield per liter of water flow.

Day	Total no. of fish	Mean individual body weight (g)	Total biomass*(Kg)	Population density* (Kg/m^2)	Yield[1] kg/l/min.
0	1300	9.20	12.00	0.75	0.025
41	1238	30.70	38.00	2.40	-
70	1218	68.85	84.00	5.25	-
106	1206	153.00	184.50	11.50	-
135	1184	225.00	266.00	16.60	0.900

*Based on mean values of body weight.
[1]L= D x 0.06 / R (17).
D= stocking density, R= water renewal rate.

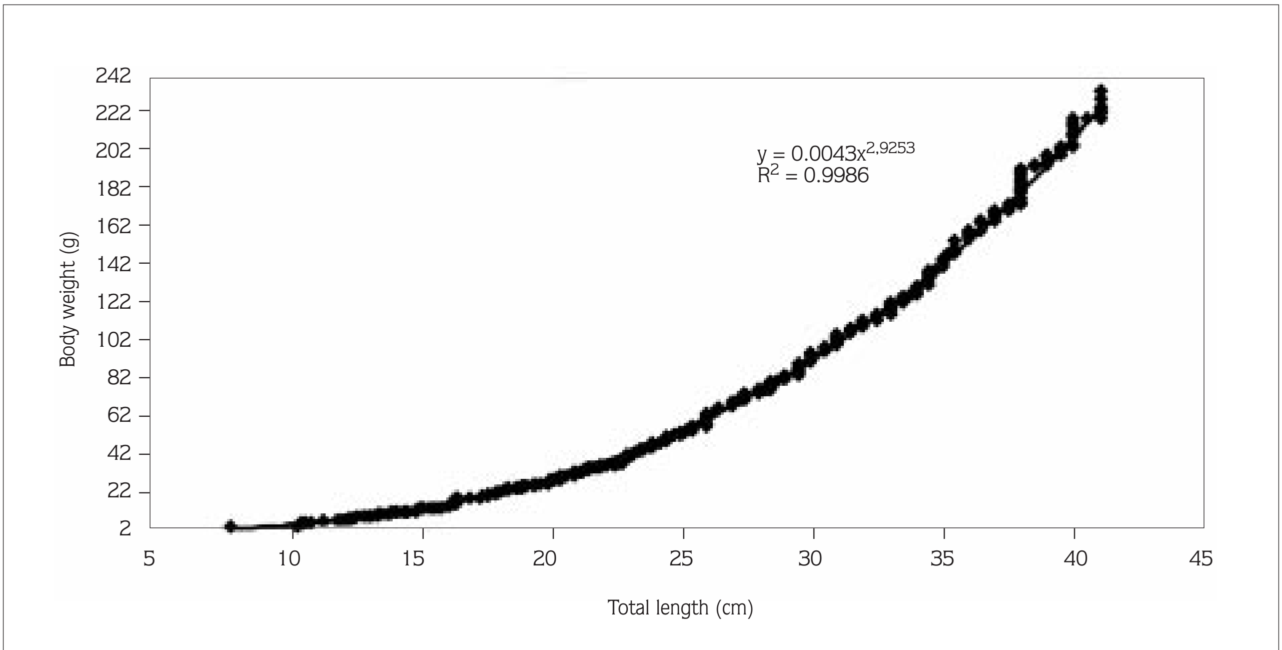

Figure 2. Weight-length relationship determined in Siberian sturgeon.

on day 41, 70 and 106 confirm the above observation. The type of rearing facility was not specified.

The specific growth rate (SGR) values obtained in our trial are also in agreement with the findings of Medale and Kaushik (11). They reported the SGR values for 3 and 10-months-old Siberian sturgeon juveniles as 1.54 and 1.03 (%day^{-1}) respectively in 17.5±1 °C. Siberian sturgeon with body weight above 20-30 g performed a SGR of 2.90-2.80 (%day^{-1}) in our experiment (Table 2). However, specific growth rate decreased with increasing age and the SGR value in the last experimental period was found to be 1.30 (%day^{-1}).

The value of body weight increase (BWI) reported by Kaushik et al.(13) at 17.5±1 °C for Siberian sturgeons with a initial mean weight of 90 g using concrete tanks (1.5x1.5x0.3m) was 179%. This value is higher than the BWG (122%) we measured in Siberian sturgeon juveniles of 68-153g (Table 2).

The low mortality rate obtained throughout the 135-day trial indicates that sturgeon juveniles are quite hardy as stated by Steffens et al. (1).

In general the results obtained in terms of growth performance are quite promising and are similar or even better than the growth of commonly cultured commercial species in Turkey e.g. rainbow trout which reaches 250-280 g portion size in 8-12 months depending on the water temperature. However, it should be mentioned that the final body weight of 225 g reached in our experiment is not a market size for sturgeon. The minimum weight of sturgeon consumed in Russia is 0.5 kg (1).

Considering the water quality characteristics used in the experiment, it can be concluded that the Siberian sturgeon is capable of performing good growth in rearing units with relatively low dissolved oxygen and high total ammonia content. This observation is consistent with the findings of Salin and Williot (12).

Feed, feeding and FCR

The commercial trout feed (45-47% protein) used in the trial meet the protein requirement of the Siberian sturgeon, which has been estimated as 40±2 % by Kaushik et al. (10).

The daily feeding rates we applied were based on the values recommended by Ronayi et al. (7). Readjustments of daily ration size were conducted according to the new body weight measurements and thus, the total growth in biomass at the end of each successive experimental period. Thus, the actual daily ration size remained below the recommended values especially towards the end of each period when the resulting growth and biomass increases were not reflected in the daily ration. Despite this fact the growth of juveniles in terms of final body weight and SGR in our experiment were above the values reported by Ronayi et al. (7). This means that the recommended daily feeding rates by Ronayi et al. (7) are high and above the actual requirements of Siberian sturgeon. We came to the conclusion that the optimum daily feeding rates of Siberian sturgeon juveniles above 30g are close to the daily optimum feeding rates recommended the for white sturgeon (*Acipenser transmontanus)* by Hung and Lutes (21); Hung et al.(22) and Hung et al (20). The findings of Kaushik et al. (13) confirm this conclusion. According to Kaushik et. al. (13) the optimum daily feeding rate for Siberian sturgeons of 90-400 g in 17.5± 1.0 °C is 1.45 % of body weight.

We obtained a feed conversion ratio of 1: 1.70 in our trial (Table 3). Medale and Kaushik (11) reported the feed/gain ratio to be 1.20 and 1.18 for 3 and 10-month-old Siberian sturgeon juveniles respectively. Along with other factors the higher daily feeding rate in our trial might explain the poorer feed conversion ratio.

It should also be noted that as Hung and Lutes (21) have stated, water temperature, size and shape of rearing tank could affect the optimum feeding rate and thus the feed conversion efficiency in sturgeons.

The overall growth rate obtained with trout feed seems satisfactory. However, Hung et al. (22) observed certain disorders (e.g. scoliosis, loss of equilibrium) in sturgeons fed on salmonid diets for a long period. We did not observe any loss of equilibrium, but a few individuals (3-6) with so-called scoliosis were observed in sturgeon yearlings (a few months after the completion of the experiment). Moreover, since the protein requirements of the Siberian sturgeon are below the requirements of salmonids, it would be economically more efficient to develop sturgeon-specific diets. Obviously, the development of sturgeon-specific feeds would depend on the national or global demand for such feeds, making it feasible for commercial production.

Population density

Siberian sturgeons seem to be able to tolerate high stocking densities. The population density was 16.60 kg/m^2 at the end of our experiment (Table 4). However, this figure should not be regarded as an upper limit and is specific to the total biomass at the 135th day of our experiment and to 225 g fish. We are applying population densities of 30 to 35 kg/m^2 for larger fish (0.5 to 1.0 kg) in our research station where the sturgeons are being kept for further investigation. Steffens et. al (1) and Ronayi et al. (7) have reported even higher values for sturgeons in general and for the Siberian sturgeon. We are not able to make any comparisons since the reported stocking and harvesting densities are given in kg/m^3. However, taking into consideration that sturgeons are benthic and use only the bottom of the pond and not the whole water volume it would be more appropriate to express the stocking densities in terms of areal densities (kg/m^2).

Ruer et al. (23) made the same comment and reported 25 kg/m^2 as an acceptable population density for the white sturgeon.

As regard to yield per liter of water flow figures, we are not able to make any comparisons and comments since we have not been able to find any similar figure for Siberian sturgeon in the literature. However, considering the reference figures given for rainbow trout in different sources (17,24,25) and the lower oxygen requirement in sturgeons, the final value we obtained is not very high and can be exceeded using water with a higher dissolved oxygen content and lower ammonia and allowing the application of a higher population density.

Conclusion

The results of our experiment in terms of growth performance and feed conversion efficiency indicate that the Siberian sturgeon could be regarded as a potential candidate for species diversification in the Turkish aquaculture sector. The grow-out techniques are quite adaptable in Turkey and international market prices are attractive for sturgeon meat and specifically smoked sturgeon. Considering the present saturated demand and declining prices for rainbow trout, sea bass and sea bream in the local and international markets, species diversification is an important tool for the further development of the sector. However, our experiment was concerned with only few aspects of sturgeon farming and needs to supported by further technical and financial research.

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