Scientific Papers. Series D. Animal Science. Vol. LXIV, No. 2, 2021
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

EFFECTS OF FEEDING LEVEL ON GROWTH PERFORMANCE AND BODY COMPOSITION OF COMMON CARP (*CYPRINUS CARPIO,* LINNAEUS, 1758) IN RECIRCULATING AQUACULTURE SYSTEMS REARING

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Abstract

A feeding trial was conducted to determine the effects of different feeding levels on growth performance and body composition. During 31 days, the experiment was carried out in the "Dunărea de Jos" University facilities from Galați, Romania. 720 fish, with an initial weight of 10.92 ± 0.17 g, were randomly distributed in twelve RAS rearing unit, with the same stocking densities. Four experimental variants were created, in triplicate: V1 - 3% from body weight per day (% BW day^{-1}), V2 - 3.9% BW day^{-1}, V3 - 4.9% BW day^{-1} and V4 -6% BW day^{-1}. Fish were fed with 45% crude protein and 16% lipids at a feeding frequency of three meals per day. At the end of the experiment, significant differences (p<0.05) were recorded between the four experimental variants. The body composition showed significant differences (p<0.05) also. The highest protein content and the lowest lipid content being recorded in variant V4 with 6% BW day^{-1}.

Key words: *growth indicators, juveniles, pellets, proteins and lipids content.*

INTRODUCTION

Aquaculture is one of the fastest-growing sectors worldwide dedicated to food production (Food and Agriculture Organization, 2018). The highest demand for fish has led to the implementation of new and modern technologies to ensure high-quality products over the entire year. In this sense, the development of aquaculture in recirculating systems is beginning to gain ground (Timmons et al., 2018; EUMOFA, 2020), mainly to the higher production which can be obtained (Timmons et al., 2002).

Growing fish in RAS systems involves various factors which can influence the final production and profitability. The most important are aspects related to growth and feed efficiency. Therefore the optimization of feeding management is crucial. Since the cost of feeding represents an important proportion of aquaculture operational costs, it is very important to estimate the optimal ratio of feed suitable for the species, its developmental stage, and the conditions of rearing (Pillay and Katty, 2005; El-Sayed, 2013; Baki and Yücel, 2017). Therefore, in a RAS system, intensification of fish growing should take into consideration the use of a proper feeding level, in order to obtain higher productions and to keep a good quality of water. If fish are underfed, the competition for feed increase (Attia et al., 2011), the growth can be suppressed, and fish variability increases (Zhou et al., 2003). Also, fish welfare can be depreciated, making them more susceptible to diseases (Rowland et al., 2005; Lim et al., 2015). On the other hand, if fish are overfed, water quality can deteriorate, the production cost increases and fish growth is reduced (Cho et al., 2007; Kim et al., 2007).

Common carp (*Cyprinus carpio*) represents one of the world's most cultivated fish species, with over 8 million tonnes being produced in 2017 (Food and Agriculture Organization, 2019). Common carp is hardy and tolerant of a wide variety of conditions, disease-resistant, an aspect that makes it an ideal candidate for freshwater aquaculture (Mohapatra and Patra, 2014).

The effects of feeding level on fish growth and feed conversion efficiency have been studied for several fish species in the conditions of the RAS systems (Firas, 2017; Crețu et al., 2019;

Petrea et al., 2020), but there are several factors which influence the feeding level in a RAS system.

The optimum feeding rate is dependent on fish species, fish size, and rearing conditions. Therefore choosing good management practices is fundamental to the success of the production. In this context, this study aimed to investigate the effects of different feeding levels on the growth performance and body composition of common carp with an initial weight of 10.92 ± 0.17 in the condition of a RAS system.

MATERIALS AND METHODS

Experimental design

The experiment was carried out at the pilot system of the Faculty of Food Science and Engineering belonging to "Dunărea de Jos" University of Galaţi, in a pilot recirculating aquaculture system (RAS). The RAS system comprised twelve rearing units with a volume of 0,132 m^3 each, mechanical filter, biological filter, UV lamp for water sterilization and disinfection, pumps, and was described by Crețu M. (2013).

The common carp fry was obtained from the extra season natural reproduction in August 2018 (Figure 1).

Figure. 1 Common carp fry (photo original)

Before the trial, fish were acclimated in laboratory conditions in a tank of 500 L volume for one week. After fish acclimatization, 720 carp fingerlings with an initial weight of 10.92±0.17 g were randomly distributed in the RAS system to create the experimental variants.

The study design included four feeding rates, in triplicate: V1- 3% from body weight per day (% BW day^{-1}), V2- 3.9% BW day^{-1}, V3- 4.9% BW day^{-1} and V4-6% BW day^{-1}. The daily rations were supplied each day in three meals, at 09:00, 14:00, and 18:00 hours. The fish was offered a commercial diet with a content of 45% crude protein and 16% lipids (Table 1).

During the experimental period, the water quality parameters such as dissolved oxygen, temperature, and pH were recorded daily with the help of Hannah 98194, while the concentration of nitrogen compounds was measured twice per week with the help of the Spectroquant Nova 400 photometer compatible with Merck kits.

Table 1. Proximate composition of experimental diets

Ingredients	U.M.	Diet
Crude protein	%	45
Crude lipids	%	16
Crude cellulose	%	2
Ash	%	7
Calcium	%	1.3
Sodium	%	0.30
Phosphorus	%	1
Vitamin A	IU/kg	10 000
Vitamin E	mg/kg	200
Vitamin C	mg/kg	150
Fe	mg/kg	60
Cu	mg/kg	5
Zn	mg/kg	100
Mn	mg/kg	25
Ca	mg/kg	2.5
BHA (E320)	mg/kg	30
BHT (E321)	mg/kg	29
Ingredients: poultry meal, wheat, fish meal, concentrated sunflower, wheat feed, blood meal, fish oil, rapeseed cake, rapeseed oil, hemoglobin powder, sodium chloride, calcium carbonate.		

Fish growth performance

After 31 experimental days, fish were weighed, and the following technological efficiency indicators were calculated: weight gain, food conversion ratio, and specific growth rate using the following equations:

Weight Gain (WG, g)

WG = Final biomass (g) – Initial biomass (g),

Individual weight gain (IWG, g)

IWG = Final Weight (Wt) – Initial Weight (W0) (g/fish),

Survival rate (%) = (final number of fish / initial number of fish) ×100,

Feed Conversion Ratio (FCR, g/g)

FCR = Total feed (F)/Total weight gain (W),

Specific Growth Rate (SGR, % Body weight day^{-1})

SGR = [(LnWt–LnW0)/t] × 100,

Body composition analysis

At the end of the experiment, seven fishes from each replicate were sacrificed for the analysis of the proximate composition of the whole body. The ash, moisture, crude protein, and lipid contents of fish were estimated by AOAC (2000). The biochemical tests were performed with three replicates and calculated on a wet weight basis.

Data analysis

Data were analyzed by one-way (ANOVA) using SPSS, version 21 for Windows. Before ANOVA, the normality of the data used for analysis was checked by Kolmogorov-Smirnov test. If any differences between the experimental variants were registered, Duncan's test was used. All experimental values are expressed as mean ± SD. Significance was determined at $\alpha = 0.05$.

RESULTS AND DISCUSSIONS

Water quality

Estimating the optimum ratio of feeding is important for determining nutrient requirements and production. In the present study, the analysis of the technical indicators was done in accordance with the monitoring of the main parameters of the water. The maintenance of good water quality is essential for the growth, survival, and production of fish species.

The water quality parameters except ammonium showed no significant differences ($p<0.05$) (Table 2). The ammonium concentrations significantly increased by increased ($p<0.05$) the feeding level. However, all the water parameters were in the optimal range for fish growing (Billard, 1995; Timmons et al., 2018).

The final weight, feed conversion ratio, specific growth rate, and protein efficiency ratio were significantly different (ANOVA, $p<0.05$) among the feeding levels. Data regarding the fish growth performance and feed conversion efficiencies of carp subjected to different feeding levels are presented in Table 3.

Initially, fish have similar weight, and no significant difference was recorded among the treatment ($p<0.05$). The weight homogeneity was verified and confirmed by Levene's test ($p>0.05$).

Table 2. The average values (± SD) of the main physicochemical parameters of water

Parameters	V1	V2	V3	V4
T°C	23.30±0.48^{a}	23.40±0.68^{a}	23.30±0.54^{a}	23.28±0.46^{a}
pH (pH units)	8.09±0.13^{a}	8.15±0.12^{a}	8.15±0.14^{a}	8.15±0.14^{a}
OD (mg L^{-1})	7.59±0.36^{a}	7.87±0.42^{a}	7.95±0.32^{a}	7.84±0.35^{a}
N-NO_2^- (mg L^{-1})	0.25 ±0.09^{a}	0.26±0.13^{a}	0.26±0.10^{a}	0.27±0.13^{a}
N-NO_3^- (mg L^{-1})	18.56±5.30^{a}	18.80±4.76^{a}	18.87±6.47^{a}	19.78±4.76^{a}
N-NH_4^+ (mg L^{-1})	0.21±0.11^{a}	0.32±0.09^{b}	0.38±0.16^{b}	0.45±0.18^{c}
P-PO_4^+ (mg L^{-1})	0.62±0.48^{a}	0.64±0.23^{a}	0.67±0.23^{a}	0.68±0.30^{a}

Note: data are presented as the mean of the triplicates; the data with the same letters were not statistically different.

Table 3. Growth performance indicators at the end of the experimental period

Growth parameters	Experimental variants			
	V1	V2	V3	V4
Initial biomass (g)	664.84±1.35^{a}	664.23±1.04^{a}	665.65±1.48^{a}	665±4.36^{a}
Final biomass (g)	1255.67±39.95^{a}	1102±2.65^{b}	1100±2.00^{b}	1093±2.00^{b}
Weight gain (g)	590.83±38.62^{a}	437.77±3.27^{b}	434.36±1.24^{b}	428±6.08^{b}
Survival (%)	98.44±1.50^{a}	94.64±4.73^{a}	97.22±1.92^{a}	97.22±1.92^{a}
Initial weight (g $fish^{-1}$)	11.08±0.02^{a}	11.07±0.02^{a}	11.09±0,02^{a}	11.08±0.07^{a}
Final weight (g $fish^{-1}$)	21.42±1.21^{a}	18.90±0.53^{b}	18.86±0.41^{b}	18.74±0.38^{b}
SGR (% day)	2.05±0.10^{a}	1.63±0.01^{a}	1.62±0.00^{a}	1.60±0.03^{b}
IWG (g)	10.34±1.19^{a}	7.83±0.53^{b}	7.77±0.38^{b}	7.66±0.34^{b}
FCR (g/g)	1.05±0.07^{a}	1.83±0.02^{b}	2.33±0.01^{c}	2.82±0.06^{d}

Note: data are presented as the mean of the triplicates; the data with the same letters were not statistically different.

After 31 experimental days the final mean weight was significantly higher ($p<0.05$) in V1 (21.42 ± 1.21g), while no significant differences ($p>0.05$) were recorded between the V2, V3, and V4 variants (18.90 ± 0.53 g in V2; 18.86 ± 0.40 g in V3, respectively 18.74 ± 0.37 g in V4).

Although in our experiment, the fish survival was high, ranging between 94.67 % and 98.33%, ANOVA analysis showed that the survival rate was not significantly ($p>0.05$) influenced by the feeding ratio. The highest survival rate is obtained at the lowest feeding ratio (V1).

Regarding the main technological indicators, it was observed that the increase in the feeding ratio did not always produce an increase in growth.

Significant differences ($p<0.05$) were recorded in the obtained values of FCR between the four experimental variants. The post hoc Duncan analysis divided the FCR values into four distinct groups belonging to each experimental variant. The best value of FCR was obtained at the lower feeding ratio (V1). A significant decline in feed conversion efficiency and protein efficiency ratio was observed at higher feeding rations which was a sign of loss of nutrients and wastage of food.

Increasing feeding wastage with the increasing of feeding ration was also reported by other authors in the case of common carp. Desai et al., 2009, studied four different rations (4%, 5%, 6%, and 7% BW day^{-1}) for common carp fry with the initial weight of 0.86 g and found that the optimum feed conversion efficiency was achieved at a lower feeding level (4% BW day^{-1}) at a temperature of 28°C and 32°C respectively. Also, Shimeno et al., 1997, observed that feeding common carp with slightly less than satiety levels, such as 90% and 80% of satiation, as compared to satiety feeding, achieved a somewhat higher feed efficiency ratio.

According to Van Ham et al., 2003, fish tend to optimize their digestion and retain nutrients more efficiently at lower feeding rates, and if they are fed above their appetite, food is wasted, and an artificially FCR will be registered (Khan et al., 2004). Also, Velázquez et al. (2006) say that reducing the daily amount of feed intake appears to compel fish to make the best use of the feed.

Comparing the obtained values of SGR between the experimental variants, the statistical analysis revealed significant differences ($p>0.05$) between the experimental variants. Better values of SGR were recorded in the V1, while no significant differences ($p>0.05$) were found between the V2, V3, and V4.

Effects of feeding levels on body composition and morphological indices are shown in Table 3. Fish body composition was significantly affected by feeding level ($p<0.05$). The findings of the present study showed that feeding level significantly affects water, protein, lipids, and ash content.

Body moisture content decreased significantly ($p<0.05$) with the increase of feeding levels. Regarding the protein content, higher values were obtained in the V4 variant, but there were no significant differences ($p>0.05$) between this variant and V1, V3, and V4.

Table 4. The proximate composition of common carp body composition reared at different stocking densities

Parameters	Experimental variants			
	V1	V2	V3	V4
Water (%)	72.68±0.17^{a}	72.98±0.16^{a}	70.43±0.17^{b}	70.43±0.13^{b}
Protein (%)	13.78±0.08^{a}	12.31±0.16^{b}	14.32±0.76^{a}	14.56±0.31^{a}
Lipid (%)	11.58±0.42^{a}	12.37±0.14^{b}	12.29±0.32^{b}	12.85±0.63^{b}
Ash (%)	1.47±0.03^{a}	1.67±0.02^{b}	1.72±0.07^{b}	1.78±0.05^{b}

Note: Data are presented as triplicate mean ± SD; the data with the same letters were not statistically different.

The lipids and ash content showed a significant increase ($p<0.05$) with the increasing of the feeding levels, the lowest values being registered in the V1 variant. The results obtained by us are comparable to those reported by other authors. Wang et al. (2019) reported for Nile tilapia an increase of lipid content in muscle and whole body with increasing feeding rates, fish fed 5% BW day^{-1} had higher values compared with that fed 3 % BW day^{-1}. Also, similar results were obtained by Ahmad et al. (2012) for common carp fingerlings or by Crețu et al. (2019) for rainbow trout.

Increasing of protein and lipid content with the increasing of feeding level was also reported by Petrea et al., 2020 in the case of *Acipenser stellatus* fed at a feeding level of 1% BW day^{-1}, respectively 2% BW day^{-1}.

Generally, the increase of lipid content with the increasing of the level of feeding was observed when the fish are fed at higher rates than that needed for the maintenance requirement, the excess energy accumulates mainly in the form of lipid in the adipose tissues (Huang et al. 2015; Liu et al., 2018).

CONCLUSIONS

In aquaculture, establishing the appropriate feeding level is important to minimize the cost of production and to make the technological production process more profitable. The main conclusion of this study is that increase in feeding level does not increase significantly the growth performance of common carp. Based on the result of the present study, it can be concluded that the optimum feeding rate for *Cyprinus carpio* (with the individual weight ranging from 11 g to 21 g) was around 3% BW day^{-1} and a feeding ratio beyond this level lead to the obtaining of unsatisfactory technological indicators, which over time can lead to low economic efficiency.

ACKNOWLEDGEMENTS

The principal author of the article thanks to the "Dunărea de Jos" University of Galați which through the University Degree Program, the doctoral studies contract has supported the achievement. Also, the authors are grateful for the technical support offered by MoRAS through the Grant POSCCE ID 1815, cod SMIS 48745 (www.moras.ugal.ro).

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