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OPTIMIZATION OF FEEDING RATE OF JUVENILE COMMON CARP, (CYPRINUS CARPIO L.), DURING SHORT INTENSIVE REARING UNDER CONTROLLED CONDITIONS

ABSTRACT

The aim of this experiment was to determine the optimum feeding dose for juvenile common carp (Cyprinus carpio L.) with the average initial body weight of 0.88g (WB) and the total length of 37.9 mm (TL). The rearing was conducted for 10 days at the temperature of 27°C under controlled conditions. The fish were divided into 6 feeding groups (in triplicate), for which the doses of feed were established at 6, 9, 12, 15, 18and 21% of the biomass per day.The biomass for each group was established every day before the first feeding.Fish were fed three times daily in equal portions, with granulate (1.5 mm granulation, Skretting, Norway: protein content 52%, fat – 20%, carbohydrates – 1.4%). After the experiment was completed, the following were determined for each feeding variant: average length (TL), average body weight (BW), Fulton's condition coefficient (K), specific growth rate (SGR), feed conversion rate (FCR), individual body mass gain (IBMG) and growth rate (GR). The dose of 12% of daily biomass should be regarded as the most suitable for juvenile common carp with the body weight ranging from 0.9 to 2.1 g, reared at the temperature of 27°C, under controlled conditions. Higher doses of feed did not increase the values of the rearing parameters. Present research showed that it is necessary to estimate the optimal feeding rates for common carp originated juveniles reared under controlled conditions.

Key words juvenile common carp; feed consumption; feeding rate; nutrition; RAS

1. INTRODUCTION

Intensification of the aquaculture processes requires developed of complete procedures of artificial reproductionincluding incubation of eggs as well as rearing larvae and older fishes, without which the whole production cycle would be impossible. One of the methods of intensification of production processes is to combine a culture processprovided in recirculating aquaculture systems (RAS) and in ponds, for example, by prior acquisition of larvae as a result of out-off-season artificial reproduction and later provided culture in ponds (Gal et al., 2012; Kristan et al., 2012). This provides an opportunity to increase the production output considerably and to reduce the duration of the production cycle. It also applies to the common carp(Cyprinus carpio L.), which is one of the major species in commercial freshwater aquaculture(http://www.fao.org/fishery/culturedspecies/Cyprinus_carpio/en), the pond-based production cycle lasts 2-3 years where the fish reach 1.5-2.5kg. In this case, larvae usually were producedduring spawning season by artificial reproduction (e.g. Brzuska, 2000, 2005). The protocol of out-of-season reproduction of the common carp and producing high-quality larvae (e.g. Kucharczyk et al., 2008) opens an opportunity to start the production cycle of the species much earlier than with the spawning conducted during the regular production cycle. However, in such case both the larvae and the juvenile stages must be then reared in RAS systems under optimum conditions. Currently, intensive rearing of fish in RAS systems allowsthe total control of the environmental and sanitary conditions and a considerable reduction in the production costs (Lazur and Britt, 1997; Żarski et al., 2008; 2010). Moreover, reusing the water reduces its consumption and the production of wastewater, which contains many biogenic compounds, produced, for example, by the decomposition of unconsumed feed (Cho and Bureau, 2001, Martins et. al., 2010) or by excreting ammonia (Nowosad et al., 2013) which are one of the main factors responsible for deterioration the quality of natural waters.

Although the common carp is one of the most frequently cultured freshwater fish species, many aspects of its RAS-based aquaculture are not studied enough. For developing optimal rearing procedure of larvae and juveniles under controlled conditions many zootechnical parameters should be tested, e.g. temperature (Kucharczyk et al. 1997; 1998; Kupren et al. 2011a), stocking density (Kupren et al. 2011b; Żarski et al. 2011a), type of offered food (Kucharczyk et al. 1998; Żarski et al. 2011b; Demenyet al. 2012) or ammonia excretion (Gomułkaet al. 2011; Nowosad et al. 2013).The available literature does not provide information on the detailed protocols offeedingcommon carp with the compound diet, especially its juvenile forms.The optimal level of feeding and temperature of water, as

well as fish origin, are among the most important factors which affect the effectiveness of rearing fish under controlled conditions (Kucharczyket al. 1998, Mandikiet al. 2004, Mohammad NejadShamoushakiet al., 2012a,b). Therefore, it is very important to estimate the optimal dose of feed, suitable for the species, its developmental stage and the conditions of rearing.The amount and composition of the feed significantly affect the growth rate, survival rate and the optimal individual development of fishes. Optimization of the feedingdose can increase the effectiveness of culture of a species and it can minimize the cost of rearing (Eroldogan et al., 2004). Since the cost of feeding fish accounts for a considerable part of the total financial expenditure in the entire breeding process(Wang et al., 2007; Turkowski, et al. 2008; Markowić et al., 2012), it is extremely important to select the optimal, properly digestible feed for the common carp with the appropriate content of nutrients (Markowić et al., 2012). It is equally important to select the optimum level of feeding which can minimize the cost of production and can make the production process more profitable. It is also important that the feed, when given in excess, falls down to the bottom, decays and makes the conditions in the rearing tank deteriorate (Ng et. al., 2000, Eroldogan et al., 2004). Moreover, removing the excess of unconsumed feed with water produces a lot of waste (Cho and Bureau, 2001). For this reason, it is extremely important to determine the optimum doses of feed, especially for species with a high growth rate, such as the common carp. Long term studies in the case of larvae and juveniles of fish with very high growth are inappropriatebecauseduring the early ontogeny growth rates and optimal feeding rates are changing rapidly and frequently. For these reasons the optimal feeding rate should be recognized for each fish stage and size during short-term studies.The right feed management can help to achieve the optimum rearing parameters at the lowest possible feed consumption, while keeping the production cost and the harmful effect on the water quality at the lowest possible level (Moore, 1985).

The aim of this study was to determine the optimaldaily feeding ratefor common carp juveniles using high protein diet reared during 10-days period under controlled conditions.

2. MATERIALS ANDMETHODS

2.1. The origin of the fish and pre-experimental rearing

The common carp larvae were obtainedby artificial reproduction conducted in accordance with the method described by Kucharczyketal. (2008) for in-season reproduction. Eyed eggswere brought from the Fishery Farm in Pasłęk (the north-east of Poland). Spawners were reproduced with the application of hormonal stimulation with Ovopel (Unic-trade, Hungary) at the total dose of 1.2 pellets kg^{-1}.The two injections (0.2 and 1 pellet per kg, respectively) were given with 12-hour interval. The eggs were stripped from 5 females and were fertilized with semen polled from 5 males. The eggs adhesiveness was removed with Woynarovichsolution (40 g NaCl and30 g urea in 10 $dm^3$of water) followed by repeated (30 and 15 s for first and second immersion, respectively) short immersion in tannic acid solution (6 g in 10 $dm^3$of water). The fertilizedeggs were incubated in Weiss jarsat 19°C (±0.3°C). Until the larvae inflated swim bladder, they were kept in a collective tank (200 L capacity) at 27±0.1°C. In the final phase of endogenous feeding (4 DPH), the larvae were placed in an experimental RAS allowinglaboratory rearing (as described by Krejszeff et al. 2010), where pre-experimental rearing was conducted. For the first 20 days fish were fed three times a dayad libitumwith freshly-hatched nauplii ofArtemia sp. Next, fish were fed solely with the compound diet (1.5 mm granulation, Skretting, Norway: protein content 52%, fat – 20%, carbohydrates – 1.4%) for 10 days.

2.2. Description of the experiment

After the 30 days of the pre-experimental rearing period, 180 specimens randomly sampled were measured. The initial average body weight and average total length were of 0.88 ± 0.03 (mean ± SD) g and the of 37.9 ± 0.5(mean ± SD) mm, respectively. The 900 fish were used in the present experiment.Randomly collected fish were stocked in a glass tanks with a total capacity of 16.0 dm^3each and a flow rate of 1 dm^3 min^{-1}. All aquaria worked in closed recirculated system.Fifty individuals were stocked in each tank (stocking density 3.13 specimen dm^{-3}). The temperature of water was set at 27^{o}C (±0.1^{o}C) and was adjusted electronically. The dissolved oxygen was over 6ppm. The total ammonia was below 0.1 ppm. The pH was between 7.6 and 8.2. The fish were randomly divided into 6 feeding groups (in triplication), for which thedoses of feed were established at 6, 9, 12, 15, 18and 21% of the biomass daily. The dose was given to the fish in the amount converted to the feed dry matter, calculated by drying a feed sample at 103°C for 12h. The common carp juveniles

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were fed with compound food (1.5 mm granulation) (Skretting Norway,protein content 52%, fat content 20%, carbohydrate content 1.4%).The feed was given to the fish by hand three times a day (9.00 a.m., 2.00 p.m., 7.00 p.m.), in accordance with the recommendations given byMohammad Nejad Shamoushakiet al. (2012a), who claimed that feeding juvenile carp three times a day is sufficient to ensure its optimum growth. Each time, the fish were fed for one hour. The amount of feed given to the fish during one feeding was equal to one third of the dose established for the particular treatment (2, 3, 4, 5, 6 and 7% of the fish biomass, respectively). Fifteen minutes after the end of each feeding, unconsumed feed was removed from the tanks. Every day before the feeding was started, the daily dose of feed(for each treatment and replication separately) was established by measuring the weight of 10 randomly-caught fish from each tank. The weight measurements were done following anesthesia in the solution of 2-phenoxyethanol 0.5 $cm^3 \cdot dm^{3-1}$ (Myszkowski et al., 2003). On the last day of rearing, 20 fish were caught from each tank and anaesthetizedand subsequently the total length (TL) was determined with a caliper(±0.1 mm) and wet body weight (BW) was determined with a laboratory balance (±0.1 mg) using the method described by Krejszeff et al. (2013). The data obtained allowed for calculation ofthe average length(TL), average body weight (BW), Fulton's condition coefficient (K), specific growth rate (SGR), food conversion ratio (FCR), Individual Body Mass Gain (IBMG), the growth rate in each feeding group (GR)and survival rate were determined. The results are shown as the average value and ± SD. The mortality rate was calculated by taking the number of dead fish at the end of the experiment compared to the initial stock. The calculations were performed from the following formulae:

$K = 100 * WBW\ TL^{-3}$, where: WBW –final wet body weight(g), TL – final total length(cm).
SGR (% day^{-1}) = $(\ln w_t - \ln w_o)(\Delta t\ 100)^{-1}$, where: w_o–initial WBW(g), w_t–final WBW(g), Δt –the number of days between the measurements.

IBMG (g)):IBMG = IFBM – IIBM,where: IFBM - individual final body mass (g), IIBM - individual initial body mass (g).
FCR = $F\ (B_k + B_p)^{-1}$,where:F – the amount of feed offered to the fish(g), B_k–fish biomass at the end of the experiment(g),B_p- fish biomass at the beginning of the experiment(g).
GR (g d^{-1}): $GR = (w_t - w_o)/\Delta t$, where: w_o = average initial unit mass of fish (g), w_t = average final unit mass of fish (g), Δt – rearing duration in days (d).

2.3. Statistical analysis

The statistical analysis was performed with the one-way analysis of variance (ANOVA) followed by the Duncan'spost-hoctest, the differences were regarded as statistically significant at the level of significance $P<0.05$. The data expressed in percentages were arc-sine transformed before the statistical analysis. All the results were presented as mean ± SD.

3. RESULTS AND DISCUSSION

This study determined the optimum dose of feeding ratesfor common carp juveniles with the initial body weight of 0.88 g, fed for 10 days with artificial feed with high protein content up to. Among the tested options of the biomass percentage: 6%, 9%, 12%, 15%, 18%and 21%, 12% of the daily biomass was regarded the optimum value when the fish were reared at the temperature of 27°C. The obtained rearing parameters are very high and the survival in all groups was 100%. There were no observed any fish body deformations. This indicates both that the rearing conditions and the type of feed given to the fish were chosen correctly.

The lowest final length (44.59±1.17mm) final weight (1.6±0.2 g) was in the group fed with 6% of the biomass, which was the smallest of the tested doses. The average final body length in the remaining feeding groups was similar ($P>0.05$) and ranged from 47.25±0.68 to 47.87±0.26 mm (Table 1). Likewise, the fish in the group fed with the smallest dose of feed (6%) featured the lowest values of all the examined parameters ($P<0.05$). The group fed at 9% of the biomass featured only a higher value ($P<0.05$) of the body length and SGR compared to the group fed at 6%. However, the average weight of the fish and the condition coefficients were comparable. No differences were observed between the analyzed parameters in the groups fed at 9 to 21% depending on the tested parameters ($P>0.05$),

although in most cases the values for the group fed with the dose at 9% of the biomass were slightly lower than in the groups fed with higher doses, i.e. BW 2.0 vs. 2.1, IMBG 1,08 vs. 1.18-1.20, SGR 8.04 vs. ≥ 8.48 for group 9% and over 9%, respectively. Therefore, 12% of the daily biomass should be regarded as the optimum dose for juvenile carp, because all the parameters are different in comparison to group 6% (Table 1). The relationship between the average mass of the fish and the duration of the rearing period showed a similarity to exist between the groups fed at 12% to 21% of biomass (Figure 1).The analysis of average individual gain rate (grams per day) in all treated groups showed that these rates are growing to the 12% of offered food per fish biomass and later did not increase (Figure 2). Its mean that increasing of offered food did not increase individual growth rates.

The final parameters of rearing the juvenile common carp, as calculated in this study,are close to, or higher than, the results of studies conducted by other researchers. Markovic et al. (2012), during 90 days of rearing observed the highest SGR 1.09 % $day^{-1}$and FCR ranging from 1.49 to 2.82, whereas Przybyłet al. (2006) calculated the SGR to be 3.34 % $day^{-1}$and FCR to bebetween 1.29 and2.66. The data calculated in present experiment ranged from 5.99 to 8.69 $day^{-1}$for SGR and 1.06 – 2.59 for FCR. The value of GR(g d^{-1}) (Tab. 1) recorded in present study was higher (0.11-012 g d^{-1}) than that in the study conducted byMohammad Nejad Shamoushaki et al. (2012a; b) where maximally was 0.09g d^{-1}.The differences in growth rate parameters might be related e.g. with water temperature (Kucharczyk et al. 1997; 1998; Kupren et al. 2011a), fish developmental stages (Kucharczyk et al. 1998; Kupren et al. 2011a; b) and kind of offered food (Kucharczyk et al. 1998; Mamcarz et al. 2011; Żarski et al. 2011a; Demenyet al. 2012).

It is very important in fish culture to establish the optimal minimum feeding rate level for the each species, age (developmental stages) and growth rate. The amount of feed given to fish can be different even between the species within one family. The optimal level of feeding of the juvenile common carpobtained in the present study(12%) is much higher than that of other juvenile cyprinid species, such as:grass carp Ctenopharyngodonidella, common tench, Tincatinca, or vyrezub, RutilusfrisiiKutum,for which the dose of feed was established as2%to 10%of thebody weight per day (Du et al., 2006; Kamler et al., 2006;Mohammad Nejad Shamoushaki et al., 2012c).The optimum dose in the juvenile tench which was a species with a low growth rate(approx. 0.05g d^{-1})(Mamcarz et al. 2011, Nowosad et al. 2012) was established at 2.5% of biomass (Kamleret al., 2006). In this last experiment it has shown that the dose of feed for the juvenile tench is almost five times lower than required by juvenile common carp to achieve the high growth rate. The difference is probably associated with the very high daily growth rate of the carp of as much as 0.12g d^{-1} (Tab. 1), as compared to the tench. Such differences can exist not only between different species, but also within one species in fish with comparable body size. If that is the case, the differences can result from the origin of the fish, the type and composition of the feed, food hydratation level in digestive track, its digestibility (Degani et al., 1997) and the physicochemical parameters of the water, including the content of oxygen and nitrogen compounds (Mohammad Nejad Shamoushaki et al., 2012b). The study conducted by Mohammad Nejad Shamoushaki et al. (2012b)at variable and slightly lower temperature than in present study (26.0±2.0^{o}C vs. 27.0±0.1^{o}C) showed the dose of 7.5% of biomass to be optimum. However, the experiment was conducted with a feed containing much less protein (32%), under different environmental conditions (water replacement in aquaria every 2 days vs. RAS) and with a different variety (subspecies) of the common carp. This study showed a decrease in the weight and length growth rates in the group fed with 10% of biomass compared to 7.5%. Such tendency was not observed in present study, which indicates that the environmental conditions did not deteriorate despite the fact that the daily dose of feed increased to 21%. Moreover, the carp is a fast growing fish, also in the juvenile stage, which makes it necessary to determine its biomass frequently to give the fish the optimal dose of feed.

4. CONCLUSIONS

The differences in terms of the optimum daily dose of feeds, shown in this study to exist between varieties (subspecies) of the carp, fed with feed containing different levels of protein, indicate the necessity of the individual determination of such doses for different places of rearing. It must be pointed out that such optimum doses are optimal for the fish in a specific development stage, at a specific temperature and when the fish are fed with feed containing a specific level of proteins.

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Parameter	Feeding group (daily dose of feed per fish biomass)					
	6%	9%	12%	15%	18%	21%
LT (mm)	44.59±1.17^{b}	47.25±0.68^{a}	47.34±0.79^{a}	47.29±2.16^{a}	47.54±0.31^{a}	47.87±0.26^{a}
BW (g)	1.6±0.2^{b}	2.0±0.1^{ab}	2.1±0.1^{a}	2.1±0.3^{a}	2.1±0.1^{a}	2.1±0.1^{a}
IBMG(g)	0.68±0.11^{b}	1.08±0.08^{a}	1.18±0.11^{a}	1.20±0.24^{a}	1.18±0.04^{a}	1.20±0.08^{a}
SGR(% day^{-1})	5.99±0.81^{b}	8.04±0.36^{a}	8.48±0.51^{a}	8.49±1.34^{a}	8.79±0.11^{a}	8.69±0.29^{a}
FCR	1.06±0.12^{b}	1.17±0.09^{ab}	1.48±0.16^{a}	1.86±0.25^{c}	2.28±0.16^{d}	2.59±0.16^{d}
GR (g d^{-1})	0.07±0.02^{b}	0.11±0.01^{a}	0.12±0.01^{a}	0.12±0.03^{a}	0.12±0.01^{a}	0.12±0.01^{a}
K	1.79±0.01^{b}	1.85±0.02^{ab}	1.89±0.03^{a}	1.90±0.06^{a}	1.92±0.06^{a}	1.89±0.04^{a}

Data marked with the same letter in rows did not differ statistically.

Table. 1. The final parameters (mean ±SD) of rearing juvenile carp fed with different dose of feed (6%, 9%, 12%, 15%, 18%and 21% of biomassdaily).

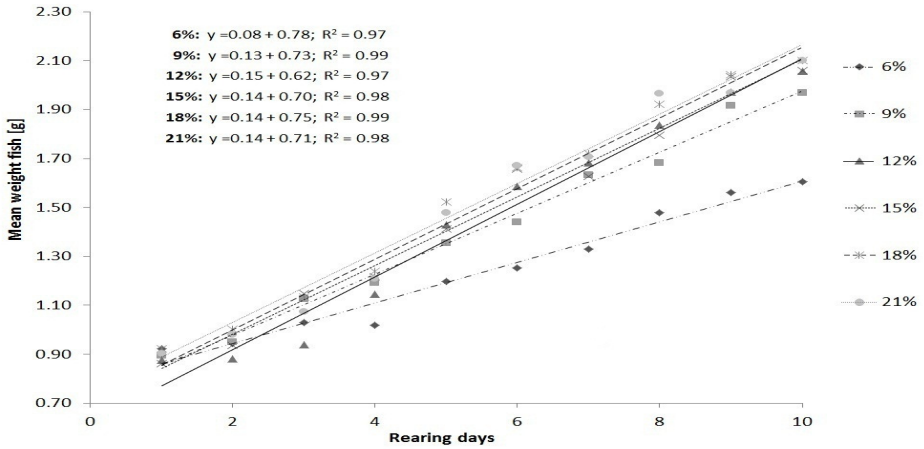

Fig. 1. The relationship between average weight and days of rearing juvenile common carp fed with different doses of artificial fed.

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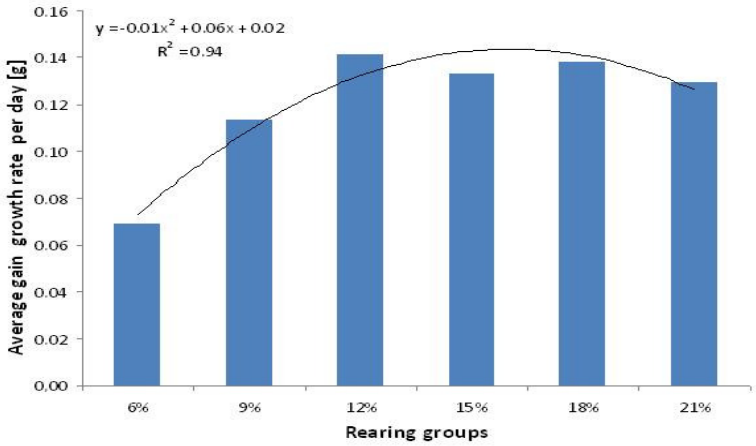

Fig. 2. The average gain growth rate per specimen (g per day) of rearied juvenile common carp fed with different doses of artificial fed.

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