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EFFECTS OF FEEDING REGIME ON GROWTH, FEED CONVERSION AND SIZE VARIATION OF *Silurus glanis*

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ABSTRACT

The present study was carried out to investigate the effects of feeding frequency on the growth, feed utilization, condition and size variation of European catfish. Triplicate groups of fish (45 specimens per treatment) weighing 59.9±12.8 g (mean ± S. D.) were fed a commercial diet (18 MJ DE kg^{-1}). Three different treatments were applied in 3-3 replicates. One group of fish was fed continuously with automatic belt feeders over 12 hrs (C). The second group of fish was fed by hand once a day (1x). The third group got three hand-fed meals per day (3x). In this case the portion was divided into three equal quantities. Feeding levels were 2.5% of actual stock weight in each group. During the 5-week trial, the final body weight (FBW), weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), condition factor (CF) and coefficient of variance CV% were determined. In the first week, remarkable differences in specific growth rate and feed conversion ratio were observed between different treatments, however, all of the differences were ceased at the end of experiment. No significant difference in growth rate, feed conversion ratio, protein efficiency ratio, size variation and condition factor were recorded between different treatments. Overall, our findings conclude that feeding frequency had no significant effect on any of the indices in *Silurus glanis*. Despite this, three times daily or more frequent feeding could be suggested, as frequent feeding regimes mitigate the harmful effects of rapid water quality changes.

How to Cite

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INTRODUCTION

Efficiency and profitability of intensive fish cultures are mainly determined by feeding. In intensive systems feeding costs exceed 50% of total costs (Müller, 1990; Fast et al., 1997). Thus, it is very important to be aware of the optimal parameters of feeding. Besides, the chemical composition of feeds, optimal feeding levels and frequency is of primary importance. Frequency of feeding potentially affects the growth rate, size variation, feed utilization and body composition (Jobling, 1983; Alanärä, 1992; Linnér and Brännäs, 2000; Zakęś et al. 2006; Silva et al., 2007). It is proven that the maximal growth rate and minimum feed conversion ratio can be achieved by adequate feeding frequency (Andrews and Page, 1975). The optimal frequency of feeding is dependent on many endogenous (species, strain, age etc.) and exogenous factors (quality of feed, temperature and other environmental attributes). Hierarchy of fish has a considerable role in increasing the size variation, however, this effect can be reduced by feeding to satiation or using a more frequent feeding regime (Jobling, 1983). Besides these obvious effects, feeding frequency has an indirect impact on growth through the changes of water quality (Phillips et al., 1998). It is observed that dissolved oxygen levels and ammonium concentration fluctuate together with the time of feedings (Giberson and Litvak, 2003).

European Catfish *Silurus glanis* has been a widely cultivated, native fish species in Europe for a long time, especially in the central region. Although its production level is still very low (approx. 1700 t year^{-1}), there is a rapidly growing interest on the market towards this fish among other catfish species (Triantafyllidis et al., 2002; Ulikowski et al., 2003; Linhart et al., 2004; Talpeş et al., 2009). Value of total production increased from 2 million to 5 million USD between 2000 and 2006 and is still increasing (Talpeş et al., 2009). It has a relatively high market value, due to the boneless, white and tasty filet (Jankowska et al., 2007; Naβ, 2013). Most of the fish is produced in pond polyculture, but the role of intensive production technologies are increasingly determinant.

Although optimal feeding regime and its effect on growth, feed utilization and size variation had already been studied in many species (Jobling, 1983; Alanärä, 1992; Linnér and Brännäs, 2000; Zakęś et al., 2006; Silva et al., 2007), the knowledge considering the feeding of Silurus glanis is quite scarce, as it feeds only upon natural feed sources in pond circumstances. According to our knowledge, only natural feeding rhythm has been determined so far (Boujard, 1995; Bolliet et al., 2001). Therefore in this paper the effects of feeding frequency on main growth parameters and indices were investigated in order to support the intensive culture of European catfish with new practical information.

MATERIALS AND METHODS

Experimental animal and system

European catfish (*Silurus glanis*) juveniles, originating from a local fish farm (Öreglaki Halász Ltd., Somogy County, Hungary), were applied during the trial. Prior to the experiment fish were reared on Skretting Nutra artificial feeds (Skretting AS, Norway) in pond monoculture. The experiment was carried out in a recirculation system with a total volume of 4 m^3, which consisted of nine aquaria (130x50x60 cm, 350 L) and five 300 L filtering and puffer tanks. Flow rate through each aquaria was about 2 L•min^{-1}, and water exchange 10%•day^{-1} in the whole system. Tap water was used and aeration was provided in each aquaria. Fifteen catfish were stocked in each experimental unit in 2.81 ± 0.12 g•L^{-1} stocking density. In total, 145 specimens were applied with 59.9±12.8 g (BWmean ± SD) initial body weights. The lights in the room were dimmed by covering windows so the light regime was natural, but the amount of light was low during daytime and there was complete darkness during night hours. The temperature was maintained between 23-25°C and was measured daily (mean ± SD: 24.0 ± 0.8°C). Oxygen saturation was also measured daily and it never fell below 75%. Concentration of harmful inorganic nitrogen forms and alkalinity were measured weekly (NH_4^+<0.26 mg L^{-1}, NH_3<0.025 mg L^{-1}, NO_2^-<0.1 mg L-1, NO_3^-<36 mg L^{-1}, pH: 8.23-8.54).

Experimental design

Three different treatments were applied in 3-3 replicates. One group of fish was fed continuously with automatic belt feeders over 12 hrs (C). The second group of fish was hand fed once a day (1x) at 14:00. The third group got three hand-fed meals per day (8:00, 14:00 and 18:00) (3x). In this case, the daily portion was divided into three equal quantities. In the case of the hand-fed groups, the (sub)portion was offered once during each occasion. The total daily amount of feed was 2.5% of the actual stock body weight in each group. COPPENS STECO SUPREME-10 (Coppens, Helmond, The Netherlands) was used as experimental feed. The proximate composition of this feed is indicated in Table 1. The experiment lasted five weeks, after two weeks of acclimatization period. During these two weeks fish were fed under the same conditions as during the experiment but the results of the first two weeks were not considered in the evaluation.

Table 1. Proximate composition of the applied feed

Declared composition	(g·100g^{-1})
Protein	49
Fat	10
Fibre	1.8
Ash	9.4
Phosphorus	1.4
Calcium	1.6
Sodium	0.4

Values declared by the manufacturer (COPPENS STECO SUPREME-10)

Measures, calculations

The individual body weight and total body length were measured weekly with 0.1 g (VIBRA AJ, Shinko Denshi Co. Ltd., Indonesia) and 0.5 cm precision, respectively.

Weight gain (WG), relative weight gain (RWG), feed conversion ratio (FCR), protein efficiency ratio (PER), specific growth rate (SGR) and condition factor (CF) were calculated from the data as below. Size variation within the stock was demonstrated by coefficient of variation (CV).

$$WG\ (g{\cdot}fish^{-1}day^{-1}) = (W_t/N_t\text{-}W_0/N_0)/t$$

$$RWG\ (\%) = BW_{mean(final)}/BW_{mean(initial)}{\cdot}100$$

$$FCR\ (feed{\cdot}gain^{-1}) = I/(W_t - W_0 + W_d)$$

$$PER = WG(t)/P$$

$$SGR\ (\%\cdot day^{-1}) = (\ln W_t - \ln W_0)/t\cdot 100$$

$$CF = (BW_{mean}/L^3)\cdot 100$$

$$CV\ (\%) = SD_{BW}/BW_{mean}\cdot 100$$

where, I(g) is the total amount of offered feed, W_0(g) is the total initial body weight, W_t(g) is the total final body weight, W_d(g) the dead fish weight, N_0 is the number of fish at the start of the trial, and N_t is the number of fish at the end of trial, t(d) is the duration of the trial, WG(t) is total weight gain in grams, P(g) is the amount of protein fed, BW is the body weight and L is the length of an individual fish (cm).

Shapiro-Wilk test and Kolmogorov-Smirnov probe were used to test normality, and Levene's test was applied to test homogeneity of variances. Means were compared by one-way analysis of variance (ANOVA) followed by Tukey and Tamhane's post hoc tests in cases of normal distribution. Where distribution was not normal, non-parametric Kruskal-Wallis test was used for comparing means. Significance was accepted at $P<0.05$.

RESULTS AND DISCUSSION

Growth

During the five weeks, continuously fed fish reached 213.8%, while 3x fed fish achieved 213.3% and 1x fed group 195.6% relative weight gain, respectively. There were no significant differences observed between the treatments regarding mean body weight (Table 2).

Table 2. Weight, lenght, condition factor, CV %, relative weight gain, feed conversion ratio and protein efficiency ratio (mean ± standard deviation) of European catfish during the experiment according to the different feeding regimes

	C	1x	3x
weight (g)			
initial	59.1 ± 11.5	61.8 ± 13.6	58.9 ± 13.3
final	126.3 ± 24.4	123.4 ± 27.9	128.5 ± 29.8
lenght (cm)			
initial	21.2 ± 1.3	21.4 ± 1.5	21.1 ± 1.5
final	27.7 ± 1.7	27.4 ± 1.9	27.9 ± 1.9
condition factor			
initial	0.62 ± 0.00	0.63 ± 0.02	0.63 ± 0.00
final	0.60 ± 0.00	0.60 ± 0.01	0.59 ± 0.01
CV %			
day 0	19.4 ± 2.3	22.3 ± 0.7	22.7 ± 4.3
day 35	19.5 ± 2.3	23.0 ± 1.7	22.7 ± 3.4
RWG (%)	213.8 ± 14.1	195.6 ± 17.8	213.3 ± 10.2
FCR	0.76 ± 0.07	0.86 ± 0.13	0.77 ± 0.07
PER	2.7 ± 0.3	2.4 ± 0.3	2.7 ± 0.2

The daily individual weight gain increased in parallel with the increasing mean weight in all three groups (Fig. 1). The intensity of growth was the lowest in the 3x fed group, initial value increased only to its 1.8-fold. This increase was twofold in the other two treatments. It has to be mentioned that during the first week of the experiment this group (3x) still had a significantly higher growing intensity than the other two. Therefore the differences which were present during the first part of the experiment became equalized later, and the significant differences between the treatments disappeared.

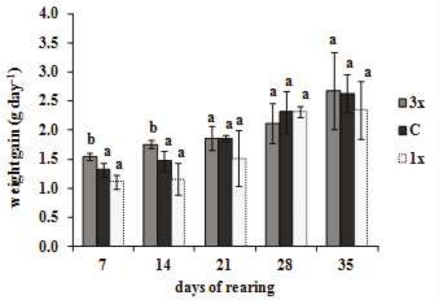

Fig 1. Daily weight gain of *Silurus glanis* during the experimental period (mean ± standard deviation). Different superscripts indicate statistical differences (P<0.05)

Remarkable differences were observed between the specific growth rate of different treatments in the first week (Fig. 2). In the beginning, the 3x fed group presented the most intense growth. By the end of the experiment this growing intensity decreased, while the other two groups increased in growth rate. Consequently in the last week the growing intensity was similar across the three groups; significant differences were not observed.

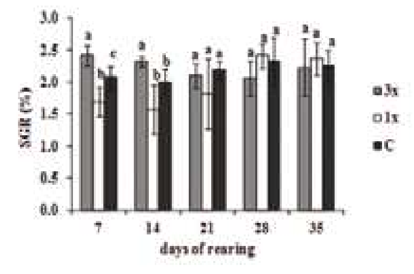

Fig 2. Specific growth rate of *Silurus glanis* during the experimental period (mean ±standard deviation). Different superscripts indicate statistical differences (P<0.05)

Condition

The condition of fish was nearly constant throughout the whole period with the mean value of 6.10 ± 0.14 (mean ± SD). Only a slight decrease was observed in their condition in all groups due to the increase of body length. The differences in the condition factor between the three groups were not significant (Table 2).

Feed utilization

Feed conversion ratio was the highest in the 1x fed group at the start of the experiment. In this group the utilization improved progressively over time. There was no significant difference between the other two groups and all differences between the three groups ceased by the end of the experiment. The feed conversion ratio calculated for the whole experiment was the highest in the 1x fed group: 0.86. There was no significant difference between the feed conversion ratio of the two other treatments (continuous: 0.76; 3x fed: 0.77). Protein efficiency ratio was similar in groups 3x and C with higher values compared to group 1x (Table 2).

Size variation

The changes of size variation were expressed as CV% values (Table 2). The treatments did not affect the size variation. The maximum alternation within one group during the experiment was only 2%. Size difference among fish of the 1x fed group increased by only 1%. The initial and final values were the same in the case of other two treatments.

DISCUSSION

The yield of fish production is highly dependent on the protein allowance, which is related to protein content of the feed and the feeding regime (Cho and Lovell, 2002). The effect of feeding frequency is influenced by many different factors. In the cases of some species it is necessary to adapt to their natural feeding rhythm, while in the case of other species, fish can easily adjust to the feeding regime. It is stated that although European catfish (*Silurus glanis*) is a highly nocturnal predator (Boujard, 1995), feed availability has greater influence on feeding rhythm than photoperiod (Bolliet et al., 2001). In this present study, fish were held in constant dimness. Optimal feeding frequency is also influenced by the passing time of gut content. It is observed by Riche et al. (2004) that Nile tilapia (*Oreochromis niloticus* L.) become hungry 4 hours post feeding at 28°C, so authors suggest feeding every four hours. According to our previous study (Havasi et al., 2012), the elimination of the gut content of Silurus glanis lasts 11-27 hours at 24°C. The reappearance of hunger was not examined in this study.

Relevant studies showed contradictory results on suggested feeding frequency in different fish species. In the case of young pikeperch (*Sander lucioperca* L.), three daily portions are suggested by Wang and Kestemont (2009). Continuous feeding is regarded optimal for fingerlings of the African catfish species, *Clarias lazera* (Valenciennes), (Hogendoorn, 1981). In the case of arctic char (*Salvelinus alpinus* L.), more frequent feeding (Linnér and Brännäs, 2001), while in the case of rainbow trout *Onchorhynchus mykiss* (Walbaum), less frequent feeding (Alanärä, 1992) affected the growth rate favourably. These discrepancies can be explained by the different feeding behaviours of these species. In those species which are aggressive and restless during feeding, like trout, frequent feeding is a stress factor, which weakens the feed utilization (Brännäs and Alanärä, 1992). Size variation within the stock did not change in our trial despite all treatments. A possible explanation is that in the case of European catfish group hierarchy is not so important if fish do not starve. Experiments on other species (Phillips et al., 1998; Zakęś et al., 2006) revealed similar results. On the other hand, Jobling (1983) experienced in the case of Arctic char that due to less frequent feeding dominance relations played a larger role, consequently causing broader size variations.

According to Eroldogan et al. (2004), less frequent feeding increases feed utilization, as fish consume more feed at once than more often fed fish. This phenomenon was observed in cases of tambaqui *Colossoma macropomum* (Cuvier), too (Silva et al., 2007). In the long term it may cause hyperphagia and the increase of the gut system capacity (Ruohonen and Grove, 1996). On the other hand, in often-fed fish passing time speeds up, the utilization of nutrients becomes worse due to the constant fullness of the gut system (Liu and Liao, 1999). These two processes together are thought to be the reason why neither the growing intensity nor the feed conversion differed between the treatments. It is typical in numerous fish species, especially in catfish species, that after a short starvation period feed utilization efficiency increases, and lagging in growth can be compensated (Kim and Lovell, 1995; Reigh et al., 2006). We would like to emphasise that this happened rather quickly, in a very short period in the case of *Silurus glanis*. Feeding frequency had no significant effect on feed conversion in our experiment. This was also observed in the case of walleye *Sander vitreus* (Phillips et al., 1998), Atlantic sturgeon *Acipenser oxyrinchus* (Mitchill) (Giberson and Litvak, 2003) and pikeperch *Sander lucioperca* (Zakęś et al., 2006). In the second part of our experiment, very good feed utilization (0.7-0.8) was observed in every experimental group, most probably due to the high crude protein content of the applied feed.

In our present study with European catfish, it was observed that different feeding regimes did not affect the growth rate of fish. Zakęś et al. (2006) had the same experience with young pikeperch (*Sander lucioperca*). Similar results were published by Phillips et al. (1998). Feeding frequency had no detectable effect on the growth of walley fingerlings, *Sander vitreus* (Mitchill), neither on the feed conversion ratio nor the size variation. However, authors emphasised the indirect effects of feeding regimes. Less frequent feeding causes the casual and rapid depletion of water quality (ammonia concentration, oxygen level) (Beliczky et al., 2013), which acts like a harmful stress factor on the growth of fish (Giberson and Litvak, 2003). Frequent feeding levels off or ceases this inconvenient impact.

Although present experiment did not record any significant effect of feeding frequency on the growing intensity, feed conversion and size variation, three times daily or more frequent feeding is suggested for feeding European catfish, as frequent feeding regime mitigate the harmful effects of rapid water quality changes.

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Sažetak

UČINCI REŽIMA HRANIDBE NA RAST, KONVERZIJU HRANE I VELIČINSKU VARIJACIJU KOD SOMA, *Silurus glanis*

Ovo istraživanje je provedeno kako bi se istražili učinci frekvencije hranjenja na rast, iskoristivost hrane, stanje i promjenu veličine europskog soma. Trostruke skupine riba (45 uzoraka po tretmanu), težine 59,9 ± 12,8g (srednja vrijednost±SD) su hranjene komercijalnom hranom (18 MJ DE kg^{-1}). Tri različita tretmana su primijenjena na 3-3 ponavljanja. Prva skupina riba je hranjena kontinuirano automatskim hranilicama tijekom 12 sati (C). Druga skupina riba je hranjena manualno jednom dnevno (1x). Trećoj skupini je obrok ponuđen 3 puta dnevno, također manualno (3x). U ovom slučaju porcije su podijeljene u tri jednaka dijela. Razina hranjenja je bila 2,5% stvarne težine u svakoj grupi. Tijekom 5 tjedana pokusa utvrđeni su: konačna tjelesna težina (FBW), dobivena težina (RS), specifična stopa rasta (SGR), omjer konverzije hrane (FCR), omjer učinkovitosti proteina (PER), kondicijski faktor (CF) i koeficijent varijance (CV). U prvom tjednu zabilježene su velike razlike u specifičnoj stopi rasta i omjera konverzije hrane između različitih tretmana, no sve razlike su prestale na kraju pokusa. Nema značajne razlike u stopi rasta, omjeru konverzije hrane, omjeru učinkovitosti proteina, promjeni veličine i faktoru kondicije između različitih tretmana. Prema tome, iz naših rezultata možemo zaključiti da frekvencija hranjenja nema značajan učinak na bilo koji od indeksa kod soma. Unatoč tome, možemo predložiti hranjenje od tri puta dnevno ili češće, budući da učestalo hranjenje dovodi do ublažavanja štetnih učinaka naglih promjena kvalitete vode.

Ključne riječi: frekvencija hranjenja, iskoristivost hrane, dobitak težine, europski som

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