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Does the feeding frequency influence the growth performance of European perch juveniles (*Perca fluviatilis*) during intensive rearing?

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SUMMARY

The European perch (Perca fluviatilis) is a predatory fish species. Its aquaculture production is increasing worldwide. Feeding and the frequency of feeding are important elements of intensive fish rearing. The aim of our experiment was to examine the optimal distribution of the amount of feed, at the same feed rations. The experiment lasted 42 days. Three treatments were applied in 4–4 replications. The first treatment was feeding twice per day (T2), the second treatment was feeding three times a day (T3), and the third group was fed four times a day (T4). 10 European perch juveniles were stocked per tank, with an individual mean body weight of 3.93 ± 0.06 g at the start of the experiment. The survival rate (S%) was above 90% for all treatments. The T2 treatments produced the most favourable harvest weight (13.96 ± 0.14 g) and specific growth rate (SGR = 3.08 ± 0.01% day^{-1}), but no significant differences were observed between groups. In terms of feed conversion ratio, the best result was obtained by (T3) (FCR =1.06 ± 0.18 g g^{-1}), but no significant difference was found for this indicator neither. The results of the trial indicate that the feeding frequency does not influence the production parameters.

Keywords: *European perch, feeding frequency, production parameters, farming technology, intensive recirculation system (RAS)*

INTRODUCTION

European perch (*Perca fluviatilis*) is a native predator fish species. A common species throughout Europe, it is often found in freshwater, particularly in the Alps, and is highly valued and frequently consumed (Fontaine & Teletchea; 2019). The European perch aquaculture production is increasing, the demand is particularly high in Switzerland, Eastern France and Northern Italy (FAO, 2022; Kestemont & Dabrowski, 1997; Mairesse et al., 2005; Steenfeldt et al., 2015). It is cultivated extensively in large ponds and reservoirs, and also farmed in small ponds for both human consumption and sport fishing (Kestemont et al., 2009; Gillet et al., 2013). However, because the global perch production is increasing, the amount of global capture is no longer able to supply the growing demand (FAO, 2022). In order to produce sufficient quantities, an optimal farming technology necessary, including the feeding protocol (Alanärä et al., 2001).

Feeding frequency is an important element of feeding protocol, therefore there is a lot of research on this topic (Silva et al., 2007). The level of feeding intensity depends on the appetite of the fish, which is also an important factor of the overall feeding protocol. The appetite of fish is also being studied in new ways, such as convolutional neural network and machine vision (Zhou et al., 2019; Ubina et al., 2021). In general, self - feeding systems are capable carry out the feed with same quantities at fixed times, which facilitate the accurate farming technology, alternating the ad libitum method, thus allowing more precise feeding protocol (Alanärä, 1996; Azzaydi et al., 1999).

In case of the European perch, it is important to note that in addition to a proper feeding protocol, they also have other environmental requirements during intensive rearing like light intensity, water temperature, optimal stocking density and the salinity (Lutz, 1972; Kestemont et al., 2015, Król & Zielinski 2015; Stejskal et al., 2020). The European perch is stress-sensitive fish, which may also affect their feeding intensity also. Summarily, in a well-designed RAS, European perch can be successfully reared under suitable environmental conditions (Rupp et al., 2019). This research focuses on feeding, including the optimal frequency of it. The knowledge of the feeding habits of the European perch is necessary to develop a suitable feeding protocol. Important consider the time of active feeding when choosing the meal time for fish, in this case the European perch is a diurnal species (López-Olmeda et al., 2012). Regarding of the feeding habits of European perch, in natural circumstances initially feeds on a variety of zooplankton species (*Daphnia, Rotifers, Copepods, Protozans, Artemia nauplii*), later its diet consists of small fish, invertebrates and insects (Vlavonou et al., 1999; Lorenzoni et al., 2007; Muñoz et al., 2021). In the nature, its prey selection varies seasonally (Kestemont et al., 2015; Yazıcıoğlu et al., 2016).

Under intensive conditions, almost the entire rearing is carried out on dry feed, but at larval age the use of live food is still essential. The most critical phase of intensive rearing is the coo-feeding period, the mortality rate is very high at this stage (Jentoft et al., 2006), (Härkönen et al., 2017). After this stage, it can be successfully rear under intensive conditions on 100% dry feed, but the proper feeding protocol also plays an important role (Lahnsteiner & Kletzl, 2018). However, in addition to the composition of the feed, the feeding rate and the feeding frequency is also important. European perch have great potential for growth, the 130–150 g market-size fish can be produced in a year with the right farming techniques (Mélard et al., 1996).

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The aim of our experiment was investigate whether the same feed rations distributed in different proportions could affect the production parameters of European perch during intensive rearing conditions.

MATERIALS AND METHODS

The experiment was carried out in a modular recirculating aquarium system of Laboratory of Aquaculture of University of Debrecen with 12 units of 30 litres net water volume (*Figure 1*). For the mechanical and biological filtration of the water individual sponge filters were used. Three treatments were applied in 4–4 replicates. The daily feed rations (*Table 1*) were set at 5% of the initial biomass, which was fed twice daily for the first treatment (T2: 8:00 am - 8:00 pm), three times daily for the second treatment (T3: 8:00 am – 2:00 pm – 8:00 pm) and four times daily for the third group (T4: 8:00 am – 12:00 am – 4:00 pm – 8:00 pm) with an automatic self-feeding system. The arrangement of the aquariums were completely randomized. The daily illumination was 12 hours light (297 ± 0.16 lux) –vcx+ 12 hours dark.

In all cases the daily feed ration was 2 g per tank (*Table 1*). Feeding was carried out with AQUA GARANT AQUA START 1.5 mm grain size sinking feed (crude protein 53%, crude fat 18%), which was dispensed by an automatic feeder. 10 European perch juveniles were stocked each tank, with an individual mean body weight of 3.93 ± 0.06 g at the start of the study. Water temperature and oxygen content (HACH LANGE HQ30d) in the tanks were monitored daily (T: 21.83 ± 0.26 °C; DO: 76.93 ± 6.36%). Fish faeces and uneaten feed were removed daily using a plastic tube.

Figure 1: **The experimental modular recirculating aquarium system**

Table 1: **The feeding protocol**

Treatment	T2	T3	T4
Feeding frequency / day	2x	3x	4x
Feeding time	8:00 am - 8:00 pm	8:00 am - 2:00 pm - 8:00 pm	8:00 am - 12:00 am - 4:00 pm – 8:00 pm
Daily feed ratio (g)	2g	2g	2g
Feeding rate (%)	5%	5%	5%

At the end of the 42 days experiment, the individual wet body weight of fish were measured individually. The following production parameters were determined:

- Survival of fish: S (%) = (number of live fish/ initial number of fish) * 100
- Specific growth rate: SGR (% day^{-1}) = (ln BWf - ln BWi) / t x 100, where: Wf: final body weight (g), Wi: initial body weight (g), t: number of days
- Feed conversation ratio: FCR (g g^{-1}) = F / (Wf-Wi), where: F: feed consumed during the experiment (g), Wf: final body weight (g), Wi: initial body weight (g)
- Coefficient of variation: CV% = SD/Wf * 100, where: SD = standard deviation, Wf: final body weight (g)

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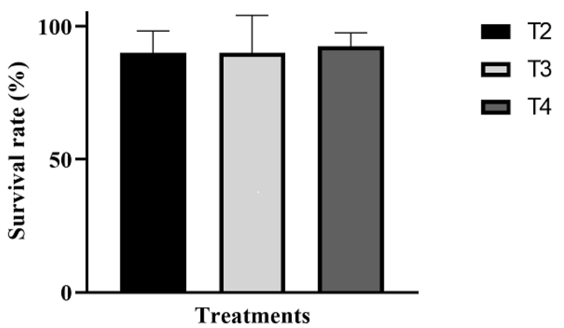
For statistical analyses of the results IBM SPSS software was used. We used the Duncan's Multiple Range Test to determine the significantly difference for the FCR and SGR between groups (Jabeen et al., 2004).

To determine the significant differences one-way ANOVA was performed. The homogeneity of data was checked by Levene-test.

RESULTS AND DISCUSSION

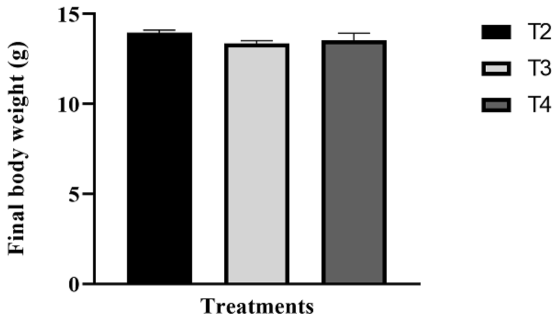
In the study, survival was above 90% for all treatments (*Figure 2*). T4 treatment produced a slightly higher survival compared to the other treatments (T4=92.5 ± 5.0), but this is presumably not due to the feeding method in our opinion. No correspondence was observed between mortality rate and feed distribution, as all treatments produced very similar numbers at the end of the experiment. The observed mortalities were probably due to the smaller individuals being less able to dominate over the larger individuals during the feeding period, and the associated cannibalism also caused mortality in the stock. Well known that European perch is susceptible to various viruses, pathogens and bacterial infections that increase mortality under intensive conditions, but we did not experience this during the experiment (Grignard et al., 1996; Rupp et al., 2019). The low mortality was facilitated by the sterile conditions, before the experiment, the system was cleaned with formalin.

Figure 2: **The survival rate of the fish**



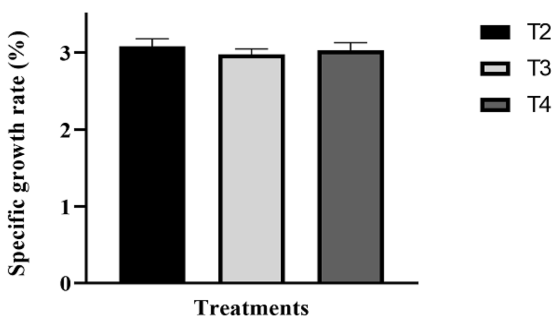
At the end of the experiment, the treatment that received the daily feed ration divided in two groups (T2) produced the most favourable harvest weight (13.96 ± 0.14 g) (*Figure 3*) and specific growth rate (SGR= 3.08 ± 0.01% day^{-1}) (*Figure 4)*, while the lowest values were obtained with the T3 treatment (BWF=13.37 ± 0.08 g, SGR=2.98 ± 0.07), but no significant differences were observed between groups. The T4 treatment showed an intermediate results, with higher values compared to T4 but lower numbers compared to T2 in these two indicators mentioned above (BWF=13.54 ± 0.39 g; SGR=3.03 ± 0.10).

Figure 3: **The final body weight**



European perch, like many other predators, showed increased feeding activity during twilight, and we presume this may have contributed to the fact that they responded most favourably to the feed distributed twice daily in the morning and evening, because these dates are the closest compared to its natural foraging behaviour (Helfman, 1986; Czarnecka et al., 2019; Muñoz, et al., 2021). Noeske & Spieler (1984) proved that the optimal feeding time is an important factor during fish rearing. They investigated the relationship between light and dark cycles and feeding time. In their experiment, the goldfish (*Carassius auratus*) were exposed to 12L:12D (12 hours light:12 hours dark). They used 4 feeding times after the light onset (0h, 6h, 12h, 18h). At the end of their experiment, they found that fish fed 18 hours after the light setting (6 hours after dark) grew more than other fish. In our study, the fish were fed at the same time after the light onset.

Figure 4: **The specific growth rate**



The possible explanation for why the T2 treatment achieved the higher results for final body weight and SGR was that this group had the longest time between feeding times, and therefore the fish were hungrier and fed more intensively. In accordance with our results the occurrence of Rowland et al. (2005). In their study they investigated the effects of different feeding frequency (1x/day, 2x/day, 3x/day) on fish growth and feed conversion during cage rearing of silver perch

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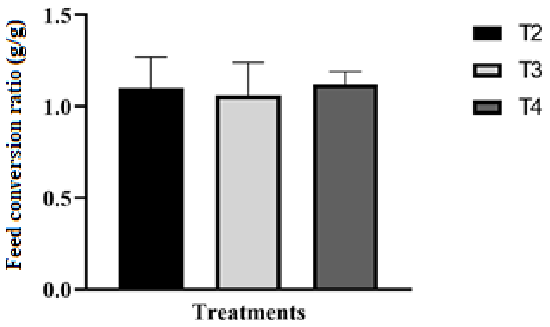
(*Bidyanus bidyanus*). The fish fed 2 times a day had the highest growth at the end of their experiment.

Figure 5: **The feed conversion ratio (g g^{-1})**



In terms of feed conversion ratio (*Figure 5*), the best result was obtained by the treatment receiving the feed in three daily portions (FCR= 1.06 ± 0.18 g g^{-1}), while the most unfavourable indicator is T4 (FCR=1.12 ± 0.07), but no significant difference was found for this indicator in this case neither. A similar experiment to ours was carried out by Silva et al., (2007). In their study, they divided the daily feed ration into two portions with two feeding intensity (5%, 10%) during cage rearing of tambaqui (*Colossoma macropomum*) and investigated the effect on production parameters. In their experiments, the feeding times of the fish were as follows: 2 times/day, (8:00 and 16:00), 3 times/day (8:00, 12:00 and 16:00 h). The authors recommend feeding 3 times/day with 10% feeding ratio during rearing tambaqui (*Colossoma macropomum*). Our results did not support this, as the fish fed 3 times (T3) did not perform better than the other two treatments (T2; T4) in terms of production parameters. However our results are confirmed by the research of Grayton & Beamish (1977). In their trial they investigated the feeding frequency of rainbow trout *(Salmo gairdneri).* At the end of their study, they found no difference in growth performance between treatments. According to their results, the feeding frequency did not affect the growth of the fish under controlled conditions. Feeding efficiency can vary between species, as noticed by Greenland & Gill (1979), who investigated the production parameters of channel catfish (*Ictalurus punctatus*) at 1, 2 and 4 feeding times per day. At the end of their experiment, the groups fed 4 times per day achieved the highest growth compared to the other treatments.

Table 2: **The production parameters of the fish**

	T2	T3	T4
S%	90 ± 8.2	90 ± 14.1	92.5 ± 5.0
Initial Biomass (g)	39.48 ± 0.35	39.35 ± 0.91	39 ± 0.61
Final Biomass (g)	125.58 ± 10.83	120.33 ± 18.66	125.3 ± 9.45
Initial body weight (g)	3.95 ± 0.04	3.94 ± 0.09	3.90 ± 0.06
Final body weight (g)	13.96 ± 0.14	13.37 ± 0.08	13.54 ± 0.39
SGR (%)	3.08 ± 0.1	2.98 ± 0.07	3.03 ± 0.10
FCR (g g^{-1})	1.10 ± 0.17	1.06 ± 0.18	1.12 ± 0.07
CV%	18.39 ± 3.34	19.63 ± 1.24	30.42 ± 10.34

Regarding the production parameters of the fish at the end of the experiment, there was also no significant difference in the homogeneity of the stock (CV%) between treatments at the end of the experiment as shown in *Table 2*, similar to the other measured parameters. The T2 (18.39 ± 3.34) and T3 (19.63 ± 1.24) treatments achieved similar results, while the T4 (30.42 ± 10.34) group achieved higher values compared to them at the end of the experiment. *Table 1* shows the group average data for the starting and ending biomass of the fish also. The largest biomass increase was achieved by the T2 (125.58 ± 10.83 g) treatment, while the smallest increase was achieved by the T3 (120.33 ± 18.66 g) treatment.

CONCLUSIONS

Although our results did not support this, determining the optimal feeding frequency is very important in fish farming, which is why there has been a lot of research on this topic (Andrews & Page, 1975; Jobling, 1982; Sundararaj et al., 1982; Lee et al., 2000). Based on the results of these feeding experiments, it can be stated that optimal feeding frequency is often species-dependent, therefore worth to carry out similar studies for all fish species in order to develop optimal farming technology.

Based on the results of the trial, it can be concluded that the distribution of daily feed ratio does not influence the production parameters of European perch juvenile, however, this is depending on the species (Greenland & Gill, 1979). Despite the fact that no statistically verifiable results were obtained, our investigation show that it is advisable to select feeding times in twice daily divisions, preferably in the morning and in the evening during rearing European perch in an intensive recirculation system. To draw more precise conclusions, further feeding trials are needed in the future.

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