The Influence of Feeding Level on Growth Performances of European Catfish (*Silurus glanis* L., 1758) Juveniles under Recirculating Water Conditions

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Abstract

The study was carried out with one summer-old *Silurus glanis* juveniles, having the mean size 23.04 ± 2.05 cm and weight 73.84 ± 19.12 g, reared in recirculating water condition, in order to assess the impact of feeding level on growth performances and body size variation of fish. Two feeding levels were tested (R1=1.5% BW/day and R2=2.5% BW/day), in duplicate, during 6 weeks, and the biomass gain (BG), feed conversion ratio (FCR), specific growth rate (SGR), protein efficiency ratio (PER), morphometric relationship between length-weight (LWR) and coefficient of variation (CV) were assessed. Data revealed that the overall mean weight of the biomass was doubled during the trial, from 14.92 kg to 31.17 kg, and the body growth significantly increases with the increment of the feeding rate (13.48 kg in R1 and 17.70 kg in R2), underlying the good potential of the species, at this life stage, for fast-growing under intense conditions. The calculated SGR in R1 was 1.43%/day and in R2, significantly higher, as 2.05 %/day, for the almost similar values of FCR (0.74 g/g) and PER (2.50 g/g) recorded between the treatments.

Keywords: *Silurus glanis*, growth performance, fish condition, feeding rate

Introduction

The growth of the European catfish in controlled environmental conditions by treating and recirculating water, like recirculating aquaculture systems (RAS), is a progressive challenge for aquaculture in Romania, at least from the perspective of business that can bring profit to investors. The optimization of production in a recirculating system implies the simultaneous satisfaction of some preconditions, particularly maintaining good water quality for rapid fish growth while implementing efficient feeding management (Timmons *et al.*, 2002). Proper feed

management keeps an optimum environment for fish biomass at the minimum cost production taking into account that the cost of feed is considered the most dominant cost (40-50 %) (Bregnballe, 2015; Silva and Anderson, 1995) with significant impact on the fish farming's feasibility. Therefore, adjusting the optimum feeding rate, according to the fish species, fish size and rearing system, is a goal to achieve in a RAS (Timmons *et al.*, 2002). Practical aspects of growth rate and feeding regime of *Silurus glanis* species in intensive conditions are increasingly being investigated in the last years (Hilge, 1985; Bekcan *et al.*, 2006;

Placinta *et al.*, 2012; Florczyk *et al.*, 2014; Havasi *et al.*, 2015) showing a robust and easy-adaptative fish (Linhart *et al.*, 2002) as long the water quality is maintaining in optimal intervals. In general, these are important arguments for fish being raised in RAS because high growth rate increases production turnover as soon as fish reach the market size. Thus, the growth parameters of this voracious fish, applying different feeding levels, are presented in this paper, in order to know more about the feeding management of the European catfish juveniles in the recirculating water condition.

Materials and methods

Experimental design

The experiment was carried out within an experimental recirculating system of the Aquaculture division in "Dunărea de Jos" University of Galati, described in previous papers (Vasilean *et al.*, 2009; Mocanu *et al.*, 2011), on one-summer old juveniles of European catfish with an initial mean weight of 73.84 ± 19.12 g and length 23.04 ± 2.05 cm. The fish were randomly distributed into the four rearing basins of the recirculating system (volume of $0.300 \text{ m}^3/\text{unit}$), thus the fish biomass was distributed approximately equally between basins (B1-47 fish, B2-51 fish, B3-51 fish, B4-53 fish).

During the trial, the juveniles were fed with two daily feeding rates, each one being tested in duplicate: R1 – 1.5 % BW/day for the basins B1&B2 and R2 – 2.5 % BW/day for the basins B3&B4, with extruded pellets represented by Nutra 0 (commercial diet for salmonids) with the composition presented in Tab. 1. The daily amount used for fish feeding was manually administrated in three equal meals (08:00, 12:00 and 16:00).

Table 1. Biochemical composition of the Nutra 0 extruded feed

Crude protein	54 %
Crude fat	18 %
Crude cellulose	0.6 %
Ash	10 %
Phosphorous	1.45 %
Vitamin A	14000 UI/kg
Vitamin D3	2300 UI/kg
Vitamin E	250 mg/kg
Vitamin C	500 mg/kg
Copper sulphate	8.5 mg/kg

During those 6 weeks of experimental period, fish were exposed to the natural photoperiod and the welfare state (swimming, feeding behavior, sanitary problems) was monitored. The water physicochemical parameters during the experiment were recorded (daily, for temperature and dissolved oxygen - determined with Hanna oxygen meter model HI 9142, as well as for pH - determined with Hanna pH meter model HI 81143; weekly, for nitrogen compounds – measured with Merck photometer model Spectroquant Nova 400 using specific manufactured Merck test kits).

Production performances

The fish were weighed and measured, individually, to the nearest 1 g and 0.5 cm. The biometry was performed on fish after 24 h stop feeding, in anesthetic conditions (2-phenoxyethanol - 0.3 mL/L water). For verifying and control of the growth performances induced by those two feeding ratios, at the beginning of the experiment, 8 fish/basin were individually tagged. The production parameters were calculated by classical methods, such as:

Total biomass production

Total biomass gain: $BG = B_f - B_i$ (g/basin), where B_i -total initial biomass, B_f -total final biomass;

Food conversion ratio: $FCR = FI/BG$ (g/g), where FI -feed intake (g/basin), BG -total biomass gain (g/basin);

Protein efficiency ratio: $PER = BG/PI$ (g/g), where BG -total biomass gain (g/basin), PI -protein intake of our food (g).

Individual fish growth

Fish weight gain: $WG = W_f - W_i$ (g), where W_i -initial fish mean weight, W_f -final fish mean weight;

Fish condition: $W = aL^b$, (length-weight relationship), where the coefficient "a" is the regression intercept and "b" is the regression slope obtained by linearization [$\ln(W) = \ln(a) + b \ln(L)$], W =fish weight (g), L =total length (cm);

Specific growth rate: $SGR = [(\ln W_f - \ln W_i)/t] \times 100$ (%/day), where t -period time of feeding experiment (days)

Data analysis

The obtained values were statistically computed using SPSS Statistics 17.0 program and analyzed for the normality of distribution with the Kolmogorov-Smirnov Z test, for homogeneity of variances with Levene's test, for the comparison of the means with T-test (one sample, independent samples and paired samples) or one-way ANOVA.

Table 2. Growth performances of European catfish juveniles during the experiment

Experimental variants Growth parameters	Variant R1 (1.5%)		Variant R2 (2.5%)	
	B1	B2	B3	B4
Initial fish mean weight - Wi (g)	78.40±25.52 ^a	72.35±15.08 ^a	73.88±19.10 ^a	71.17±15.45 ^a
Final fish mean weight - Wf (g)	144.36±49.00 ^b	131.31±32.99 ^b	178.62±45.94 ^c	165.25±37.11 ^c
Fish weight gain - WG (g/fish)	65.96	58.96	104.74	94.08
Total initial biomass - Bi (g)	3685.00	3690.00	3768.00	3772.00
Total final biomass - Bf (g)	6785.00	6697.00	8931.00	8758.00
Biomass gain - BG (g/basin)	3100.00	3007.00	5163.00	4986.00
Survival (%)	100.00	100.00	98.04	100.00

Note: Different letters between data denote significant differences ($p < 0.05$).

Significance was accepted at $p < 0.05$. Data are presented as mean $\pm$ standard deviation (M $\pm$ SD). Also, the size of heterogeneity within stock was assessed by the coefficient of variation (CV, %).

Results and discussions

Water quality

During the experiment, the water quality was kept in the optimum range, as a result of the daily replacement with clean water after its lost in the flushing process of removing the suspended solids from the mechanical filter (exchange rate did not exceed 10% of the total volume of water in the system). In consequence, water temperature varied in narrow limits, between 20.70-21.20 °C, not so far from the range recommended for specie's reproduction (21-23 °C) by Woynarovich, and Horváth (1980) or for fingerlings growth (25-28 °C) by Hilge (1985). Due to supplementary aeration, the DO level was kept in an optimum range between 5.30-7.60 mg/L, as well as the pH between 6.79-7.26 upH. The dynamics of the ammonium, nitrite and nitrate concentrations varied in the following intervals of minimum and maximum: 0.11-0.14 mg/L, 0.13-0.22 mg/L and 18.93-23.59 mg/L, respectively. In consequence, under the described circumstances, the experimental recirculating system offered admissible conditions, from the water quality perspective, for growing the European catfish juveniles.

Growth performances

The series of values analyzed for each level (basin/experimental variant/total stock) of the initial and final fish mean weight showed no deviations from the normal distribution ($p > 0.05$ with K-S test) that permitted us to apply the

parametric tests further. One-way ANOVA (for equal variances not assumed) applied at the beginning of the experiment, showed insignificant differences between all basins for the fish mean weight ($p = 0.26 > 0.05$). The T-test applied between the two feeding rate groups (equal variances assumed) confirmed the similarity of the fish mean weight ($p = 0.31 > 0.05$), too.

After 42 days of the trial, the individual fish weight was doubled reaching an overall mean value of 155.08 $\pm$ 45.13 g, underlying the good potential of the species for growing under intense conditions, at this life stage. At the end of the experiment, the final mean weight showed significantly higher values for the group fed with 2.5 % BW/day (T-test, equal variances assumed, $p < 0.001$). No variations between duplicates (intra-treatment) were recorded, emphasizing the above somatic response. The results regarding growth performances in both experimental variants are summarized in Tab. 2.

The values of the SGR (specific growth rate) and FCR (food conversion ratio), considered as most important factors indicating the effectiveness of feed management and production performances in aquaculture, were determined for each feeding level (figure 1). The highest SGR was registered in variant fed with R2 (2.5%) having a mean value with 43.21 % higher than R1 (1.5%).

Since the individual SGR values computed for the tagged fish showed no significant difference from the basin's overall mean (T-test one sample, $p > 0.05$), that allowed us to apply statistical comparison between intra- and inter- experimental variants. There were no differences between the basins' SGRs belonging to the same feeding level (B1 and B2, respectively B3 and B4, T-test two sample, $p > 0.05$),

Figure 1. The growth performances of the *Silurus glanis* juveniles recorded at different feeding rates

but variant R2 was significantly higher (with 0.616 %/day) relative to R1 (T-test two sample, $p=0.001$). Our data is close to those obtained by Havasi *et al.* (2015) who summarized, graphically, the means between 1.7-2.5%/day into an experiment on European catfish juveniles weighting 59.9 ± 12.9 g in the aim of assessing the effects of meals' frequency on fingerlings growth, fed with 2.5%BW/day. In their trial, during 5 weeks, the SGR evolution patterns varied in a peculiar manner between the different treatments (continuous, 1/day or 3/day): remarkably different at the beginning of the trial and becoming quite equal to the end.

The close values of FCR between basins indicate that almost 74% of the food provided to the catfish during the trial was assimilated in body mass. Lower FCRs is related to high-quality feed and more efficient retention of the nutrients (Fry *et al.*, 2018). This is the fitting situation in R2 feeding ratio, taken SGR into account, too, indicating the positive effect of the increased ration level (2.5%) on growth at this life stage of catfish, due to the higher efficiency of transforming food energy for living tissues' construction. Also, sub-unitary values of FCR indicate less waste polluting the water and, in consequence, better water quality maintenance in the production system.

Also, the other parameter - PER (protein efficiency ratio) is considered one of the most popular means for quantifying the nutritional value of protein due to the fact that protein is the most expensive macronutrient in the fish diet with an economic impact in production turnover. In our study,

PER presented almost a constant intergroups value of $2.50 (\pm 0.04)$, indicating the higher efficiency with which the catfish have converted nutrients from feed into body mass and consequently, in nutrients for human food supply. Our results reinforced the data obtained by, Havasi *et al.* (2015) in the experiment presented above, on European catfish juveniles fed with a commercial diet having 49 % crude protein, with good results of the feed intake ($FCR=0.77 \pm 0.07$, $PER=2.7 \pm 0.2$) for the 3 times/day of the meal's frequency. In another study about four experimental diets with different percentages of protein, during a 112 days trial on European catfish fingerlings (46,4 g), Bekcan *et al.* (2006) obtained values quite similar to ours of the feed intake for the group fed with 40 % protein level ($FCR = 0.97 \pm 0.010$, $PER = 2.62 \pm 0.028$), but smaller $SGR=0.74 \pm 0.002$ %/day in the conditions of *ad libitum* distribution of the food, twice/day.

A proper feeding level is an important component for the success of European catfish production and must take into consideration besides the production system type, the fish life stage (Florczyk *et al.*, 2014, Placinta *et al.*, 2012), fish welfare (Dediu *et al.*, 2010), the water's temperature and quality (Muscalu *et al.*, 2010). For example, Florczyk *et al.*, (2014) testing 3 diets containing different protein/lipid levels on smaller size of *Silurus glanis* fingerlings (4.2 ± 0.15 g), for 50 days, with continuous administration of the food (level feeding not specified, so supposing *ad libitum*) obtained, at the trial finish, the best results for SGR (2.63 ± 0.04 %/day) in the group 45/20, the most favourable PER (2.36 ± 0.14) in the group

(37/12) even if FCR in all 3 groups (45/20, 45/15 and 37/12) was quasi-invariable. Placinta *et al.* (2012) obtained better production parameters for *Silurus glanis* fingerlings weighting 8.61 ± 0.24 g (at a feeding rate of 6 %BW/day, 50% crude protein and a good quality water), such as: SGR - 3.52 %/day, FCR - 0.79, PER - 2.52. In the growth experiment presented by Muscalu *et al.* (2010), on one summer old *Silurus glanis* tested in 3 densities (mean fish weight ranged 36-37.8 g inter-densities), as an auxiliary species

in a RAS for cultured sturgeons during the winter, observed that under 17°C fish don't consume the feed; but with the rise of temperature, the level of feeding increased gradually, so at 22 °C it reaches 2.5 %BW/day, like in our experiment. Also, in their system it was assessed a FCR between 1.20 (higher density) and 1.265 (lower density) in the conditions of a feeding accorded to appetite during the entire experiment.

Figure 2. The body growth expression revealed by the length-weight regression for *Silurus glanis* juveniles obtained at different feeding rates

Fish condition

Silurus glanis has an elongated body that is laterally decompressed behind its broad head, which accounts for almost 20% of the entire body length (Copp *et al.*, 2009), or less, depending on fish age (Măgdici *et al.*, 2014; Arteni, 2010). In their paper review, Copp *et al.* (2009) point out that the growth of *Silurus glanis* in natural environment is most intensive in the first year of life when the yearlings can reach a total length of 38–48 cm and it is highly variable as adaptation to the different diet and environmental conditions (geographical habitat, water temperature, food abundance etc.).

In the current study, we used the length-weight relationship to assess the fish condition among the experimental groups assuming that heavier fish at a given length is in better condition after the feeding treatments. Determining the exponent “b” and the difference from “3.0” value indicates the direction of condition changes. As in other fish species, $b < 3.0$ indicates a decrease in condition or elongation in form, $b > 3.0$ indicates an increase in the condition when the increase in weight exceeds the increase in length. The larger the difference from 3.0, the larger the change in condition or form. Also, the determination coefficients (R^2) was computed for suggesting the percentage of weight gain that can be attributed to the length increment.

The variation of the condition factor among the experiment, as well as the determination coefficients (R^2), are presented in Figure 2.

From the “condition factor” point of view, a slight improvement of the nutritional status at the end of experiment in all basins could be observed. The inter-variants analysis indicates that, apparently, the individuals from the R1 feeding level have a better approach (mean “b” value was 3.023 compared with 2.870 in R2, at the end of the experiment). Correlating with the similarity of the recorded R^2 values, this situation suggesting a possible competition for food even in the experimental variant with higher feeding rate R2. Taking into account our results reported to those found by Havasi *et al.* (2015), the continuous repartition of the daily food could be a better solution for catfish feeding because, besides elevated feeding rates, increasing the feeding frequency could be the answer in order to obtain a homogenous population in aggressive specie like *Silurus glanis*. The coefficient of variation (CV %) recorded a larger variation by analysing the final moment (R1, 27.73 %→30.34% > R2, 23.87%→24.44%). For this predatory species,

Zaikov *et al.* (2008) found for one summer old fish raised in ponds a considerable variation (153.33 %), explained either by the individual variability within the limits of its species or as results of the specific growing conditions.

Conclusion

Determining the optimum feeding level in accord with the age is important to maximize the fish growth and feed use efficiency because the feed costs are the greatest operating expense in fish farming so the economics of feed conversion is therefore of high importance. Our results regarding the growth performances of the one summer old European catfish, expressed by production parameters SGR, FCR and PER, indicated a good increment of the biomass weight in parallel with the increasing of the feeding level. Usually, the high growth rate increases production turnover because a fast-growing fish will reach in advance the market size. The analyze of the fish condition during our experiment underlines the importance of applying a proper feeding frequency, too, in order to minimize the size differences within the population. As a voracious fish with a larger mouth, European catfish can magnify any initial advantage in size through competition in food, resulting in biased subpopulations (the R1 experimental variant’s case). The use of the self-feeders for this species seems to be a better operating action for increasing the feed acquisition, resulting in a more homogenous population and better feed management, too.

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