EFFECT OF FEEDING RATE ON GROWTH PERFORMANCE OF *A. stellatus* (PALLAS, 1771) REARED IN A RECIRCULATING AQUACULTURE SYSTEM

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Abstract

Recirculating aquaculture systems (RAS) represents the most suitable solution for rearing sturgeons in intensive conditions, situation which imposes the use of a proper technology, respectively feeding rate, for a certain fish development stage. The aim of present study is to evaluate the effect of feeding rate on growth performance of stellate sturgeon (330.55±44.27 g) reared in RAS conditions. Two feeding rates were tested (F1 - 1% BW, respectively F2 - 2% BW), in replicate Biomass measurements were made at the middle of the experimental period, in order to adjust the daily administrated feed quantity. The average specific growth rate indicates a superior fish production at F2 (1.15 %BW/day), compared to F1 (0.65 %BW/day) experimental variant. However, from the perspective of feeding strategy efficiency, the average food conversion ratio (FCR) indicates better values for F1 experimental variant (1.5 g feed/g biomass gain), compared to F2 (1.61 g feed/g biomass gain). The protein efficiency ratio (PER) registered higher values at F1 experimental variant (1.67), compared to F2 (1.53), revealing the ability of fish organism to utilize proteins, which positively affects growth rate. Therefore, as a conclusion, it can be stated that during the analyzed stellate sturgeon development stage a better cost efficiency is recorded when applying 1% BW feeding rate, although if production maximization is targeted, 2% BW feeding rate is recommended.

Key words: stellate sturgeon, RAS, feeding rate, FCR, PER, SGR

INTRODUCTION

In a recirculating aquaculture system (RAS), the technological performance of fish biomass is closely related with a multitude of factors which implies rearing conditions and nutritional requirements, therefore optimizing the feed conversion coefficient [6].

The majority of recirculating aquaculture systems have a daily technological water exchange rate between 5-10%, with the purpose of preventing ammonia nitrogen, as well as the other nitrogen compounds (nitrites and nitrates), to reach alarming concentrations, but also to re-establish the quantity of technological water lost due to the processes of evaporation and mechanical filter self-cleaning [2, 6]. As a result, the uses of high-end equipment for mechanical and biological filtration are generally the proposed technical solutions in order to achieve a more efficient technological water treatment process and therefore, to improve growth performance parameters. Biological filtration performance is significantly influenced by the type of biofilter used, specific surface and porosity of bio balls. The design and dimensioning of biofilters are made according to the concentration of ammonia predicted to be present in technological water during the production cycle. Therefore, a series of technological variables as fish stocking

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density and feeding rate must be considered when design the biofiltration unit in RAS. Most of the RAS nowadays need to be adaptable to a series of technological conditions while maintaining low operational costs, therefore multiple recirculating loop systems are recommended.

As the operational costs are superior in RAS, compared to other production systems, high values fish species as sturgeons are recommended to be reared in order to maintain the profitability. Although still practiced on a small scale, the sturgeon's aquaculture has development perspectives in Romania due to its basic activity (rearing of native sturgeons) which respects the principles of aquaculture sustainable development.

Stellate sturgeon rearing technology is complex, mostly due to its sensitivity regarding technological water quality. Therefore, establishing 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.

The aim of this study is to identify an optimal feeding rate for stellate sturgeon *(330.55±44.27 g)*, reared in RAS conditions, with dual loop biofiltration.

MATERIALS AND METHODS

The recirculating aquaculture system with dual loop biofiltration

The present experiment took place in the RAS pilot station of Food Science, Food Engineering, Biotechnology and Aquaculture Department, Food Science and Engineering Faculty - „Dunărea de Jos'' University of Galați. The configuration of the pilot recirculating main system was sized according to specific technology described by Cristea (2008) [1]. The RAS pilot system was described in fig. 1 [4]. The sand filter and activated charcoal filter have been bypassed, therefore they did not contribute to technological water conditioning process.

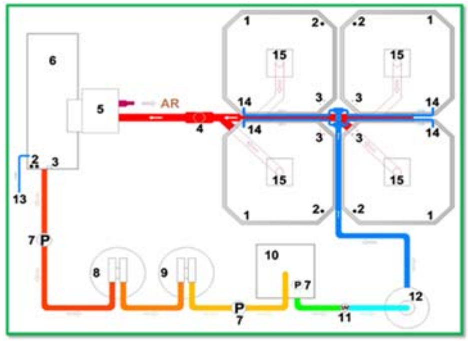

Fig. 1. The design of RAS pilot station: rearing units -No.1, nitrogen compounds sensors - No.2; water level sensors – No.3; RAS outlet structure – No.4; mechanical drum filter – No.5; sump – No.6; pumps–No.7; sand filter – No.8; activated charcoal filter – No. 9; biological trickling filtration unit – 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.

The dual loop biofiltration process was assured inside the loop described in fig. 1 and also, by adding 3 chamber LECA (light expanded clay aggregate) based biofilters, with common direct inlet and individual outlet, placed above the rearing units and coupled by them through a submerged pump system, as described in fig. 2.

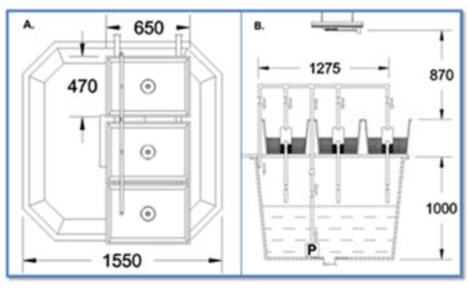

Fig. 2 Second loop biological LECA based filtration unit

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: $K=W/L^{-3}x100$, with, W – body weight, L – body length (6)

Variation coefficient: $CV_{w/L}$ = (Dev. St. / Avg $_{w/L}$) x 100 [%], with Dev. St. – standard deviation, $Avg_{w/L}$ – fish body weight/length

Water quality assessment

In order to determine the water quality parameters throughout the experimental period, temperature, dissolved oxygen (DO) and pH were measured daily. Also, the rest of water quality parameters, presented in tab. 1, were determined twice per week. The water quality evaluation methods and equipment are presented in tab. 1

Table 1 Water quality evaluation methods and equipment

Analysed Parameter	Method	Equipment
DO pH Temperature	Sensor method	HQ40d Portable Multi-Parameter (HACH)
NO_3 NO_2 NH_4 PO4 COD	Spectrophotometric method using Merk kits	Spectroquant photometer, Nova 400
Percentage removal of BOD_5	Winkler`s method	Velp IP54 analyzer
Turbidity	Spectrophotometric method	Turbidometer VELP, TB1.

Water samples were taken from the fish rearing units (B1, respectively B2), LECA biofilter inlet/outlet (BH) and Biological trickling filter inlet/outlet.

Removal rates

The NH_4 removal rates for both LECA biofilters and trickling biofilter were calculated with the following formula [3, 5]: NH_4 removal rate (g/m^2 /day)= ((Q/V*(Cin-Cout)–dC/dt)*d, where, Q= flow rate (m^3 /day), V= biofilter volume (m^3), Cin=concentration of NH_4 at inlet (g/m^3), Cout=concentration of NH_4 at outlet (g/m^3), dC = difference between recorded NH_4 concentration at inlet and outlet, during a 24h time period; d= biofilter depth (m), t=time (d).

Biological material and experimental design

The fish biomass composed of 92 specimens of stellate sturgeon (330.55±44.27 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.

Statistical methods

Statistical analysis was performed using the IBM SPSS Statistics 20 for Windows. Statistical differences between treatments were tested using T test (α=0.05) after a normality test (Kolmogorov-Smirnov). Comparisons between variants were assessed using post-hoc Duncan test for multiple comparisons (ANOVA).

RESULTS AND DISCUSSIONS

Water quality parameter

The average value of water temperature was 23.39±0.36°C. The analysis of water quality parameters revealed better values at F1, compared to F2 experimental variants in terms of nitrogen compounds, PO_4, pH, turbidity, BOD5, DO, and COD (tab. 2). Also, the results emphasize the functionality of double loop biological filtration technical solution, ensuring therefore optimal concentrations of nitrogen compounds and PO_4 for rearing stellate sturgeons (tab. 2). The high feed quantity administrated at F2 experimental variant generates higher values for turbidity, BOD5 and COD concentration, compared to F1, signs of a superior organic matter accumulation rate (tab.2). Also, the biological trickling filter ensures a better water oxygenation, due to higher column, but a possible higher accumulation of organic matter (revealed by higher values for turbidity, BOD5 and COD concentration), since it had a continuous functioning regime for 12 months, while LECA had functioned only for 4 months before trial start-up (tab. 2). Also, by analyzing the NH_4 removal rate, it can be stated that feeding rate significantly ($p<0.05$) influence the oxidizing process at the level of biological filtration unit (tab. 3). Also, LECA has a better NH_4 removal performance, compared to bio balls (tab. 3), although on a long time period and in intensive feeding conditions its performance may drop, as emphasized by the values recorded at BH2 (tab. 3), due to lower value of free surface between the media, encountered at LECA, compared to bio balls.

Table 2 Water quality parameters

Water quality parameter	BH1 LECA biofilter inlet (B1)	BH1 LECA biofilter outlet	BH2 LECA biofilter inlet (B2)	BH2 LECA biofilter outlet	Biological trickiling filter inlet	Biological trickiling filter outlet
NH_4 (mg L^{-1})	0.45±0.07	0.39±0.05	0.50±0.08	0.48±0.05	0.35±0.04	0.21±0.02
NO_2 (mg L^{-1})	0.06±0.01	0.05±0.01	0.08±0.02	0.07±0.01	0.07±0.01	0.06±0.02
NO_3 (mg L^{-1})	41.57±4.7	43.30±3.7	43.53±5.3	46.20±3.2	44.35±6.9	45.43±7.3
PO_4 (mg L^{-1})	28.58±3.3	25.00±4.7	30.04±3.7	29.50±2.1	31.00±3.6	22.50±5.9
pH	5.82±0.25	5.73±0.18	5.78±0.25	5.24±0.11	5.43±0.22	5.40±0.17
Turbidity (NTU)	2.34±0.77	1.93±0.88	2.71±0.58	2.07±0.73	3.55±0.91	2.85±0.88
BOD5 (%)	28.08±4.55	19.01±3.74	34.99±5,53	23.25±4.96	63.37±4.05	56.97±5.89
DO (mg L^{-1})	8.25±1,27	8.50±0.84	8.16±1,22	8.25±1.35	8.84±0.93	8.90±0.78
COD (mg L^{-1})	59.00±3.78	62.00±5.11	59.67±5.65	63.33±4.56	70.10±6.21	71.30±5.98

Table 3 The biological filters NH_4 removal rate

NH_4 removal rate (g/m²/day)	BH1 LECA biofilter	BH2 LECA biofilter	Biological trickiling filter
Average per filtration unit	0.170±0.06	0.053±0.021	0.368±0.161
Total (group of 3 LECA based filtration units)	0.51	0.16	-

The growth performance indicators (tab. 4) reveled no mortalities during the trial, therefore confirming the good results registered in terms of water quality. The average specific growth rate indicates a superior fish production at F2 (1.15 %BW/day), compared to F1 (0,65 %BW/day) experimental variant (tab.4.). However, from the perspective of feeding strategy efficiency, the average food conversion ratio (FCR) indicates better values for F1 experimental variant (1.5 g feed/g biomass gain), compared to F2 (1.61 g feed/g biomass gain) (tab. 4). The average protein efficiency ratio (PER) registered higher values at F1 experimental variant (1.67), compared to F2 (1.53), revealing the ability of fish organism to utilize proteins, which positively affects growth rate (tab.4). By analyzing the variation coefficients, it can be stated that both experimental variants had registered a high homogeneity degree among the specimens (tab. 4).

Table 4 Growth performance indicators for each of the experimental variants

TECHNOLOGICAL INDICATOR	EXPERIMENTAL PERIOD	EXPERIMENTAL VARIANTS	
		F1 (1%)	F2 (2%)
No. of fish	*Initial*	46	46
	Int.	46	46
	Final	46	46
Experimental period (days)	*Initial - Int.*	14	14
	Int. - Final	14	14
Survival (%)	*Initial*	100	100
	Int.	100	100
	Final	100	100
Total biomass (g)	*Initial*	15213	15198
	Int.	16434	17636
	Final	18256	20993
Individual average biomass (g/fish)	*Initial*	330.72	330.39
	St.Dev. Initial	56.52	43.17
	Int.	357.25	383.39
	St.dev. Int.	62.46	47.58
	Final	396.87	456.37
	St.Dev. Final	70.83	62.31
Individual average length (cm/fish)	*Initial*	48.01	48.72
	St.Dev.Initial	2.62	2.35
	Int.	49.62	50.59
	St.Dev.Int.	2.86	2.23
	Final	52.41	53.76
	St.Dev. Final	2.86	2.29
Fish stocking density (kg/m^2)	*Initial*	4.50	4.50
	Int.	4.86	5.22
	Final	5.40	6.21
Total biomass gain (g)	*Initial - Int.*	1221	2438
	Int. - Final	1822	3357
Individual biomass gain (g/fish)	*Initial - Int.*	26.5	53.0
	Int. - Final	39.6	73.0
Fish stocking density gain (kg/m^2)	*Initial - Int.*	0.36	0.72
	Int. - Final	0.54	0.99
Daily growth rate (g/day)	*Initial - Int.*	87.21	174.14
	Int. - Final	130.14	239.79
Relative growth rate (g/g/day)	*Initial - Int.*	0.0057	0.0115
	Int. - Final	0.0079	0.0136
Total quantity of feed distributed during the experimental period (g)	*Initial-Int.*	2130	4255
	Int. - Final	2301	4938
Feed protein (%)		41	41
Daily feeding ratio (% BW)		1	2
Specific growth rate - SGR (%BW/day)	*Initial-Int.*	0.55	1.06
	Int. - Final	0.75	1.24
Individual total length gain (%BL/day)	*Initial - Final*	0.63	0.70
Feed conversion ratio - FCR (g feed / g biomass gain)	*Initial - Int.*	1.74	1.75
	Int. - Final	1.26	1.47
Protein efficiency ratio – PER (g/g)	*Initial - Int.*	1.398	1.397
	Int. - Final	1.931	1.658
Weight variation coefficient - CVw (%)	*Initial*	17.09	13.06
	Int.	17.48	12.41
	Final	17.85	13.65
Length variation coefficient - CV_L (%)	Initial	5.46	4.81
	Int.	5.76	4.41
	Final	5.46	4.26

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).

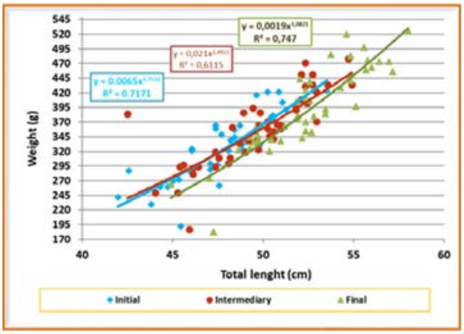

Fig. 3 Total Length-Weight relation for F1 biomass, during the experimental period

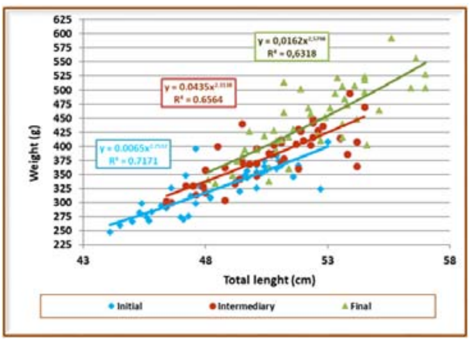

Fig. 4 Total Length-Weight relation for F2 biomass, during the experimental period

It can be observed that allometric exponent "b" has its values under three units in all cases, except F1 – final stage (b=3.08), fact that indicates a faster growth in length rather than weight (fig. 3, 4). Also, the K condition factor registered lower average values at the end of the trial at F1 (K=0.276), compared to F2 (K=0.294).

CONCLUSIONS

As a conclusion, it can be stated that during the analyzed stellate sturgeon development stage a better cost efficiency is recorded when applying 1% BW feeding rate, although if production maximization is targeted, 2% BW feeding rate is recommended. Also, the use of present dual loop biofiltration RAS for rearing stellate sturgeons during the development stage mentioned in present study is suitable for maintaining water quality parameters into a optimal range, even if a 2% BW feeding rate is applied.

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