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THE INFLUENCE OF FEEDING RATE ON GROWTH PERFORMANCE OF *Acipenser stellatus* (Pallas, 1771) REARED IN INTENSIVE CONDITIONS

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Abstract

In order to assure high financial sustainability of intensive sturgeon aquaculture, a proper feeding rate must be identified for different stages of growth. Therefore, the present study aims to evaluate the effect of two different feeding rates (F1 - 1% biomass weight BW, respectively F2 - 2% BW) on growth performance of A. stellatus, with a mean individual biomass of 201.7±32.82 g, reared in intensive conditions. The F2 experimental variant register, overall, a better feeding efficiency, revealed by feed conversion rate (FCR) average value (1.02 g feed/g biomass gain), compared to F1 (1.28 g feed/g biomass gain). Also, the sturgeon exemplars from F2 experimental variant manifested, overall, a superior ability of using feed protein for growth (higher average protein efficiency ratio - PER: 2.39 g/g), compared to F1 (PER: 1.95 g/g). The feeding rate applied at F2 assures the maximization of sturgeon production quantity, emphasized by the higher overall values of average specific growth rate (SGR: 1.74% BW/day at F2, compared to 0.78% BW/day at F1). The biomass and length coefficients of variation (CVw, respectively CV_L) indicate, for both experimental variants, a high homogeneity degree of stellate sturgeon experimental population (CVw: 16.51% at F1 and 12.53% at F2, respectively CV_L: 5.29% at F1 and 4.43% at F2, both registered at the end of the experiment). Therefore, it is recommended to apply 2% feeding rate in order to assure a better efficiency of sturgeons rearing technology, during the analyzed growth stage.

Key words: *FCR, feeding rate, intensive aquaculture, PER, stellate sturgeon.*

INTRODUCTION

The need of ensuring a global sustainable development, on medium and long term, of fisheries and aquaculture is obvious.
Thus, increasing the sustainability of aquaculture production systems is absolutely necessary, as they play a dual role in achieving the aforementioned goal, as follows: ensuring the necessary fish production for human consumption and contributing, actively, to the activities within the repopulation programmes.
This hypothesis is confirmed also by Memiș et al. (2008), addressing specifically to sturgeon's aquaculture, in order to emphasize the potential of this economic activity to contribute to the conservation of wild declined populations, through restocking and by providing a consistent sturgeons products supply, without exploiting wild population.
As Cristea et al. (2002) mentioned, in aquaculture, production systems are classified according to a multitude of technical, technological and ecological criteria.
Among the various types of production systems, recirculating aquaculture systems (RAS) offer the possibility of a rigorous control of the technological process (Cristea et al., 2002; Timmons et al., 2018) throughout the entire production cycle, aiming to ensure optimal growing conditions for differed fish species.
The high operational cost of fish produced in recirculating systems can causes a multitude of technical and financial problems, which must be solved in real time, in order to ensure their RAS competitiveness (Engle, 2010). Thus, the increase of technological maturity, involving rearing various fish species in different development stages, in RAS, is necessary.

Sturgeons are fish species which are suitable to be reared in RAS conditions, as they are considered of having a high market value. However, in order to maximize the profitability of sturgeon's aquaculture by optimizing the variable costs, proper feeding technologies must be applied for each development stage.
According to Dorojan et al. (2014), stellate sturgeon is considered one of the most studied species in terms of super-intensive growth. Also, Dicu et al. (2013) confirmed that among scientific studies which target stellate sturgeon rearing technology, there is little information regarding the nutritional requirements for different development stages.
Also, Petrea et al. (2019) stated that the establishing of a proper feeding rate for a certain development stage is important in order to maintain proper rearing conditions and to assure an efficient feeding management.
Thus, the present study aims to evaluate the effect of two different feeding rates (F1 - 1% biomass weight BW, respectively F2 - 2% BW) on growth performance of *A. stellatus*, with a mean individual biomass of 201.7±32.82 g, reared in intensive conditions.

MATERIALS AND METHODS

The description of RAS Pilot Station
The present study was conducted in RAS pilot station within "Dunărea de Jos" University of Galați, during a 46 days experimental period. The experimental intensive production system was designed and configurated according to the indications presented by Cristea (2008). The detailed designed of the aquaculture intensive production system is described in Figure 1.

Technological indicators
The analysed technological indicators were as follows: *Individual biomass gain*: IBG = (Bf)-(Bi)/fish number [g/fish], with Bf - final fish biomass; Bi - initial fish biomass (1); *Relative growth rate*: RGR = ((Bf-Bi)/t)/Bi [g/g/day], with Bf - final fish biomass; Bi - initial fish biomass, t - duration of the experiment (2); *Specific growth rate*: SGR = 100 x (ln Bf - ln Bi)/t [% fish biomass/day], with Bf - final fish biomass, Bi - initial fish biomass, t - duration of the experiment (3); *Feed conversion ratio*: FCR = F/IBG [kg feed intake/kg fish biomass gain], with F - feed intake, FBG - individual biomass gain (4); *Protein efficiency ratio*: PER = IBG/(F*CP/100) [kg/kg], with FBG - individual biomass gain, F - feed intake, CP - crude protein (5); *Condition factor*: K=W/L-3x100, with, W - body weight, L - body length (6); *Variation coefficient*: CVw/L = (Dev. St./Avg w/L) x 100 [%], with Dev. St. - standard deviation, Avgw/L - fish body weight/length (7).

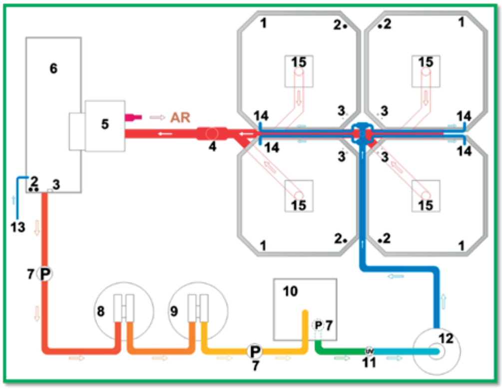

Figure 1. The design of RAS pilot station: rearing units - No. 1; nitrogen compounds sensors - No. 2; water level sensors - No. 3; RAS outlet structure - No. 4; mechanical drum filter - No. 5; sump - No. 6; pumps - No. 7; sand filter - No. 8; activated charcoal filter - No. 9; biological trickling filtration unit - No. 10; sterilization UV filter - No. 11; oxygenation unit - No. 12; automatically fresh water inlet No. 13; rearing units water inlet/outlet structure - No. 14, 15 (Petrea et al., 2019)

Technological indicators
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(6); *Variation coefficient*: CVw/L = (Dev. St./Avg w/L) x 100 [%], with Dev. St. - standard deviation, Avgw/L - fish body weight/length (7).

Biological material and experimental design

The fish biomass composed of stellate sturgeon specimens (242.6±38.7 g), which are the subject of the present study, was equally distributed within the four rearing units.

Two feeding rates were tested (F1 - 1% BW, respectively F2 - 2% BW), in replicate.

Feed was administrated by using automatic feeders. Intermediary biometric and biomass measurements were made in order to upgrade the daily administrated feed quantity.

Water quality assessment

The daily water quality parameters (temperature, dissolved oxygen (DO) and pH) were measured using portable sensors - HQ40d Portable, Multi-Parameter (HACH).

The nitrogen compounds ($N\text{-}NH_4$, $N\text{-}NO_2$, $N\text{-}NO_3$), phosphorus (P_2O_5), chemical oxygen demand (COD), percentage removal of BOD5 and turbidity were measured twice per week.

The spectrophotometric method, using Merk kits for spectroquant photometer, Nova 400, was used for determining the nitrogen compounds, phosphorus (P_2O_5) and chemical oxygen demand (COD) concentrations in the technological water.

Also, the percentage removal of BOD5 from technological water was determined by applying Winkler`s method on a Velp IP54 analyzer.

The spectrophotometric method was applied, by using a turbidimeter VELP, TB1, for the determinations of technological water turbidity.

Statistical methods

The software IBM SPSS Statistics 20 for Windows was used for the statistical analysis presented in present paper.

The T test ($\alpha=0.05$) was applied in order to identify the statistical differences between treatments, after the Kolmogorov-Smirnov normality test was performed. The ANOVA test (post-hoc Duncan test) was performed in order to compare variants.

RESULTS AND DISCUSSIONS

Water quality parameters

The technological water quality parameters registered proper concentrations for rearing stellate sturgeon in the analysed development stage (Table 1). Thus, the nitrogen compounds, as well as phosphorus, registered a higher average concentration for both F2 duplicate trials (*B3*: 0.28±0.08 mg L^{-1} $N\text{-}NH_4$, 0.13±0.04 mg L^{-1} $N\text{-}NO_2$, 91.83±11.6 mg L^{-1} $N\text{-}NO_3$, 25.11±6.9 mg L^{-1} P_2O_5; *B4*: 0.30±0.11 mg L^{-1} $N\text{-}NH_4$, 0.11±0.05 mg L^{-1} $N\text{-}NO_2$, 87.39±16.1 mg L^{-1} $N\text{-}NO_3$, 23.94±5.1 mg L^{-1} P_2O_5), compared to F1 duplicate trials (*B1*: 0.21±0.09 mg L^{-1} $N\text{-}NH_4$, 0.09±0.03 mg L^{-1} $N\text{-}NO_2$, 79.26±18.6 mg L^{-1} $N\text{-}NO_3$, 21.32±6.2 mg L^{-1} P_2O_5; *B2*: 0.22±0.07 mg L^{-1} $N\text{-}NH_4$, 0.08±0.02 mg L^{-1} $N\text{-}NO_2$, 74.74±14.9 mg L^{-1} $N\text{-}NO_3$, 19.77±5.3 mg L^{-1} P_2O_5) (Table 1). This may be due to the different feeding rate applied, respectively different quantity of feed input.

The difference between F1 and F2 experimental variants in terms of water quality parameters may indicate the need of practicing a higher recirculation flow for the RAS Pilot Station, in order to prevent fast accumulation of nitrogen compounds, as well as phosphorus, in the technological water, at the level of the rearing units, thus, decreasing the hydraulic retention time.

However, the low pH values (6.18±0.54 upH at B3, respectively 6.15±0.51 upH at B4, compared to 6.32±0.43 upH at B1, respectively 6.37±0.48 upH at B2) correlated with superior nitrogen compounds and phosphorus concentration, recorded in B3 and B4, compared to B1 and B2, may indicate a higher organic matter accumulation at the level of F2 experimental variant rearing units, compared to F1 (Table 1). This situation is confirmed by the results registered in terms of DO (lower concentration of DO registered in *F2*: 7.42±0.88 mg L^{-1} at B3, respectively 7.49±1.09 mg L^{-1} at B4, compared to *F1*: 7.76±0.62 mg L^{-1} at B1, respectively 7.63±0.56 mg L^{-1} at B2), BOD5 removal percentage and COD concentration (higher values registered in *F2*: 64.95±16.85 % BOD 5 at B3, 67.68±15.86% BOD5 at B4, 81.07±22.79 mg L^{-1} COD at B3, 79.81±24.93 mg L^{-1} COD at B4, compared to *F1*: 56.96±14.78 % BOD 5 at B1, 53.73±12.84

% BOD5 at B2, 68.45±14.84 mg L^{-1} COD at B1, 73.12±16.04 mg L^{-1} COD at B2) (Table 1).

Stellate sturgeon growth performance indicators

No mortalities were registered during the experimental trial, therefore confirming the proper functionality of RAS Pilot Station.

The average specific growth rate indicates a superior fish production at F2, both after 23 days (intermediary stage of experimental period) - 1.77 %BW/day and after 46 days (final stage of experimental period) - 1.72 %BW/day, compared to F1 experimental variant (0.87 %BW/day, respectively 0.65% BW/day) (Table 2.).

From the perspective of feeding strategy efficiency, the average food conversion ratio (FCR) indicates similar values at the intermediary stage of the experimental period (1.09 g feed/g biomass gain at F1, respectively 1.01 g feed/g biomass gain at F2), while at the end of the experimental trial F2 register significantly better results (1.04 g feed/g biomass gain), compared to F1 (1.47 g feed/g biomass gain) (Table 2).

The average protein efficiency ratio (PER) registered higher values in the first part of the experimental period, for both F1 and F2, compared to the last part of experimental trial (Table 2).

However, although F2 registered better average PER values in both experimental stages (2.43 g/g, respectively 2.36 g/g), compared to F1 (2.25 g/g, respectively 1.66 g/g), the differences between the experimental variants are more obvious in the last part of the experimental period.

Therefore, the PER results revealed a superior ability of fish organism reared in F2 to utilize proteins, which positively affects growth rate, compared to F1 (Table 2).

This situation is correlated with the superior results registered for RGR in F2 experimental variant, compared to F1 (Table 2).

Table 1. Water quality parameters

WATER QUALITY PARAMETER	B1	B2	B3	B4
$N\text{-}NH_4$ (mg L^{-1})	0.21±0.09	0.22±0.07	0.28±0.08	0.30±0.11
$N\text{-}NO_2$ (mg L^{-1})	0.09±0.03	0.08±0.02	0.13±0.04	0.11±0.05
$N\text{-}NO_3$ (mg L^{-1})	79.26±18.6	74.74±14.9	91.83±11.6	87.39±16.1
P_2O_5 (mg L^{-1})	21.32±6.2	19.77±5.3	25.11±6.9	23.94±5.1
pH	6.32±0.43	6.37±0.48	6.18±0.54	6.15±0.51
Turbidity (NTU)	4.88±0.38	4.68±0.49	5.33±0.52	5.19±0.42
BOD5 (%)	56.96±14.78	53.73±12.84	64.95±16.85	67.68±15.86
DO (mg L^{-1})	7.76±0.62	7.63±0.56	7.42±0.88	7.49±1.09
Temperature (ºC)	22.82±0.44	22.83±0.46	22.90±0.39	23.17±0.41
COD (mg L^{-1})	68.45±14.84	73.12±16.04	81.07±22.79	79.81±24.93

Table 2. Growth performance indicators for each of the experimental variants

TECHNOLOGICAL INDICATOR	EXPERIMENTAL PERIOD	EXPERIMENTAL VARIANTS			
		F1		F2	
		B1 (1%)	B2 (1%)	B3(2%)	B4(2%)
Experimental period (days)	*Initial - Intermediary*	13	13	13	13
	Intermediary - Final	13	13	13	13
Survival (%)	*Initial*	100	100	100	100
	Intermediary	100	100	100	100
	Final	100	100	100	100
Individual average biomass (g/fish)	*Initial*	240.0	243.1	246.5	240.7
	St. Dev. Initial	32.34	45.53	35.08	41.89
	Intermediary	268.6	272.4	309.3	303.7
	St.dev. Intermediary	34.86	53.81	38.53	37.62
	Final	291.5	297.3	381.0	385.7
	St. Dev. Final	36.50	60.96	46.57	49.50
Individual average length (cm/fish)	*Initial*	46.6	46.7	47.1	46.2
	St. Dev.Initial	2.54	3.43	2.76	3.15
	Final	48.9	48.5	50.4	50.8
	St. Dev. Final	2.28	2.88	2.25	2.23
Fish stocking density (kg/m^2)	*Initial*	3.27	3.31	3.36	3.28
	Intermediary	3.66	3.71	4.21	4.13
	Final	3.97	4.05	5.19	5.25
Individual biomass gain (g/fish)	*Initial - Intermediary*	28.6	29.3	62.8	63.0
	Intermediary - Final	22.9	24.9	71.8	82.0

Fish stocking density gain (kg/m²)	*Initial - Intermediary*	0.4	0.4	0.9	0.9
	Intermediary - Final	0.3	0.3	1.0	1.1
Relative growth rate (g/g/day)	*Initial - Intermediary*	0.0092	0.0093	0.0196	0.0201
	Intermediary - Final	0.0066	0.0070	0.0179	0.0208
Feed protein (%)		41	41	41	41
Daily feeding ratio (% BW)		1	1	2	2
Specific growth rate - SGR (% BW/day)	*Initial-Intermediary*	0.87	0.88	1.74	1.79
	Intermediary - Final	0.63	0.67	1.61	1.84
Individual total length gain (% BL/day)	*Initial - Final*	2.36	1.87	3.30	4.59
Feed conversion ratio - FCR (g feed / g biomass gain)	*Initial - Intermediary*	1.09	1.08	1.02	0.99
	Intermediary - Final	1.52	1.42	1.12	0.96
Protein efficiency ratio - PER (g/g)	*Initial - Intermediary*	2.23	2.26	2.39	2.46
	Intermediary - Final	1.60	1.71	2.18	2.53
Weight variation coefficient - CVw (%)	*Initial*	13.47	18.73	14.23	17.40
	Intermediary	12.98	19.75	12.46	12.39
	Final	12.52	20.50	12.22	12.83
Length variation coefficient - CV_L (%)	Initial	5.46	7.36	5.85	6.82
	Final	4.66	5.93	4.47	4.40

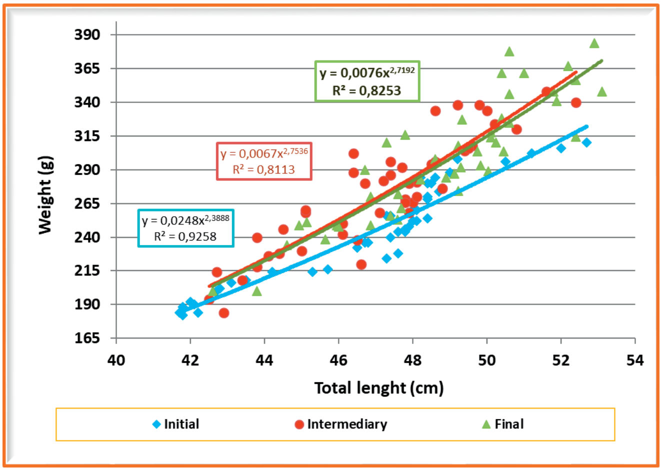

Figure 2. Total Length-Weight relation for F1 biomass, during the experimental period

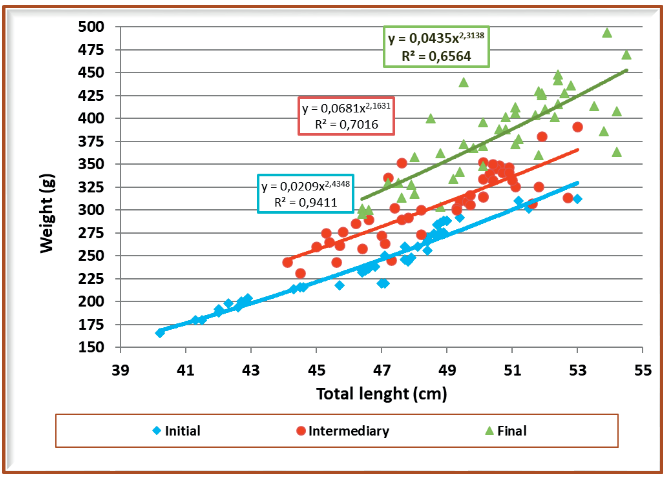

Figure 3. Total Length-Weight relation for F2 biomass, during the experimental period

Table 3. Growth performance indicators of stellate sturgeons reared in RAS, during similar development stage, reported by different authors

Reference	Stellate sturgeon average biomass (g)	SGR (%BW/day)	FCR (g feed / g biomass gain)	PER (g/g)
Dorojan et al., 2015	188.33-201.03	1.68-1.81	1.01-1.13	1.93-2.14
Dorojan et al., 2014	121.21-122.78	0.78-0.79	1.46-1.48	1.4-1.43
Dicu et al., 2013	204 ± 8	2.32-2.52	> 2	2.33-2.60
Petrea et al., 2019	396.87-456.37	0.65-1.15	1.5-1.61	1.53-1.67

By analyzing the variation coefficients, it can be stated that both experimental variants had registered a high homogeneity degree among the specimens (Table 2). However, higher values of average weight variation coefficient, registered at F1 in both experimental stages (16.37% at the intermediary stage, respectively 16.51% at the final stage of the experiment), compared to F2 (12.42% at the intermediary stage, respectively 12.53% at the final stage of the experiment) reveals a high competition for feed among F1 fish specimens, compared to F2 stellate sturgeons.

This can be due to the feeding management applied (feeding rate of 1% BW/day at F1, compared to 2% BW/day at F2).

The hypothesis is also confirmed if analysing the registered values for length variation coefficient. Thus, higher values of average length variation coefficient, registered at F1 in both experimental stages (6.41% at the intermediary stage, respectively 5.29 % at the final stage of the experiment), compared to F2 (6.34 % at the intermediary stage, respectively 4.43 % at the final stage of the experiment).

As mentioned by Petrea et al. (2019), the condition status of biological material was evaluated by using the allometric condition factor F ($F = \frac{W}{L^b}$, where b = allometric exponent, experimentally determined).

It can be observed that allometric exponent "b" has its values under three units in both intermediary and final stages of the experimental period, for both F1 and F2 experimental trials, fact that indicates a faster growth in length rather than weight (Figures 2 and 3).

Also, the K condition factor registered lower values at the end of the trial at F1 (0.249 for B1, respectively 0.260 for B2), compared to F2 (0.298 for B1, respectively 0.294 for B2).

By analysing the data reported by different authors, related to growth performance indicators of stellate sturgeons reared in RAS during similar development stage, it can be stated that the SGR results recorded in present study are similar to those reported by Dorojan et al. (2014) (0.78-0.79% BW/day) and Petrea et al. (2019) (0.65-1.15% BW/day) and lower compared to the results reported by Dorojan et al. (2015) (1.68-1.81% BW/day) and Dicu et al. (2013) (2.32-2.52% BW/day) (Table 3).

Also, the FCR and PER results recorded in present study are similar to those reported by Dorojan et al. (2015) (FCR: 1.01-1.13 g feed/g biomass gain; PER: 1.93-2.14 g/g) and better compared to the results reported by Dorojan et al. (2014) (FCR: 1.46-1.48 g feed/g biomass gain; PER: 1.40-1.43 g/g), Dicu et al. (2013) (FCR: over 2 g feed/g biomass gain; PER: 2.33-2.60 g/g) and Petrea et al. (2019) (FCR: 1.50-1.61 g feed/g biomass gain; PER: 1.53-1.67 g/g).

However, the growth performance is strongly related to the technical performance of RAS production system.

CONCLUSIONS

As a conclusion, it can be stated that during the analyzed stellate sturgeon development stage, better production and cost efficiency and achieved if 2% BW feeding rate is applied.

Also, the intensive production system is suitable for maintaining water quality parameters into an optimal range for rearing stellate sturgeons during the analysed development stage, even if a 2% BW feeding rate is applied.

It is recommended, in future similar studies, to extend the experimental period in order to have a better view related to the influence of feeding rate on stellate sturgeon growth performance.

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