The effect of feeding rate on growth performance and body composition of Russian sturgeon (*Acipenser gueldenstaedtii*) juveniles

Raluca C. Andrei (Guriencu), Victor Cristea, Mirela Crețu, Lorena Dediu, Angelica I. Docan

"Dunărea de Jos" University of Galati, Faculty of Food Science and Engineering, Galati, Romania. Corresponding author: R. C. Andrei (Guriencu), raluca.andrei@ugal.ro

Abstract. Growth performance and body composition of Russian sturgeon (*Acipenser gueldenstaedii*) juveniles were determined at four different feeding rates (FR; % body weight [BW] per day). The experiment was carried out in four experimental variants, two replications each. The experimental variants were: V1 - 1.0% BW day^{-1}, V2 - 1.5% BW day^{-1}, V3 - 2% BW day^{-1} and V4-ad libitum feeding. Fish were distributed into eight tanks; each tank was populated with 18 Russian sturgeon juveniles with an average body mass of 248.19±1.6 g. The fish were fed with extruded pellets with a protein content of 42% and a fat content of 18%. Feeding rate had a significant ($p < 0.05$) effect on the body weight (BW) and specific growth rate (SGR). At the end of the trial SGR calculated in V1 variant was 0.61% g day^{-1}, in V2 - 0.90% g day^{-1}, V3 - 1.18% g day^{-1} and V4 - 1.66% g day^{-1} and the feed conversion ratio (FCR) was for V1 - 1.69, V2 - 1.29, V3 - 1.12 and V4 - 1.01. The best BW was obtained in the group V4, followed by V3 group. The body compositions of muscle were also significantly ($p < 0.05$) different among treatments. The results of our study suggest for Russian sturgeon an optimal feeding rate between 2% BW day^{-1} and ad libitum (which was calculated at 2.8% BW day^{-1}), but analyzing the obtained results from an economical point of view and because protein is the most expensive macronutrient in fish diet, we can conclude that the optimum feeding rate for Russian sturgeon juveniles with a mean weight of 248.194 ± 1.59 g can be 2% BW day^{-1}.

Key Words: Russian sturgeon, recirculating aquaculture system, specific growth rate, feed conversion ratio.

Introduction. Since feed costs are the greatest operating expense in aquaculture enterprises (De Silva & Anderson 1995; Lee et al 2016), it is important to optimize feeding strategy in order to maximize growth and feed conversion, minimize size heterogeneity and limit waste and cutting costs (Schnaittacher et al 2005).

Rearing condition, feeding rate, water quality and fish size are the most important factors affecting the growth of fish (Brett 1979; Gershanovich & Taufik 1992; Wang et al 2009) and thus determining the optimal feeding rate is important to the success of its culture (Deng at al 2003). Also, the economics of feed conversion and the establishment of feed requirements for this sturgeon is crucial to increase production and operational benefits (Hung et al 1987; Vasilieva 2000; Deng 2000). Overfeeding results in deterioration of water quality, disease proliferation, fish mortality, reduction of feeding and production capacity (Hung et al 1989; Dwyer et al 2002; Ertan et al 2015), while underfeeding can lead to mortalities, diseases or decrease of fish growth (Bureau et al 2006; Mizanur et al 2014).

Sturgeons are one of the most endangered fishes in the world (Secor et al 2002). The decrease of wild sturgeons' stocks as a result of overexploitation, water pollution or dam construction (Steffens et al 1990; Billard & Lecointre 2001) lead to the developing of the reproduction and growth technologies of these fishes in captivity, under controlled environment. Sturgeons are very sensitive to habitat conditions, that is why when they are reared in captivity, some essential conditions must be provided, like a moderate temperature of 20 to 26°C and a constant supply of dissolved oxygen and a proper feeding practices (Mims et al 2002; Secor & Niklitschek 2001; Chebanov et al 2011).

Among all the sturgeon species, Russian sturgeon (*Acipenser gueldenstaedtii*) is proper for aquaculture because of its fast growth and tolerance to variable rearing conditions (Memiş et al 2009; Bronzi et al 2011; Moini et al 2012). However, very few data are available on feed requirements and nutrition.

For this reason, the purpose of this experiment was to evaluate the effects of different daily feeding ratio on the specific growth rate, food conversion and body composition of Russian sturgeon juveniles.

Material and Method

Experimental design and fish diet. This study was performed at the Romanian Center for the Modeling of Recirculating Aquaculture Systems (MoRAS), facility of University Dunărea de Jos, Galați, Romania, during 45 days (June-July 2016), using Russian sturgeon juveniles with an initial weight of 248.19±1.6 g (mean±SD). The recirculating system construction particularities have been described in our previous paper (Andrei et al 2017).

Prior to the experiment, fish were acclimatized to laboratory conditions for two weeks and fed with a maintenance diet. After this period, fish were randomly distributed into eight tanks (with a water volume of 0.700 m^3 each). Trial conditions included eighteen fish per tank and four feeding ratios, each feeding ratio being experimentally tested in duplicate: V1 - 1% BW day^{-1}; V2 - 1.5% BW day^{-1}; V3 - 2% BW day^{-1}; and V4 - ad libitum. The ad libitum feeding was done until the fish have not shown interest in administered fed (over an hour).

Fish were fed with extruded pellets with a protein content of 42% and fat content of 18%. Feed was manually administrated at 08:00, 16:00 and 20:00. The data on the gross composition of diet are presented in Table 1. Fish were kept under natural photoperiod of approximately 12/12 h light/dark cycle.

Table 1

Composition of the experimental diet

Parameters	*Quantity*
Crude protein (%)	42
Crude fat (%)	18
Crude cellulose (%)	1.2
Ash (%)	6.1
Phosphorus (%)	0.9
Vitamin A (IU)	10.000
Vitamin C (mg Kg^{-1})	150
Vitamin E (mg Kg^{-1})	200
Vitamin D3 (IU)	2430
Gross energy (MJ)	21.5
Digestible energy (MJ)	19.6
Metabolizable energy (MJ)	17.6

Ingredients: fish meal, soybean extracts, maize gluten, rape oil, hemoglobin, wheat gluten, blood meal.

Water quality. Temperature, dissolved oxygen and pH were measured with integrated sensors from the recirculating aquaculture system. Weekly, the nitrogen compounds (N-NO_2^-, N-NO_3^-, N-NH_4^+) were determined using a Spectroquant Nova 400 spectrophotometer, compatible with Merck kits.

Proximate analysis of fish meat and energy content. At the end of the trial fish from each experimental variant (n = 5) were randomly selected and sacrificed for chemical analysis of tissue (crude protein, crude lipid, moisture content, ash and gross energy). Muscles samples from each fish were homogenized in a blender and from the mixture homogeneous samples were taken. Crude protein was analyzed using Dumas method (N x 6.25) and crude lipids were determinate by Soxhlet method, using petroleum ether as a solvent. Moisture was determined by oven drying at 105±2ºC and ash was evaluated using a furnace at temperatures of 550±20°C. All methods were done according to standard of AOAC (2000). Energy content was determined with a calorimetric bomb (Parr 6400). For each parameter, triplicate samples were determined and the mean of determinations was taken as the result when the relative deviation was less than 2%.

Calculations. Fish were weighed and measured individually at the beginning and at end of the experiment. After 3 experimental weeks, fish from each tank were weight, and the amount of administrated food was adjusted accordingly. All biometric data were taken only after feeding had been stopped for 24 h and the fish were anaesthetized (0.3 mL L^{-1} of 2-phenoxyethanol). The following variables were calculated:

Weight Gain (WG) = 100 * (Final body weight (g) – Initial body weight)/Initial body weight (g)

Feed efficiency (FE) = Final body weight (g) – Initial body weight (g)/feed intake (g)

Specific growth rate (SGR) (% day^{-1}) = 100 × (ln final body weight – ln Initial body weight)/t, where t represents the days of the feeding trial

Food Conversion Ratio (FCR) = Feed intake (g)/(Final body weight (g) – Initial body weight) (g)

Protein efficiency ratio (PER) = WG/protein intake (g).

Statistical analysis. One-way ANOVA was used to compare the effects of feeding ratio on the performance and feed utilization. When a significant effect was found, a Duncan's test for multiple comparisons of means was performed. All statistical analyses were conducted using SPSS version 21 and was assessed at a significance level of $p < 0.05$.

Results

Water quality. In this experiment the water temperature recorded a minimum of 19.6°C and a maximum of 23.2°C. Dissolved oxygen recorded a minimum value of 6.96 mg L^{-1} and a maximum of 8.42 mg L^{-1} and pH a minimum of 7.01 pH units and a maximum of 7.92 pH units. Regarding the dynamics of water nitrogen compounds, the minimum and maximum concentrations of nitrate, nitrite and ammonium were as followed: 5.95 and 19.05 mg L^{-1}, 0.0005 and 0.02 mg L^{-1}, 0.024 and 0.067 mg L^{-1} respectively.

Weight gain, feed efficiency, specific growth rate and feed conversion ratio. The initial mean weight of the Russian sturgeon juveniles was not significantly different ($p > 0.05$) for each group. After three experimental weeks fish body weight from the group V1 (284.88±60.37 g) and V2 (330.17±51.71 g) showed no significant differences ($p > 0.05$), while the body weight of the fish from the V4 (426.94±72.31 g) is significantly ($p < 0.05$) higher than those from V3 (367.91±66.08 g). At the end of the trial, Duncan test divided the four experimental variants into three distinct groups: the body weight of fish from V1 group (309.50±86.88 g) being significantly lower than those from V2 (415.50±73.69 g), V3 (430.75±110.58 g) and V4 (535.25±102.29 g) (Figure 1). The fish from the variant V4 doubled their initial weight during the 45 days, suggesting a very good growth.

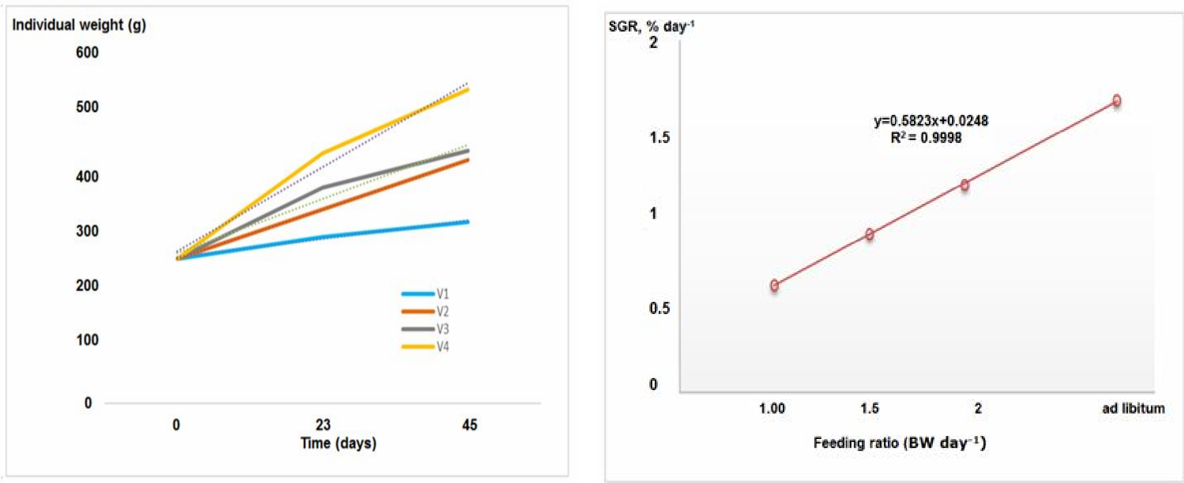

Figure 1. The evolution of the average individual weight at the initial moment, after three experimental weeks and at the final moment of the experimental period for Russian sturgeon fed with various feeding ratios (left); SGR of juvenile Russian sturgeon fed at different feeding ratio (right).

Weight gain (WG, g/fish), specific growth rate (SGR, % BW day^{-1}) and feed conversion rate (FCR) of Russian sturgeon juveniles fed at different feeding rate are presented in Table 2.

Table 2

Growth parameters of Russian sturgeon juveniles fed with various feeding ratios

Growth parameter	*Experimental variants*			
	V1	*V2*	*V3*	*V4*
Initial weight (g/fish)	246.83±2.51	247.88±2.04	248.02±2.00	249.02±1.82
Final weight (g/fish)	309.50±50.02	415.50±98.42	430.75±92.36	535.25±66.51
Weight gain (%)	25.42±0.20	67.63±1.18	72.98±0.23	114.96±2.59
Feed efficiency (%)	3.57±0.06	6.41±0.16	5.12±0.01	5.67±0.10
SGR (% BW day^{-1})	0.61±0.10	0.90±0.09	1.18±0.01	1.66±0.08
FCR	1.69±0.38	1.29±0.02	1.12±0	1.01±0.06

Regarding SGR, significantly differences were found ($p < 0.05$). SGR of Russian sturgeon juveniles significantly increased with increasing of feeding rate: Y = 0.5823 (SGR) x (feeding ratio) + 0.0248 (R^2 = 0.9998) (Figure 1). Also, WG registered a significant increase ($p < 0.05$) with the increasing of the feeding level. The best FCR were obtained in the ad libitum feeding (1.01±0.06 g/g) followed by the group V3 (1.12 g/g), without significantly differences between all groups ($p > 0.05$).

PER showed an increasing trend, the values being significantly different ($p < 0.05$) between the four treatments. Duncan's test showed that the PER values from the V1 and V2 were significantly ($p < 0.05$) lower in comparison with those registered for the group V3 and V4.

Proximate analysis of fish meat and energy content. The proximate composition of Russian sturgeon juveniles muscle is presented in Table 3. Moisture, crude fat and ash content were significantly different ($p < 0.05$). The content of lipids, ash and gross energy significantly increased ($p < 0.05$), while the water content significantly decreased ($p < 0.05$) with the increasing of the feeding level. Both, crude fat and energy content from the V1 and V2 treatments were significantly ($p < 0.05$) lower than those from the treatments V3 and V4. The protein content from the fish muscle was not influenced by the feeding ratio.

Table 3

Final proximate body composition from muscle of Russian sturgeon fish feed at various feeding ratios (mean±SD)

Parameters	*V1*	*V2*	*V3*	*V4*	*p*
Ash (%)	1.107±0.08	1.102±0.012	1.021±0.03	1.150±0.046	0.025
Proteins (%)	18.205±0.163	18.480±0.198	18.588±0.235	18.652±0.694	0.149
Lipids (%)	2.228±0.05	2.469±0.07	2.867±0.344	3.181±0.04	0.026
Moisture (%)	78.97±0.042	77.72±0.035	77.32±0.092	77.08±0.028	0.00
Gross energy (MJ/kg)	21.060±0.02	21.292±0.30	23.367±0.02	23.755±0.4	0.00
PER (g/g)	1.44±0.32	1.84±0.04	2.13±0.0	2.36±0.14	0.025

Values are means± SD; n = 5 for moisture, crude protein, crude fat, ash; mean were tested by ANOVA and ranked by Duncan's test.

Discussion. In an intensive fish farm, feeding cost can achieve 50-80% of total production costs (Rad et al 2003; Hasan et al 2007) that`s why determining the best feed rate for sturgeons is an important concept in aquaculture, mainly for economically considerations (Hung et al 1995). Choosing a good feeding rate depends on environmental conditions, such as water temperature. Some authors suggest for an optimal growth of sturgeons a water temperature between 20 and 26°C (Hung et al 1993; Mims et al 2002). In our experimental condition all the monitored parameters of water were within the range recommended for sturgeon culture (Chebanov & Galich 2013), without major variations throughout the trial period.

In this experimental trial, fish growth was positively influenced by increasing feeding ratio. A linear increasing trend was observed between the feeding ratio and WG, SGR. Increasing of WG and SGR with the increasing of feeding ratio is also reported by Rad et al (2003), for Siberian sturgeon (mean body weight of 1736±37 g) at a feeding rate of 1 and 1.25% BW day^{-1}. Also, Cristea et al (2012) reported for five months old *Acipenser stellatus* with an average mass of 46 g/fish an increase of SGR and WG with the increasing of feeding ratio. It is well known that at higher feeding ratio fish can easily increase the chance to access food and use the provided energy for growth (Sun et al 2006), while in lower feeding rate fish do not have enough energy to sustain their normal growth or the dietary nutrients are used for maintenance (Hung et al 1989). On the other side, according to some authors (Brett 1979; Cacho et al 1990) fish maximum growth occurs at the limit of voluntary food intake (satiation), while maximum feed efficiency occurs at some level below satiation. Our results are supported by the statements of these authors, being observed that in the experimental variant V4, where fish were fed to satiation, the obtained FCR values were better than those obtained in group V3. Overall, for the ad libitum group, the feeding ratio calculated at the end of the experimental period was around 2.8% BW day^{-1} and it seems to be the optimal feeding rate for Russian sturgeon juveniles in our culture condition (T = 21.82±1.45ºC), but since obtained values of FCR are very close to each other a feeding rate at 2% BW day^{-1} seems be more suitable as far as economic considerations are concerned.

For this size of Russian sturgeon juveniles (248.19±1.6 g; mean±SD), there are few information available regarding the feeding, nutritional requirements and growth performance. Nathanailides et al (2002) studied growth of Russian sturgeon in hatching time and post-hatch period, while Memiş et al (2006) determined effects of two commercial diets (for rainbow trout and carp) on growth performance and body composition of Russian sturgeon, with an individual body weight of 399±12 g and 404±13.1 g. Since we don't find in the literature data regarding the optimum feeding level for Russian sturgeon juveniles it is difficult to compare our results with others trials. However, some authors (Hung & Lutes 1987) recommended a similar feeding rate of 2% BW day^{-1} for white sturgeon juveniles with a body weight between 30-100 g reared at 20ºC. Also, Mohseni et al (2006) reported in the case of *Huso huso* with a body weight of 900±9.2 g an optimum feeding rate of 2% BW day^{-1} in three meals/day. Based on the quadratic broken-line model for the estimation of the optimum feeding rate, Lee et al (2016), estimated for young-of-the-year white sturgeon (360 g) a feeding rate of 1.5 BW day^{-1}. Also, Şener et al (2005), who studied the effects of different dietary lipids on growth performance of Russian sturgeon used a feeding rate of 2% BW.

The body moisture, ash, lipids and gross energy were significantly affected by the feeding ratio. Meat moisture contents showed a decrease whereas body lipid, ash and gross energy contents had an increase with increase feeding rates. According to Love (1970, 1980) the decrease of body moisture and increase of body lipid contents with increasing feeding rates to the optimum it is a well-established inverse relationship for many species of fish. Some authors showed that a lower body lipid content in fish meat is the result of choosing a lower feeding rate than optimum rate, while others suggests that a higher feeding rate than needed for maintenance requirement, lead to storage of excessive energy accumulates in the muscle, liver and viscera, mainly in the form of lipid (Storebakken & Austreng 1987; Lee et al 2000; Dwyer et al 2002). In this study, body protein content wasn't affected by the chosen feeding rates. Although, the protein content in muscle tissue was lower in feeding rate of 1% BW day^{-1}, the supply of dietary protein was enough to maintain the body protein level as long as the fish from this experimental variant recorded an increase of body weight.

Conclusions. Given the economic importance of the cost in terms of feeding, a good understanding of how effective assimilation feeding is very important. In conclusion, the results of this study suggest that a feeding rate of 2% BW day^{-1} is the more efficient feeding strategy for Russian sturgeon juveniles, because it provides greater growth and production, with a low cost for feeding.

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Authors:
Raluca Cristina (Guriencu) Andrei, "Dunărea de Jos" University of Galaţi, Faculty of Food Science and Engineering, Department of Aquaculture, Environmental Sciences and Cadastre, Romania, Galaţi 800201, 111 Domnească Street, e-mail: raluca.andrei@ugal.ro
Victor Cristea, "Dunărea de Jos" University of Galaţi, Faculty of Food Science and Engineering, Department of Aquaculture, Environmental Sciences and Cadastre, Romania, Galaţi 800201, 111 Domnească Street, e-mail: v.cristea@ugal.ro
Mirela Creţu, "Dunărea de Jos" University of Galaţi, Faculty of Food Science and Engineering, Department of Aquaculture, Environmental Sciences and Cadastre, Romania, Galaţi 800201, 111 Domnească Street, e-mail: mirela.cretu@ugal.ro
Lorena Dediu, "Dunărea de Jos" University of Galaţi, Faculty of Food Science and Engineering, Department of Aquaculture, Environmental Sciences and Cadastre, Romania, Galaţi 800201, 111 Domnească Street, e-mail: lorena.dediu@ugal.ro
Angelica Ionelia Docan, "Dunărea de Jos" University of Galaţi, Faculty of Food Science and Engineering, Department of Aquaculture, Environmental Sciences and Cadastre, Romania, Galaţi 800201, 111 Domnească Street, e-mail: Angelica.Docan@ugal.ro

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